

From context-adaptive applications to context-aware actors

- Context-aware computing in a CSCW perspective

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The reader should note that the theme of this thesis has changed from the one described in the project agreement handed in to the study administration in late January 2003.

In the original project agreement, the original project description of the thesis was to 'explore the challenges and opportunities related to developing computer support for mobile work settings by exploring the problems that cooperative workers face in mobile work settings'. However in late March 2003 I decided to change the theme of the thesis to one reported here. This decision was prompted by the introduction to the computing paradigm 'context-aware computing' I was given in the course 'Global and Mobile Applications – IT for Mobile Workers' at ITU in the spring 2003.

The thesis is written within the field of CSCW, a field in which I had a fair insight prior to the thesis. The thesis conveys new knowledge to me about the context-aware computing paradigm and how it can be used as computer support in cooperative work.

Abstract

This thesis takes its point of departure in a discussion of how context-aware technologies can be utilised as computer support for cooperative work (CSCW). The thesis argues that instead of merely using context-aware technologies to enable applications to adapt to the discovered context, context-aware applications should be designed to discover and present contextual information that serves as *resources* for cooperative actors handling particular activities by making these actors context-aware. Based on this approach to the utilisation of context-aware technologies, a methodological framework that aids the design of context-aware applications that advance context-awareness for cooperative actors is put forward and discussed. The framework consists of an analytical model distinguishing between three different levels of abstraction that context information might serve as resources for cooperative actors, and a computational architecture that enables applications to provide context-information on the three levels of abstraction if certain characteristics are present in the cooperative work setting.

The usefulness of this methodological framework is tested in an empirical study of how context information is gathered and used in the handling of activities related to workflow logistics in a building project. Based on the findings of this empirical study, it is argued that due to certain characteristics of the cooperative work setting, it is questionable that context-aware applications are able to provide even some of the context information that has any relevance for the cooperative actors handling the activities related to workflow logistics. And that even if the applications discussed in the thesis *can* be developed, the advantages of those applications for the handling of workflow logistics are limited.

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Dedicated to my mother and father

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1. Introduction

This thesis is written within the research field Computer Supported Cooperative Work (CSCW) and reflects upon how a particular group of technologies – context-aware technologies – might be utilised as computer support for cooperative work.

This choice of subject is motivated by the introduction to the computing paradigm 'context-aware computing' that I was given in the course 'Global and Mobile Applications – IT for Mobile Workers' at ITU in the spring 2003¹. I found the technologies within this computing paradigm highly interesting, but at the same time I found that the literature in the course neglected some important perspectives on how context-aware technologies could be used within CSCW.

In particular, I found that the majority of researchers within the context-aware computing paradigm seem to consider the possibility to enable applications to automatically adapt according to the discovered context the most advantageous use of context-aware technologies. As will be further discussed later, I see some crucial problems with this vision being realised. But apart from those problems, I also find that this approach neglects an important way that context-aware technology can be utilised as computer support for cooperative work. This use came to my attention in the work of Nilsson et.al (2000), which describes a prototype where context-aware technologies are used to enable cooperative actors at a wastewater treatment plant to get information about how the plant functions. Information that enables the process operators of the plant to handle their activities related to keeping the plant running.

I found this approach highly interesting, as context-aware technologies were not used by Nilsson et.al. to design context-*adaptive* applications, but to enable an application to present contextual information that serves as resources for cooperative actors handling particular activities. Context-aware technologies thus enabled the cooperative actors to become *context-aware*.

To further explore how context-aware technology can be utilized to advance context-awareness in cooperative work, in this thesis I have aimed to *develop, present and test a methodological framework that aids the design of context-aware applications (CAA) that advance context-awareness for cooperative actors*. The methodological framework put forward will serve as optics for how an exploration of a cooperative work setting should be carried out to make it useful for a discussion of the possibilities for design of CAA that advance context-awareness among cooperative actors, enabling them to handle their activities more easily.

In chapter two of the thesis, some critical remarks on the way that context-awareness is typically understood and utilised within the context-aware computing paradigm are put forward. Based on these critical remarks, the methodological framework for design of CAA that advance context-awareness among cooperative actors will be developed in chapter three. The methodology put forward consists of two elements. First the 'Context Information serving as Resources for Cooperative Actors' model (in short, the CIRCA model) is put forward to illuminate how context information serves as resources for cooperative actors on three different levels of abstraction. And second a computational architecture is put forward that enables CAA to provide context-

¹ I took this course solely as an inspiration for my thesis, I did not take any exams.

information to users on the three different levels of abstraction that the CIRCA model distinguishes between if certain prerequisites are met.

Chapter four comments on exactly how a cooperative work activity should be examined to find out which context information on the three levels of abstraction that serves as resources for the actors handling that work activity. And to find out whether the prerequisites for defining a computational architecture that enables CAA to provide this context information can be met. To aid this discussion, Alfred Schutz's theory of relevancies as well as Kjeld Schmidt's remarks on the relationship between parts of Schutz's theory and the concept of complexity will be reviewed and discussed.

Based on these remarks, chapter five reports an empirical study of how workflow logistics is handled in the construction of a ferry terminal in the Port of Copenhagen. This aim of this study was to try out in practice the use of the methodological framework developed in chapter three and four.

After a general introduction to how workflow logistics are handled in the building project, the context information relevant for the handling of one of the activities related to workflow logistics is analysed by the use of the CIRCA model. Following this analysis, it is examined if the prerequisites can be met for defining a computational architecture that enables CAA to provide the context information that has been relevant in the CIRCA analysis.

Finally, chapter six points towards the way in which the analysis presented in the thesis can form the design of CAA that might advance context awareness for actors handling workflow logistics in building projects more easily.

2. Context-awareness in context-aware computing

In this chapter, I will outline my position within the computing paradigm, which deals with the issue of context-awareness: context-aware computing. In the first part of the chapter some problems with the way context-awareness is typically understood and utilised within this computing paradigm are put forward. Based on these remarks, I will argue for an expansion of how to understand and use context-aware technologies. Apart from focusing on how to make *applications* context-aware, I would suggest that the context-aware computing paradigm should also focus on how context-aware technology can be utilised to enable context-aware *actors*.

Context-aware Computing and context-aware functionality

In a survey of Context-Aware Mobile Computing research, G. Chen & D. Kotz defines context-aware computing as a mobile computing paradigm in which applications can discover and take advantage of contextual information (Chen & Kotz 2000). As such, context-aware computing is not limited to a particular type of technology, but is the name for a whole range of technologies that are all in some way able to discover contextual information. The parameter that is most often referred to within the context-aware computing paradigm is technologies that are able to discover the location of objects and actors (Schmidt et.al 1999), but numerous other technologies also exist. Examples are sensors measuring temperature; optical sensors measuring light intensity; motion sensors measuring orientation (horizontal/vertical), vibration, motion patterns and acceleration; audio sensors measuring loudness, type of background noise; and bio-sensors measuring heartbeat pulse, blood pressure (Schmidt et.al 1999, Chen & Kotz 2000, Gaver 2002).

Looking at how applications can effectively use context information, Chen & Kotz argues, that it is valuable to distinguish between two kinds of context-aware applications (CAA): active and passive context-awareness (Chen & Kotz 2000). Active context-awareness comprise applications that change according to the discovered context, passive context-awareness on the other hand comprise applications that merely present the new or updated context to the user, hereby letting him choose to utilise this information in different fashions (Ibid.).

Chen & Kotz review a range of different CAA, relating them to the concepts of active and passive context-awareness. The 'Shopping Assistant' developed by AT&T Bell Laboratories is mentioned as an example of an active CAA. The application uses information about the customer's location within the store to guide the shoppers around the supermarket as well as to provide details of items within proximity. The 'Active Map' system developed by Xerox PARC is mentioned as an example of passive context-awareness. The Active Map application collects information about people's location, but does not use this information to adapt its behaviour. The location information is just 'passed on' to the users of the Active Map system.

Although reviews of a range of different CAA developed include examples of both kinds of context-aware functionality (Dey et.al 2001, Chen & Kotz 2000), it seems like the researchers within the context-aware computing paradigm show a special passion for the development of active CAA. This may be due to the fact that Schilit & Theimer, the first to actually use the word context-

awareness (Barkhuus 2002), defined context-awareness as “the ability of a mobile user’s application to discover and *react* to changes in the environment they are situated in” (Schilit & Theimer in Barkhuus 2002, emphasis added). Chen & Kotz have broadened Shilit & Theimers definition in defining context-awareness as the applications ability to discover and *take advantage of* contextual information, but they still claim that “active context-aware computing is more interesting, as it may help to eliminate unnecessary user cooperation and make technology as ‘calm’ as possible” (Chen & Kotz 2000: 3). In their anchor article of the Human-Computer-Interaction special issue on context-aware computing, Dey et.al (2001) notes in a similar vein, that “one hypothesis that a number of ubiquitous computing researchers share is that enabling devices and applications to automatically adapt to changes in their surrounding physical and electronic environments will lead to an enhancement of the user experience” (Dey et.al 2001: 100).

In this thesis, I will take a critical stance towards the trend within the context-aware computing paradigm to only strive for the design of applications that adapt according to the discovered context. I agree that the development of active CAA in some situations may help to eliminate unnecessary user cooperation and enhance user experience. However, I will argue that this might be an exception rather than the rule. In the following I will argue why this is so by highlighting some important issues that designers of active CAA seems to neglect even though they affect the applications ability to be context-aware.

What is the problem with active context awareness?

My critique of active context-awareness takes as an assumption, that an applications ability to eliminate unnecessary user cooperation and enhance user experience depends upon its ability to be aware of the actual use-situation and environment it is part of. Only if the application is able to be context-aware to an extent that it can figure out the situation that the user is situated within, *as he understands it*, is it able to successfully trigger a command on behalf of the user, hereby eliminating ‘unnecessary user cooperation’.

Even the researchers that are dedicated to developing active CAA agree that such applications are not always able to infer the situation that the user is situated within. Dey et.al admits that the taxonomy of context that is put forward in their Context Toolkit – a conceptual framework to aid the design and implementation of CAA - might not be fine-grained enough for all kinds of context-aware applications (Dey et.al 2001: 157). Chen & Kotz mentions, that rule-based systems that aims to compute high-level context such as the users’ ‘current activity’, suffer from the difficulties originating from ambiguity, boundary conditions, contingencies and undefined models (Chen & Kotz 2000:9). As a consequence of this Dey et.al suggest that future research within CAA have to tackle difficult issues of knowledge modelling and representation as well as thinking about how to make more general context that cannot be sensed directly from the environment available to the applications.

Looking at Dey et.al’s argument, what they find problematic about the present state of context-aware computing is not the general belief that it is in fact possible to enable applications to infer the

use-context they are situated within. Rather the present technological possibilities for making applications context-aware are seen as the hindrance for developing effective active CAA. Although not explicit in Dey et.al's argument, this way of reasoning seems to equal the way researchers within the cognitivist approach to Artificial Intelligence has argued for years. Very briefly, cognitivism (at least in its radical sense) postulates that the brain is simply an information-processor, which generates intelligent behaviour by manipulating symbols by means of formal rules (Dreyfus 1988:100f). Because of this, the cognitivist approach to AI sees the capturing of the formal rules used by reasoning human practitioners as a key to creating artificial intelligence. The ultimate goal in the radical cognitivist approach to AI then becomes to feed the computer with a symbol system of sufficient size to 'think' through every problem faced by that computer. Following this, difficulties for the computer to think through particular problems is due to the symbolic system not being developed sufficiently, just as Dey et.al explains the current problems with context-aware computing with lack of technological possibilities for making applications context-aware². In their arguments both assume that the world *is* possible to describe in full and that such an exhaustive description is what to strive for.

I will argue that the assumption that the world is possible to describe in full has two severe flaws, which both affects the extent to which CAA can be developed to eliminate unnecessary user cooperation.

First, ontologically there will always be a difference in the level of granularity between the world and *representations* of the world. A representation will always be finite in its expression, only focusing on a limited part of the world, whereas the world unmediated by representations can always be explored in greater detail.

Second, epistemologically the premise that the world is possible to describe in full may be considered as false, as there is always another perspective under which things can be seen. The 'situated actions' approach put forward by Lucy Suchman (1987) shows us why this is so. The 'situated actions' approach to human-computer interaction implies that the understanding of a technology and its use is not inherent in the technology itself, but is constituted throughout ongoing practical activity amongst social actors. Following this line Suchman argues that the rationality behind and shared understanding of a given activity and the context it is situated within, is always situated and therefore not possible to describe in full, when de-contextualised from the particular situation in which the activity happened. This way of understanding social reality draws upon insights from the sociological tradition Ethnomethodology. Harold Garfinkel, one of the central writers within this tradition, understands the way social actors carry out their activities in the following way. "Instead of seeing social actors as 'programmed by their cultures' to agree on definitions of the situation and hence patterns of appropriate activity, Garfinkel treats the

² It is important to mention, that this is not the only way that researchers within the AI community strive for enabling artificial intelligence. Neural network is another approach to AI that is not based on information processing by formal rules (Dreyfus 1988:110).

determination of ‘what is going on’ and ‘ what is appropriate’ as the outcome of ‘local’, ‘occasioned’ and ‘situated’ action.” (Anderson 1997: 11). Ethnomethodology claims that social facts does not exist *a priori*, on the contrary social facts always stand in an indexical relationship with the particular situational context in which shared meaning is established. This lack of a priori social facts or stable body of shared meanings (Suchman 1987: 63) is the reason why the world is not possible to describe in full.

Although I very much agree with both Suchman and Garfinkel, that social facts is not just, as the sociologist Emilé Durkheim claimed, a priori ‘out there’ in a scientific sense (Guneriussen 2001), I do think that the argument that a stable body of shared meaning does not exist a priori is a bit too undifferentiated. The sociologist Egon Bittner makes this clear in his paper “Objectivitis and realism in Sociology” (Bittner 1973). By reference to the phenomenologist Alfred Schutz, he argues that even though the highly skilled fieldworker learns quickly to recognise things according to the sense assigned to them within the field of his study, he will always perceive this ‘sense-making’ differently than the actor he seeks to understand. “Since the field worker, as field worker of course, always sees things from a freely chosen vantage point...he tends to experience reality as being of subjective origin to a far greater extent than is typical in the natural attitude [of the actor]... When someone [the actor] has business with the world, or any part of it, he must be prepared to deal with it on the world’s terms” (Bittner 1973: 121f.). Or in other words, even though the social scientist commit himself to the epistemology of ethnomethodology; that social facts does not in any scientific sense exist a priori, he must be aware that social actors navigating the everyday world, rely on a great body of stable meaning as actually inherent in the circumstances of their existence. The fallacy of the fieldworker to “not perceive those traits of depth, stability, and necessity that people recognise” (Ibid. 123) is what I suggest that Garfinkel and Suchman tend to fall into. How to understand this ‘unreflective ness’ of social actors and the consequences it has for the design of CAA will be further explored in chapter four, with reference to the phenomenology of Alfred Schutz.

The finiteness of representations as well as the fact that there is always another perspective under which things can be seen implies, that the issues of knowledge modelling and representation that Dey et.al sees as a challenge for future work within the context-awareness computing paradigm will never lead to applications that will be fully able to infer the situation that the user is situated within. No matter how complex and extensive context is modelled, such decontextualised rules does not take into account the ongoing establishment of shared understanding of the situation at hand that is inherent in any situated activity. Because of this, in the situations where an application is not able to figure out the situation that the user is situated within or misinterprets it, the active CAA will fail to successfully trigger a command on behalf of the user. In these situations, user experience is worsened rather than enhanced and the need for user cooperation heightened, as the user faces the challenge of figuring out how he can control and hereby change the choice of command triggered by the CAA.

Recognising the theoretical position of the less radical version of the situated actions approach, what are the possibilities for utilising context aware functionality? This is the theme of the following paragraph.

Context aware computing in a situated actions perspective

Responding to the problem that the situated actions approach sets for the design of context-aware computing, the computer scientist Philip Agre suggests using what he names the 'capture model' to aid the design of context-aware applications (Agre 2001). The capture model is a design methodology that aims to restructure the activity itself in such a way that the computer can capture the relevant aspects of it. This is done by devising a *grammar of interaction*, drawing upon an analysis of the current work situation, that may serve as a form of 'common language' that enable human activity to be understood by the computer system. This grammar is introduced into the current social system, imposing the actors a certain way of pursuing their tasks. Because of this approach, using the capture model always implies a trade-off: The more structure a system imposes, the more functionality it can provide; but the capture of structured information imposes costs of its own in the form of social engineering (Agre 2001:188).

Based in these arguments Agre argues, that the situated actions approach forces the designer of context-aware systems to choose between one of three design strategies (Ibid.):

1. Confine the system to registering those few aspects of context that are not defined in institutional terms (largely physical parameters like temperature), or to those aspects of context that are already captured by computerised tools whose grammars of action have already been imposed and instrumented in the activity.
2. Perform the social engineering necessary to impose a fine-grained grammar on the activity and its participants.
3. Reject the capture model, and instead register aspects of the environment that can serve as rough, heuristic (and therefore fallible) proxies for the institutional variables that are the real objects of interest.

Agre claims that the 3rd design strategy is the one used most often within context-aware computing, but argues that the 2nd strategy in most cases would be a better option. He argues that the 3rd design strategy can be a reasonable design choice if the consequences of error are slight, but as soon as a context-aware system's choices become significant, the fallibility of its context cues will become problematic for users. The moment that the context-aware systems choices do not comply with the user's intentions (due to the fallibility of its context cues), the users wish to exert control over the systems choices. As no grammar of action has been imposed on the user's engagement with the system, the user has to figure out the way the system work before he can exert such control. In other words, the users want to learn the grammar of action that the system understands so that they can act according to it, which is exactly what the social engineering that is central in the 2nd design strategy is all about. Because of this, Agre argues that in most design situations, you might as well choose to perform the social engineering necessary as the fallibility of the context-aware system

sooner or later will make the users wish to learn the different modes of interaction that the system understands.

Looking at Agre's arguments, they certainly do not equal the hypothesis put forward by Chen & Kotz that context-aware computing may help to eliminate unnecessary user cooperation. In Agre's view, integrating context-aware computer systems into social systems always comes with the price of forcing social actors to act according to a grammar that the computer system can understand. It is the users, not the technology that have the sole responsibility for a successful fit between the social and the technological system.

This makes Agre rather pessimistic with regards to how context-aware computing can be utilised. In fact, Agre seems to reduce the use of context-aware technology to a question of developing new modes of interaction (head movements, physical movements) with a computer system.³

Although Agre's capture model highlights some problems related to implementing context-aware computer systems into a cooperative work setting, I will argue that Agre's rather pessimistic view on the utilisation of context aware computing stems partly from his rather dogmatic interpretation of the situated actions approach and partly because he is blind to alternative uses of context-aware technologies.

As noted earlier in Bittner's critical remarks on ethnomethodology, the meaning that social actors bestow upon the world are to a far extent experienced by those actors as taken for granted. Agre does not take this into consideration, but states that when the application cannot participate in the situated ongoing achievement of shared understanding of a given activity, it will be incapable of registering some of the most basic aspects of context, making the very nature of the activity poorly understood (Agre 2001: 186). However, Bittner show us that this shared understanding is *not* always achieved again and again, but is to a far extent taken for granted by the competent actor. In the same way the CSCW researcher Kjeld Schmidt argues that formal constructs does *not* always serve as maps, merely informing the actor of what things should come to and not necessarily how they should arrive there (Schmidt 1998). On the contrary, formal constructs may determine action in a far stronger sense. Taking the form of *scripts*, formal constructs provide a 'precomputed' selection of safety-critical tasks, as well as a precomputed sequence for their execution, that the actors will follow, unless they have good reasons not to do so (Ibid. 144). Bittner's remarks and Schmidt's insights on how formal constructs may determine action in a far stronger sense than Suchman's map-metaphor show, that the design of CAA might be able to take advantage of those pre-computed work practices and relied-upon meaning structures that guide cooperative actors in their everyday work. Neglecting this aspect seems to be a major flaw in Agre's capture model.

Apart from the conceptual problems with Agre's theoretical position, I also think that his view on the potential use of context-aware technology is too limited. Agre's arguments are based on the assumption that the social actors and the context-aware system *have* to obtain a shared

³ This is not to say, that such use of context-aware computing is of no use at all. See Svanæs (2001) and Dourish (2001) for interesting examples of the importance of bodily conduct in designing user interfaces.

understanding of the present situation to utilise context-aware technology. This is what the 'grammar of actions' in the Capture Model seeks to facilitate: that the social actors narrow down their repertoire of possible ways of handling their everyday tasks to be just as rigid and uncreative as the computing system. However there is another way that context-aware technologies can be utilised that does *not* require this shared understanding, hereby not forcing social actors to reduce their activities to a rigid and defined set of possible actions. This approach shifts the focus from designing context-adaptive *applications* to enabling context-aware *actors*.

3. From context-adaptive applications to context-aware actors

Utilising context-aware technologies to enable context-aware actors implies designing context-aware applications that discover and presents contextual information that serves as *resources* for human actors handling particular activities by making these actors context-aware. This approach makes context-aware technology merely a resource for human actors to be used in the ongoing accomplishment of their everyday tasks. Because of this, mutual intelligibility amongst the actors and the computer system is not a necessity, as the goal of the computer system is not limited to enabling it to trigger commands based on its understanding of the situation that the user is situated within.

Only one paper, written by Bellotti & Edwards (2001), has come to my attention that takes a similar approach to the design of context-aware computing as the ‘context-aware actors’ approach described above. Bellotti & Edwards argue that “In the absence of the ability of a system to make meaningful inferences about human context, instead, a set of design principles are required that enable human beings to reason for themselves about the nature of their systems and environments, empowering them to decide how best to proceed” (Bellotti & Edwards 2001: 195). Although Bellotti & Edwards do not explicitly mention the link to the situated actions approach, the quote shows exactly why it is important that designers of CAA recognise the use of such applications as *resources*, hereby shifting the focus of attention from the application to the actor. Only by doing this, designers can start asking themselves the question that Bellotti & Edwards implicitly raises; *what makes the best resources for situated actions?*

In the discussion of what features context-aware systems should support to allow users to make informed decisions based on context, Bellotti & Edwards emphasises two key principles: Intelligibility and accountability.

Intelligibility includes informing the actor about the ‘technical context’ that the user is situated within and what this implies for the users (what systems is the user detected by, what role/situation is he ascribed etc). It also includes providing feedback to the user about whether and how a context-aware system acquires information about the user and his actions, how it is used and whom it is available for.

Accountability includes enabling the context-aware system to detect the identity, activities, presence etc. of the actors as well as presenting how the system interprets these parameters to the users. It also includes enabling user control of the system.

Of these design principles, especially Bellotti & Edwards thoughts on how to provide user control is interesting in the discussion of what kind of contextual information makes the best resources for situated actions. As an answer to the problem that if systems don’t do anything, *there will be too many matters that users must deal with themselves*, they argue that “Effective control is not simply about whether the user is intimately involved in execution, it is more a matter of how easily the user attains the desired outcome (by whatever means)” (Bellotti & Edwards 2001:208).

Bellotti & Edwards present three different design strategies for providing user control that are appropriate under different conditions:

1. “If there is only slight doubt about what the desired outcome might be, the user must be offered an effective means to *correct the system action*. In most cases the system will do the right thing.
2. If there is significant doubt about the desired outcome, the user must be able to *confirm the action* the system intends to take.
3. If there is no real basis for inferring the desired outcome, the user must be offered available *choices for system action*.” (Bellotti & Edwards 2001: 209 *original emphases*)

Relating Bellotti & Edwards’s thoughts on user control to the question of what CAA makes the best resources for situated actions; it is interesting that passive CAA might not always serve as the best resources for situated actions. In the situations where there is only slight doubt about what the desired outcome might be, applications that act on behalf on the user will most likely serve as better resources than applications that merely present the available choices for system action to the user. In Chen & Kotz’ terminology, such applications would fall under the category active context-awareness with the little twist that the user is able to correct the system’s actions.

Bellotti and Edwards argues, that the choice between the three design strategies depend upon the systems chance of inferring the outcome that the actor desires. But they don’t give explanation to what influences the systems chance of making such an inference. Neither do they give explanation to what enables the system to infer what system action is needed to attain the desired outcome that the application has inferred.

Because of these absences I find Bellotti & Edwards design strategies insufficient as a methodological framework for design of CAA that serves as resources for cooperative actors by making these actors context-aware.

In the remains of this chapter I will put forward and discuss an alternative methodological framework for design of CAA within the ‘context-aware actors’ perspective that acknowledges Bellotti & Edwards’ insight that in some situations, active CAA might serve as better resources than passive CAA. But at the same time seeks to illuminate the important question that is neglected in Bellotti & Edwards methodology: With what optics should a cooperative work activity be examined to decide in what ways CAA are able to advance context awareness among cooperative actors handling this activity?

I suggest that such a methodological framework should illuminate two important questions:

- How does context information serve as resources for cooperative actors handling a particular work activity?
- How is it possible to enable CAA to provide this context information to the cooperative users in a way that enables them to handle the particular work activity more easily?

I will start by discussing the first of these questions. Following the insight that both active and passive CAA may serve as resources for cooperative actors, an analytical model will be put forward

distinguishing between three different *levels of abstraction* that context-information serve as relevant resources for cooperative workers. After the presentation of this model, a computational architecture is put forward that enables CAA to provide context information on those three levels of abstraction if certain characteristics are present in the cooperative work setting.

How does context information serve as resources for cooperative actors?

I suggest that an exploration of how context information serves as resources for cooperative actors must take its point of departure in the very understanding of cooperative work within CSCW.

The core of the conception of cooperative work is the notion of mutual dependency *in work* which means, that A relies positively on the quality and timeliness of B's work and vice versa (Schmidt & Bannon 1992: 13). This mutual dependency is what requires actors to cooperate in order to get the work done.

Within CSCW, two analytical concepts are central in defining a cooperative work setting. These concepts are the 'field of work' and the 'cooperative work arrangement'. The field of work is defined as "The part of the world that is affected (controlled or transformed) by the work of the actors (Schmidt 1994: 59). This also includes the interfaces to this part of the world, such as sensors, representations etc. The cooperative work arrangement is defined as "The setting of interdependent actors as constituted by a system of interdependent activities" (Schmidt 2002: 21). Both are conceptual constructs that mutually constitute and delimit each other. For ease of reading, the term 'cooperative work setting' (in short CWS) will be used in the remains of the thesis as a term for the part of the world delimited by the field of work *and* the cooperative work arrangement.

Because of this mutual dependency *in work* and due to the fact that no omniscient and omnipotent agent is present in a cooperative work arrangement (Ibid: 18), an actor in a cooperative work arrangement is dependent on contextual information about the state of the field of work, including how the other actors in the cooperative work arrangement relate to the field of work, that is not always directly available to him. This information is *relevant* for him because it is only by obtaining this contextual information that he is able to figure out how to handle the cooperative work activity successfully.

Looking at how collaborative actors obtain such contextual knowledge, many CSCW workplace studies show, that actors in cooperative work settings (CWS) find *numerous* sources of context information relevant when handling particular activities. Schjørring (2002) has developed the concept of an information ecology, defined as 'the collection of different sources of information that is taken into consideration in different aspects of the actions that people pursue' to acknowledge this joint use of different sources of information. Furthermore, research within the CSCW area has shown that different sources of information also come to be used in being mutually determinative. Harper & Hughes (1993) show the importance of this insight in an ethnographic study of air traffic control. Taking the use of a radar and flight strips as an example, it is argued that "These sources of information are not distinctly separate items of information which are, as it were additive, but they mutually explicate the sense of each other. What each source of information means is reflexively determined by the sense made of the others." (Harper & Hughes 1993:138). Harper & Sellen (2002) elaborate further on the interdependence of different sources of information

by emphasising that this interdependence does not have to be physically embodied. Quite often the relations between the interdependent informational resources are spread out over time (Harper & Sellen 2002: 189).

Context-information on three different levels of abstraction – the CIRCA model

Taking all of the above into consideration, it seems possible to distinguish between *three different levels of abstraction* that context information might serve as resources for a cooperative actor handling a cooperative work activity. With reference to Bellotti & Edwards, context information that serves as resources is to be understood as context information that enables the user to attain his desired outcome. The three levels of abstraction are defined in the ‘Context Information serving as Resources for Cooperative Actors’ model (in short the CIRCA model) below:

Level 1: Fragmented context information	Each fragmented context information is relevant to the activity at hand, but is not in itself adequate to act upon
Level 2: Adequate context information	The understanding of the state of the cooperative work setting that the actor finds adequate to act upon
Level 3: Post-action context information	The choice of action that has been carried out to change the state of the field of work in a way that is found appropriate to handle the particular activity examined.

Figure 1: The CIRCA model - three different levels of abstraction that context-information serve as resources for cooperative actors.

To explain how the three levels should be understood, what connects them and what distinguishes them from each other, Heath & Luff’s (1992) famous study of cooperative work in a Line Control Room in London Underground can be used as an illustrative example. The Divisional Information Assistant’s (DIA) task to provide information about changes to the time plan to passengers (Ibid: 71) is chosen as the activity examined.

Level 1: Fragmented context information

Looking at how the DIA handles the task to provide information about changes to the time plan to passengers; Heath & Luff mentions several aspects of the work context that the DIA has to obtain knowledge about. This includes information about those changes made by the controller to the running order of the service, that affect how the DIA should proceed with his task of providing information to passengers. The course of reasoning involved in the controller’s decision-making is also important contextual information used by the DIA to assess the grounds for and consequences of the controller’s decision to affect the field of work in the light of possible alternatives. The DIA also need information about the present distribution of trains along the Bakerloo Line (by using the fixed line diagram). He needs information about the ordinary timetable and the changes made to it by the controller (By using the manually updated timetable). And he needs information about which trains are at what stations (by using CCTV).

Knowledge about all these aspects of context are *relevant* for the DIA when he is trying to understand the current situation of the Bakerloo Line, but none of them does in themselves provide information about the current state of the CWS, that is adequate to act upon. Hence all those aspects of context would be listed as discrete fragmented context information in the CIRCA model, defined as pieces of context information that is relevant to the activity at hand, but not in itself adequate to act upon.

Level 2: Adequate context information

In the London Underground case, the DIA does not have access to one single representation of the state of the field of work that gives him an understanding of the state of the CWS that he finds sufficient to act upon. Instead he uses all the different sources to contextual information noted above to infer such an understanding that could be something like ‘train A is going to be delayed 3 minutes due to a 4 minute delay on train B’. All other things being equal, this is the understanding of the CWS that the DIA need to decide how to handle the ongoing activity of informing the passengers about changes to the time plan.⁴ It is adequate in the sense that it is the understanding of the state of the CWS that the actor finds adequate to act upon. As such, adequate context information relates to the different kinds of fragmented context information as the actor infers an adequate understanding of the state of the CWS from all those fragmented sources of information listed on the first level of the CIRCA model.

Level 3: Post-action context information

Finally, information about what choice of action the DIA has carried out to handle his task of providing information about changes to the time plan to passengers (e.g. that the station manager has been warned that a train is late and the passengers have been informed about this delay) can be considered *post-action* context information. Post-action context information is defined as information about the choice of action that has been carried out to change the state of the field of work in a way that is found appropriate to handle the particular activity examined. Situations in which the actor has decided *not* to alter the state of the field of work as well as the situations in which he *has* chosen to alter the state of the field of work are both examples of post-action context information. Post-action context information relates to the adequate context information on the second level of abstraction, as the actor’s judgement of what course of action is ‘appropriate’ to handle the activity examined is dependent on his understanding of the present state of the CWS.

⁴ The example is purely illustrative. How often this ‘other things being equal’ holds need to be determined empirically.

Design challenges for context-aware applications

Above I have argued that analytically it is reasonable to distinguish between three different levels of abstraction that context information is useful for cooperative actors in handling particular activities. But one thing is the use of the CIRCA model as an *analytical* tool to analyse how cooperative actors handling particular activities in general use context information on different levels of abstraction. Another is how the CIRCA model can be used as a *design* tool to reflect upon the possibilities for designing CAA that serves as resources for cooperative actors by providing context information on the three different levels of abstraction.

In this thesis I will highlight three ways that CAA may provide context information to cooperative actors enabling them to handle an activity more easily.

1. Gathering fragmented context information

Understanding fragmented context information, as context information on the lowest level of abstraction does not mean that gathering such fragmented contextual information is trivial for cooperative actors. As will be further explored in the following chapters, characteristics of the field of work and the cooperative work arrangement often make it difficult or even impossible to gather fragmented context information considered relevant for the activity at hand. Targeting this potential problem, CAA might make it easier for cooperative actors to gather fragmented context information that is presently difficult to obtain.

In this matter it is important to acknowledge that contextual information provided by CAA is just one of many possible resources that actors may use in handling cooperative work activities. Juhlin & Weilenmann (2001) show the importance of this acknowledgement in a study of the use of location-based technologies to support snow-sweepers in airports. Amongst other things they find that an application called SnowCard, which show the location of the snow-sweepers, is not used at all, simply because the sweepers can tell that by looking out the windshield (Ibid: 387). Because of this, designers should not by all means try to make all contextual information that a work-place study has revealed as relevant for a cooperative actor, available on a CAA. Rather the challenge is to find out how CAA may fit into the already existing information ecologies of particular activities (Schjørring 2002).

2. Comparing fragmented context information

Characteristics of the field of work and the cooperative work arrangement also influence the extent to which an actor is able to compare and use fragmented contextual information jointly to infer an adequate understanding of the CWS. This is e.g. the case if these fragmented informational sources are spread across space and time. Targeting this potential problem, CAA might be able to make it easier for actors to compare the sum of relevant fragmented context information by making this information available 'at a glance'. This would make it easier for the actor to infer an adequate understanding of the CWS.

3. Providing adequate or post-action context information

Finally CAA might make it easier for cooperative actors to handle the activity at hand by providing context information on *higher levels of abstraction*. In my critique of Agre, I argued that his pessimistic view on the utilisation of context-aware technology partly stems from the fact that he sees mutual intelligibility amongst the actors and the computer as a *necessity*. However my critique does not imply that such mutual intelligibility is not a *possibility*. Bittner's and Schmidt's remarks made this clear. Following this, if mutual intelligibility is possible, then applications that act on behalf on the user will most likely serve as better resources than applications that merely presents fragmented context information to the user.

Referring to Heath & Luff's study as an illustrative example, CAA might be able to provide the adequate context information that 'train A is going to be delayed 3 minutes due to a 4 minutes delay on train B'. If this adequate context information equals the understanding of the CWS that the actor himself would give his assent to, then such applications saves the DIA from aligning the sum of fragmented context information that he presently uses to infer this adequate context information. In the same way CAA might even be able to carry out the choice of action that the cooperative actor himself would give his assent to, only informing him that this has been done. For the DIA, such an application would warn the station manager that a train is late as well as inform the passengers on the different stations about this delay, only providing the DIA with the post-action context information that this has been done.

Remarks on the use of the CIRCA model as a design tool

The CIRCA model is part of my suggestion to a methodological framework to aid the design of CAA that advance context-awareness among cooperative actors. In this context it is important to emphasise that the 'context-aware actors' approach and hence also the CIRCA model is limited to the design of CAA that do *not* aim to infer their users activity. This is because the actors that these applications aim to support are already aware of their own activity; instead using context information to understand the current state of the CWS they are part of. This is also the reason why the CIRCA model is defined from the point of view of an individual actor facing a particular activity.

Only focusing on applications that do not aim to infer their users current activity has one design limitation that need to be emphasised here. As will be further explained in chapter four with reference to Alfred Schutz's theory of relevancies, an actors understanding of the context he is situated within, including what parts of the context he considers relevant, is relative to the activity he is carrying out. This is why the CIRCA model is defined relative to a particular activity. If the application should support numerous different activities, the application thus needs information about which of these activities that context information should be provided for. As applications designed within the 'context-aware actors' approach do *not* aim to infer their users current activity, it is the responsibility of the users to provide this information to the application.

This demand for active user-engagement may be unsatisfying for some designers of CAA. However I suggest that the approach to design of CAA put forward in this theses can be a way to move beyond what in my opinion tend to be a strict division between the AI community's goal to enable

applications to act on behalf of users. And the radical situated actions perspective, that seems to reject the possibility of enabling an application to associate a particular constellation of fragmented context information with a particular adequate context description or a particular adequate context description with a particular choice of action. If my approach can help to mediate just a tiny bit between these two approaches to the design of CAA, I find the above-mentioned demand for active user-engagement an acceptable trade-off.

How to enable CAA to provide context information on the three levels of abstraction?

Above I have argued that context information serves as resources on three different levels of abstraction. The question that remains to be solved is how to enable CAA to provide context information on the three levels of abstraction that the CIRCA model distinguishes between. In this matter, I find Gellersen et.al’s (2002) suggestion to a ‘layered architecture for sensor-based computation of context’ highly inspiring. The architecture is developed by Gellersen et.al to facilitate context-awareness in mobile devices. The architecture is thus developed with a different agenda than the one put forward in this thesis, but is nevertheless with small modifications applicable to it.

Gellersen et.al suggests that using multi-sensor data (motion, orientation, location, temperature etc.) instead of one sensor is a powerful way to facilitate context awareness in mobile devices. As illustrated below, data from multiple sensors is aligned and analysed to abstract the situational context of the device.

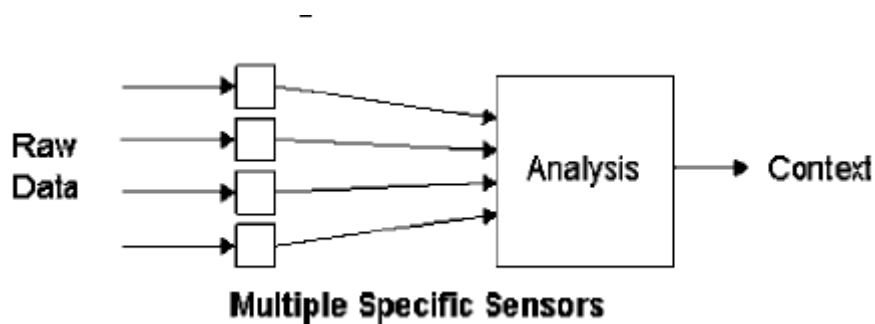


Figure 2: Use of multiple specific sensors to abstract context (Gellersen et.al 2002: 344)

Gellersen et.al puts forward an architecture consisting of a two-step abstraction from raw data to context. For each sensor, a number of cues are defined, acting as an abstraction of the raw sensor data. As an example, cues for a sensor measuring temperature could be ‘cold’, ‘warm’ and ‘hot’. These cues are abstracted from raw sensor data by defined criteria, e.g. that temperatures below 10C equals ‘cold’, temperatures from 10C- 40C equals ‘warm’ and temperatures above 40C equals hot. The context layer introduces a set of contexts, which are abstractions of real world situations, each defined as a function of the available cues of each sensor and not the raw data.

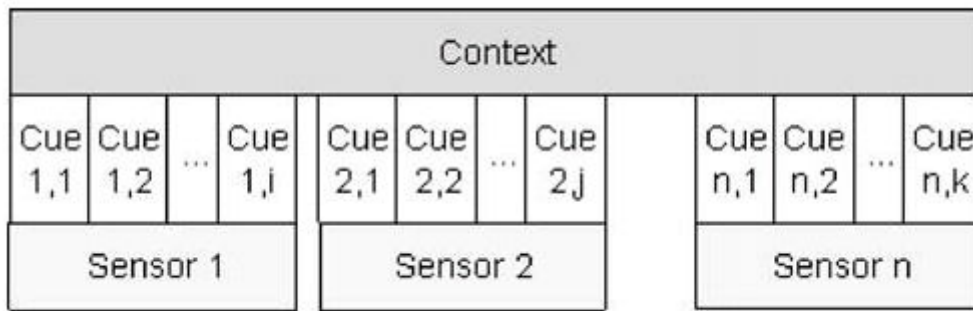


Figure 3: The layered architecture for abstracting context from raw data (Gellersen et.al 2002: 345)

Applying Gellersen's architecture to the distinction between the three different levels of abstraction in the CIRCA model, a layered architecture for 'discrete context information-based computation of adequate and post-action context information' could look like the following:

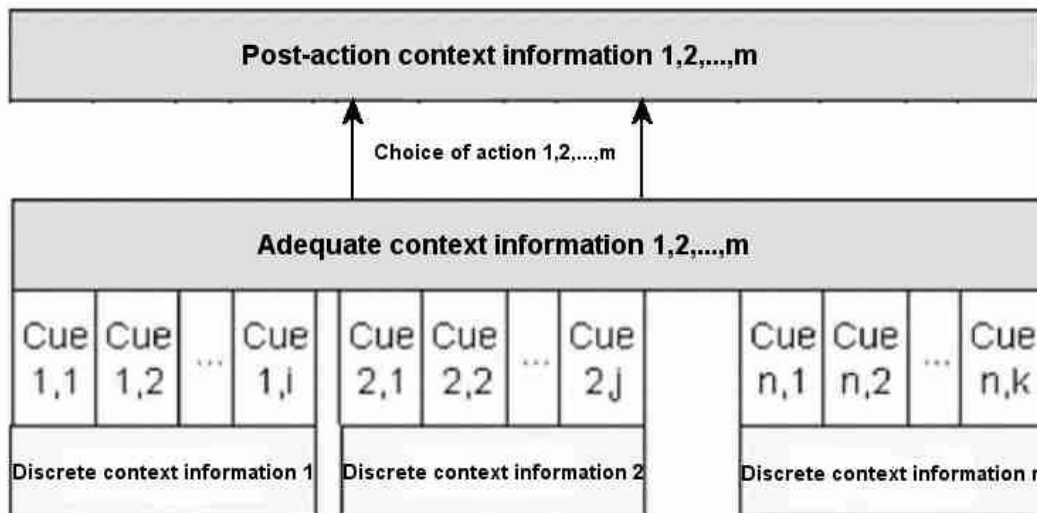


Figure 4: The layered architecture for discrete context information-based computation of adequate and post-action context information

As illustrated in figure four, the bottom layer of the architecture consists of *discrete* context information. The context information on this layer is termed 'discrete' because the fragmented context information that is presently used by cooperative actors to infer particular understandings of the state of CWS is *not* the only context information that an application may use to infer higher-level context information. This will be explained in more detail in chapter four of the thesis. Contrary to Gellersen's architecture, this bottom layer is not limited to sensor data, as sign-based information like work plans; coordination mechanisms etc. might also be useful for enabling an application to infer higher-level context information from a particular constellation of discrete context cues.

For the discrete context information, cues are defined in the same way as in Gellersen's architecture. Adequate context information is thus inferred by associating a particular constellation of discrete context cues with a particular state of the CWS. In the same way post-action context information is

inferred by associating particular adequate context information with a particular choice of action. Although it might be possible to expand the architecture to allow the adequate context information to be aligned with additional data, I have chosen not to allow this in the architecture put forward in this thesis. Because of this, the relationship between different states of the CWS and choices of action is defined as a one-to-one relationship.

Whether or not it is possible for a CAA to provide the fragmented, adequate and post-action context information that a CIRCA analysis has shown relevant thus depend on the extent to which an architecture as the one above can be defined that enables the application to infer the fragmented, adequate and post-action context information that the actor himself would give his assent to. Gjellersen however does not prescribe the methods for calculating cues from raw data, neither how to calculate context from cues. Although it is beyond the scope of this thesis to fully develop such methods, I suggest that two prerequisites have to be met for such architecture to be defined.

The first prerequisite is partially put forward by Gellersen et.al as they argue that the mapping from cues to context may be explicit for instance when certain cues are known to be relevant indicators of a specific context (Gellersen et.al 2002: 345). The prerequisite that Gellersen seems to raise here is that a relationship between the different layers in the architecture (including the relationship between raw data and cues) can be found in the work setting explored that is at least to some extent *unambiguous*. As mentioned above, it is *not* a prerequisite that these relationships are the same as the ones that the actor currently makes between the fragmented, adequate and post-action context information when handling a particular activity.

This unambiguousness is important because it is the association between e.g. a particular constellation of discrete context cues and a particular state of the CWS that enables the application to provide adequate context information to the user. If this relationship is *not* unambiguous, then the CAA will not in all situations be able to infer the state of the CWS that the user would give his assent to.

I suggest that such a relationship can be ambiguous for two different reasons. First a particular state of the CWS may *not* always be expressed in a particular constellation of discrete context cues in the work setting. If this is the case, then the CAA is not able to provide adequate context information about that particular state of the CWS if it is expressed in other ways than the constellation of discrete context cues that the adequate context information is associated with in the layered architecture.

Second a relationship between a particular constellation of discrete context cues and *several* states of the CWS might be present in the work setting. Based on that particular constellation of discrete context cues, the CAA is not able to distinguish between these states of the CWS. Instead it will always associate that particular constellation of discrete context cues with the adequate context information that this constellation is associated with in the layered architecture.

The degree of unambiguity required for a layered architecture to be defined depends on the degree of unambiguity of the inferred context information that is *acceptable* for the cooperative actors. This has to be determined empirically.

The second prerequisite is that information about what fragmented, adequate and post-action context information is relevant for handling a particular activity as well as what unambiguous relationships in the CWS enables CAA to provide this context information is *available* for the CAA. Only if this information is defined within the 'layered architecture' is the CAA able to provide the context information that is relevant for the actor handling a particular activity.

Exploring the extent to which the relevant fragmented, adequate and post-action context information as well as the unambiguous relationships in the CWS are *generic* features of that activity is important in this matter. If these features are generic for the activity, then system designers are able to define the layered architecture once and for all.

However, that those features are generic for the particular activity is not a *necessity* for satisfying this second prerequisite. This is because the user of the application can be enabled to make temporary or permanent additions to the layered architecture during his line of action. For example, the user could be allowed to tag actors or artefacts in the work setting with location-aware technologies hereby enabling location-aware applications to provide him with information about the physical location of these actors and artefacts.⁵

Exploring the use of the CIRCA model and the layered architecture for 'discrete context information-based computation of adequate and post-action context information' as a methodological framework to aid the design of CAA within the 'context-aware actors' approach will be central to the rest of this thesis. This will be done by testing the use of the methodological framework in a field study of how workflow logistics are handled in construction work.

First however I find it necessary to add some comments on exactly what designers need to know about a cooperative work activity to decide whether or not it is possible for CAA to target the three design challenges discussed earlier, hereby enabling the activity to be handled easier. This includes first of all how to find out what fragmented, adequate and post-action context information is relevant for cooperative actors handling a particular activity. And second how to find out if it is possible to meet the prerequisites for defining a layered architecture that enable an application to provide the fragmented, adequate and post-action context information that has shown relevant in a CIRCA analysis.

Continuing my affiliation with the interpretative approach to the understanding of human reasoning, I will ground my comments to these questions in insights from the German phenomenologist Alfred Schutz, especially his concept of a 'system of relevance'. Discussing Schutz's theory and how it can be used to aid the analysis of a particular cooperative work activity is the theme for the following chapter.

⁵ Nilsson et.al's (2000) design of the 'pocketizer' application is an interesting example of a context-aware application where the users are able to configure the application by not only annotating but also bookmarking and creating links between objects in the work setting.

4. How to examine relevance in cooperative work

In this chapter, I will look deeper into how the concept of relevance in cooperative work can be understood. The chapter will review and discuss Alfred Schutz's phenomenological writings on the structure of common-sense life, as well as a paper by the CSCW researcher Kjeld Schmidt, who argues that the concept of complexity can be used to further differentiate parts of Schutz's theory of relevance. Based on these theoretical remarks, I will discuss the consequences of Schutz's theory for the methodological framework put forward in chapter three. This includes the consequences for how to find out what context information is relevant on the three levels of abstraction in the CIRCA model. And second how to find out if the prerequisites can be met for defining a layered architecture that enable an application to provide the fragmented, adequate and post-action context information that has shown relevant in a CIRCA analysis of a particular activity.

Schutz and the phenomenology of common-sense life

In his work, the phenomenologist Alfred Schutz elaborated on exactly how an individual, acting in a world shared with others, nevertheless acts in modes which, epistemologically, need to be understood as consisting of multiple realities. Following the phenomenological tradition, especially that of Husserl, Schutz took as a point of departure, that "There are no such things as facts, pure and simple. All facts are from the outset facts selected from a universal context by the activities of our mind" (Schutz 1962a:5). This argument, that all facts are by nature-interpreted facts, equals Garfinkel's thoughts on social facts, mentioned in chapter two of this thesis. However, Schutz's contribution was unique as he argued that the way in which actors define their situations is *not* always by an explicit interpretative process where numerous different perspectives are taken into consideration. Rather, the common-sense world is from the point of view of the actor, to a large extent taken for granted. "What he [the actor] puts in brackets is the doubt that the world and its objects might be otherwise than it appears to him. We propose to call this *the epoché of the natural attitude*" (Schutz 1962b: 229, original emphasis).

To understand the way that the actor, in the natural attitude, navigates the common-sense world, Schutz brings in the concepts of *typifications* and *system of relevancies*. Schutz argued that at any moment in a person's life, the individual has what Schutz terms a "stock of knowledge at hand". This stock is made up of *typifications* of the common-sense world (Natanson 1962: xxviii). These typifications act as a vast number of "recipes" which serve as techniques for understanding or at least controlling aspects of the actor's experience (Ibid: xxviii). The point to make is that we perceive the situation at hand through these "recipes" of understanding.

Although the concept of typifications is important in understanding social actors navigating in the common-sense world, it only gives explanation to *how* an actor typifies a particular object or activity in a certain way. To fully understand the typifications that people act through, and the extent to which they rely on them, it is crucial to understand how typifications relate to the *system of relevancies* that the actor is acting within. The system of relevance is the null point in terms of which all evaluative prediction takes on significance and direction (Natanson 1962: xli), and as such

it is what guides man within his natural attitude in daily life (Schutz 1962b: 228). It is the reference to an underlying system of relevance that gives explanation to *why* an actor typifies the world in a particular way when handling a particular problem at hand. What makes up the stock of knowledge at hand as well as the system of relevancies, differs according to the social actors *biographical situation*, which Schutz defines as the sedimentation of all man's previous experiences (Ibid: 9). This is both our own experiences and those handed down to us by others.⁶

In understanding how the typifications act as "recipes" of understanding, Schutz argues that interpreting an experience in a particular way, perceiving it as a particular 'type' is not always trivial. In general it is the extent to which the stock of knowledge at hand is adequate to solve a particular problem that determines the extent to which people will take different perspectives into consideration when solving that particular problem. "Men stop and think only when the sequence of doing is interrupted, and the disjunction in the form of a problem forces them to stop and rehearse alternative ways – over, around or through – which their past experience in collision with this problem suggest" (Schutz 1964a:77). In other words, a typification is a pre-interpreted understanding of the situation at hand that is not questioned unless there is a practical reason for it. This way of acting is key to the understanding of social life in the *epoché* of the natural attitude.

To further explain how an actors stock of knowledge and system of relevancies is brought into play in a particular situation, as well as the extent to which this stock of knowledge is 'adequate', Schutz distinguishes between three different *kinds* of relevance. To explain the difference between these three kinds of relevancies as well as how they guide man's understanding of a particular situation, Schutz describes a situation, where a man enters a poorly illuminated room and observes in the corner something that looks like a pile of rope:

"He sees the thing, but not clearly. Is it really a pile of rope or is it a serpent? Either is equally possible – reason enough for the man to distrust his first interpretation...The man now becomes uneasy...Approaching the object he thinks that it is a rope: it does not move, and so on. On the other hand, he "comes to think of it" that the colour of serpents is very similar to that of rope and that in wintertime serpents, made rigid by the cold, do not move. He therefore moves around his representation without coming to a solution because each of the alternatives has its own weight, one balances the other. If he is inclined to believe that he erroneously assumed the object to be dangerous, he may feel the need to obtain a higher degree of certitude. He will look for proof...Thus, the man may take a stick and hit the object, but it still does not move...With this last proof he has completed *in detail* the tour around his representation and he may establish giving his now well-founded assent or conviction that he was mistaken to think that the object was a serpent." (Schutz 1970: 20f.)

⁶ This thesis does not focus on the constitutive processes which lead to the sedimentation of the stock of knowledge/ system of relevancies. The focus is merely to understand what the stock of knowledge/ system of relevancies are and how they 'work', guiding people in their activities. See (Schutz 1970: 75 – 133) for Schutz's comments on the constitution of the stock of knowledge/ system of relevancies.

Schutz uses the example as a way to illuminate different questions related to what guides the man's reasoning when he enters the room. First of all, the example illustrates that typifying a particular event is not always trivial. Sometimes it takes work – either logical reasoning or activity in the outer world – to decide which interpretation, each of them capable of being connected with the actors previous experiences, at least as to the type inherent in them, is to become thematic of his activity. But the example also illuminates other questions that are central to understanding the way actors prescribe meaning to the world: What makes the 'something in the corner of the room' stand out over against all the other things in the room as a theme of interest for the man entering the room? What makes him interpret it as either a snake or a rope and not something third? And what determines the extent to which the actor seeks to gather further information about the 'something in the corner', before giving his assent to one of the two problematic possibilities? These questions all relate to the question of what is *relevant* for the actor in that particular situation. And it is in this matter, that Schutz distinguishes between three kinds of relevance. These are topical, interpretative and motivational relevance, each of them taking the form of either imposed or intrinsic relevancies.

Topical relevancies

Topical relevance "is the relevance, by virtue of which something is constituted as problematic in the midst of the unstructured field of unproblematic familiarity" (Schutz 1970: 26). As such it is the topical relevancies that determine which experiences are made thematically as well as the depth or level of investigation required to solve the problem in an adequate manner (Ibid. 103). In the example where the man enters the poorly illuminated room, it is the topical relevancies that make the 'something in the corner' stand out over against all the other things in the room as a theme of interest. Schutz emphasises that it is the whole setting of a particular situation that determine which experiences are made of topical relevance (Ibid. 38f). Whereas the unexpectedness of the 'something in the corner' makes it of topical relevance for the actor entering a dark room, on a ship the 'something in the corner' might not become of topical relevance at all for the actor. Finding a pile of rope on a ship would be so familiar, that the presence of the pile of rope would remain unquestioned for the actor navigating the common-sense world.

Interpretative relevancies

Interpretative relevance is the relevance, by virtue of which the experience, made of topical relevance for the actor, is interpreted as something particular. In Schutz's example, it is the interpretative relevance that guides the actor's interpretation of the 'something in the corner', making him interpret it as either a snake or a pile of rope.

As noted earlier, such an interpretation means to subsume an experience, as to its typicality, to the stock of knowledge at hand. "*But not everything within the latter [stock of knowledge at hand] is used as a scheme of interpretation*" (Schutz 1970: 36, original emphasis). The interpretative relevancies are what determine the parts of the stock of knowledge that are relevant for interpreting the experience of topical relevance. In doing this, the interpretative relevance has a double function: "*Not only is it interpretatively relevant that part of our stock of knowledge at hand has 'something to do' with the thematic object now given to our interpretation; but, uno actu, certain particular*

moments of the object perceived obtain the character of major or minor interpretative relevance for the task of recognizing and interpreting the actually experienced segment of the world" (Ibid. 36f, original emphasis). What Schutz argue is that not all parts of the 'something in the corner' are equally relevant when interpreting it, i.e. aligning it with the stock of knowledge at hand. In Schutz's example, the shape and colour of the 'something in the corner' is most likely of interpretative relevance when the actor is trying to make an interpretation unbent, whereas its weight is most likely not.⁷

It is important to emphasise that the actor uses the total number of interpretative relevancies jointly to interpret the experience of topical relevance for him. In interpreting the 'something in the corner', the actor takes into consideration both colour, shape and probably many other things, subsuming the experience of topical relevance to his previous experiences (i.e. his stock of knowledge at hand). It is the totality of these interpretative relevancies that makes him interpret the 'something in the corner' as either a snake or a rope. Testing the different problematic possibilities, in Schutz's example by hitting the 'something in the corner' with a stick thus means to establish additional interpretative relevancies (Schutz 1970: 40). But the outcome of the test, the way the 'something in the corner' responds to being hit with a stick, is interpreted in the light of *all* the interpretative relevancies, enabling the actor to give his assent to one of the problematic possibilities tested. The point where the actor is able to give his assent to a particular interpretation is also the point where the actor breaks off gathering additional interpretative relevant material.

Motivational relevancies

Motivational relevancies deal with how to understand the relevance of different actions chosen by an actor – how these actions are *motivated*. Here, Schutz distinguishes between in-order-to and because motives. In-order-to motivational relevancies are what guide the actor when he acts *in order to* bring about a particular state of affairs. In Schutz's example, the actor entering the room decides to hit the 'something in the corner' with a stick in order to find out, whether it is a snake or a rope. Taking the example further, the actor has to obtain such a clarification in order to find out whether or not he wants to sleep in the dark room. What this example illustrates is, that the in-order-to motivational relevancies are organised in a hierarchy relative to the paramount project of the actor. As action is characterised by its purposive and projective character, hence having its source in the consciousness of the actor (Schutz 1962b: 211), Schutz also includes 'negative action', understood as purposive abstention from acting as an action in itself (Schutz 1962a: 20). Examples of this are the surgeon's decision not to operate or the businessman's decision not to sell. As to the 'because motivational relevance', Schutz distinguishes between spurious and genuine because-motives. Spurious because-motives are merely in-order-to motivational relevancies viewed retrospectively. (I will hit the 'something in the corner' with a stick *because* I want to find out whether it is a snake or a rope). A genuine because-motive on the other hand deal with the *motivation for the establishment of the paramount project itself*, whereas the in-order-to relevancies

⁷ The example is merely illustrative. What parts of the experience is interpretatively relevant in a particular case cannot be defined in general, but is relative to the actors system of relevance

motivationally emanate from the already established paramount project (Schutz 1970: 50). In Schutz's example, the actor wants to find out whether the thing in the corner is a rope or a snake *because* he is afraid of snakes. In other words, it is the because-motive, which makes the 'something in the corner' thematic for the actor in the first place.

Imposed and intrinsic relevancies

Finally, all three kinds of relevance may take the form of either imposed or intrinsic relevancies. The distinction between imposed and intrinsic relevancies is made according to whether the experience is made topical, interpretational or motivational relevant volitionally or whether the relevance has been imposed upon the actor. However, even intrinsic relevancies have a certain structure that limit the actor's choice of perspective: "Surely we are free to choose what we are interested in, but this interest, once established, determines the system of relevancies intrinsic to the chosen interest. We have to put up with the relevancies thus set, to accept the situation determined by their internal structure, to comply with their requirements." (Schutz 1964b: 126). The relevancies *intrinsic to a particular problem at hand* thus determine the way the actor typifies that particular problem. As such intrinsic relevancies are key to understanding the unreflective epoché of the natural attitude. The system of relevancies intrinsic to a particular problem at hand makes the actor unreflectively interpret that problem in a particular way, making him stick to this interpretation unless there is a good reason not to do so. Such a reason may be, if other relevancies *impose* upon us. "Imposed upon us as relevant are situations and events which are not connected with interests chosen by us, which do not originate in acts of our discretion, and which we have to take just as they are..." (Schutz 1964b: 126)

The difference between imposed and intrinsic relevancies is therefore not relative to whether the actor is able to volitionally alter the intrinsic structure of his system of relevancies, as this structure is simply taken for granted in the natural attitude. Rather the difference is relative to whether the actor is able to volitionally shift the problem at hand, thereby modifying the relevancies intrinsic to it (Ibid.).

Schutz's theory applied to the 'context-aware actors' methodology

Summing up, Schutz's rather philosophical conceptions illuminate numerous important insights on what designers need to know about a cooperative work activity to decide whether or not it is possible for CAA to advance context awareness for the cooperative actors handling that activity.

First of all, Schutz's theory raise some important questions that designers need answers to when deciding what context information should be included in the CIRCA model on the three levels of abstraction. In general, knowledge has to be obtained about how the actors stock of knowledge and systems of relevancies are brought into play in a particular situation, typifying it in a particular way. In this matter, I will highlight the following questions of special importance:

1. In understanding the activity that the CIRCA model is defined relative to, it is important to distinguish between the 'in-order-to' and the 'because' motivational relevancies. 'In-order-to'

motives are important, as they reveal how the actions carried out by the actor relate to his 'paramount project at hand'. Gathering fragmented context information of topical relevance is thus carried out in-order-to obtain an understanding of the state of the CWS that is sufficient to act upon. Which is itself done in-order-to handle the activity that is being analysed by the CIRCA model. On the other hand the because motive explains why this paramount problem is established in the first place. As such, the 'because' motive reveals what 'triggers' the paramount project at hand.⁸

2. The 'because' motivational relevance furthermore determines both the limits up to which the actor have to follow the intrinsic interpretative relevancies in order to be satisfied. Hence the degree of certitude that the actor requires when he gives his assent to an understanding of a particular situation (Schutz 1970: 50) is determined by the because-motive of his activities.

3. The sum of fragmented context information that the actor uses when giving his assent to a particular understanding of a state of the CWS can be understood as the context information that is interpretatively relevant for making such an inference. Exploring how the actor gives his assent to a particular understanding of a state of the CWS thus includes exploring when an actor finds the sum of interpretative relevancies sufficiently complete to make an unequivocal interpretation. It also includes exploring when he needs to establish additional interpretative relevancies and how the actor chooses to establish these additional interpretative relevancies. Exploring how the totality of interpretative relevancies mutually ascribes meaning to each other is part of this question.⁹

4. Exploring what fragmented context-information is relevant for a particular activity, includes both to gather knowledge about what an actor finds topical relevant in a particular situation *as well as what parts of this topically relevant object or experience, that is interpretatively relevant*. This reveals the granularity of context information relevant to the problem at hand.

5. In exploring how the actor chooses to act based on particular states of the work setting, it is important to bear in mind that negative action is also an action in itself.

Schultz's theory also illuminate important insights to what should be known about a work activity to find out if the prerequisites can be met for defining a layered architecture that enable CAA to provide the context information that has shown relevant in a CIRCA analysis. These prerequisites are that relationships between the different layers in the architecture can be found in the work

⁸ It is important to emphasise that this because motive can be either spurious or genuine. Schutz argues that it is only the actor carrying out the particular task who is able to determine what is the genuine because-motive for his activities. (Schutz 1975: 38)

⁹ In this matter it is important to emphasise that the actor may also gather and use numerous interpretative relevancies when giving his assent to a particular understanding of a *fragmented* context information. I will explain this phenomena by referring to the argument that the delimitation of an activity is *recursive*. This means that the gathering of interpretative relevant material to give an assent to a particular understanding of a part of the CWS can be considered as an activity that is carried out in-order-to use this information in combination with other fragmented context information to obtain an understanding of the state of the CWS that is adequate to act upon. As will be shown in the analysis of the empirical workstudy, acknowledging this is important when defining CIRCA models for particular work activities.

setting that is at least to some extent unambiguous. And that information about these relationships plus what context information is relevant for handling a particular activity is *available* for the CAA. Exploring the extent to which these features are generic for the activity examined was important in this matter.

First of all it is important to explore the degree of certitude that the actor requires when giving his assent to an understanding of fragmented or adequate context information or a particular choice of action. The higher degree of certitude that the actor requires, the more important it is that relationships can be found in the work setting between the different layers in the architecture that are unambiguous. As mentioned, the degree of certitude required by the actor is determined by the because-motive of his activities.

Schutz's distinction between imposed and intrinsic relevancies is furthermore highly important in exploring if the two prerequisites can be met. Schutz's concept of *intrinsic* relevancies show us, that even the typification of experiences that an actor by a volitional act considers relevant, is determined by the system of relevancies intrinsic to a chosen interest. The intrinsicness of this system of relevance is why the typifications, functioning as a pre-interpreted understanding of the situation at hand, is not questioned unless there is a practical reason for it. Because of this, the typification of experiences of intrinsic relevance does not shift randomly, and is therefore to some extent generic for that particular problem at hand. In the same way the intrinsicness of the system of relevancies makes the relationship between a chosen interest and how the actor typifies it to some extent unambiguous. Knowledge about how the system of relevancies intrinsic to a particular problem at hand makes the actor always typify the experiences of intrinsic relevance in a particular way is thus important.

Furthermore Schutz concept of *imposed* relevancies show us that the actor does only rely on his stock of knowledge as long as no other relevancies are imposed upon him. This imposition is what makes the actor 'stop and think'. Because of this, if relevancies are imposed upon the actor, the generic typifications and unambiguous relationships that spring from the intrinsic relevancies is disturbed. However this does not mean that generic typifications and unambiguous relationships cannot be found when relevancies are imposed on the actor. This is because relevancies might impose on the actor in a way that makes the relevant fragmented, adequate context information as well as the unambiguous relationships that enable CAA to provide this information generic for that particular activity.

Thus knowledge about the extent to which relevancies are always imposed on the actor *in the same way* is also needed to decide what the possibilities are for defining a layered architecture. To explore this, it is necessary to examine *what imposes relevancies on the actor handling a particular activity*. Such knowledge is both useful in understanding the way that the actors currently use context information on the three different levels of abstraction. But also to find out if discrete context information *other* than the fragmented context information currently used by the cooperative actors is present that enable an association to be made between particular constellations of discrete context cues and a particular state of the CWS.

To my knowledge, Schutz's theory does not elaborate on exactly *how* the physical and social surroundings (In CSCW terms, the characteristics of the Field of Work and the Cooperative Work Arrangement) impose relevancies upon the actor. To further explore this important question, I will therefore turn to the last part of the theoretical grounding of this thesis: the CSCW researcher Kjeld Schmidt, who argues that *complexities in cooperative work* are what impose relevancies upon the actors in a CWS.

Complexity and imposed relevancies

In his paper 'Remarks on Complexity' (Schmidt 2002), Schmidt argues that it is valuable to base a systematic conceptualisation of the coordinative and integrative challenges of cooperative work on the concept of complexity. He argues that it is possible to conceive of cooperative work activities in *systemic* terms and defines complexity relative to the delimitation of the system as the *space of possible interactions* within this system (Schmidt 2002: 5). To delimitate the system as well as to define the metric of complexity within this system, Schmidt argues that "a system is always defined under a certain perspective and hence in terms of certain principles of abstraction, distinction, aggregation, and representation." (Ibid: 9). Following Schutz, the perspective under which to define the system and its metric of complexity cannot be defined in objective terms, but is always a *researchable* issue. "What must be investigated are the 'system of relevancies' and the practices that competent practitioners have developed and employ in their daily work. What the concept of complexity helps us to do in this context is to handle important systemic aspects of cooperative work, namely causal relationships, means/ends relationships, part/whole relationships, temporal order, etc., in short, what Schutz call 'imposed relevancies.'" (Ibid: 16).

In order to understand the constraints and interrelationships that a cooperative actor experience in carrying out his cooperative effort, Schmidt distinguishes between three different 'systems', each of them capable of being more or less complex. These are the three basic concepts within CSCW: the common field of work and the cooperative work arrangement, defined in chapter three. And articulation work, defined as the activities through which the cooperative work activities are coordinated and integrated (Ibid: 28). In short, articulation work is work to make cooperative work work.

In my comments to Schutz's theory of relevance, I argued that it lacks explanation to exactly *how* the physical and social surroundings impose relevancies upon the actor handling a particular work activity. By giving a suggestion to what influence the complexity of the three different systems, Schmidt illuminates this question. His suggestions to what makes the systems more or less complex can be seen as a conceptualisation of how these systems impose relevancies upon the cooperative actor. Analysing the complexities of the field of work, the already established cooperative work arrangement and the articulation work is thus important when analysing how the physical and social surroundings impose themselves as relevant upon the actor.

Complexities of the common field of work

Schmidt gives the following suggestion to what influences the complexity of the common field of work (Schmidt 2002: 21-23). The characteristics listed below are all sources of complexities because they add to the space of possible interactions within the system:

1. Structural sources of complexity

- Number of interacting elements
- Heterogeneity of the elements (are all the elements the same or do they possess different kinds of properties, behaviours)
- The number and intensity of interdependencies among elements
- The heterogeneity of interdependencies among elements
- The degree of freedom of the individual elements (i.e. the number of possible states that each element may take)
- The stability, operability and consistency of constraints

2. Intensity of interdependencies

- Tight vs. loose coupling (To what extent is the work time-critical)
- Rate of spontaneous changes in the field of work (i.e. changes not induced by actors). The extent that the actors are able to control the changes of the field of work
- Rate of propagation of state changes among elements of the system
- The irreversibility of changes
- The systems reactivity to induced changes from outside the system
- The frequency of interactions among elements

3. Apperceptive sources of complexity (uncertainty)

- Inadequacy of indicators or sensors with respect to the state of the field of work
- Inadequacy of effectors with respect to the state of the system (e.g. sluggishness)
- Inadequacy of available information
- Ambiguity
- Missing information
- Dubious information

Complexities of the cooperative work arrangement

The complexities of the cooperative work arrangement spring from the very constitution and reconstitution of the cooperative work arrangement itself, comprising the processes of reciprocal 'mapping' of interdependent activities onto interdependent actors and vice versa. The complexity of the cooperative work arrangement reflects the complexity of the field of work *as mediated* by a *particular configuration* of the cooperative work arrangement (Ibid: 23, original emphasis). Although a very interesting aspect of cooperative work, this thesis is not interested in how a particular mapping of activities to actors makes the cooperative work arrangement more or less

complex. The interest is limited to how the complexity of the field of work is reflected in an already established cooperative work arrangement and how the cooperative actors that make up the cooperative work arrangement handle this complexity. In other words, what is of interest is the need for articulation in the cooperative work activity and how the cooperative actors carry out this articulation.

Complexities of articulation work

The extent to which cooperative actors experience articulation work as complex depends on the extent to which the interdependencies of the cooperative effort transcend what Schmidt names the 'local practices' of those actors. Local practices are understood as the actors' knowledge of and familiarity with the structural and behavioural characteristics of the field of work (Schmidt 2002: 32). The reason why articulation work within the local practices of the cooperative actors is not experienced as complex is explained with reference to the concept of 'mutual awareness'. Mutual awareness covers those practices through which cooperative activities are somehow tacitly and unobtrusively articulated (Schmidt 2002b: 3). These practices are carried out 'seamlessly', hence not experienced as complex from the point of view of the cooperative actors.

Mutual awareness are carried out seamlessly in two different fashions, each of them bounded by the local practices of the cooperative actors: First, the competent actor is, within the scope of his local practices, able to make sense of and understand what his colleagues are doing, simply from observing the state of the field of work and the changes to it (Schmidt 2002:29). The actions of the co-workers are so to speak 'embodied' in the field of work and are to the actor, within his local practices immediately meaningful.

Secondly, mutual awareness includes *selective* and *active* monitoring and displaying. Actors modulate their activities to highlight and draw attention to those aspects of their activities that are important for their co-workers to know about. This is done by the use of mutually shared procedures, signs, signals, cues etc., all immediately meaningful to the actors within their local practices.

Schmidt's argument that in mutual awareness, "competent actors do not *infer*, they *see* the problems and intentions of their colleagues" (Schmidt 2002: 29) makes it reasonable to suggest that the extent to which the cooperative work activity can be articulated seamlessly equals the extent to which the actor is able to *typify* particular states of the field of work as particular problems and intentions of his colleagues. This suggestion implies that the situations where the interdependencies in the field of work transcend local practices is to be understood as the situations in which the actor need to gather additional interpretative relevancies in order to give his assent to an interpretation of the situation at hand.

As mutual awareness is limited by the actors' local practices, the more complex that the field of work and the cooperative work arrangement is, the more domain knowledge does the cooperative actors need to possess about the space of possible interactions within these systems to articulate their activities by mutual awareness. The complexity of the field of work and the cooperative work

arrangement is thus reflected in the complexities of articulation work, not directly but mediated by the local practices of the particular cooperative workers.

Schmidt's remarks applied to the 'context-aware actors' methodology

Schmidt's remarks on complexity are included in the thesis as a theoretical basis for exploring how the physical and social surroundings of a cooperative work activity impose relevancies upon the actor handling a particular cooperative activity. According to Schmidt, the *space of possible interactions* within the three different 'systems' common field of work, cooperative work arrangement and articulation work is what imposes relevancies on the actor handling a cooperative work activity.

Exploring the complexity in the field of work, including how this complexity is reflected in the way that the actors in the cooperative work arrangement articulate their activities, is thus one way to explore if the two prerequisites for defining a layered architecture can be met. Schmidt's suggestions to sources of complexity in the field of work is first of all a useful observation guide for exploring if unambiguous relationships can be found in the work setting that satisfy the prerequisite of unambiguousness between the different layers in the layered architecture. In the same way, an exploration of the complexities of the field of work can also illuminate if the fragmented, adequate and post-action context information that has shown relevant in a CIRCA analysis as well as the unambiguous relationships that enable CAA to provide this information are generic or transient features of the activity explored. This knowledge is needed to decide if the layered architecture can be defined once and for all, or if the user of the application should be enabled to make temporary or permanent additions to the layered architecture during his line of actions.

Finally, Schmidt's notion of mutual awareness, especially in the form of 'embodied actions' is key to understanding why it is not a prerequisite that the application need to measure the *same* discrete context information as the actor presently uses to provide context information on the three different levels of abstraction. As mentioned earlier, articulation by 'embodied actions' is possible because the competent actor, within the scope of his local practices, is able to make sense of and understand what his colleagues are doing simply from observing the state of the field of work and the changes to it. Referring to Schutz, that the actions of his colleagues are 'embodied' means that the actor typifies a particular characteristic of the *field of work* as an activity carried out by one of the actors in the *cooperative work arrangement*.

I suggest that in the same way, the competent actor might also be able to typify a particular characteristic of the field of work as a *different* characteristic of the field of work or a particular characteristic of the cooperative work arrangement as a characteristic of the field of work. Typifying information about one characteristic of the CWS as information about another characteristic of the CWS is possible if a to some extent unambiguous relationship between these two characteristics can be found in the structural and behavioural characteristics of the CWS. This interpretation of the 'embodied actions' approach is key to understanding how context-aware technologies might be used to provide context information on the three different levels of abstraction that has shown relevant for users in a CIRCA analysis of a particular activity.

Referring back to the three design challenges for CAA, such applications might make it easier for cooperative actors to gather fragmented context information that is presently difficult to obtain. Or they might provide fragmented context information in a way that enables cooperative actors to make an ‘at a glance’ comparison between the fragmented context information currently used. One way that CAA can aid the actors in this way is by *directly* measuring the context information, that the user currently considers relevant fragmented context information. If a CIRCA analysis has revealed that information about the location of particular elements in the field of work is relevant fragmented context information, location-based technologies are able to provide this information to users by *directly* measuring the location of these elements. However this opportunity to directly measure the fragmented context information considered relevant by the cooperative actors are far from always present. As an example, location-based technologies are not able to directly measure if a co-worker is working or not as all it can measure directly is the physical location of actors or artefacts. However, the competent actor might be able to *typify* the location of the co-worker as whether he is working or not if a to some extent unambiguous relationship between these two characteristics can be found in the structural and behavioural characteristics of the CWS. In this way, the possibilities for CAA to provide fragmented context information to the actors are *not* limited to what information that these applications can measure directly.

In this matter it is important to emphasise that when examining the extent to which unambiguous relationships can be found that enables CAA to provide context information other than it is able to measure directly, these relationships does not necessarily have to be defined one-to-one. As an example, the relationship between the location of a co-worker and whether or not he is working might be quite ambiguous, if he is able to do many other things than work in a particular location. However these ambiguities might be eliminated if the information about whether or not the co-worker is working is typified from information about both the location of the co-worker *and* e.g. the location of his tools.¹⁰ If this is the case, the application may provide this location information to the actor that, if knowledge about this unambiguous relationship is within the local practices of the actor, is able to typify it as whether or not the co-worker is working. The application may also, by using a framework similar to Gjellerens's layered architecture, itself associate the location of the co-worker and his tools with information about whether or not the co-worker is working, only presenting this associated information to the actor. In this way the CAA is enabled to provide exactly the same information as the actor currently obtains, but it infers this information *on another basis* than the actor currently does.

Apart from this, CAA may utilise *other* discrete context information than is currently used by the cooperative actors to infer the higher-level context information that has shown relevant in a CIRCA analysis of a particular activity. As mentioned earlier, the sum of fragmented context information that the actor finds relevant to the activity at hand can be understood as the sum of interpretatively relevant context information that the actor finds sufficient to give his assent to a particular

¹⁰ This approach is inspired from Schutz's description of how an actor may gather additional interpretative relevancies to give his assent to a particular understanding of the object of topical relevance with a higher degree of certitude.

understanding of the state of the CWS. Discrete context cues can however be available in the CWS that might serve as *better* interpretative relevancies because they stand in a more unambiguous relationship with the particular state of the CWS that is adequate for the actor to act upon. The actor however may not be able to utilise these discrete context cues for inferring a particular state of the CWS either because the information is not directly available to him or because it is available to him in a form that transcends his local practices. CAA may thus be able to measure these discrete context cues, making some of the fragmented context cues that the actor currently uses superfluous for inferring a particular state of the CWS.

5. Context awareness in construction work

Based on the remarks put forward on how context aware technology may be utilised to enable context aware actors, the remaining part of this thesis reports an empirical study of how workflow logistics is handled on a construction site. Even though it would be much appreciated if the findings of this study would be used to inform actual design of CAA, it is important to note that the primary goal with this study has been to try out in practice the methodological framework put forward in this thesis.

The empirical study is reported in two parts. The first part seeks to explore what context information is relevant for the actors when handling the activities by which workflow logistics is handled on the construction site and how this context information is used to decide how the activities should be handled. This is analysed by the use of the CIRCA model.

The second part seeks to explore if the prerequisites can be met for defining a 'layered architecture for discrete context information-based computation of adequate and post-action context information' that enables CAA to provide the context information that has shown relevant in the CIRCA – analysis.

In this part of the study I have found it rewarding to limit the examination to aspects of context that can be measured by one particular type of context-aware technology: Technologies that are able to provide information about the physical location of actors or objects, in short *location-aware technologies*. This type of technology is chosen because of my interest in 'Crossroads Copenhagen's' project B on 'Situation-based Mobile Services'¹¹, more particularly to the research proposal 'Location-Based Services in Industrial Settings' (LBSIS) for which the IT-University of Copenhagen is currently applying for funding.

Method

The construction industry was chosen as the work domain for my empirical study because I had the understanding that the geographical location of actors and artefacts has significance to actors on a construction site, as opposed to e.g. office work where the work largely consists in processing signs and signals. The significance of location in the work domain was important due to my interest in location-aware technologies. Apart from this, the construction industry was chosen because, to my knowledge, hardly any studies have been made of cooperative work on construction sites (With Heath and Luff's study of micro-mobility on construction sites as a noteworthy exception (Luff & Heath 1998)). Finally according to Anders Thomsen from 'Teknologisk Institut Danmark' (Technological Institute of Denmark), the construction industry has for many years been behind the industry in general when it comes to the uptake and utilisation of new technologies (Thomsen

¹¹ Crossroads Copenhagen is a professional network of public and private enterprises aimed at transforming Ørestad Nord in Copenhagen, Denmark into an international centre of development for culture, media and communications technology. (www.crossroadscopenhagen.com)

2003). Considering that the construction industry is one of the biggest industries in Denmark with an annual turnover in 2002 of 131, 5 billion DKr (Dansk Byggeri 2002), I found it highly interesting to explore the work on a construction site to comment on the potential for CAA in this work domain.

My original plan was to focus on how the material logistics in a particular building project was handled. Material logistics covers the coordination of how and when materials are ordered, arrive at the construction site, stored (if needed), assembled (if needed) and fitted into the building. I had an assumption that this activity would potentially be interesting to support by the use of location-aware technologies. This assumption was based on my understanding prior to the study that the flow of materials had to be coordinated due to limitations in storage space on the construction site and due to the fact that numerous different subcontractors, each responsible for their own contract, had to share this limited space.

However, early in my field studies I found out that although material logistics *is* an activity that is given priority in most building projects, it was not a priority in the particular building project that I have studied. This was due to characteristics of the particular building project that is described in annex 1.

As I didn't have time to find another case where material logistics was given higher priority, I decided to change the focus of my field studies to another aspect of logistics on the construction site that came to my attention early in the process: Workflow logistics¹². Workflow logistics covers the task of securing that the different pieces of work are done in the right order and on time. In other words workflow logistics is about allocating the different pieces of work to particular parts of the building in particular periods of time. The work activities analysed in this thesis are thus activities related to the handling of workflow logistics.

The choice of building project for the field study was made in collaboration with NCC Denmark (Nordic Construction Company). Contacts with NCC had already been established in the above-mentioned research project LBSIS and thanks to Kristian Billeskov Bøving (one of the researchers on the project), I was able to use these contacts to get access to a construction site. I wrote a short description of the field study that I wanted to pursue, including some ideal criteria that NCC could take into consideration when choosing a construction site for me to study (see annex 2). These criteria were that the building project should be of such a size that handling the flow of materials would be necessary; that the building project was advanced to an extent where several different subcontractors was working on the site at the same time; and that the construction site was situated near Copenhagen. Based on these criteria NCC chose the construction of a new ferry terminal in the Port of Copenhagen as the case for my field study. This building project fitted all the above-mentioned ideal criteria, but as mentioned earlier these criteria turned out to be insufficient to ensure that handling the flow of materials would be important and time-consuming.

¹² The distinction between material logistics and workflow logistics is a distinction that the people I have interviewed from NCC make themselves.

Methodology

The data collection has been made by the use of a combination of literature studies, interviews and observations. In total I have spend 16 days collecting data on the construction site, throughout a two month period from late November 2003 to late January 2004.

As my knowledge about the construction industry was almost non-existing prior to the study, I started out by reading some basic books about construction work in general and the handling of logistics in particular (Fonseca & Menne-Thomsen 1995, Clausen 1995, Walløe & Haugaard 2001, Bygge & Boligstyrelsen 1993). These literature studies were a great help in specifying the focus for my study, including the ideal criteria for choosing a specific building project. But the knowledge obtained from these studies was also helpful during the actual fieldwork, as it saved me from using valuable interview time on very basic questions about the construction process. I am also convinced that knowing just some basic things about the building process has helped to prevent the workers on the construction site to categorise me as an academic with a know-all attitude - something I was quite concerned about prior to the study.

The actual fieldwork was carried out in two stages. The first part of the fieldwork included thirteen days/ 49 hours of observations and interviews and had as a primary focus to get a general understanding of the work setting and particularly how material- and workflow logistics were handled on the construction site. This included exploring the activities by which material- and workflow logistics were handled on the construction site, who had the responsibility for handling these activities, what context information was relevant for these actors to handle these activities and how this information was used. Information that should enable me to define CIRCA models for the activities related to workflow logistics.

Interviews and observations were made with the persons from the NCC control unit who were responsible for the overall handling of material- and workflow logistics in the building project. A civil engineer from the subcontractor who was responsible for the making of the front of the building was also interviewed three times to explore the relationship between NCC and the different subcontractors with regards to the handling of material logistics. The findings from these interviews are however not reported in this thesis.

The second part of the fieldwork had as a primary focus to explore if unambiguous relationships could be found between the location of actors and artefacts in the CWS and context information relevant for handling one of the activities related to workflow logistics. This part included 3 full days/ 24 hours of observation and interviews and focused on if the location of actors and artefacts from one of the subcontractors on the construction site could be used as indicators of how far the work of this subcontractor had progressed.

My data includes pictures, transcripts of formal interviews, field notes and various charts, drawings and other document resources used on the construction site¹³

¹³ If supervisor or external examiner want to see this data, please contact me

The building project – ‘project ferry’

In the following I will start out by giving a short description of the building project that I have been studying. After this, the analysis of how workflow logistics are handled by the NCC control unit is presented.

Project ferry is the official name for the building project that I have been following during my fieldwork – the construction of a new ferry terminal in the Port of Copenhagen serving ferries going to Norway and Poland. The building owner in project ferry is the Port of Copenhagen and the project comprises the construction of two buildings: A passenger terminal and a control building. The construction of the two buildings started in February 2003 and is expected to end in May 2004. The total cost of the buildings is approximately 90 million DKr.

The passenger terminal is 165m long, 10m wide and three storeys high (including the ground floor) with a total of 4500 m² of floor space. The ground floor of the terminal serves as a warehouse for supplies to the ferries. The first floor facilitates ticket sales, customs, a small supermarket and waiting rooms. The second floor facilitates passport control and office space for 60 persons.

The control building is two oblong one-storey buildings connected by a big roof, adding an extra 774 m² of roofed space to the 900 m² of floor space. The control building facilitates car-check in, cargo-office, storage space and facilities for spot-checking of both cargo and passengers.

Apart from the construction of the two buildings, project ferry also includes the layout of ground space for containers as well as a deployment area for the passengers travelling with the ferries by car. This makes the size of the construction site a total of app. 6000 m². Compared to the ground size of the two buildings, the site is much larger than a common construction site.

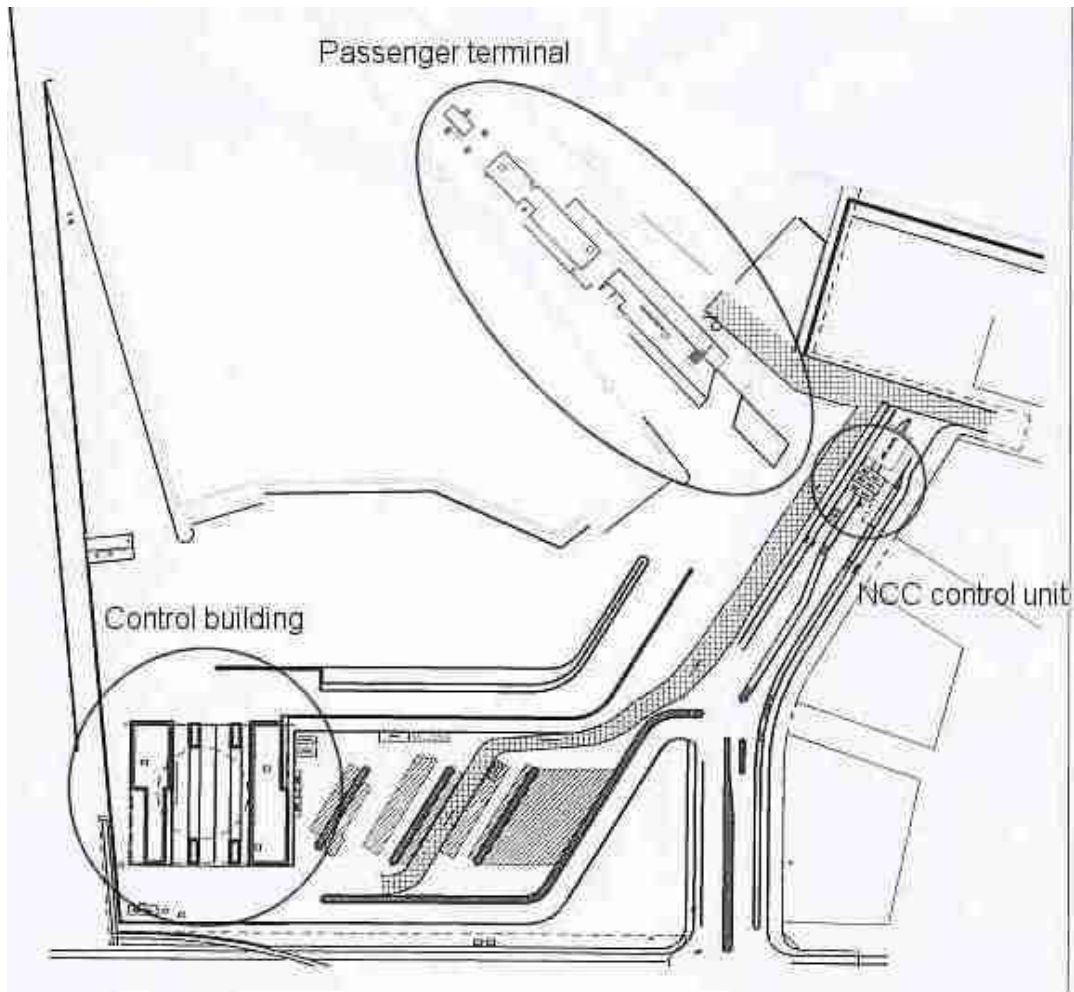


Figure 5: Overview of the construction site

Project ferry is carried out as two all-inclusive contracts. One for the construction of the two buildings¹⁴; and one for the surfacing work of the outdoor areas (including the container storage and deployment area) plus the underground infrastructure (piping systems, cabling, heating, telecommunications etc)¹⁵. NCC has signed the former contract and MT Højgaard has signed the latter. The field study reported here has only focused on the construction work related to one of these contracts: NCC's contract for the construction of the two buildings.

¹⁴ In danish: Byggeenterprisen

¹⁵ In danish: Anlægsenterprisen

The work organisation in project ferry

In project ferry, the formal responsibilities related to the construction of the buildings are organised as illustrated in figure six:

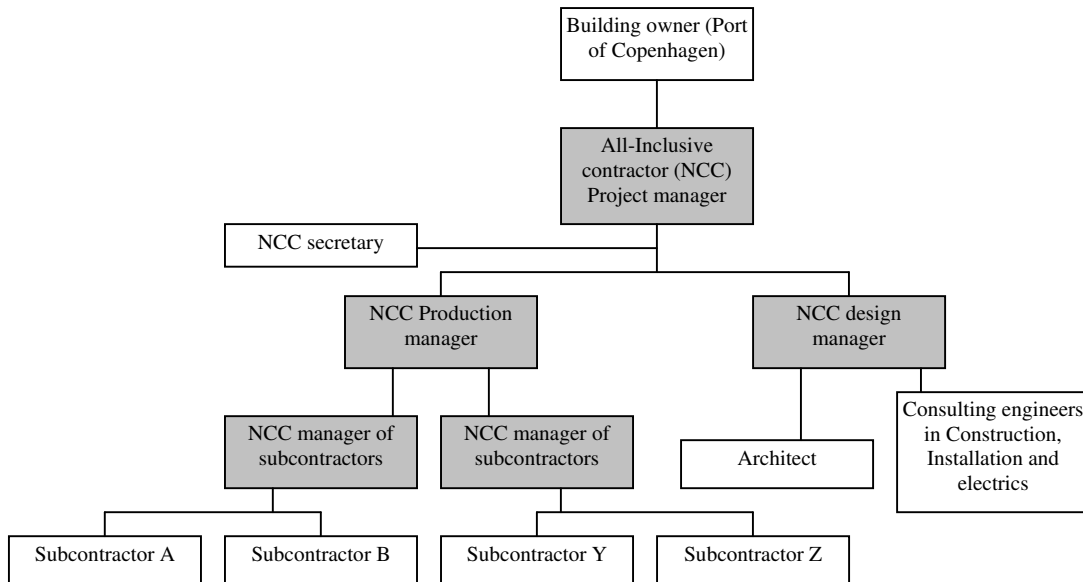


Figure 6: Organisation chart of project ferry. The boxes marked with grey are part of the NCC control unit.

Carrying out the building project as an all-inclusive contract implies that NCC is both responsible for designing the buildings based on some more or less specific parameters given by the Port of Copenhagen as well as building them. This however does not mean that NCC is pursuing all the designing and building on its own. On the contrary NCC is merely functioning as a *control unit* that is responsible for hiring the subcontractors, architects and consulting engineers necessary for carrying out the building project. NCC is also responsible for coordinating and planning the work of all the different actors during the building project so that they are doing their job in accordance with the design, in the right order and on time. The number of subcontractors present at the construction site differs throughout the building process from only one when the foundations are being made to around fifteen.

The NCC control unit comprises four persons including a trainee. In figure six, the boxes marked with grey are the responsibilities of the NCC control unit.

The *project manager* has the overall responsibility for the building project, which means that he is the link between the building owner and the daily work on the construction site. The person who is the project manager also takes the role of the *design manager* whose responsibility is to make sure that all questions related to the design of the building is settled by the architect and the consulting engineers. The *production manager* has the overall responsibility for the economy of the construction of the buildings on the construction site. And finally the *managers of subcontractors* are responsible for the overall coordination of the work of the individual subcontractors, including handling the day-to-day problems that might prevent the subcontractors from carrying out their

work.¹⁶ As such, it is the managers of subcontractors who are responsible for the workflow logistics on project ferry. As the number of subcontractors varies throughout the building process, the number of subcontractors that each of the managers of subcontractors is responsible for differs. Finally, the trainee helps the others out with their tasks.

According to the project manager, having a control unit whose responsibility is to coordinate the work of all the different subcontractors is characteristic for almost all building projects where NCC acts as an all-inclusive contractor.

Workflow logistics on project ferry

As mentioned earlier, workflow logistics covers the task of securing that the different pieces of work are done in the right order and on time. In other words workflow logistics includes allocating the different pieces of work of the different subcontractors to particular parts of the building in a particular time-period of the building project. The handling of workflow logistics is the responsibility of the NCC control unit and is primarily carried out by the managers of subcontractors.

Workflow logistics are important for two different reasons. First of all, there is a *sequential dependency* in the construction of a building. An obvious example of this is that the concrete walls have to be poured before the electrician can mill the cables into the walls.

Apart from this sequential dependency, *spatial dependency* is also an issue that makes workflow logistics an important issue in a building project like project ferry. Spatial dependency arises because the number of workmen, materials and equipment that can be situated in a particular part of the building at a particular time is limited by the available space. An example of this is that even though both the plumbing and heating, the ventilation and the electricity can be fitted as soon as the raw concrete ceiling is finished, if all three subcontractors responsible for this work carried it out in a particular part of the building at the same time, their people, materials and equipment would be in the way of each other. Using the words of Schutz, the spatial and sequential dependencies in the construction of a building is thus the because-motivational relevance for handling the workflow logistics in the building project.

To describe how the cooperative task of handling the workflow logistics in project ferry is handled, I will start by defining the field of work and the cooperative work arrangement for this activity.

Field of work and cooperative work arrangement

The delimitation of the field of work for the task of handling the workflow logistics on project ferry has to be relative to a particular point in time, as the field of work changes constantly in time with the progress of the building process. At a particular time in the building process, the field of work is made up of the construction site including the buildings under construction, the building materials, the equipment for assembling and fitting and the workmen working on the buildings. But also materials, workmen of present and new subcontractors, equipment and the suppliers of these that is

¹⁶ The person who is the production manager also takes the role of one of the managers of subcontractor.

going to be used on the site *in the future*, but has to be checked for delivery at the particular time in the building process, is part of the field of work. This is because this checking is part of securing the workflow logistics.

In my opinion the field of work in construction work is quite unique in the sense that the construction of a building is one long process from the first turf is cut to the finished building – a process that is only carried out once. Other cases like e.g. Heath and Luff's (1992) study of London Underground or Schmidt's (2000) study of the Danish Steel Work Ltd show that even though the field of work is constantly changing, those changes are still happening within an overall fixed process that is repeated again and again (keeping the Bakerloo Line running or processing a unit of scrap iron into quality steel).

The cooperative work arrangement for the task of handling the workflow logistics on project ferry includes the four persons in the NCC control unit (including the trainee), the foremen of the different subcontracts working on the site and the clerk of work¹⁷ for the subcontractors who has signed such a person.

The foreman of a subcontract is the workman of the gang that is responsible for the day-to-day planning of the work that is carried out by that subcontractor. The foreman is present at the construction site every day, as he is only working on one building project at the time. Apart from planning the day-to-day work, the foreman is also responsible for carrying out ordinary workmanship like the rest of the gang. The bigger the subcontract, the more time the foreman spends on planning.

The clerk of work on the other hand is responsible for informing NCC about aspects in the field of work that is a potential hindrance for the ongoing work of the subcontract he is responsible for and about how many men the subcontractor has on site and if he is going to man up (hire more workmen than planned) or down (send some of the workmen home). Although the clerk of work has the formal responsibility for informing NCC about the issues mentioned above, in *discovering and deciding* on these issues he is very dependent on his foreman's knowledge about the present state of the work activities on the construction site. This is because one clerk of work has the responsibility for many construction sites at a time and is thus, contrary to the foreman, not on the individual construction site every day to follow the work of his own and other subcontracts. Only the bigger subcontractors operate with a clerk of work. For the smaller contractors, the foremen handle the tasks of the clerk of work.

Planning the workflow prior to the building process – the time plan

That construction work is quite unique as it takes the form of just one long process that is only repeated once does not mean that the workflow of the building process is planned ad hoc throughout the building process. On the contrary, in project ferry like in virtually all building projects today, an overall *time plan* is made stating when all the different pieces of work that make up the construction of the buildings is going to be carried out as well as who has the responsibility for carrying them

¹⁷ In danish: Konduktør

out. In project ferry, one time plan is made for each of the two buildings. The NCC control unit makes the first version of this time plan even before contracts have been signed with the different subcontractors. By using their experience from other building projects, NCC makes a rough estimate of what work is needed for the construction of each of the buildings as well as how long time this work should take. These estimates are then sent to a line of subcontractors who then puts in an offer for a contract. The subcontractors who win the contracts then discuss potential problems with the first version of the time plan with NCC. Based on these discussions, NCC draw up an overall time plan that serves as the primary management tool for handling the workflow logistics throughout the building process.

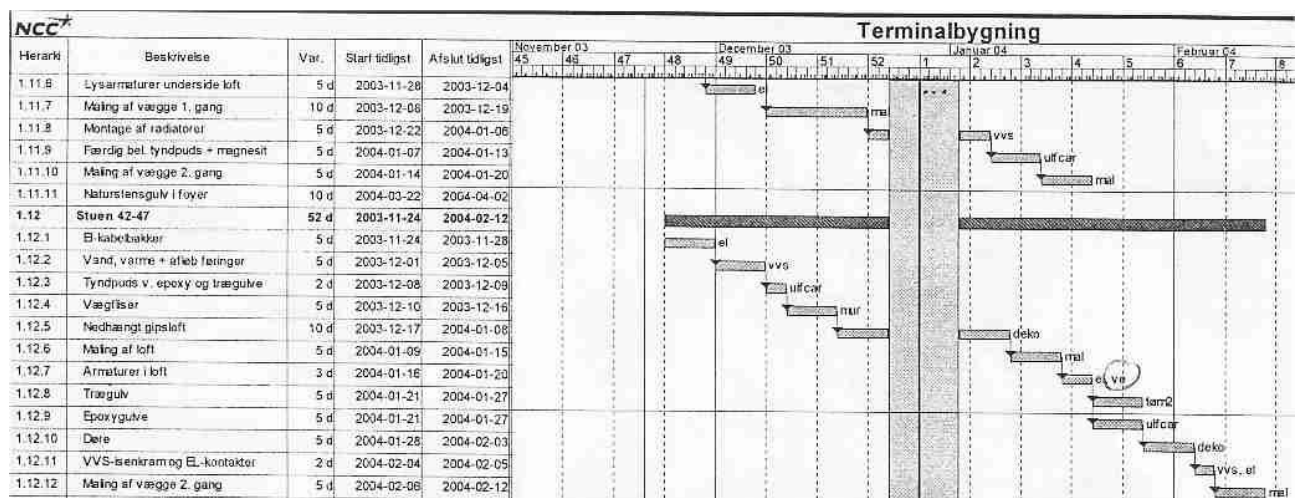


Figure 7: The time plan specifying the workflow for the construction of the passenger terminal

The time plan is a Gantt chart with time (divided into days) on the horizontal axis and the description of the different parts of the construction of the building on the vertical axis. The vertical axis is divided into two levels: *Activities* and *work*¹⁸.

The construction of the ferry terminal is first of all divided into 32 activities, each covering a part of the building. The activities that cover the indoor parts of the terminal are delimited by the spatial division of the building. Vertically the building is divided according to the three storeys of the building. And horizontally the building is divided based on some *modular lines*¹⁹ that divides the building lengthwise and across. These lines are drawn on the *architect drawings* of each of the three storeys of the passenger terminal. In the architect drawings, the modular lines lengthwise are marked with numbers from 1 to 55 and the distance between them is 3000 mm. The modular lines across are marked with letters from A-D. The distance between them differs from 5400mm to 8400mm to 4200mm. In total, the first and the second floor of the terminal are each divided into three activities, one from modular line 1-13, one from modular line 13-40 and one from modular line 41-55. The ground floor is divided into two activities, one from modular line 42-47 and one for the rest.

¹⁸ In Danish: Aktiviteter og arbejder

¹⁹ In Danish: Modullinier

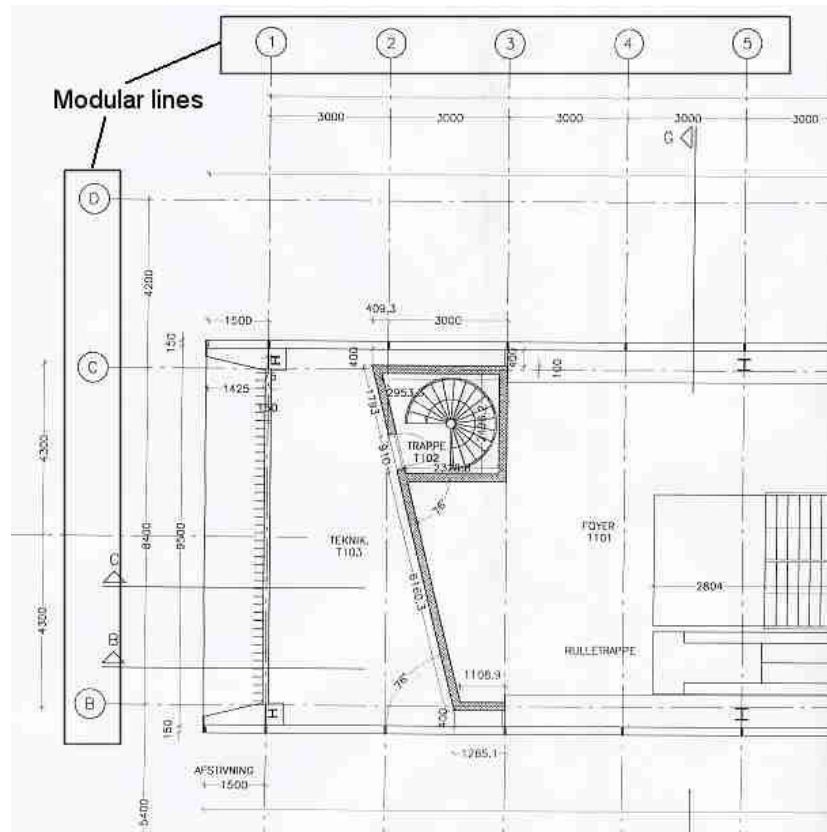


Figure 8: The architect drawing, the modular lines are marked with boxes

According to NCC, the oblong shape of the terminal has made the planning of the workflow easier than in a standard building project, as the different subcontractors can work staggered both horizontally and vertically. In more compact buildings the different subcontractors are only able to work staggered vertically according to the different storeys of the building. Some activities are not delimited horizontally or vertically but simply by the type of work. The making of e.g. the roof or the front of the building is each just one activity that is not divided according to the modular lines.

Each of the activities is furthermore divided into a number of *work*. Work are all the separate operations that are necessary to complete an activity. As an example, the activity '1st floor modular line 40-55' includes 19 different work that has to be carried out in a particular order. These work are indicated on the vertical axis of the time plan beneath the activity they are part of. The internal dependencies between the work are marked with arrows in the time plan. The initials of the subcontractor responsible for a particular piece of work is written on the time plan next to the horizontal line that indicates when the work is going to be carried out.

The division of an activity into work is made from knowledge about the internal dependencies in the work needed for carrying out the activity. In every case where internal dependencies in the work necessary to complete an activity requires this work to be carried out in a particular order, the activity is divided into work according to these dependencies. Or in more general terms, the higher degree of spatial and sequential dependency, the more work are the activity divided into. Thus, the

way that the different activities are divided into work in the time plan can be seen as an expression of NCC's estimate of the internal dependencies in the work needed for carrying out those activities²⁰.

The making of the time plan prior to the actual building process is without doubt a very important part of handling the workflow logistics in the building project. However no matter how experienced the persons who makes the time plan are, they will never be able to clarify all the different dependencies in the building process even before it starts. Nor can they be sure that the building process will automatically follow the time plan. A great part of the daily work of the NCC control unit is thus to make sure that work is able to proceed according to the time plan and that the time plan reflects the internal dependencies in the making of the building. How the NCC control unit secures the workflow logistics throughout the building process is described in the following.

Managing the workflow logistics throughout the building process

As mentioned, the overall objective of managing the workflow logistics throughout the building process is to make sure that the work on the construction site is coordinated so that the individual work are carried out in the right order and on time. This prevents the building process from taking more time than NCC has committed to in their all-inclusive contract or is unnecessarily expensive for NCC.

In the following, I will give a general description of the four main activities that has shown important in the management of the workflow logistics in project ferry. After this description, the use of contextual information within one of these activities will be analysed by the use of the CIRCA model.

Four activities in the management of workflow logistics in project ferry

In delimitating the activities by which workflow logistics is handled in project ferry, Schutz's concept of in-order-to motivational relevancies has been useful. Currently NCC carries out a number of different activities on the construction site related to workflow logistics. Such activities are meetings with subcontractors, telephone calls, informal conversations, e-mail correspondence, walks around the construction site and so forth. However it is important not to mistake these activities for the activities that these are carried out *in-order-to* handle. These overall activities are what designers of CAA should aim to support. To my knowledge, the four activities presented below are the overall activities by which workflow logistics is handled in project ferry

1. Checking how the present state of the building activities relate to the time plan

First of all, NCC need to check how the present state of the building activities relate to the time plan to see if the activities are running according to the plan, behind or even ahead of the plan. This is

²⁰ Dividing the time plan into activities and work is a standard that is also described in textbooks for the different building trades (Fonseca & Menne-Thomsen 1995: 126-131)

important because delays in some of the work specified in the time plan may cause the time plan (i.e. the coordination of the spatial and sequential dependencies in the forthcoming work) to slip. Checking if the work are behind schedule is also important because the workmen of the different subcontractors arrive on the construction site according to the time plan. If the work are running late, this might prevent the preconditions for the forthcoming work to be settled on the date specified in the time plan. Thus if the subcontractors who are responsible for these forthcoming work are not informed about these delays, they will arrive on the construction site without being able to start their work. On the contrary, if the work are ahead of the time plan, then NCC might examine the opportunity for the following work to start a few days earlier than planned, saving some valuable time.

2. Securing that the work carried out is made in accordance with the design

Apart from checking whether or not the building activities are running behind schedule, NCC also need to secure that the work is made in accordance with the design made by the architects and consulting engineers. The activity of securing that the work is made in accordance with the design is called *quality control* and is actually an activity in its own right that NCC is also responsible for. However, work that doesn't satisfy the design might also cause the planned workflow of the forthcoming work in the building process to be disturbed. This happens if the work already made is so unsatisfactory, that it has to be redone. This of course causes delays.

But also the cases where the architects accept deviations from the design and consulting engineers might disturb the planned workflow. This is because the planning of the forthcoming work is based on the assumption that the previous work is made according to the design. This implies that it might not be possible to carry out the forthcoming work as planned if the previous work is not made according to the design.

3. Checking whether or not the workflow specified in the time plan is the most efficient way of coordinating the spatial and sequential dependencies in the forthcoming work

As described earlier, in making the time plan NCC seeks to coordinate the spatial and sequential dependencies in the work needed to carry out the building project. The time plan thus acts as a coordination mechanism articulating the cooperative work activity of constructing the buildings. However as the time plan is made before the building process has even started, it is inevitable that during the building process, some spatial or sequential dependencies in the construction work will occur that is not coordinated by simply following the time plan. Some parts of the work may simply not be included in the time plan at all. Or the amount of time assigned to each of these work might not be sufficient for carrying out the work. Furthermore the delimitation of the individual work in the time plan is quite coarse with some of the larger work taking 10-15 working days with up to 15 men working at a time. This also makes the time plan insufficient for coordinating smaller dependencies e.g. if one subcontractor need to occupy a part of the construction site for a few hours where another subcontractor is currently working.

Finally, in some situations the quite coarse delimitation of the work in the time plan makes the flow of the individual work specified in the time plan less efficient than it could be. Quite often, two

work that, according to the time plan, has to follow each other might partially be able to be carried out at the same time in the same part of the building delimited in the time plan. NCC thus also needs to keep an eye open to take advantage of such possibilities.

4. Managing dependencies within the work of the individual subcontractors that influence whether or not the work is able to proceed according to the time plan

Apart from the spatial and sequential dependencies *between* the different subcontractors that the time plan seeks to coordinate, relevancies also impose themselves within the work of the *individual* subcontractors. First the design of the work that the subcontractor is to carry out has to be settled by the architects and consulting engineers as the design prescribes how the work should be carried out. Second the materials needed to complete the work have to be available on the construction site when the work is about to start. The second condition is, according to NCC, formally the responsibility of the subcontractor, but as delays caused by missing materials causes a lot of extra coordination work for NCC, NCC considers checking that critical loads of materials can be delivered on time part of their job.

Handling the activity of checking how the present state of the building activities relates to the time plan

In the following I will analyse in more detail how one of the four activities described above is handled by the NCC control unit. The activity analysed is checking how the present state of the building activities relates to the time plan. The first part of the analysis will include an examination of what fragmented contextual information is used by NCC when carrying out this activity, as well as how this fragmented context information is used to delimitate particular states of the CWS. It will also be examined what NCC's choices of action are given their understanding of different states of the CWS.

The second part of the analysis will sum up this examination of context information usage by completing a CIRCA model for the activity of checking how the present state of the building activities relates to the time plan. This part of the analysis will also reflect on the usefulness of the CIRCA model as an analytical tool.

Information usage

To check how the present state of the building activities relate to the time plan, NCC first of all need information about how far the work specified in the time plan have progressed as well as how far these work *should* have progressed to enable the work to be completed on the dates specified in the time plan.

Information about how far the work have progressed is readily available in a materialised form in the actual building under construction. This means that NCC can obtain this information simply by looking at the building under construction. As most of the activities in the time plan are delimited by the spatial division of the building, the time plan also gives directions to where in the building the work listed in the time plan are carried out. NCC has access to this materialised information first of all simply by looking out of the window from their office on the construction site. This view is

however only a very general one as all the small details of the building cannot be seen and because only a part of the building is visible from the office windows.



Figure 9: The view from NCC's office on the construction site

NCC obtains more detailed information about how far the work specified in the time plan have progressed by walking around the construction site. The frequency with which such rounds are made differs quite a lot between the two managers of the subcontractors in project ferry. One of them makes such a round almost every day and the other does it quite rarely, because he finds it quite time-consuming.

Even though NCC, simply by looking at the buildings under construction, can get an idea of how far the work have progressed, aligning this information with information about how the activities are *planned* to progress is trickier. This is because the time plan made by NCC is not fine-grained enough to tell how far a particular work should have proceeded on a particular day. Neither does the time plan state in detail what work the individual work includes. Taking the construction of the front of the building as an example, the only information that NCC can obtain from the time plan is that work 'front of the building, 1st and 2nd floor, modular line 1-13' should start on day A and finish on day B. What work is included in the construction of the front of the building on the first and second floor in the part of the building delimited by the modular lines 1-13, as well as how it is going to be carried out is not planned by NCC. NCC is only responsible for planning when the individual work are going to start and end.

Because of the very coarse granularity of the time plan, walking around the construction site aligning information about how far the work have progressed with the time plan only gives NCC a

rough idea of whether or not the activities are running according to the plan. For a more precise picture of this, NCC need more detailed information about what is included in carrying out a particular work as well as how it is planned to be carried out. NCC obtains this information from the foremen of the different subcontracts. The foremen are responsible for planning in detail how the particular work are to be carried out. They are also responsible for the day-to-day planning of the work of their own subcontract on the construction site. This enables them to give qualified information about whether or not their work is progressing according to NCC's time plan.

Obtaining this information from the foremen is done on the weekly *Lean Construction meeting*.²¹ At the Lean Construction meeting the foremen of all the different subcontracts working on the construction site and one or two persons from NCC take a round on the construction site together. On this round they discuss how the activities that is going to be carried out the following five to ten working days should progress while being situated right next to these activities. Thus the progress of the activities in a particular room of the building is discussed while all the foremen and NCC is situated in that particular room. Detailed context information about the present state of the activities that are discussed is thus readily available to the people attending the Lean Construction meeting.

During these meetings, NCC carries along three different sources of information:

- A *five-week time plan* that is an extract of the overall time plan, only showing the work that is going to be carried out for the next five weeks. This makes it easier for NCC to get an at a glance overview of what work that have to be checked.
- The architect drawings, showing a 'from the top' overview of how each of the floors in the building should be constructed
- The minutes of last weeks lean construction meeting, summing up what work the individual subcontractors have committed to as well as the hindrances for the forthcoming work discussed at the meeting last week.

When situated in a particular part of the building, the persons from NCC runs through the five-week time plan asking the different foremen how far the work have progressed; when they are about to be finished; what potential hindrances there might be for the further progress of these work; and what the consequences are if one of more work are delayed. The individual subcontractors planning in detail of their forthcoming work is also coordinated on these meetings. In each part of the building, NCC also runs through the minutes of the last lean construction meeting to check if the delays, problems etc. revealed and discussed at the last meeting have been solved. If they haven't they are transferred to the minutes of the present meeting. Delays, problems etc. revealed in the present meeting are also written down in the minutes.

²¹ Lean Construction is an all-inclusive framework to project management of construction projects that is described on www.leanconstruction.org. However, the only thing from this framework that NCC has applied to 'project ferry' is the weekly Lean Construction meeting that is in fact just a traditional foremen meeting except from the fact that the meeting takes the form of a tour around the buildings.

As such, the Lean Construction meetings are central for NCC in gathering information, not just about how the present state of the building activities relate to the time plan, but also information relevant to the other three activities by which workflow logistics is handled on project ferry.

Looking at how this fragmented context information is used by NCC to infer an understanding of the present state of the CWS that is adequate to act upon as well as what NCC's choices of action are given particular states of the CWS, the overall role of NCC is *not* to give solutions to all the problems related to workflow logistics that may occur throughout the building process. Rather NCC takes the role of a *process coordinator* responsible for creating a setting where the foremen of the subcontracts are able to get together and discuss whatever problems might be a hindrance for the workflow in the building project. Because of this, in general NCC doesn't use fragmented context information to decide on a solution in the situations when the activities are not running according to the time plan. Rather NCC uses the context information to assess whose expertise should be utilised to assess the consequences of the activities not running according to the plan as well as how these consequences are most appropriately handled.

In the three Lean Construction meetings that I have attended, NCC has based their choices of action on the following distinctions between different states of the CWS:

- If all the work are running according to the time plan, then obviously no action is required to secure that the work are running according to the plan.
- If one of the work is running behind, NCC asks the foreman of the subcontract responsible for the particular piece of work if the work is able to catch up or not. If the work is undoubtedly able to catch up, then it is written down in the minutes that the subcontractor has agreed on catching up. If the work only has a fair chance to catch up, NCC asks the foremen of the other subcontracts how their forthcoming work is affected if the delayed work is not caught up. If the impact of the forthcoming work is extensive, NCC walks down to the part of the construction site where the delayed work is carried out a couple of times during the following week to keep an eye on how the delayed work is catching up.
- If the delayed work is not able to catch up, NCC asks the foremen of the subcontracts responsible for the work following the delayed work how this delay may influence the forthcoming work. If the forthcoming work are affected by the delay, the foremen whose work are influenced by the delay then discuss possible solutions to how the consequences of the delay can be handled. An example of such a solution is to agree that the forthcoming subcontractor starts X days later than planned. Another example is that the forthcoming work starts on the date specified in the time plan even though the delayed work hasn't yet been finished. As the foremen of *all* the subcontracts on the construction site are overhearing this conversation, they are able to join the discussion if the delay, or the possible solutions to the delay, influences their forthcoming work even though it is not stated in the time plan. If the consequences of the delay are quite extensive NCC might ask the foreman of

the delayed work if NCC should hire some external workmen to enable the delayed work to catch up so that the time plan doesn't slip.

The information usage analysed by the CIRCA model

In the following I will sum up the context-information usage within the activity of securing that the work activities are progressing according to the time plan by completing a CIRCA model for this activity. As described in detail in chapter three, the CIRCA model distinguishes between three different levels of abstraction that context information might serve as relevant resources for cooperative actors: Fragmented, adequate and post-action context information, defined as below:

Level 1: Fragmented context information	Each fragmented context information is relevant to the activity at hand, but is not in itself adequate to act upon
Level 2: Adequate context information	The understanding of the state of the cooperative work setting that the actor finds adequate to act upon
Level 3: Post-action context information	The choice of action that has been carried out to change the state of the field of work in a way that is found appropriate to handle the particular activity examined.

Figure 1: the CIRCA model - Three different levels of abstraction that context-information might serve as resources for cooperative actors.

Interestingly, using the CIRCA model to analyse the activity of securing that the work are progressing according to the time plan reveals, that the distinction between the three levels of abstractions is not sufficient when analysing the way that NCC handles this activity. Or to be more precise, *distinguishing* between the three levels of abstraction seems to be valid, but *delimitating* the different states of the CWS (and hence also the sum of fragmented context information that the adequate context information describing these states is inferred from, as well as the choice of action found appropriate given this adequate context information) is done with different *degrees of specificity* by NCC when handling the activity of securing that the work are progressing according to the time plan. Taking a closer look at the states of the CWS that NCC distinguishes between when handling this activity, there seems to be a hierarchy in the way that these states of the CWS are delimited:

Very generally, NCC distinguishes between different states of the CWS according to whether or not the work are progressing according to the time plan.²²

1. The work are progressing according to the time plan
2. One or more work are running late

²² I have not included the state of the cooperative work setting 'activities are ahead of time' in the analysis. This is because I haven't experienced situations where this has been the case.

In the situations where one or more of the work are running late, NCC further distinguishes between three different states of the CWS according to whether or not the work running late are able to catch up:

- 2.1 One or more work are running late, but the work are undoubtedly able to catch up
- 2.2 One or more work are running late, but the work have a fair chance to catch up
- 2.3 One or more work are running late, and the work are not able to catch up

Finally in the situations where the work running late have a fair chance to catch up or are not able to catch up, NCC makes even more specific distinctions between different states of the cooperative work arrangement. In both situation 2.2 and 2.3, this distinction is made according to how the workflow of the forthcoming work are affected if the delay is not caught up:

- 2.2.1 One or more work are running late, the work have a fair chance to catch up; the forthcoming work are not affected if the delay is not caught up.
- 2.2.2 One or more work are running late, the work have a fair chance to catch up, the forthcoming work are affected if the delay is not caught up, but the subcontractors responsible for the forthcoming work are able to find a solution to the problems caused by the potential delay, making the consequences of the delay minor.
- 2.2.3 One or more work are running late, the work have a fair chance to catch up, the forthcoming work are affected if the delay is not caught up, and the subcontractors responsible for the forthcoming work are not able to find a solution to the problems caused by the potential delay, making the consequences of the delay extensive.
- 2.3.1 One or more work are running late, the work are not able to catch up; the forthcoming work are not affected by the delay.
- 2.3.2 One or more work are running late, the work are not able to catch up, the forthcoming work are affected by the delay, but the subcontractors responsible for the forthcoming work are able to find a solution to the problems caused by the delay, making the consequences of the delay minor.
- 2.3.3 One or more work are running late, the work are not able to catch up, the forthcoming work are affected by the delay, and the subcontractors responsible for the forthcoming work are not able to find a solution to the problems caused by the delay, making the consequences of the delay extensive.

As illustrated above, the very general distinction that NCC makes between two states of the CWS (whether the work are progressing according to the time plan or are running late) is further divided into more specifically defined states. What is interesting though is that a more specific delimitation of the different states of the CWS is only needed given *one* of the two general states of the CWS. In the situations when the work are progressing according to the time plan, no further information

about the state of the CWS is needed to decide on what choice of action (simply not to act) is most appropriate to secure that the work are running according to the time plan.

On the contrary in the situations when the work are running late, a more detailed understanding of the state of the CWS is needed to decide how the delay is most appropriately handled. Because of this, when NCC has obtained the 'adequate' context information that one or more work are running late, they do *not* decide on how this delay is most appropriately handled. Not because referring from acting is considered the most appropriate way of handling this delay, but because this general understanding of the state of the CWS is not sufficiently detailed to act upon. NCC thus *initiates a further exploration of the state of the CWS* so that an understanding of the CWS detailed enough to act upon can be obtained.

Further exploring the state of the CWS to obtain a more detailed understanding of it can thus be considered a choice of action in itself that is triggered by the 'adequate' context information that one or more work are running late. The context information that one or more work are running late is thus not adequate to decide how the delay should be handled, but adequate to decide that a further exploration of the state of the CWS is needed to find out how the delay should be handled.

The fact that the degree of specificity with which the state of the CWS need to be defined differs makes me suggest that the general activity of securing that the work are progressing according to the time plan should not be analysed by only one CIRCA model. If the choice of action that spring from *some* but not *all* the states of the CWS defined with particular level of specificity is to get a more detailed understanding of the CWS, a separate CIRCA model should be defined analysing how this more detailed understanding is obtained. In the CIRCA model defined for the activity of obtaining a more detailed understanding of the state of the CWS, the 'adequate' context information that triggered this additional exploration is now to be considered *fragmented* context information. This is because the adequate context information needs to be aligned with additional fragmented context information to obtain a more detailed understanding of the state of the CWS.

I suggest that the analysis should be carried out in this way because the additional fragmented context information that enables NCC to obtain a more detailed understanding of the state of the CWS is only relevant given *some* but not *all* of the more general states of the CWS. Splitting the analysis into separate CIRCA models thus reveals in what situations that states of the CWS, defined with different degrees of specificity, is considered adequate to act upon.

Based on these remarks, the analysis of the way that NCC handles the overall activity of securing that the work are progressing according to the time plan is analysed by four separate CIRCA models. The four activities are related as illustrated in figure 10. The arrows indicate that e.g. activity B is initiated based on information about one of the states of the CWS delimited in activity A. The activities are thus connected in what Schutz terms a hierarchy of in-order-to relevancies, meaning that the activities that are initiated are carried out in-order-to handle the activities they are initiated by.

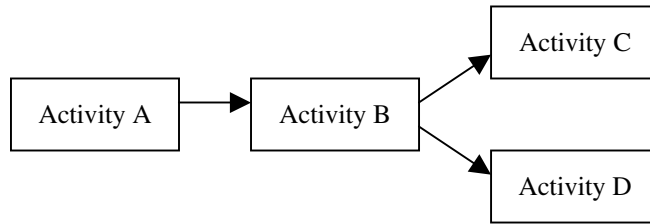


Figure 10: How the different CIRCA models analysing the task of securing that the work are progressing according to the time plan relate to each other

The four CIRCA models analysing the activity of securing that the work are progressing according to the time plan are presented in the following. As can be seen in the four CIRCA models, the delimitation of the different states of the cooperative work arrangement that NCC finds adequate to act upon is defined in rather loose terms. As an example, NCC distinguishes between if the consequences of a delay are *minor* or *extensive*. I have not been able to make a more precise definition of what makes the consequences being categorised as minor or extensive as it is an estimate that NCC makes relative to the particular circumstances of the individual cases.

The first CIRCA model analyses how NCC obtains the most general overview of the state of the CWS when finding out how the present state of the building activities relate to the time plan (activity A):

Fragmented context information	State of the cooperative work setting	Post-action context information
<ul style="list-style-type: none"> - How far the work specified in the time plan have progressed - How the work are planned to progress 	<ol style="list-style-type: none"> 1. The work are running on time 2. One or more work are running late 	<ul style="list-style-type: none"> Ad1. Negative action: State of the field of work is not altered. Ad2. A further exploration of the state of the CWS is initiated: Asking the foremen of the work running late if the work are able to catch up (Activity B).

Activity A: Find out how the present state of the building activities relates to the time plan

As seen in the analysis of activity A, based on the adequate context information that one or more work are running late, NCC initiates a further exploration of the state of the CWS. What context information is relevant for obtaining this more detailed understanding of the state of the CWS and how this information is used is analysed in the following CIRCA model:

Fragmented context information	State of the cooperative work setting	Post-action context information
<ul style="list-style-type: none"> - One or more work are running late - Are the work running late able to catch up? 	<ol style="list-style-type: none"> 1. The work are undoubtedly able to catch up 2. The work have a fair chance to catch up 3. The work are not able to catch up 	<p>Ad1. Negative action: State of the FOW is not altered</p> <p>Ad2. A further exploration of the state of the CWS is initiated: Asking the foremen responsible for the forthcoming work how the workflow of the forthcoming work is affected if the delayed work are not caught up (Activity C).</p> <p>Ad3. A further exploration of the state of the CWS is initiated: Asking the foremen responsible for the forthcoming work how the workflow of the forthcoming work is affected by the delay (Activity D).</p>

Activity B: Find out if the activities running late are able to catch up

Based on two of the three states of the CWS delimited in the CIRCA model for activity B, NCC initiates an even further exploration of the state of the CWS (activity C and D). Even though the additional context information that needs to be obtained is the same for each of these activities, they are analysed in two separate CIRCA models. This is because the choice of action based on the more detailed understanding of the state of the CWS differs according to whether the work has a fair chance to catch up or is not able to catch up.

Fragmented context information	State of the cooperative work setting	Post-action context information
<ul style="list-style-type: none"> - One or more work are running late and the work have a fair chance to catch up - How the delay affect the workflow of the forthcoming work 	<ol style="list-style-type: none"> 1. The forthcoming work are not affected if the delay is not caught up. 2. The forthcoming work are affected if the delay is not caught up, but the subcontractors responsible for the forthcoming work are able to find a solution to the problems caused by the potential delay, making the consequences of the delay minor. 3. The forthcoming work are affected if the delay is not caught up, and the subcontractors responsible for the forthcoming work are not able to find a solution to the problems caused by the potential delay, making the consequences of the delay extensive. 	<p>Ad1. It has been written in the minutes of the Lean Construction meeting that the work are late but that they will catch up so that the work will be finished on the date specified in the time plan.</p> <p>Ad2. It has been written in the minutes of the Lean Construction meeting that the work are late but that they will catch up so that the work will be finished on the date specified in the time plan.</p> <p>Ad3. It has been written in the minutes of the Lean Construction meeting that the work are late but that they will catch up so that the work will be finished on the date specified in the time plan. Apart from this, a new activity is initiated: checking the status of the delayed work a few times during the week to see if it catches up.</p>

Activity C: Find out how the workflow of the forthcoming work is affected if the work is not caught up

Fragmented context information	State of the cooperative work setting	Post-action context information
<ul style="list-style-type: none"> - One or more activities are running late and the work are not able to catch up - How the delay affect the workflow of the forthcoming work 	<ol style="list-style-type: none"> 1. The forthcoming work are not affected by the delay 2. The forthcoming work are affected by the delay but the subcontractors responsible for the forthcoming work are able to find a solution to the problems caused by the delay, making the consequences of the delay minor. 3. The subcontractors responsible for the forthcoming work are not able to find a solution to the problems caused by the delay, making the consequences of the delay extensive. 	<p>Ad1. It has been written in the minutes of the Lean Construction meeting that the delayed work are going to be finished X days later than specified in the time plan, and that the forthcoming work are not affected by the delay.</p> <p>Ad2. It has been written in the minutes of the Lean Construction meeting that the delayed work are going to be finished X days later than specified in the time plan, and that the subcontractors responsible for the forthcoming work have agreed on solution X so that the workflow is not extensively disturbed.</p> <p>Ad3. NCC hires external workmen to enable the delayed work to be completed on the date specified in the time plan.</p>

Activity D: find out how the delay affects the workflow of the forthcoming work

In what ways are CAA able to provide information that has shown relevant for the activity analysed?

The analysis above has revealed what context information is used by NCC in-order-to handle the activity of checking whether or not the work activities are progressing according to the time plan. In the remains of the analysis I will report an examination of whether the prerequisites can be met for defining a layered architecture that enables CAA to provide the fragmented, adequate or post-action context information that has shown relevant for NCC. The exploration has been limited to find out if characteristics of the CWS are present that can enable CAA to provide information about *how far the work specified in the time plan have progressed*.

With reference to Schmidt's (2002) concept of 'embodied actions' I have argued that CAA are able to provide this relevant context information in two ways. One way is to directly measure the information that has shown relevant for cooperative actors handling a particular activity. But apart from this, CAA are also able to provide this relevant context information indirectly by measuring context information about *other* parts of the CWS. This is possible if a more or less unambiguous relationship is present between the context information that has shown relevant for the cooperative actors and context information about other parts of the CWS that CAA are able to measure.

Looking at the possibilities for CAA to provide context information about how far the work specified in the time plan have progressed, measuring this context information directly does not seem to be a possibility. Because of this, a prerequisite for CAA to provide this relevant fragmented context information is that a more or less unambiguous relationship can be found between context information about other parts of the CWS and how far the work specified in the time plan have progressed.

In the following I will present an examination of whether such unambiguous relationships can be found. Due to my interest in location-aware technologies, the examination has been limited to exploring the relationship between the *physical location* of the actors and objects that are part of the CWS and how far the work specified in the time plan have progressed. Due to time-constraints I have only explored the work of one of the subcontractors working on project ferry: The contractor responsible for the ventilation (VE) work in the building. The analysis is made on the basis of three full days of fieldwork.

Summing up my remarks in chapter four, the following research questions has guided the examination:

The relationship between the location of the parts of the CWS and the work activities carried out by the VE contractor

First of all, the relationship between the location of the actors and artefacts that is part of the CWS and the work activities of the VE contractor has been examined. Prior to my fieldwork I decided to focus on the location of the materials and equipment needed for completing the work included in the VE subcontract as well as the workmen carrying it out. Although a relationship between the progress of the work carried out by the VE contractor and the location of equipment, materials & workmen of *other* subcontractors could potentially be present in the work setting, I chose not to explore this in my fieldwork.

The extent to which these relationships are unambiguous

The extent to which these relationships are unambiguous has also been explored. I have done this by first looking at if particular work activities carried out by the VE subcontractor are always expressed in particular locations of particular actors or artefacts. Secondly I have explored if the location of these actors or artefacts also stand in a relationship with other features of the CWS. For example, if the actors or artefacts are not only located in a particular place while work activity A is carried out, but also while activity B and C is carried out.

As mentioned in chapter four, exploring the complexity in the field of work is one way to find out if such unambiguous relationships can be found. Because of this, Schmidt's (2002) suggestions to what makes the field of work more or less complex has been a useful resource in examining what affects the location of the different parts of the CWS.

The availability of additional interpretatively relevant information

In exploring the extent to which unambiguous relationships between the location of an actor or artefact and the work activities of the VE contractor can be found on the construction site, I have also looked for the availability of additional informational resources that might make these relationships more unambiguous. Such informational resources may either be sign-based information, e.g. formalised work procedures, lists of how many pieces of material is going to be used for finishing the particular work etc. But it might also be information about the location of other actors or artefacts in the CWS.

Exploring the availability of additional interpretatively relevant information is a virtually unlimited task as it potentially comprises an analysis of the entire space of possible interactions within the CWS, including how the sign-based information present in the work setting might be used to give explanation to these possible interactions. Giving a suggestion to how to limit as well as carry out this immense task in a profitable way is not within the scope of this thesis. I have merely explored how a few sign-based informational resources might be used as interpretatively relevant information to make the relationship between location information and a feature of the CWS that is relevant for NCC to obtain knowledge about more unambiguous.

The extent to which the relationships are generic

Finally, in exploring the relationships above, I have also examined the extent to which these relationships are *generic* features of construction work. As argued in chapter four, the extent to which the relationships are generic features of the work affects the extent to which it is possible for system designers to define the layered architecture once and for all. In my examination I have examined what relationships are generic for all building projects. What relationships are generic for the individual building project, meaning that the presence of the relationships is known prior to the start of the project? And what relationships are merely generic for the particular situations, meaning that they are not known prior to the start of the project but arise during the line of action.

Findings

When NCC allocates the different work of the subcontractors to particular parts of the building in a particular time-period of the building project, they distinguish between three different kinds of work activities within the ventilation subcontract. These are fitting the ventilating plant, fitting the ventilation ducts and fitting the air gratings that lead air from the ducts into the rooms of the finished building. Only one of these work is reported in this thesis: the fitting of the ventilation ducts.

In general this work activity includes putting up the ventilation ducts leading air from the already fitted ventilating plant and round in the building. These ducts consists of some large main ducts leading the air around the building as well as some smaller ducts called trimmings leading air to/from the main ventilation duct into the rooms of the finished building. Fitting the air gratings that leads air from the trimmings into the rooms of the finished building are not part of the work activity of fitting the ventilation ducts because the grating cannot be fitted before the ceiling is made.

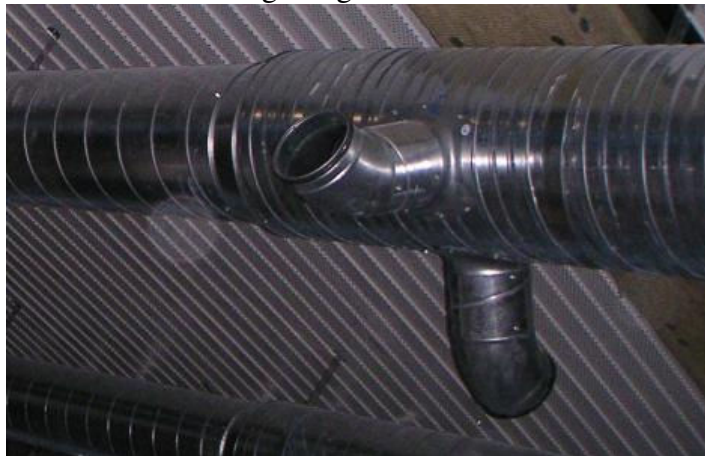


Figure 11: The trimmings leading air to/from the main ventilation duct into the rooms of the finished building.

The ducts are fitted according to a technical drawing made by VE's engineer. This drawing includes information about where the ducts should be fitted according to the modular lines of the building as

well as the dimensions of the parts that the ducts is to be made from. The ducts are made from different parts that are assembled on the floor of the building in convenient chunks and fitted onto the concrete ceiling.

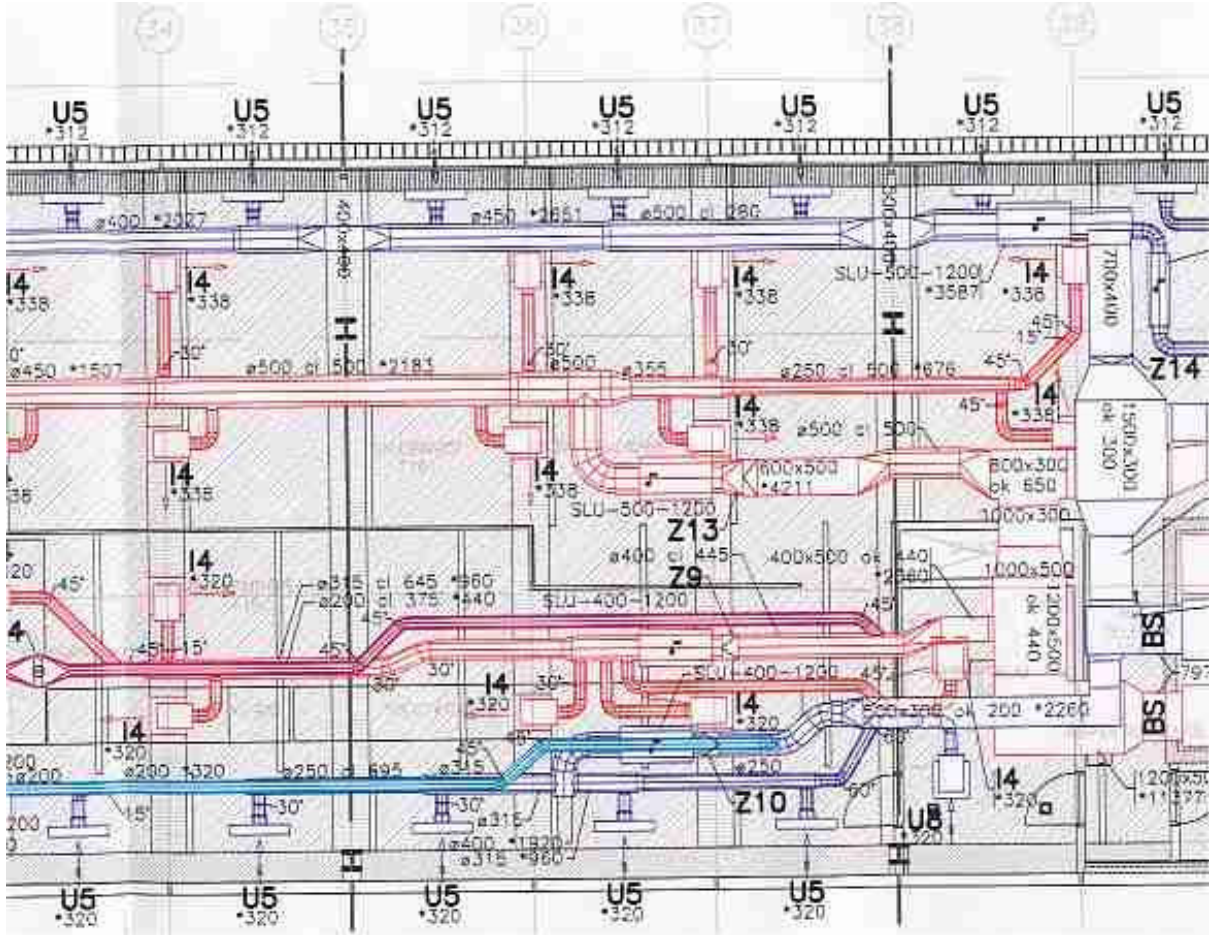


Figure 12: Extract of the technical drawing

How does the location of the materials that the ventilation ducts are made from relate to the fitting of the ducts?

During my field study, I focused on how the location of both materials, equipment and workmen of the VE-subcontractor relate to the work activity of fitting the ventilation ducts. However this thesis only reports an analysis of how the location of the *materials* that the ventilation ducts are made from relates to the work activity of fitting the ventilation ducts. The materials are chosen as the object of the analysis because the relationship between the location of the materials and the work activity examined seemed to be the least ambiguous of the relationships I examined during my field study.

As mentioned earlier, the ventilation ducts are made from a number of different parts:

Standard ducts – ready made ducts that are used in all VE contracts

Purpose-made ducts – custom-made ducts for the project ferry contract

Reducers – used for connecting two ducts with different diameter
LS lists – used to connect two purpose-made ducts of equal diameter
Adaptors²³ – used to connect two standard ducts of equal diameter
Trimming²⁴ – leading air to/from the main ventilation duct into the rooms of the finished building
Assemblers²⁵ – used to connect the trimmings with the main ducts
T ducts – used to split one main duct into two ducts
Bendings – used to bend the main ventilation ducts
Fittings – used to fit the main ventilation ducts onto the concrete ceiling
Silencer – used to reduce the noise in ducts with high air pressure

Because the ducts are assembled in-situ, the parts that the ducts are made from are stored on the construction site before they are assembled and fitted into the building. This means that a particular part present on the construction site can either have the status as *stored*, *assembled but not fitted* or *fitted*. Because of this, I found it interesting to explore if information about the location of these parts could serve as an indicator of whether the parts were *stored* or *fitted*. Information that to my knowledge prior to the fieldwork could potentially serve as an indicator of how far the work had progressed.²⁶

In the following I will start by describing the extent to which an unambiguous relationship between the location of the materials present on the construction site and their status as either stored/ not stored or fitted/ not fitted is present on the construction site. After this I will discuss two ways that relationships can be defined between what materials are stored/ fitted and how far the fitting of the ventilation ducts has progressed.

The relationship between the location of the materials and their status as stored materials

A prerequisite for a relationship to be found between the location of the materials used by VE and whether the materials are stored or not stored is that it is possible to demarcate the spatial layout of the construction site into 'storage space' and 'not storage space'. My fieldwork revealed that such a demarcation is difficult to make for the following reasons:

First of all the physical location where the materials are stored is not the same from the time when they arrive at the construction site and until they are fitted into the building. Upon the time of arrival to the construction site, the workmen from VE makes sure that the load of materials are stored inside the building under construction as close as possible to the part of the building where they are going to be used. NCC assigns where VE is allowed to store the materials, but within this rough demarcation it is up to the workmen to choose the exact storage place. NCC is not informed about the exact position where the materials are stored. If a previous load of materials is already present on the construction site the two orders are kept separate, as they are to be used in two different parts of the building.

²³ In Danish: Nippel

²⁴ In Danish: Afgrening

²⁵ In Danish: Påstik

²⁶ The extent to which information about the location of these parts could serve as an indicator of whether the parts were assembled was not examined because assembling is an intermediate position between stored and fitted.

However, because some of the duct-parts are very bulky measuring up to six metres in length and fifty centimetres in diameter, they are often in the way of the workmen of the other subcontractors. This requires part of the materials in a particular load to be moved from one physical location to another, either by the workmen of the other subcontractors or by VE's own workmen. This happens at least a few times a week and is not planned in advance, the workmen simply moves the materials when needed. Mostly but not always the workmen inform each other about the change in location of the stored materials, but NCC is not informed about these changes in location. Thus for NCC these location changes for the stored materials appears as spontaneous changes in the FOW, one of the sources of complexity in the FOW mentioned by Schmidt (2002).

Apart from this, materials may be positioned on the same 2D coordinates on a particular floor of the building when they are stored and fitted. This is because the parts are stored on the floor but fitted in the ceiling. In 2D, the location of the materials thus potentially stands in a relationship with two features of the CWS: 'stored materials' and 'fitted materials'.

The relationship between the location of the materials and their status as fitted materials

In my fieldwork I also explored if information about the location of the materials that the ventilation ducts are made from can be used to classify these materials as fitted into the building. I found this interesting to explore because of the availability of one informational resource that I assumed interpretatively relevant for defining such a relationship unambiguously: the technical drawings of how the ducts should be fitted into the building. As mentioned earlier, this drawing includes information about where the ducts should be fitted according to the modular lines of the building as well as the dimensions of the parts that the ducts is to be made from.

Because the technical drawing is what enables a potential relationship to be defined between the location of a piece of material and whether or not it is fitted, I first of all examined the extent to which the ducts are always fitted in the same location as specified in the technical drawings. If the ducts were fitted differently than specified in the technical drawings, then materials that were in fact fitted would, if their location information was aligned with the technical drawing, be classified as non – fitted because they were fitted in a different place than planned. My fieldwork revealed that in their work, the workmen quite rigidly follow the technical drawing of where the ducts are fitted. Thus for the workmen, the technical drawing does not serve as a map in the Suchmanian sense (Suchman 1987), but rather as a script (Schmidt 1998) making the workmen fit the materials on the exact same location as stated in the technical drawings.

As mentioned above, in 2D coordinates on the particular floor of the building, the materials may be situated in the same place when they are stored and fitted. This becomes a problem when the materials are stored on a location where some of them are going to be fitted. But it also becomes a problem for another reason: Before the workmen start assembling a particular part of the ducts, they collect all the materials needed to assemble that part of the duct. These parts are placed on the floor right beneath where they are going to be fitted. In the situations where the assembling and fitting is done straight after the materials are collected, this is not a problem as assembling and fitting a part of the duct takes no more than a few hours at most. Sometimes however, the workmen have collected almost all the materials needed but then find out that one part is missing. In those cases

the materials already collected are just left beneath where they are going to be fitted until the missing materials are ordered and delivered to the construction site. In 2D on the particular floor of the building, these materials have the same location when left on the ground and fitted into the ceiling.

Summing up, a rather unambiguous relationship between the location of the materials defined in 3D coordinates and their status as 'fitted' seems to be present in the CWS if the location information is aligned with the technical drawing. If the location is merely defined in 2D on the particular floor of the building, this adds ambiguities to this relationship.

I have examined if a relationship could be found between the location of the materials and their status as either fitted/ non-fitted or stored/ non-stored because, to my knowledge, this information could potentially serve as an indicator of how far the fitting of the ventilation ducts has progressed. In my fieldwork I have explored two ways that a relationship can be defined between what materials are stored/ fitted and how far the fitting of the ventilation ducts has progressed. One is to explore if information about what parts are needed to fit the ducts in a particular part of the building can be aligned with information about what materials are presently stored/fitted to get an estimate of how far the work has progressed. Another is to explore if a relationship can be found between the fitting of certain materials and how far the work has progressed.

Using information about what parts are needed to fit the ducts in a particular part of the building to get an estimate of how far the work has progressed

My fieldwork has revealed two informational resources that provide information about what parts are needed to fit the ducts in a particular part of the building. These resources are the technical drawing and the invoices of the materials ordered.

The technical drawing provides information about where the ducts should be located when they are completed as well as the dimensions of the parts that the ducts should be made from. However the technical drawing does not in a textual form provide information about what parts or how many parts the ducts should be made from.

An estimate of this is found in the invoices of the materials ordered to complete the ducts. When the foreman of VE orders a load of materials, he delimits the order relative to what materials are needed to fit the ducts in a particular part of the building. As an example, all the materials needed to fit the ventilation ducts on the first floor, modular line 28-40 is ordered and delivered as one load of materials that is stored separately from the materials ordered to be used in other parts of the building. When the foreman estimates what materials are needed to fit the ducts in a particular part of the building he uses his expertise to 'count' on the technical drawing what materials are needed to fit the ducts according to the drawing. The invoice listing all the materials included in a particular order thus provides information about the foreman's estimate of what materials are needed to fit the ducts in a particular part of the building.

The question then is if these informational resources can be aligned with information about what materials are presently stored/fitted to get an estimate of how far the work has progressed.

One way to make such an alignment could be to use information about what materials from a particular load of materials is presently fitted/ stored as an indicator of how far the fitting of the ducts in the part of the building that the load of materials were ordered for has progressed. However a prerequisite for such an indicator to be exact is that the fitting of all the materials in one load would complete the ducts in the part of the building the load were ordered for. This however is not the case for the following reasons:

First of all the foreman's estimate of what materials are needed to fit the ducts in a particular part of the building is rarely precise. Even though he is very skilled, the technical drawing is quite complex which makes it difficult to get a precise estimate of what materials are needed by 'counting' on the technical drawing. Because of this it is almost certain that he either orders too many or too few of some of the materials. The workmen discover what parts are missing while they carry out their work. The foreman then makes an additional order to be delivered the next day. According to the foreman, approximately 10 percent of the materials are ordered on additional orders.

Apart from this, even though the materials are ordered and stored according to where in the building they are going to be used, sometimes the workmen working on different parts of the building borrow standard materials from each other if they cannot find these parts in their own load. Thus some of the materials ordered for use in one part of the building are used in another part. The workmen does not consider this borrowing a problem as long as they are informed about what parts are borrowed so that new parts can be ordered. But according to the workmen, informing each other about what parts are borrowed does not always happen.

Finally quite often the workmen cannot find the materials needed for fitting the ducts even though those materials are actually present in the load of materials. This is because the ducts are made from a quite large number of parts, one of Schmidt's (2002) sources of complexity. This causes the workmen to put in an additional order on the materials that they cannot find. When the fitting of the ducts is completed, the materials that couldn't be found are thus still left.

These problems makes the relationship between the number of stored/ fitted materials from one load relative to the total number of materials included in that load an inexact estimate of how far the fitting of the ducts that these materials were ordered for has progressed. However aligning this relationship with the information available in the technical drawing might make the relationship more unambiguous. This is because the technical drawing contains information about where the ducts should be located when they are completed. Aligning information about in what locations that ducts are presently *fitted* with information about where the ducts should be located when they are completed could thus provide an estimate of how far the work has progressed. As an example, if ducts are only fitted in half the locations where the finished ducts should be located and if only five pieces of materials from one load have the status 'stored', then chances are good that the ducts are *not* completed with the fitting of those five parts.

An alignment with the information available in the technical drawing thus eliminates some of the ambiguities with using information about the number of stored/ fitted materials from one load relative to the total number of materials included in that load as an estimate of how far the fitting of the ducts that these materials were ordered for has progressed. But this alignment is not able to eliminate another problem with using this information as an indicator of how far the fitting of the ducts has progressed. This problem arises because of the source of complexity of the FOW that Schmidt (2002) names 'Heterogeneity of the interacting elements'. As mentioned earlier the ducts are made from many different parts. This is a problem because some parts of the ducts are much more time-consuming to fit than others. As an example, fitting a six metre long standard duct-part onto the main ventilation duct merely includes to fasten an adaptor in the end of the duct-part that connects it to the main ventilation duct. On the contrary, adding a fifty centimetres trimming to the main ventilation ducts includes measuring where the trimming should be fitted, cutting a hole in the main ventilation duct, gluing an assembler onto the main duct and screwing the trimming to the assembler.

Apart from this, the *same* type of material is also more or less time-consuming to fit according to where in the building it has to be fitted. The amount of available space is one factor that influences how much time it takes to fit a particular duct because larger parts can be assembled on the ground before they are fitted onto the ceiling if plenty of space is available. The extent to which the ducts have to run through plaster or chipboard walls is another factor as it is the responsibility of the VE workmen to cut the holes in the walls that the ducts should run through.

These differences in how much time it takes to fit the different types of materials into the building makes it more complex to define a relationship between what materials are fitted/stored and how far the work has progressed. The simple relationship that if X percent of the materials are fitted, then the work has progressed X percent is thus very imprecise as it does not take into consideration the time-differences in the fitting of the materials mentioned above.

The relationship between the fitting of certain parts and how far the work has progressed

Above I explored if information about what parts are needed to fit the ducts in a particular part of the building can be aligned with information about what materials are presently stored/fitted to get an estimate of how far the work has progressed. Apart from this, I have also explored if a relationship can be defined between the fitting of *certain* materials and how far the work has progressed. If such a relationship can be found in the CWS, then it is not necessary to measure the location of *all* the materials but only some of them to get an estimate of how far the work has progressed.

A prerequisite for such a relationship to be found is that the ducts are to some extent fitted in a particular order so that e.g. material X is always fitted precisely after material A-V. In my fieldwork I explored two things that influences the extent to which such a particular order of the fitting can be found: the presence of coordination mechanisms and whether the internal dependencies of the FOW requires the fitting to be done in a particular order.

The only coordination mechanism that regulates in what order the workmen from VE should fit the ventilation ducts in the building is the time plan made by NCC. Within this very broad demarcation of the building²⁷, the foreman plans the day-to-day work by simply assigning different parts of the building to the different workmen to work on. The way he demarcates the building for the workmen to work on equals the demarcation that the materials are ordered relative to. The demarcation also equals the work specified in the NCC time plan with the exception that the larger work in the time plan is sometimes split into smaller parts.

Within the parts of the building that the different workmen has been assigned they are free to choose in what order they want to fit the ducts as long as they do it according to the technical drawing.

However this absence of coordination mechanisms does not mean that the ducts are fitted in a totally random order. This is because the internal dependencies in the field of work influence in what order the ducts are fitted.

First of all, the workmen always start as close as possible to the ventilation plant that the finished ducts will be connected to. They do this because the ducts closest to the ventilation plant have the biggest diameter. This requires them to be fitted more precisely than the ducts with a smaller diameter. For example the workmen that had been assigned first floor, modular line 13-28 started fitting the ducts at modular line 13 because the ventilation plant is situated between modular line 1 and 2.

Apart from this, unless the workmen start on a whole new part of the building, they always continue assembling additional materials onto the ducts already fitted into the ceiling instead of fitting unconnected parts into the ceiling. This is done first of all because connecting two ducts already fitted into the ceiling is much more difficult than just extending one of the already fitted ducts with additional materials. But also because chances are that two separate ducts cannot be connected if they are fitted unevenly into the ceiling. For the workmen, the smallest possible number of loose ends is thus preferable.

The complexities of the FOW thus make the workmen fit the ducts in a to some extent particular order as they start in the end of the building that is closest to the ventilation plant and then work their way away from the plant. However as can be seen in the extract of the technical drawing in figure 12, quite a few ducts are running parallel through the building. This means that despite the workmen aims to have the smallest possible number of loose ends, they can at any point in time choose to work on maybe five – ten different ducts. The internal dependencies in the field of work do not force the workmen to finish the fitting of one duct to a certain extent before continuing the work on another duct. The fitting of each of these ducts can thus always be stopped at a randomly chosen spot.

²⁷ Each of the floors is divided into just three different parts covering 13, 27 and 15 modular lines (39, 81 and 45 metres),

In the analysis above I have explored if an unambiguous relationship can be found in the CWS between the physical location of the materials needed to complete the fitting of the ventilation ducts in the building project and their status as either stored or fitted. I have also explored two ways that a relationship can be defined between what materials are stored/ fitted and how far the fitting of the ventilation ducts has progressed.

The question that remains to be solved then is if these relationships are sufficiently unambiguous to enable CAA to provide information about how far the fitting of the ducts has progressed by directly measuring the location of the materials, aligning this information with the additional informational sources mentioned in the analysis. How to make such an evaluation will be touched upon in the following chapter discussing the implications that the workplace study has for design of CAA that advance context awareness for cooperative actors.

6. Implications for Design

In this chapter, I will point towards the way in which the empirical field study presented in chapter five can inform the design of CAA that might advance context awareness for NCC in their task of handling the workflow logistics on project ferry.

In chapter three of the thesis I highlighted three different problems with gathering and using context information that CAA might address to advance context-awareness for cooperative actors handling a particular activity. These were gathering fragmented context information, comparing fragmented context information and providing adequate or post-action context information.

In this chapter I will discuss if CAA are able to address some of these three problems. The discussion will start by discussing if it is *possible* for CAA to provide the fragmented, adequate and post-action context information that has shown relevant for NCC when checking how the present state of the building activities relate to the time plan. The analysis of the relationship between the location of the materials used to fit the ventilation ducts and how far the fitting of these ducts has progressed will form the ground for this discussion.

After this it will be discussed if such designs will serve as better resources than the ones that NCC currently uses, i.e. if such designs enable NCC to handle workflow logistics more easily.

As the intention in this thesis is not to undertake design, the discussion is limited to *what* context information that might enable CAA to provide context information on the three levels of abstraction. The discussion will not touch upon *how* this context information should be measured, e.g. what technologies should be used to measure the location of the materials on the construction site.

Possibilities for design of context-aware applications

The analysis of checking how the present state of the building activities relates to the time plan has been analysed by not one but four separate CIRCA models connected in a hierarchy of in-order-to motivational relevancies. This was done because the additional fragmented context information that enables NCC to obtain a more detailed understanding of the state of the CWS is only relevant given *some* but not *all* of the more general states of the CWS.

Splitting the analysis into separate CIRCA models makes the model a better design tool because it reveals in what situations that states of the CWS defined with different degrees of specificity is considered adequate to act upon. Designers are thus able to evaluate what activities that CAA providing fragmented, adequate and post-action context information listed in each of the four CIRCA models are able to or not able to support.

In the following I will thus for each of the four CIRCA models discuss whether CAA are able to provide the fragmented, adequate and post-action context information that has shown relevant in each of the CIRCA models. The letters A – D refers to how the activities are named in the CIRCA models presented in chapter five.

Providing fragmented context information that has shown relevant in activity A

When NCC is checking how the present state of the building activities relate to the time plan, the most general understanding of the state of the CWS that NCC infers is if ‘the work are running on time’ or ‘one or more work are running late’ (Activity A). To obtain this understanding of the state of the CWS, information about two aspects of the CWS are considered relevant fragmented context information. This is information about how far work specified in the time plan have progressed and information about how far these work should have progressed to enable the work to be completed on the dates specified in the time plan.

In chapter five I argued that directly measuring how far the work have progressed does not seem possible. Because of this, I explored if CAA can be enabled to provide information about how far one of the work specified in the NCC time plan (the fitting of the ventilation ducts) has progressed by directly measuring the location of the materials used to complete the ventilation ducts, aligning this information with the additional informational sources mentioned in the analysis.

The analysis revealed that the relationships that could enable CAA to provide this information are not unambiguous. The question then is if these ambiguities make context information about the progress of the work useless if it is inferred from the location of the materials aligned with the additional informational sources mentioned in the analysis. I suggest that such an evaluation need to be based on knowledge about the degree of unambiguity and specificity with which NCC *presently* obtains information about the progress of the work specified in the time plan.

Currently NCC obtains information about how far the work specified in the time plan have progressed by walking around the construction site. This is done at least once every week during the Lean Construction meetings but can be done at any point in time simply by taking a walk round the construction site. As mentioned, the frequency with which these rounds are made differs quite a lot between the two managers of the subcontractors in project ferry. However even the manager who is making these rounds with the highest frequency rarely makes them more than once a day. This together with the fact that the time plan is defined in days, not hours makes it reasonable to suggest that providing information about how far the work has progressed with a degree of specificity in days rather than hours could be acceptable.

For the same reasons, if the ambiguities in the relationships examined in chapter five causes a miscalculation that equals less than plus/ minus what can be carried out in one day; these ambiguities could as well be acceptable.

The question that remains to be solved then is if context information about how far the fitting of the ducts has progressed that is inferred from the location of the materials aligned with the additional informational sources mentioned in the analysis, is able to satisfy these prerequisites. Unfortunately I do not consider my analysis sufficient for answering this question as it lacks some estimates of what the consequences of the ambiguities are in terms of miscalculations of how far the work has progressed. Apart from this, the answer is also relative to what algorithms are used to define the relationships examined in chapter five. Discussing such algorithms is without the scope of this thesis.

Despite the absence of these important insights, the insights that the analysis *has* revealed makes me suggest that using location information to classify a piece of material as fitted/ not fitted seems to be less ambiguous than categorising it as stored/ not stored. This is because the interpretatively relevant information that enables a relationship between the location of the materials and their status as fitted/ not fitted to be defined (the technical drawing) serves as a script that is followed quite rigidly. However to make sure that the materials stored on the ground are not mistaken for materials fitted into the ceiling, the location of the materials should preferably be measured in 3D. As some of the materials are piled on the floor, the difference in height between a stored and fitted piece of material is sometimes no more than approximately one metre. In 2D the location should be defined with accuracy sufficient to measure the smallest ducts measuring 160 mm in diameter. The relationship between what materials are fitted and how far the fitting of the ducts has progressed also seems less ambiguous than the relationship between what materials are stored and how far the work has progressed. This is because this relationship can be defined relative to both the invoice (providing information about the foreman's estimate of what materials are needed to fit the ducts in a particular part of the building) and the technical drawing (providing information about where the ducts should be located when they are completed).

Based on these relationships between the location of the materials and their status as fitted/ not fitted and between what materials are fitted and how far the work has progressed, I suggest that a CAA could provide information about how far the fitting of the ducts has progressed in two different ways.

First the application could provide the information that the fitting is presently X percent completed. To provide such information, the application need to be able to associate information about what materials are fitted with how many percent the fitting is presently completed. As mentioned in the analysis, making such an association is complex due to the heterogeneity of the materials as well as the physical context that the materials are fitted in.

Because of this, enabling CAA to provide information about what parts are fitted, leaving it to the *actor* and not the application to associate or more precisely *typify* the fitting of certain materials with how many percent the fitting is completed might be a better option. Marking on the technical drawing in what locations that ducts are presently fitted could be one way of doing this.²⁸

A combination of these two design suggestions could also be a possibility.

Finally, the analysis of how the internal dependencies in the field of work make the workmen fit the ducts in a to some extent particular order points towards the possibility of using the location of only *some* of the materials as an indicator of how far the fitting of the ducts has progressed. However more research has to be pursued on what materials might serve as the best indicators as well as how many should be measured to enable the application to provide a sufficiently specific estimate of how far the fitting has progressed.

²⁸ This design suggestion is inspired by the 'fixed line diagram' in the Bakerloo Line control room in London Underground (Heath & Luff 1992).

Comparing fragmented context information that has shown relevant in activity A

CAA like the ones discussed above also target the second design challenge put forward in this thesis: comparing fragmented context information. Today, the closest NCC can get to an ‘at a glance’ comparison between how far the work have progressed and how the work are planned to progress is to take the paper-based time plan with them on their walk around the construction site. But considering that one round on the construction site takes approximately 20-30 minutes, the comparison is hard to describe as ‘at a glance’. Applications like the ones discussed above on the other hand can potentially enable NCC to make an at a glance comparison between the two fragmented context information that is used to infer if the work are running on time or not.

Providing adequate or post-action context information that has shown relevant in activity A

CAA are enabled to provide adequate context information by associating particular constellations of discrete context cues with particular states of the CWS in the ‘layered architecture for discrete context information-based computation of adequate and post-action context information’. In chapter four I argued that the constellation of discrete context cues that the particular states of the CWS is associated with in the layered architecture does *not* necessarily have to be the same as the fragmented context information that the cooperative actors currently use. This is because discrete context cues might be available that serves as *better* interpretative relevancies than the ones that the cooperative actors currently use. This is the case if these cues stand in a more unambiguous relationship with the particular states of the CWS that the actors distinguish between when deciding what choice of action is most appropriate to handle the activity examined.

However my fieldwork has not revealed the presence of such discrete context cues. To enable CAA to provide adequate context information, associations thus has to be defined in the layered architecture between context cues for the two fragmented context information that NCC currently use and the two states of the CWS that they distinguish between. These states are ‘the work are running on time’ and ‘one or more work are running late’.

Above I have argued that CAA might be able to provide information that the fitting of the ducts are presently X percent completed, although such an estimate is influenced by several ambiguities. Such an estimate could, if aligned with cues stating that at day Y, the fitting is planned to be Z percent completed, enable a CAA to distinguish between the two states of the CWS considered relevant by NCC. However such precise cues are not presently available for NCC. This is because the time plan does not list the work planned to be carried out and on which days, but only when the work should start and end. As mentioned earlier, the foremen is responsible for the planning in detail of the work specified in the time plan so that the work is completed on the date specified in the time plan. Thus in order to precisely define cues stating that at day Y the work is planned to be Z percent completed, the foremen’s planning in detail should be available for the CAA. As described in the analysis of how the ventilation ducts are fitted in the building, the foreman of VE does *not* carry out such a formalised planning in detail of the work, nor does he write down the loose planning that he pursues. Informal conversations with the foremen of the other subcontracts

show that this absence of formal and written down planning in detail is more the rule than the exception.

Because of this, I consider it unrealistic that the foremen's planning in detail of the work specified in the time plan can serve as a basis for defining cues stating that at day Y, the work is planned to be Z percent completed. Such cues can however be coarsely defined by using the information stated in the time plan about how many workdays the individual work should take to complete. As an example, if a particular work is planned to take five workdays, cues could be defined that on day one the work should have progressed 20%, on day 2 the work should have progressed 40% and so forth. Defining the cues in this way is however only rough estimates as the number of men working to complete a particular work might differ from day to day.

Summing up, defining cues for each of the two fragmented context information that NCC currently use to infer whether the work are progressing according to the time plan is subject to several ambiguities. For that reason I consider it highly questionable that a layered architecture can be defined that enable CAA to provide the adequate context information that 'the work are running on time' and 'one or more of the work are running late'.

If CAA are not able to associate particular constellations of discrete context cues with particular states of the CWS, neither are they able to initiate particular choices of action, only providing the actor with post-action context information that this has been done. Even though unambiguous relationships *can* be found in the work setting between particular states of the CWS and particular choices of actions, then CAA are only able to initiate these choices of actions if they are able to infer the current state of the CWS.

However I find it interesting that even *if* CAA were able to infer the current state of the CWS, then the choice of action that springs from the adequate context information that 'one or more of the work are running late' is to initiate the *new* activity: To gather further information about the state of the CWS, in this case to find out if the work running late are able to catch up. Presently this information is obtained by asking the foremen of the work running late. A CAA providing post action context information to the user would thus in some way establish a communication channel (phone, e-mail etc) between the NCC control unit and the foreman of the work running late, providing NCC with post-action context information that this had been done.

However apart from exploring the opportunities for CAA to provide such post-action context information, in the situations where the choice of action is to gather further information about the state of the CWS, designers should also explore the possibilities for the CAA to *provide this additional context information needed*. If this is possible, then CAA are able to merge the two activities 'find out how the present state of the building activities relate to the time plan' and 'find out if the activities running late are able to catch up'. From the users point of view these two activities would then be perceived as only *one* activity. This is because the CAA in this case would be able to provide the user with more subtle distinctions between different states of the FOW. In this example, that 'the work are running on time' and 'One or more work are running late, but the work are undoubtedly able to catch up/ have a fair chance to catch up/ are not able to catch up'.

In the following I will comment on whether CAA are able to provide this additional context information by referring to the CIRCA model analysing how this additional context information is presently gathered and used. (Activity B)

Design challenges in activity B-D

The analysis of how information about whether or not the activities running late are able to catch up is gathered (Activity B) shows that this information is presently a result of *negotiations* with the foreman of the subcontract responsible for the delayed work. When NCC asks the foreman if the delayed work is able to catch up, then the answer is not a simple yes or no. Instead NCC and the foreman discuss the possibilities for the foreman to man up, moving some of his workmen working in other parts of the building to the part of the building where the work is delayed and other things that might enable the work to catch up. Whether or not the delayed work is able to catch up is thus *relative* to which of these possibilities for enabling the work to be completed faster that NCC and the foreman agree upon.

A prerequisite for a CAA to provide information about whether the delayed work is able to catch up is thus that the foreman's knowledge of the possibilities for catching up is available to the CAA. I consider this neither possible nor feasible.

For the same reason I do not consider it possible for CAA to provide information about how the workflow of the forthcoming work are affected if the work is not caught up (Activity C) or find out how the delay affect the workflow of the forthcoming work (Activity D). Again the answer is not a simple yes or no, but is a result of negotiations, not only with the foreman of the subcontract responsible for the work running late, but with the foremen of *all* the subcontracts working on the construction site.

Are the relationships generic features of a building project?

The possibilities for design of CAA discussed above are based on an examination of just one of the work specified in the time plan. However workflow logistics is about coordinating the work of *all* the different subcontractors working on the construction site throughout the building process.

Information about how far all these work have progressed is thus needed to handle the activity of checking how the present state of the building activities relates to the time plan.

In this matter it is a problem that the relationships by which the CAA discussed above might infer how far the work has progressed is not a generic feature of *all* work on the construction site. As an example, pouring the concrete ceiling is not about fitting some ready-made materials into the building but about pouring concrete in different shapes and sizes. Because of this, an examination of the relationship between the actors and artefacts in the CWS and how far the individual work has progressed has to be made for *all* the work of *all* the different subcontractors.

Such an examination is naturally very time-consuming. But apart from this, the relationships by which CAA might provide information about how far the individual work has progressed will most likely differ among the individual work. If this is the case, the layered architecture will appear as a large 'patchwork quilt' of all different kinds of relationships, each with their own ambiguities that influences the precision with which information about how far the individual work has progressed can be inferred. Some of these relationships might not even enable information about how far the

work has progressed to be inferred with an accurate enough to satisfy the needs of NCC (in this case +/- what work can be carried out in one day). This not only makes these inaccurate estimates of little use for NCC when checking that the work are running according to the time plan, it also makes the estimates of how far all the other work have progressed less useful. This is because information about how far *all* the individual work have progressed is needed to handle the workflow logistics in the building project.

Apart from this, the relationships by which CAA might provide information about how far the individual work has progressed are only to some extent generic across different building projects. This is due to the quite unique characteristic of construction work that the construction of a building is one long process from the first turf is cut to the finished building that is not repeated. Thus two building processes are never exactly the same.

However this does not mean that *some* generic features of e.g. fitting ventilation ducts in a building cannot be found. Even though the design of the ventilation ducts differs from project to project, a generic feature for all building projects is that technical drawings are present that provides information about where the ducts should be located when the fitting is completed. It is also a generic feature of all building projects that the workmen follow these technical drawings quite rigidly. Thus a generic relationship might be defined that 'An alignment between the technical drawing and the location of the ducts enables a relationship to be defined between the location of the ducts and their status as fitted'.

On the contrary, the relationship between what ducts are fitted and how far the work has progressed seems more tied to the individual building project because the time it takes to fit the ducts are relative to the characteristics of the particular building. However on industry level some rough estimates of how much time it takes to fit particular types of ducts might be developed.

Finally the internal dependencies that makes the workmen fit the ducts in a to some extend particular order is also generic for all building projects. However as the design of the ducts are unique for each building project, deciding exactly what materials should be used as indicators of how far the fitting of the ducts has progressed seems to vary for each and every building project.

Does the design possibilities aid the handling of workflow logistics?

Above I have argued that although there is a good chance that CAA are able to provide information about how far the fitting of the ventilation ducts has progressed, it is questionable that such applications can provide information about how far *all* the work specified in the time plan has progressed. But even *if* applications are able to provide this information, this does not automatically imply that such applications will serve as *better* resources than the ones that NCC currently uses. A discussion of whether this is the case need to take into consideration how such applications affect the way that *each* of the four activities that have been important in the management of workflow logistics can be handled. As will be revealed in the discussion, this is very important because applications that serve as resources for one of the four activities might make it more *difficult* to handle another of these activities.

Checking how the present state of the building activities relate to the time plan

Information about how far the work specified in the time plan have progressed is presently obtained by walking around the construction site. This is rather time-consuming which could indicate that CAA like the ones discussed could be quite timesaving for NCC as they can provide an at a glance overview of how far the work have progressed. This however is only the case if the monitoring of how far the work have progressed is viewed *in isolation*. Even though NCC can get a coarse picture of whether or not the work are progressing according to the time plan by aligning the information provided by the CAA with the time plan, they need to talk to the foremen of the different subcontracts to get a precise estimate of this. Secondly and more important, because the CAA is not able to provide the more detailed context information needed when one or more work are running late, NCC still need to create a setting where the foremen of the subcontracts are able to get together and discuss solutions to these delays. This setting – the Lean Construction meetings - is also the setting where NCC presently obtains the most detailed information about whether or not the work are progressing according to the time plan. Thus even though CAA might enable NCC to obtain an at a glance overview of whether or not the work are progressing according to the time plan, such CAA are not able to render the activities where this information is presently obtained superfluous. In this perspective the applications are thus not timesaving for NCC when checking how the present state of the building activities relate to the time plan.

Such applications might however be an advantage in handling the activity that is initiated when the consequences of a delay that has a fair chance to catch up are extensive: checking the status of a delayed work a few times during the week to see if it catches up. Because the applications can provide information on how far this particular work has progressed, NCC does not need to walk down to the place on the construction site where the delayed work is carried out just to check how far this work has progressed.

Checking whether or not the workflow specified in the time plan is the most efficient way of coordinating the spatial and sequential dependencies in the forthcoming work

Information about how far the work have progressed in the different parts of the building seems highly relevant for the handling of this activity. This is because the work specified in the time plan are presently very coarsely delimited, most of them covering approximately 500m² of floor space. Because of this coarse delimitation, two work that according to the time plan are to follow each other in a particular part of the building are potentially able to work in that particular part of the building at the *same* time. This is the case if work A is half completed in one part of the building delimited in the time plan. In this situation, work B might be able to start working in the area where work A is already completed, even though work A is not fully completed in the part of the building delimited in the time plan. Information about how far work A has progressed could thus potentially enable NCC to make a more fine-grained assignment of the different work to the different parts of the building, enabling work B to follow work A in a way as described above. This could potentially enable the construction of the building to be completed faster.

Managing dependencies within the work of the individual subcontractors that influence whether or not the work is able to proceed according to the time plan

Information about how far the work have progressed is also relevant for NCC when handling the activity of making sure that the design of the work are settled before the work are planned to be carried out. This information is also relevant for NCC when handling the activity of checking if the materials needed to complete the work can be delivered on the construction site in time for the work to start according to the time plan.

Securing that the work carried out is made in accordance with the design

Above I have argued that three of the four activities that have been important for NCC in handling the workflow logistics in project ferry might at least to some extent benefit from the applications discussed. However for the fourth of these activities: ensuring that the work is made in accordance with the design (or in short, quality control), there is a danger that such applications might affect this activity in a negative way.

First of all the CAA's estimate on how far the work has progressed is based on information about *if* the materials are fitted. However, quality control is about making sure that the materials are fitted *in the right way*. Because of this, the information provided by CAA like the ones mentioned in this thesis is not sufficient for securing that the work is carried out in accordance with the design.

In fact, this problem also affect the extent to which the miscalculations in the CAA's estimate on how far the work has progressed equals less than +/- what can be carried out in one day, the degree of ambiguity I argued was acceptable for NCC. This is because parts of the already completed work might have to be remade if the deviations from the design are too extensive. This of course sets back the progress of that work. If materials are fitted but not fitted in the right way, the CAA thus infers a wrong estimate of how far the work has progressed.

Secondly and very interestingly, enabling NCC to obtain information about how far the different work have progressed by the use of CAA like the ones mentioned in this thesis might result in *more* work not being made in accordance with the design. This is because NCC does not need to take a round on the construction site to obtain information about how far the work have progressed if such applications are available. One of the incentives for taking a round on the site is thus removed. This might cause the quality control to be handled worse than today because it is on these rounds that NCC discovers work that is not made in accordance with the design as it occurs. On these rounds NCC also engages in informal and unplanned discussions with the workmen on the site concerning the work that is about to start, thus proactively securing that these work are made in accordance with the design. According to one of the construction managers on project ferry, a general increase in the amount of paperwork and legal problems in the construction industry has contributed to the construction managers spending more of their time in the office and less time walking around on the construction site. He finds this trend negative because his experience is that walking around the construction site engaging in discussions with the foremen is the only way to spot the problems that might affect the workflow in the building project before they occur. Developing CAA like the ones

mentioned in this thesis might thus add to this negative trend among the new classes of construction managers.²⁹

To design or not design – that is the question

In this chapter I have touched upon the possibilities for design of CAA that are able to provide the fragmented, adequate and post-action context information used by NCC when handling the activity of checking if the work are progressing according to the time plan.

The analysis of a particular work in NCC's time plan has revealed the possibility for design of CAA that are able to provide context information about how far this work has progressed. This may either be in a 'typified' form, telling the actor that the work is presently X percent completed. Or in 'raw' form, only providing an overview of where in the building that the materials are currently fitted, leaving it to the actor to typify this information as how far the work has progressed. Of these two, the application that provides this information in 'raw' form seems to be the most realistic to develop. This is because the relationship between what ducts are fitted and how far the work has progressed is both hard to define *within* a particular building and differs *between* different building projects. Finally one major problem with designing applications that are able to provide information about how far *all* the work specified in the time plan has progressed is that the relationships by which this information can be provided are not a generic feature of all the work specified in the time plan.

The analysis has furthermore revealed that although such applications might make it less time-consuming for NCC to obtain information about how far the work have progressed, the activities where this information is currently obtained still have to be carried out. Apart from this, the activity of pursuing quality control might be affected negatively if NCC is able to get information about how far the individual work have progressed without doing a round on the construction site.

Finally it is important to bear in mind that information about how far the work have progressed are readily available in a materialised form in the actual building under construction. Thus there is a potential danger that applications providing information about how far the work have progressed might suffer from the same problem that the SnowCard application described by Juhlin & Weilenmann (2001). As described in chapter three of the thesis, the SnowCard application was not used at all because the information it provided was readily available for the users simply by looking out of their windshield. Because of this, the more time the actors spend walking around on the construction site, the higher is the risk that they will consider an application providing information about how far the work have progressed superfluous.

Thus there are many arguments that points toward the conclusion that applications like the ones discussed in this chapter will be both difficult to develop and of limited use for NCC.

²⁹ In a similar way, Heath and Luff (1998) reports that a critical feature of the foreman's work is to roam around the site to monitor problems as they occur. According to Heath and Luff, one problem with the technology they studied on the construction site was that the technology impeded such discussions because the technology became the primary focus of the conversation.

7. Conclusion

In this thesis I have argued for a shift in focus from using context-aware technologies to design context-adaptive applications to using these technologies to enable context-aware actors. Based on this shift in focus, I have put forward a methodological framework serving as optics for how an exploration of a work activity should be carried out to make it useful for a discussion of the possibilities for design of CAA within the ‘context-aware actors’ approach. This methodology consists of two different models, each illuminating a question central to the design of such applications. The CIRCA model has aimed to illuminate how context information serves as resources for cooperative actors on three different levels of abstraction. The ‘layered architecture for discrete context information-based computation of adequate and post-action context information’ has been put forward as a computational framework that can enable CAA to provide context information on the three levels of abstraction that the CIRCA model distinguishes between.

To further explore exactly what designers need to know about a cooperative work activity to decide whether or not it is possible for CAA to enable context-aware actors, Schutz’s theory of relevancies as well as Kjeld Schmidt’s further elaboration on the relationship between Schutz’s notion of imposed relevancies and the concept of complexity was reviewed and discussed. I have argued that Schutz’s distinction between topical, interpretative and motivational relevancies, each of them taking the form of either imposed or intrinsic relevancies, is highly useful when exploring what context information is relevant on the three levels of abstraction in the CIRCA model. Schmidt’s remarks on the relationship between imposed relevancies and complexities in cooperative work furthermore provided a useful suggestion to exactly how relevancies are imposed on the actor. I have argued that such an examination can illuminate if the prerequisites that I have put forward for a layered architecture to be defined can be met. With reference to Schmidt’s notion of ‘embodied actions’ I have also argued that it is not a prerequisite that the application need to measure the *same* discrete context information as the actor presently uses to provide context information on the three different levels of abstraction.

The empirical study of how workflow logistics is handled on a construction site has aimed to try out the use of the methodological framework in practice. Of the four different activities that showed important in-order-to handle the workflow logistics in the building project, the context information relevant for the activity of checking how the present state of the building activities relate to the time plan has been analysed by the use of the CIRCA model. The analysis revealed that when handling this activity, the fragmented context information that enables NCC to obtain a more detailed understanding of the state of the CWS is only relevant given *some* but not *all* of the more general states of the CWS. This made me analyse the activity by four separate CIRCA models connected in a hierarchy of in-order-to relevancies.

In the second part of the analysis I have explored the possibilities for CAA to provide the fragmented, adequate and post-action context information that has shown relevant in the four CIRCA models. I argued that CAA are not able to directly measure the relevant fragmented context

information about how far the individual work in NCC's time plan have progressed. Because of this I explored if unambiguous relationships could be found between the physical location of the materials used to fit the ventilation ducts in the building and how far the fitting of these ducts has progressed. The analysis showed that to some extent unambiguous relationship can be found between the location of the materials and their status as fitted if the relationship is aligned with the information available in the technical drawing.

Finally, I have pointed towards the way in which the analysis presented in the thesis can inform the design of CAA that might advance context awareness for NCC in their task of handling the workflow logistics in the building project. Here I argued that applications might be able to provide fragmented context information about how far the fitting of the ducts have progressed, either in 'raw' or 'typified' form. However because the relationships by which this information can be inferred are not a generic feature of all the work specified in the time plan, it is questionable if CAA are able to provide information about how far *all* the work specified in the time plan have progressed.

I argued that even though applications providing information about how far the work have progressed might enable some activities within workflow logistics to be handled easier, in general the advantages of implementing such applications on the construction site seems minor. This is because the CAA are not able to render the activities by which information about how far the work have progressed is currently obtained superfluous. Such applications might also affect the handling of quality control in a negative way. And finally information about how far the work have progressed is already available in a materialised form in the actual building under construction. This made me conclude that applications like the ones discussed in the thesis will be both difficult to develop and of limited use for NCC in the handling of workflow logistics.

Pointing towards directions for future research into the development of methodologies for design of CAA within the 'context-aware actors' approach, further developing a methodology of how to explore the availability of additional interpretatively relevant information that might enable a relationship between two characteristics of the CWS to be unambiguously defined is highly requested. The development of a robust and rich context model by means of which the interrelationships between the various contextual parameters can be efficiently and consistently expressed is one way that this can be done. The LBSIS research proposal (Schmidt et.al 2003) mentioned earlier is an example of how the development of such a context model could be carried out.

I also suggest that collaboration with researchers within the 'context-adaptive applications' approach could be highly rewarding in discussing in what ways the relationships between the different layers in the layered architecture put forward can be defined to enable CAA to infer context information on the three levels of abstraction. Looking into the possibilities for applying the statistical models that is presently used to enable context-adaptive applications to 'recognise' particular contexts to the layered architecture put forward in this thesis is one way to benefit from such collaboration.

Finally more research into how the *interactional* issues of dealing with context information affects the extent to which this information is considered relevant by cooperative actors is important. The methodology put forward in this thesis has merely aimed to explore what context information might serve as relevant resources for cooperative workers as well as how to enable CAA to provide this information. However to enable a qualified discussion on how CAA serving as *sources* of information should provide context information to the actors, these interactional issues need to be taken into consideration. Applying the concept of affordances to the analysis (Norman 1999) is one way that this perspective can be analysed.

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Appendix

Appendix 1: Material logistics on project ferry

As mentioned in the thesis, the case for my empirical study wasn't appropriate for studying how material logistics were handled on a construction site, simply because this activity was not a priority on project ferry. However to aid the readers who could find it interesting to pursue an additional field study of material logistics on construction sites, I have included a short description of the reasons why material logistics were not a priority in project ferry. The knowledge I have obtained about how material logistics are handled in building projects where it is given higher priority is also described.

Material logistics covers the coordination of how and when materials are ordered, arrive at the construction site, stored (if needed), assembled (if needed) and fitted into the building.

For NCC, the activities related to the handling of material logistics differ according to the characteristics of the particular building project. In some building projects it is necessary with a very tight control of all deliveries of materials to the construction site and in others it is not necessary. Project ferry is an example of the latter. According to the NCC control unit this is due to the following characteristics of project ferry:

First of all the size of the building matters as the more square metres of building space, the more material is needed to build it. But the way the building is designed also influence the extent to which a tight handling of material logistics is considered necessary. The passenger terminal is long, slim and only two storeys high which means that there is quite a lot of available space both inside and outside the building where materials, scaffolds etc can be put. Had the building been more compact (i.e. very tall and narrow) then a scaffold used by just one subcontractor or one load of materials could easily occupy one full side of the building.

The fact that the construction site is very big compared to the size of the buildings also means that there is plenty of space for the materials that need to be stored on site. The carriage roads for the big trucks and cranes delivering the materials have also been very good in project ferry due to the open space around the buildings. If this had not been the case, a more tight control of the deliverances would have been necessary to secure that the trucks are able to unload. Finally the construction of the ferry terminal is to a large extent made of large prefabricated elements. Most of the concrete elements, the steel constructions, the whole front of the building and the roof are all made of prefabricated elements. The use of prefabricated elements reduces the need for storage and assembling space on the construction site as the prefabricated elements are often craned straight from the truck and fitted into the building. It is also far easier to keep order on a 3x3 m front element than the maybe 500 small parts it consists of.

Because of this, the flow of materials has not been controlled by NCC in project ferry meaning that the different subcontractors has not been told to inform NCC about when and how many loads of materials arrive to the site. The subcontractors must not however store their materials wherever they want. They are each assigned a particular part of the construction site that they can use for what they like and as much as they like. Hence in project ferry the planning of the flow of materials are

not specified down to individual deliveries, but merely to the allocation of storage space to the different subcontractors. This assignment is changed approximately every five weeks and is described in a *construction site plan*. If one of the subcontractors needs more space than he has been assigned, he has to inform NCC 14 days in advance. NCC will then try to find the extra space needed. Because the construction site plan is only changed every five weeks or so, quite often the subcontractors need to occupy a part of the construction site that is not assigned to them for a few hours. This is e.g. if they need to unload from a big truck. NCC does not formally coordinate these cases, but by the foremen of the two subcontracts on the weekly foremen meeting or the Lean Construction meeting, both hosted by NCC. According to NCC this very loose handling of the material logistics have not led to any major problems during the building process of the ferry terminal.

In more compact buildings with very little storage space and small carriage roads, the flow of materials are much more tightly planned and handled. In those projects, NCC includes a central coordinator of materials in the organisational chart whose responsibility is to coordinate all deliveries of both materials and equipment for assembling and fitting. In such building projects weekly production plans are made, stating exactly what deliveries are needed and when they should arrive to the construction site. In such projects, the different subcontractors are responsible for making 'unit lists' of all the materials they need for their entire work where one unit equals one load of materials delivered to the construction site. The subcontractors have to make these lists already in the beginning of the building project. The unit lists doesn't state the exact delivery dates for the units, the subcontractors have to inform NCC about the exact delivery date and time at least one week in advance. The porter on the construction site then checks all deliveries and if NCC hasn't been notified of a delivery in advance, the delivery might be send away if there is no storage space for it.

Appendix 2: Introductory letter to NCC (In Danish)

Feltstudie af arbejdet på en af NCC's byggepladser

Baggrund og formål

Feltstudiet er en del af et speciale på IT - Højskolen i København, som beskæftiger sig med IT understøttelse af samarbejdssituationer, herunder specielt de potentielle anvendelsesmuligheder for en bestemt gruppe af teknologier kaldet 'kontext aware computing'. Kontext aware computing er defineret som forskellige typer af teknologi, som har det til fælles at de er i stand til at registrere og videreformidle nogle tilstande/ egenskaber ved den kontekst (de omgivelser), som en person befinder sig i (fx fysisk placering af andre personer eller ting, temperaturændringer etc.). Kontekst aware computing kan således bruges til at gøre det lettere for en arbejdende person at få adgang til kontekstinformation, som er relevant for den arbejdsopgave der skal varetages.

Feltstudiet har på denne baggrund til formål at påpege nogle problematikker i forbindelse med det observerede arbejde på byggepladsen, som potentielt vil kunne understøttes vha. kontekst aware teknologi. Her vil der være særligt fokus på potentialet for kontekst aware teknologi, som er i stand til at registrere og videreformidle information om personer og tings fysiske placering.

For at afstemme forventningerne til output er det vigtigt at slå fast, at feltstudiet ikke vil munde ud i udvikling af konkret teknologi.

Fokus

Feltstudiet vil fokusere på *materialelogistik* i selve produktionen af et bygværk/nybyggeri, dvs. materialestrømmen på byggepladsen fra det tidspunkt materialerne bliver bestilt → modtagelse/kontrol → evt. oplagring → indbygning/montage i byggeriet.

Det er således materialelogistik på det *operationelle* niveau som er i fokus, dvs. selve den fysiske transport og håndtering af materialer på byggepladsen.

Hvem skal feltstudiet fokusere på?

Som en følge af projektets fokus er det de *udførende* parter (byggeledere, entreprenører, underentreprenører, håndværkere) i byggeriet og ikke de projekterende (arkitekten og ingeniøren), som er fokus for feltstudiet. Når det er sagt så vil jeg naturligvis ikke være blind for, at beslutninger taget under selve projekteringen, samt de projekterendes løbende kontrol af byggeriet, kan have betydning for materialelogistikken. Men i denne sammenhæng vil jeg kun interessere mig for, hvordan de udførende parter opfatter betydningen af de projekterendes arbejde for materialestrømmen på byggepladsen.

Mit kendskab til selve byggeprocessen er desværre for begrænset til præcis at vurdere, hvilke personer jeg gerne vil observere/ interviewe i løbet af feltstudiet. Jeg har aldrig selv været på en byggeplads, men på baggrund af tre dages litteraturstudier af, hvordan en byggeproces forløber, har jeg lavet nedenstående liste over aktiviteter, som jeg finder interessante at observere/interviewe omkring. Det skal bemærkes at listen er meget midlertidig, og jeg vil derfor i mit feltstudie være meget opmærksom på andre aktiviteter, som måtte påvirke materialestrømmen på byggepladsen. Det er også muligt at jeg i løbet af feltstudiet vælger kun at fokusere på en del af de listede aktiviteter:

- Bestilling og modtagelse/kontrol
 - Leveranceplanlægning
 - Bestilling af materialer
 - Aftaler om leveranceform, leveringstidspunkt
 - Afkald af varer
 - Modtagekontrol

- Oplagring/ pladsstyring
 - Aflæsning/ placering af de leverede materialer på byggepladsen
 - Sortering af materialer
 - Til og afdækning af materialer

- Indbygning/ montage i byggeriet
 - Finde materialer, som håndværkerne skal bruge
 - Transportere materialer internt på byggepladsen
 - Finde materiel, som skal bruges til indbygningen/ montagen af materialerne (kraner, stilladser etc.)

- Affaldsbehandling

Hvordan skal feltstudiet udføres?

Fokus for feltarbejdet vil først og fremmest være at få en overordnet forståelse af, hvordan materialestrømmen igennem byggepladsen foregår fra bestilling til indbygning/ montage. På baggrund af denne overordnede forståelse vil jeg udvælge en eller to nøglepersoner, som spiller en central rolle i håndteringen af materialestrømmen. Disse personers arbejde vil jeg i resten af feltstudiet forsøge at opnå en forståelse af. Herunder specielt en forståelse af, hvilken viden om konteksten (både byggepladsens tilstand, samt det arbejde som andre aktører udfører på byggepladsen), som disse nøglepersoner er afhængige af, for at kunne udføre deres arbejde i relation til håndtering af materialestrømmen tilfredsstillende.

Da mit kendskab til hverdagen på en byggeplads er meget begrænset, er det svært på forhånd at sige præcist hvordan feltarbejdet skal udføres, samt over hvor mange dage det skal forløbe. Men jeg forestiller mig følgende:

Ang. udførelsen forestiller jeg mig at feltstudiet vil omfatte kontekstuelle interviews (dvs. interviews udført i den faktiske arbejdssituation), samt observationer af arbejdet på byggepladsen. Først og fremmest har jeg brug for en generel introduktion til arbejdet på den konkrete byggeplads i almindelighed og materialehåndteringen i særdeleshed, samt en rundvisning på byggepladsen. Her kunne jeg forestille mig, at et interview med byggelederen vil være passende. På baggrund af denne introduktion vil jeg bedre være i stand til at planlægge, hvilke personer som det vil være relevant at observere/interviewe i resten af feltarbejdet.

Ang. længden af feltarbejdet så forventer jeg, at ca. 20 dage på byggepladsen, fordelt over halvanden til to måneder, vil være en passende størrelse. Det kan umiddelbart lyde som meget, men det er vigtigt at understrege, at jeg i de 20 dage på byggepladsen ikke vil lægge beslag på 20 fulde mandedage af medarbejdernes tid. Min dataindsamling vil primært foregå som observation og kontekstuelle interviews, hvilket tillader de involverede personer at arbejde i langt størstedelen af den tid, hvor jeg observerer/ interviewer dem. Jeg vil med andre ord indsamle data ved at være 'føl'

for de enkelte medarbejdere, dvs. følges med dem rundt på byggepladsen, sidde sammen med dem på deres kontor, tage med til byggemøder, modtagekontrol etc. og kun spørge ind til deres arbejde, når det er nødvendigt. Der vil også gå en del tid, hvor jeg blot sidder for mig selv i et af byggepladsens skure og nedskriver dagens observationer.

Da feltstudiet brutto kun forløber over halvanden til to måneder, kan jeg i sagens natur ikke i denne periode få indblik i alle byggeriets faser (hvilket i øvrigt også ville blive alt for komplekst). Jeg vil derfor i mit indledende interview med byggelederen spørge ind til byggeriets opdeling i byggeafsnit/ delarbejder og bruge denne viden til at vurdere, hvordan feltstudiet kan afgrænses i forhold til de enkelte byggeafsnit/delarbejder eller i forhold til andre parametre, jeg pt. ikke har viden om.

Starttidspunkt

Da jeg skal aflevere mit speciale senest 1. marts 2004, så kunne jeg godt tænke mig at komme i gang med feltarbejdet så hurtigt som muligt – hvis det er muligt allerede i starten/ midten af November. Jeg er klar over, at det er meget kort varsel og er derfor også fleksibel i forhold til starttidspunkt for feltarbejdets udførelse.

Valg af byggeplads

For at være så fleksibel som mulig, vil jeg ikke i udgangspunktet stille egentlige krav til valg af byggeplads. Følgende vil dog være fordelagtigt at tage med i overvejelserne, når der skal vælges en byggeplads:

- Byggeriet må helst gerne være af en sådan størrelse af der er nogle koordineringsproblematikker i forbindelse med materialestrømmen til byggeriet, uden at disse dog bliver for komplekse. Med andre ord så vil det være fint, hvis byggeprojektet hverken er opførelsen af et operahus eller et en-familieshus.
- Ang. fremskredenheden i byggeriet, så vil det være meget fint, hvis jeg kan komme ud på en byggeplads, hvor arbejdet allerede er godt i gang. Byggepladsen må således gerne allerede være arbejdspladsmodnet, kontorer og skure anlagt og tildannelsessteder og lagerarealer etableret. Dette begrundes med, at det primært er strømmen af materialer, som skal bruges til det egentlige byggeri, som jeg finder interessant. Udover dette må der gerne være mere end et fagområde i gang på byggepladsen i den periode, hvor jeg laver feltstudier. Fundamentet må derfor gerne allerede være støbt.
- Rent logistisk vil det være en fordel, hvis byggepladsen ligger inden for HT området.

Jeg håber at ovenstående giver et fornuftigt billede af, hvad det er for en type feltarbejde jeg kunne tænke mig at lave, og at det har vakt interesse. Hvis der er nogen spørgsmål, så tøv ikke med at kontakte mig.

Venlig hilsen

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