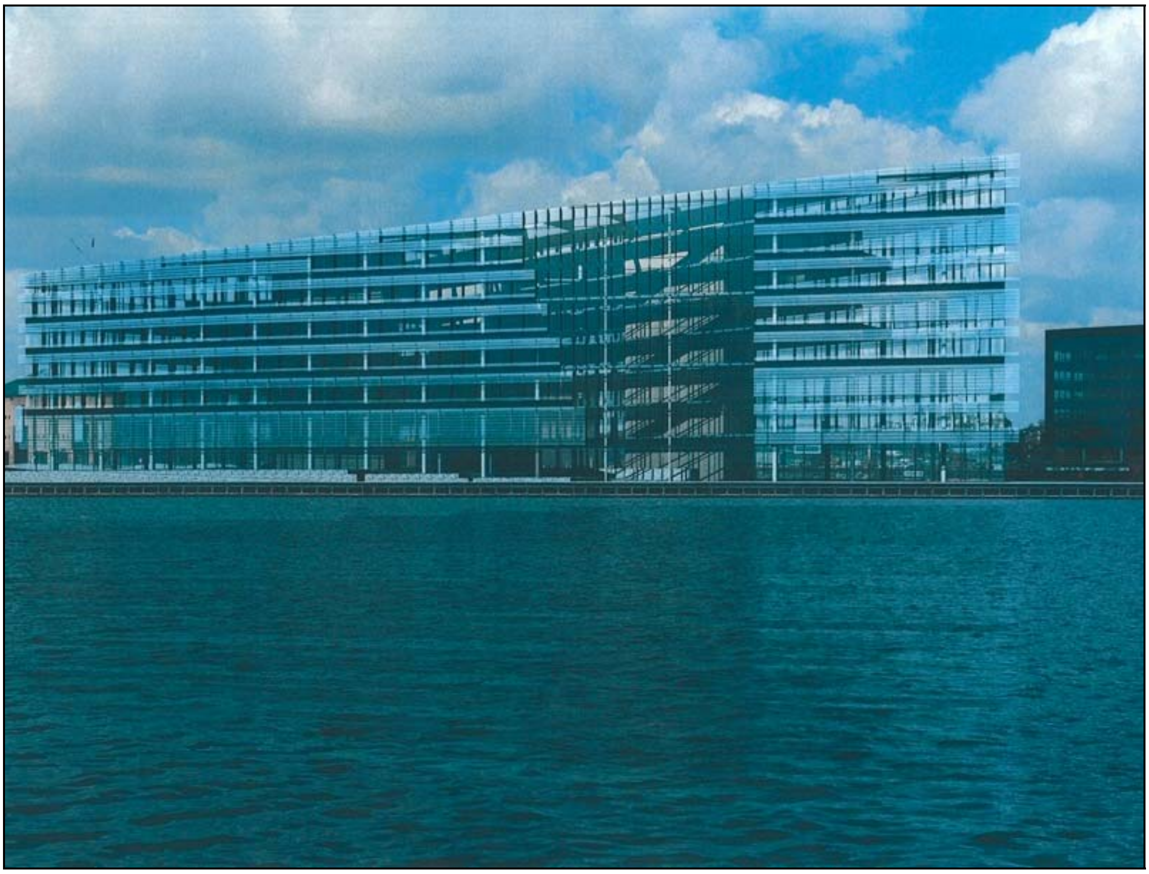
The Coordination of the Building Process

Articulation Work and Practices of Stigmergy



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The Coordination of the Building Process: Articulation Work and Practices of Stigmergy

Thesis to obtain the degree of Ph.D. from the IT-University of Copenhagen.

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PREFACE

This dissertation is the outcome of three years of research. I would like to take the opportunity to express my gratitude for the wonderful inspiration and encouragement I have received along the way.

First, I would like to thank my advisor Kjeld Schmidt sincerely for his unflagging support and enthusiasm. Kjeld Schmidt has been a major source of inspiration all the way, and I am thankful for his ability to stay involved while leaving me room to work independently. It is safe to say that without Kjeld Schmidt I would never have become a researcher.

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Through his impeccable eye for language Morten Visby has provided my writings, including this dissertation, with high quality proofreading. Thank you.

I am indebted to my family Lilli Tobiasen, Henning Christensen, and Nicoline Tobiasen for their care and support. Mette Mathiassen agreed to follow me from Greenland to Denmark simply because I wanted to pursue Ph.D. research here. I thank to you and Bjørk for being an inexhaustible source of love.

Lars Rune Christensen,

Copenhagen, September 2009.

ABSTRACT

The building process is a complex cooperative endeavour. On the basis of a field study, this dissertation discusses how the building process is achieved and coordinated. More specifically, it is discussed how architectural design relates to construction work and vice versa, how skills pertaining to the use of architectural plans may be acquired through apprenticeship, what coordinative practices the building process entails, how these practices can be conceptualised and what implications this has for the research field of CSCW. In regard to the central question of coordination, a distinction between practices of stigmergy and articulation work is made. Stigmergy is understood as coordination of cooperative work achieved by virtue of individuals acting on the material evidence of work previously accomplished by others and articulation work is understood as supra-type efforts to coordinate cooperative work.

INTRODUCTION

Question

How is cooperative work coordinated in the building process?

Introduction to the chapters

The following provides a brief overview of the chapters. The objective is not to repeat the arguments in each chapter, but to provide a sense of how each chapter adds to the emerging views on the building process, including the coordination and integration of cooperative work. Generally speaking, the dissertation starts out somewhat descriptive and moves towards discussions of a more conceptual nature.

In chapter one, an attempt is made to provide an introduction to the building process. It is described as a complex endeavour, constituted by numerous distributed and interdependent tasks carried out by a diverse work ensemble. The tasks in the building process are said mainly to fall within two interconnected domains: design on the one hand and construction on the other.

In chapter two, the question of how design relates to construction and *vice versa* is addressed. It is observed that design and construction are overlapping and interdependent endeavours: Design is related to construction in the sense that design is partly a matter of designing spaces that will need to be realised during construction, and construction is related to design in the sense that construction may be influenced by actions taken previously in design.

In chapter three, a case of apprenticeship and visual skills is investigated. It is argued that participating in practices based on complex representation artifacts is an *acquired* skill that may be passed on through apprenticeship.

Chapter four addresses the question of how distributed tasks within the building process are integrated and coordinated. A range of specialised coordinative practices described as *articulation work* is accounted for. In addition it is described how distributed tasks may be integrated through individual acting on the physical evidence of work previously accomplished by others.

Chapter five reflects on the concept of *stigmergy*. It is described as a concept that is not well established in relation to the analysis of the integration of cooperative work tasks, and it is argued that it may be a useful addition to the conceptual toolkit if used in conjuncture with concepts such as *articulation work and awareness*.

In chapter six, the study's implications for the field of computer supported cooperative work (CSCW) are discussed. The focus is not least on how computer technology may support practices of stigmergy. In addition the main propositions of the study are reiterated and summarised.

The methods of the study

This dissertation is based on fieldwork carried out in the course of fourteen months in architectural offices and on building sites. In this period, work within the domains of design, planning and construction in relation to several building projects was studied. One of the building projects, the development of the new domicile for a publishing house, is a multi-storey building in glass, steel and concrete constructed at the city of Copenhagen's waterfront. It is a relatively large building of 18,000 m2 distributed across eight floors (see figure 1). A combination of observation and interviews was used. The fieldwork also included collecting (scanning, taking screenshots or photographs of) artifacts used and produced by the actors engaged in the building projects.

Since the research questions centre on practical, everyday activities in the building process, ethnographic methods have informed the fieldwork strategy. Ethnography directs the focus on the manner in which a phenomenon is enacted in practice and data or ethnographic material are generated through participation, observation, interviews and the collection of artifacts. Anthropologists and other social scientists refer to this particular modality of qualitative method as 'ethnography' or 'participant observation'. This latter phrasing implies the dual role of the ethnographer as both observer and participant, gaining insight by an active engagement with the unfamiliar, an engagement with a blurred line between observation and participation. Furthermore, the researcher aims to describe the world as perceived by those within that world. As Malinowski put it during his seminal study of Pacific Islanders in the early 20th century, the aim is 'to grasp the native's point of view, his relation to life, to realise his vision of his world' (Malinowski 1984). In addition, it must be kept in mind that all actors including the ethnographer are situated, and that this unavoidably informs the generation of data - the situated and interested ethnographer generates rather than gathers data. Ethnographic material is not out there to be found, it has to be made in a 'conversation' with the phenomena of the field site (Winthereik 2004, p.12).

According to Silverman (2008), there is a distinction to be made between 'naturally occurring' situations for data generation and those that are not. For Silverman the term 'naturally occurring' referrers to situation that ordinarily happens in the world of the actors such as for example meetings between actors or the performance of their individual tasks, what is not 'naturally occurring' is situations created solely at the initiative of the researcher such as for example interview situations or social science experiments. Bluntly put, Silverman applauds the generation of data in relation to 'naturally occurring' situation and somewhat dislikes those situations created solely at the initiative of the researchers such as for example formal or semi-formal interviews. According to Silverman, the latter techniques (e.g. interviews) are far too dependent on the researcher's intuitions and imagination not least in regard to the formulation of interview questions. Silverman finds support for this position in Sacks (1992) who holds that intuitions and imagination rarely give us a good guide to how actors actually perform. By contrast, data generated in 'naturally occurring' situations give us an insight into things that we could never imagine. As Sacks puts it, using what ordinarily happens in the actor's world 'we can start with things that are not currently imaginable, by showing that they happened' (Sacks 1992, p.420). Potter (2002, p.540) extends Sacks arguments by making a series of related points: (1) 'naturally occurring data' do not flood the research setting with the researcher's own categories (e.g. embedded in interview questions, probes etc.). (2) It opens up a wide variety of novel issues that are outside the prior expectations embedded in for example interview questions. (3) It may provide a rich record of practice. None of Potter's points denies that interviews or social scientific experiments for that matter can ever be useful or revealing. However, they do suggest that it is these techniques that should be justified, rather than techniques related to 'naturally occurring' settings. As Potter puts it, 'the question is not why should we study natural material, but why should we not?' (Potter 2002, p.540).

In this spirit, the pages ahead are full of references, descriptions and excerpts all related to observation and recordings of 'naturally occurring' situations such as meetings between actors in architectural offices and on the building site, and actors working on their individual tasks such as building design and construction work. Artifacts such as architectural plans collected from the architectural office or building site also appear frequently. In contrast, very few references to interviews have found way into the pages ahead. In fact, no interview transcripts will appear. Although a series of interviews were made. I found that my interviews served one purpose especially well and it was *not* informing on work practice, rather it was creating rapport with the actors. One way of getting to know an actor in a friendly manner, one way of showing respect and interest in his or her work is by doing an interview. The interview transcripts may not be of great value, but the process may build rapport and the interview situation may provide an overview of the activities of the actor - for example it may draw attention to a series of regular meetings that the particular actor is involved in, meetings that may later be observed and recorded. In this manner interviews does serve a purpose and I did approximately twenty-five of them. Of course, interviews may inform on work practice to some degree, but in this study they take a backseat not least to observations.

The study also relies on the collection of artifacts, a technique as old as ethnography itself. The collection of ethnographical artifacts, material artifacts, taken from the fieldwork setting, has been and still is a trusted way of exhibiting the unfamiliar ways of 'foreign' cultures in museums and the like (Atkinson et al. 2001). In this study, the collection of artifacts take on a different role, they are collected with data-generation in mind rather than exhibition or illustration. I have followed the path or 'life cycle' of documents, descriptions, time schedules, sketches, architectural plans and the like through the work organisation of a building project, and the flow and nature of, records, protocols, checklists, and forms. This has been done, inspired by Harper (2000), in order to generate part of the material for the ethnography. It provided a rudimentary view of the building process to follow, for example, the various modalities of an architectural plan as applied in a building project.

Although useful in this discussion above, we could interject that the phrase 'naturally occurring situations for data generation' is somewhat dubious. That is, there are a number of reasons why we should not take an undoubted appeal to 'naturally occurring data' too far: First of all, doesn't it assume a polarity between what is 'natural' and what is 'artificial'? As anthropologist Mary Douglas have shown, we need to investigate how the distinction between the 'natural' and the 'artificial' is achieved, rather than simply take it for granted (see Douglas 2002). Moreover, even when we think that we are not 'intervening' in a particular field setting (e.g. by refraining from casting actors as interviewees), our setting for data generation cannot be entirely 'natural' as it is mediated by our presence and the presence of for example our recording equipment. For example, a setting such as a meeting between actors may be influenced by the presence of the researcher and his or her recording equipment, which may prompt some actors to modulate their behaviour, e.g. by talking in a more formal tone that usual.[1] Furthermore, even if we ‘just’ observe, we need to find some means of recording our observations such as through field notes. Attention to the craft of writing field notes may prompt us to consider the categories we use to describe our observations. These categories may originate with the intuitions, imagination and theoretical baggage of the researcher and we are back at making the observation that the whole enterprise depends on a situated and interested ethnographer. Field notes for example are not to be considered representations of the field ‘as it really is’, they are authored representations (e.g. Clifford and Marcus 1986). Field notes help the researcher re-adjust the design of the study as it unfolds. As analysis and data generation intersect, field notes are validated through surfacing, in an explicit manner, the theoretical underpinnings that support them. The question of their validity is not cast in terms of ‘accuracy’ of representation’, but rather, in terms of ‘adequacy’ of representation. Third, in assessing the value of any data source (e.g. observation, interview, experiment etc.), much if not everything depends on the character of the research project. For example, how are we to study the internal conversations of actors, as Archer (2003) have done in her study of the inner dialogue of individuals reflecting upon their social situation, without recourse to interviewing? Our methods are dependent on our research interests (Silverman 2008).

These considerations aside, there is something to be said in favour of ‘naturally occurring situations for data generation’ not least the fact that, and this is meant to reiterate a point made above, using what ordinarily happens in the actor’s world ‘we can start with things that are not currently imaginable, by showing that they happened’ (Sacks 1992, p.420). That is, we may open up a wide variety of novel issues that may be outside prior expectations if we focus on work practice as it unfolds. Much of the fieldwork in this study has been conducted in this exploratory spirit.

Finally, doing ethnography implies that writing up the research has a different function than merely reporting the results at the end of a study. Writing makes the setting under study available for the researcher, as writing gives the field a concrete form for the researcher to reflect upon. Writing is an integrated part of generating ethnographic material through field notes, data-generation, analysing and writing up. This is not a series of discrete steps, but part of the same process (Silverman 2008). What this implies, among other things, is that every

[1] I have had this suspicion on a number of occasions.

piece of writing is authored by a situated and interested author. This includes the pages ahead.

CHAPTER ONE: INTRODUCTION TO THE BUILDING PROCESS

This chapter contains an introduction to the building process that points to the complexity of the process. First we will describe the network of actors involved, subsequently we will turn to describe the tasks in which they are involved.

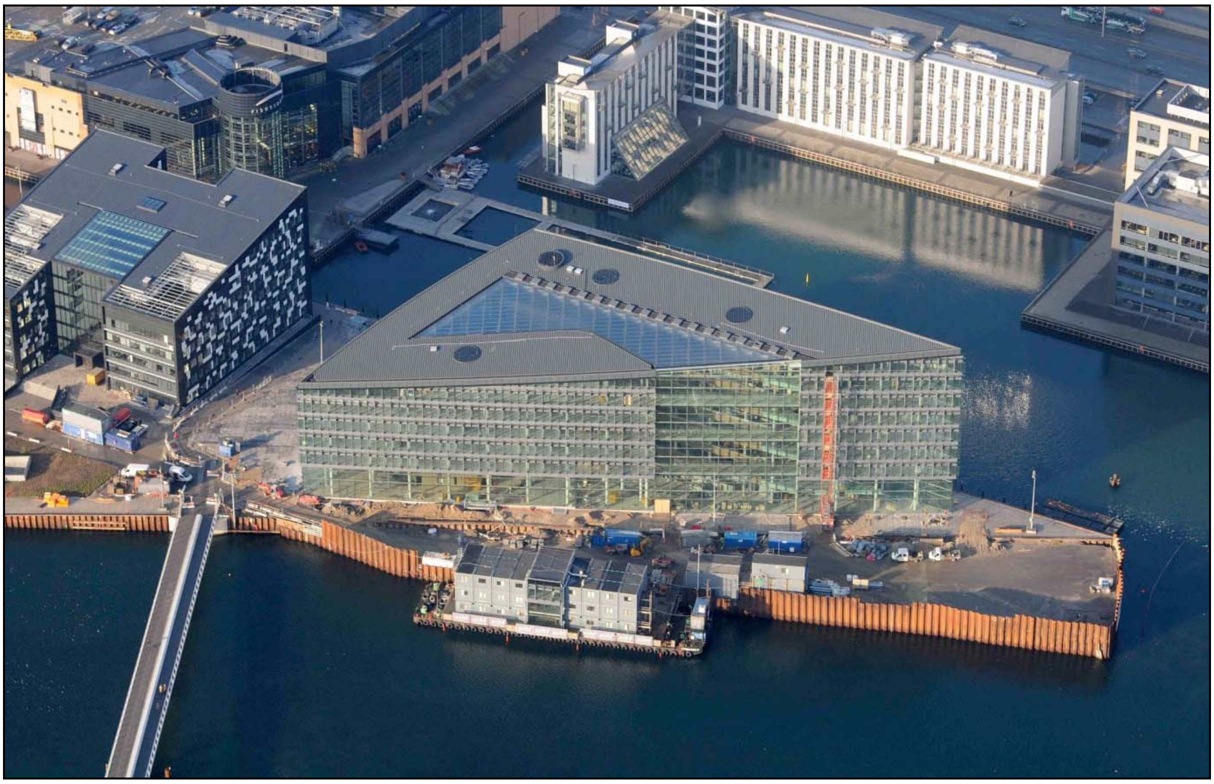

Figure 1: One of the building projects studied, a new domicile for a publishing house, nearing completion April 2009.

The building processes studied here involves the creation of unique structures rather than mass-produced entities (see e.g. figure 1). Such projects almost always start with a client approaching an architect with the intent to acquire a new building. Briefly put, the building project that follows is planned and worked out step-by-step, phase-by-phase. Gradually the project takes shape, the requirements (e.g. size, materials, functions etc.) of the proposed building are put down on paper as written text and the first conceptual design sketches are drawn up. The number of people involved increases, sketches become scale drawings, and architectural plans become the basis for applications to the authorities. After an initial building permit has been issued, tenders are invited from contractors, and commission is awarded to a general contractor. The general contractor then hires the various subcontractors and the aim of putting up the building is within reach once the final architectural plans have been made and the subcontractors with their craftsmen, builders and workers has been coordinated on the building site. That was the short version. Here follows a bit more elaborate one.

The network of actors

For each unique major building project a network of actors is created or configured. The network is a diverse ensemble from many different professions, working for many different companies (see figure 2). Some such as the client and the main architects are with the project from start to finish, while others such as the various subcontractors are associated with the project only for the duration of their allotted tasks.

In regard to design we may say that the actors directly involved in the design development, those that actually draw and model the building, are the architects, construction engineers and consultants such as static engineers, building services engineers and landscapers. In addition some of the vendors may employ engineers that contribute to the design of prefabricated[2] building elements.

In connection to construction we may say that the actors directly involved in the construction work, those that actually build the building are the subcontractors employed by the general contractor, including concrete specialists, carpenters, plumbers, electricians, painters, roofing specialists, ventilation specialists etc.

We may interject that large building projects are performed in a fast-track manner, which implies that design and construction overlap in a temporal sense (Sabbagh 1989). For example, the physical construction of a building's foundation may be well underway before the design of the buildings roof is finalised. That is to say that much design work is very much concurrent with the construction of the building.[3] However, the design of a specific building element generally precedes its construction. For example, the design of a roof is most often finalised before it is physically constructed.

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[2] Building components such as whole wall sections may be produced in a facility off the building site and are in this sense considered ‘prefabricated’.

[3] This is mainly grounded in a desire to save time by virtue of *not* having to wait until the whole building has been designed before commencing with its construction (Sabbagh 1989).

Client	**Architects**	**General Contractor**	**Authorities**
Initiates the process	Responsible for overall design	Moderates the design of the working plans	Building permit and regulations
Contracts architect and general contractor	Coordinates the design process	Plans the construction process	Environmental assessments
Formulates building program with architect	Formulates building program with client	Hires subcontractors and retains architect	
Users	**Consultants**	**Subcontractors**	**Vendors**
Contributes to requirements	Specialists for statics, lightning, building services and more.	Retain the craftsmen that actually construct the building.	Provides building material and fabricate components
			Design building components

Figure.2: The ensemble of actors involved in a large building project.

The networks of actors found in the building process differ from other organizations of work such as manufacturing or services that may enjoy far more extended longevity. That is, the concrete configuration of actors (i.e. client, architects, general contractor, subcontractors, vendors etc.) is specific to the particular building project and dissolves as the project ends. However, a number of arrangements counteract these ‘transient’ tendencies of the network. First of all, the major players in the business may have worked together on various projects in the past. For instance the architect and the general contractors may be familiar with one another from prior engagements. Furthermore, it is not uncommon that for example the general contractor relies on a small group of trusted subcontractors when recruiting for a project. For example, in the domicile project mentioned above the general contractors and a large part of the group of subcontractors had worked together on a previous project. Secondly, the various actors are all part of the construction industry at large, and although they may meet as strangers in relation to a specific project, they bring with them rather precise expectations of the manner in which the project ought to be carried out (Kreiner 1976, p.83). The actors, then, are part of the same work domain, i.e. the building process, and as such they are familiar with the norms and practices that are part and parcel of it. Consequently, roles and responsibilities for example may merely have to be aligned anew for every project, rather than ‘invented’ from a clean slate.

Taskscapes

We will now turn to describe the collections of tasks in which the network of actors are involved. We will describe them in terms of taskscapes.

The network of actors is configured in relation to performing a complex series of interwoven and interdependent tasks. Using a concept coined by Ingold (2000), these collections of tasks could, be described in terms of 'taskscapes'.

> 'How, then, should we describe the practices of work in its particulars? For this purpose I shall adopt the term 'task', defined by any practical operation, carried out by a skilled agent in an environment, as part of his or her normal business of life [...] Every task takes its meaning from its position in an ensemble of tasks, performed in series or in parallel, and usually by many people working together [...] It is to the entire ensemble of tasks, in their mutual interlocking, that I refer by the concept of *taskscape*.' (Ingold 2000, p.195. Ingold's italics.)

The notion of taskscape, then, refers to an ensemble of tasks where each individual task (partly) take it's meaning from its position in the ensemble of tasks at large. This seems to be one of the many characteristics of tasks in the building process, as we shall see. Employing the notion of taskscape, then, we will attempt to give an overview of the building process. The descriptions of the taskscapes is meant as an overview (and no more) of the scope, complexity and distributed nature of the building process. We will first consider the taskscape of design and then we will consider the taskscape of construction.[4]

The taskscape of design

In this section we will describe the taskscape of design. As indicated above, there are stages in the life of a design project, some are even legally defined, and the progression is one of ongoing refinement and increased specificity. Generally speaking, the initial representations of the building are mere sketches, hand drawn on paper. These are mainly used to develop the overall design concept. The sketches are later turned into models using computer aided design (CAD). These CAD models have a modest detail level and are initially made for tendering purposes. Tendering is the process of finding a contractor able and willing to

[4] However, keep in mind that design and construction are two highly interrelated endeavours - we will return to this below.

construct the building at the right price. A special set of CAD plans and documents are made for this purpose. Finally, once the contractors have been found, the CAD models are fully detailed, they are turned into so-called ‘working plans’, so the men and women doing the actual construction work can use them. Occasionally, of course, design is revised and things have to be undone. That is, the process has its iterative moments as well.

We shall now turn to describe the taskscape of design in more detail. However, before we do so, we will familiarise ourselves with a technology and method commonly used in contemporary building design, namely computer aided design.

Computer aided design

In the last 30 years or so, computers have become a prominent tool in the design process, and we speak of computer aided design (CAD). In the design process the central representational artifact is the CAD system of plans and models. As an ensemble, they incorporate a project’s trajectory; they absorb and reflect all decisions taken and changes made, as plans are gradually detailed and modified (Schmidt and Wagner 2004). That is, the CAD system of plans and models may be said to be the representational nexus of the design project in that design decisions that have been worked out in various forms - sketches, calculations, descriptions and so on - are reflected in the CAD models.

Most commonly, CAD design is carried out in two-dimensions (see Schmidt and Wagner 2004). Recently, however, it has become increasingly commonplace to design buildings with the use of CAD models that capture the three-dimensional aspects of buildings. For example, in the domicile project studied here much design work was carried out with the use of three-dimensional CAD techniques in conjunction with other forms of representational artifacts such as hand drawn sketches and models made of foam or paper.

In the three-dimensional approach to CAD design, used in for example the domicile project, the medium for the designer is in three dimensions, while the end result, to be used for example by the contractors and builders, is in two dimensions. The architect or building engineer working with the three-dimensional CAD model selects a number of views of the building (elevation view, section view, plan view, detail view etc.) and exports them from the CAD application as two-dimensional plans in PDF format to be printed out by those that may be inclined to do so. The architects use the two-dimensional paper format in design meetings where the paper printouts are spread out on a table and discussed, and the contractors and builders use them on the building site where they are applied to the construction work (once that stage has been reached).

A quick word on terminology: in one of the main projects studied, i.e. the domicile, three-dimensional CAD was the dominant approach[5], and unless otherwise stated we will be referring to this approach when we speak of CAD design in the following. Also, architectural *models* refer to the three-dimensional entities that the designers are creating and working with in their computer applications, just as architectural *plans* refer to the two-dimensional entities that are created from these three-dimensional models.

Perhaps we are now in a position to describe the taskscape of design. We will start at the beginning with conceptual design, secondly we will consider the tendering project, third is the working plans for the main architecture, and fourth is the working plans for the building services. These are overlapping phases, rather than a strict sequential process, and the descriptions of them are merely meant as an overview.

Conceptual design

The conceptual design phase takes place at the very beginning of the building project in the office space of an architectural firm. The initial development of the design concept for a large building is mainly concerned with the exploration of geometry, volume, colour and materials as well as the flow of people within and around the projected building.

Using various types of representational artifacts, the architects explore and develop the building's design. Loose sketches are used by the architects to explore the geometry of the building. In the case of the domicile it is a triangular shape with an atrium drawing light into the centre (see figure 3). Other sketches represent the flow of people and things, through entryways such as doors, stairs and elevators rendered with patterns of loose lines. In addition, colour samples assembled on a piece of paper set the palette for the building, for example a 'maritime' colour scheme in the case of the domicile (in line with its placement at the waterfront). Finally several models are crafted in wood or cut in foam in order to visualize the volume and proportions of the building in a concrete physical form in three-dimensions.

[5] There were exceptions to this, e.g. some vendors of building elements did their design using exclusively a two-dimensional approach, making CAD representations that could *not* be incorporated into the central aggregated model of the building.

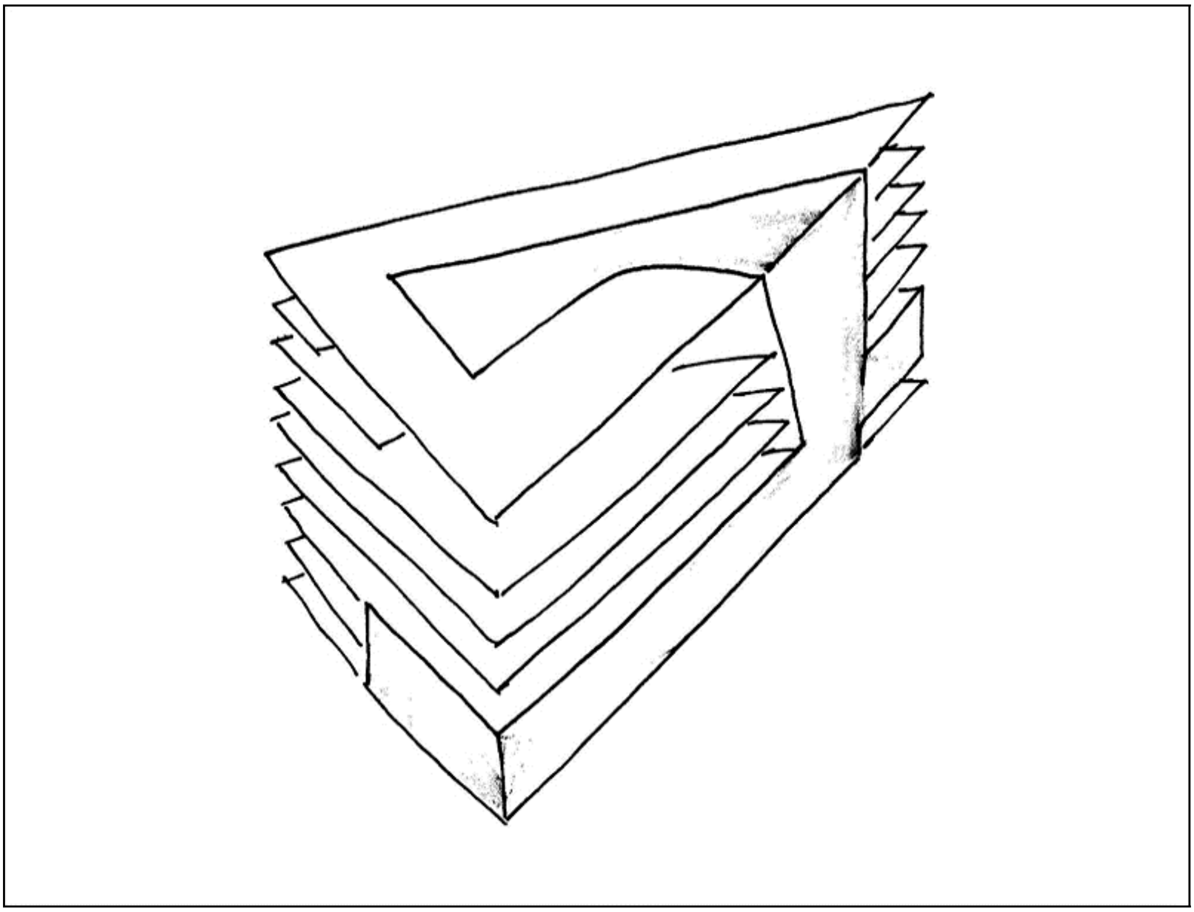

Figure 3: Sketch of geometry.

These sketches and models are made in a process of design exploration with the purpose of inviting further exploration. At this juncture, then, the representations are made for the benefit of the architects' own design process and not in direct support of, for example, the builders' construction effort (representations meant to serve the actual construction of the building are called 'working plans' and these are made at a more advanced stage of the building process). Furthermore, the scope of the collection of representations made at this point mainly includes broad design features (i.e. main geometry, volume, materials, colour, flow etc.); numerous details still need to be worked out as the conceptual design stage draws to a close.

In sum, the developing of the design concept consists of tasks such as exploring volume, texture, colour palette, lighting and traffic patterns.

Tendering project

Parallel to and exceeding the conceptual design work is the creation of the tendering project. Once the client and architects feel confident in the design, a contractor able and willing to construct the building must be found. This process is called tendering and the main task involves the creation of the invitation to tender. This invitation takes the form of descriptions and architectural plans, and the bid for the building contract is made on the basis of this invitation. It must convey the overall complexity and size of the project, its build quality, the construction principles asked for, the time frame set for the construction and so on. This is done in order to give the potential contractor a fair impression of what they are asked to build.

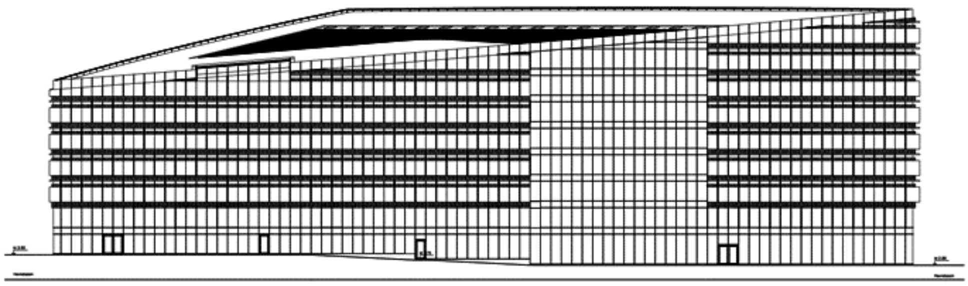

Figure 4: Architectural plan made for tendering purposes.

The architectural representations of the tendering project are created with CAD. At this stage the architects have developed the conceptual design, now this concept must be elaborated and drawn to scale for tendering purposes with CAD techniques. That is, based on the conceptual design, three-dimensional CAD models of the building must be made. In practice, this may involve a division of labour in which the architect's hand drawn conceptual design sketches made with pencil and paper are reproduced in a CAD application by a construction engineer. The hand-made sketches are transposed and made to scale in three dimensions with straight lines and perfect geometry. This may be a matter of the construction engineer placing the sketch next to his CAD workstation and referring to it as he develops the CAD rendering of the building's geometry.

In this manner the CAD model is created with a limited number of details covering the main proportions of the building's geometry. An overall sense of proportion is given in the hand drawn sketches; however, the systematic interrelations of the exact measures must be computed by the construction engineer in this first fixing of the building design in a CAD model. In these representations, dimensioning is restricted to rough measurements.

A number of two-dimensional plans are generated from the three-dimensional models of the building, printed out and attached to the invitation to tender. These include: a land registry plan showing the position of the building in relation to the surroundings, a location plan showing the position on the lot, plan views showing the building in the horizontal plane, elevation views in the vertical plane showing the building from the outside, section views in the vertical plane cutting through the building, detail views showing principles of montage, plans showing the proposed interior decoration, and plans showing the static or load bearing elements of the building. These plans are created with the purpose of conveying an impression of the building sufficient in scope and detail to serve as a basis for contractual negotiations for the building contract. That is, the representations at this juncture are not made for the benefit of the architects' own design process; it is made in direct support of the tendering process. This does not entail, however, that the representations considered as a whole are fully detailed and of full scope. In the words of one architect, 'the tendering project is made on a need to know basis. We know that much of it is going to be revised later on anyway, so there is no point in making too much of it'.

In regard to the written descriptions, we may say that they convey the project's excepted build quality, the construction principles asked for, the time frame set for the construction and so on. This is done as a companion to the architectural plans.

The invitation to tender consists of a total of fifty-four plans generated from the main three-dimensional model and ninety-six pages of written description - in comparison, the collection of working plans generated from a much more elaborate building model, that we will turn to shortly, numbers some two thousand plans and several thousand pages of written descriptions.

In sum, the creation of the invitation to tender consists of tasks such as turning the conceptual design into CAD models and making descriptions that may provide an impression of the overall complexity and size of the project.

Working plans for main architecture

Only after the negotiations for the general building contract have been resolved and a general contractor has been found, does the creation of the working plans begin to gain momentum. The creation of working plans takes place throughout the construction of the building. That is, the creation of a particular working plan may be ahead of the construction of the depicted section of the building by a few weeks or so, sometimes even less.

The model from which the working plans are generated is a direct elaboration of the three-dimensional CAD model that was initiated in the tendering stage. The models made in the tendering project are of a limited detail level, and now this detail level is increased.

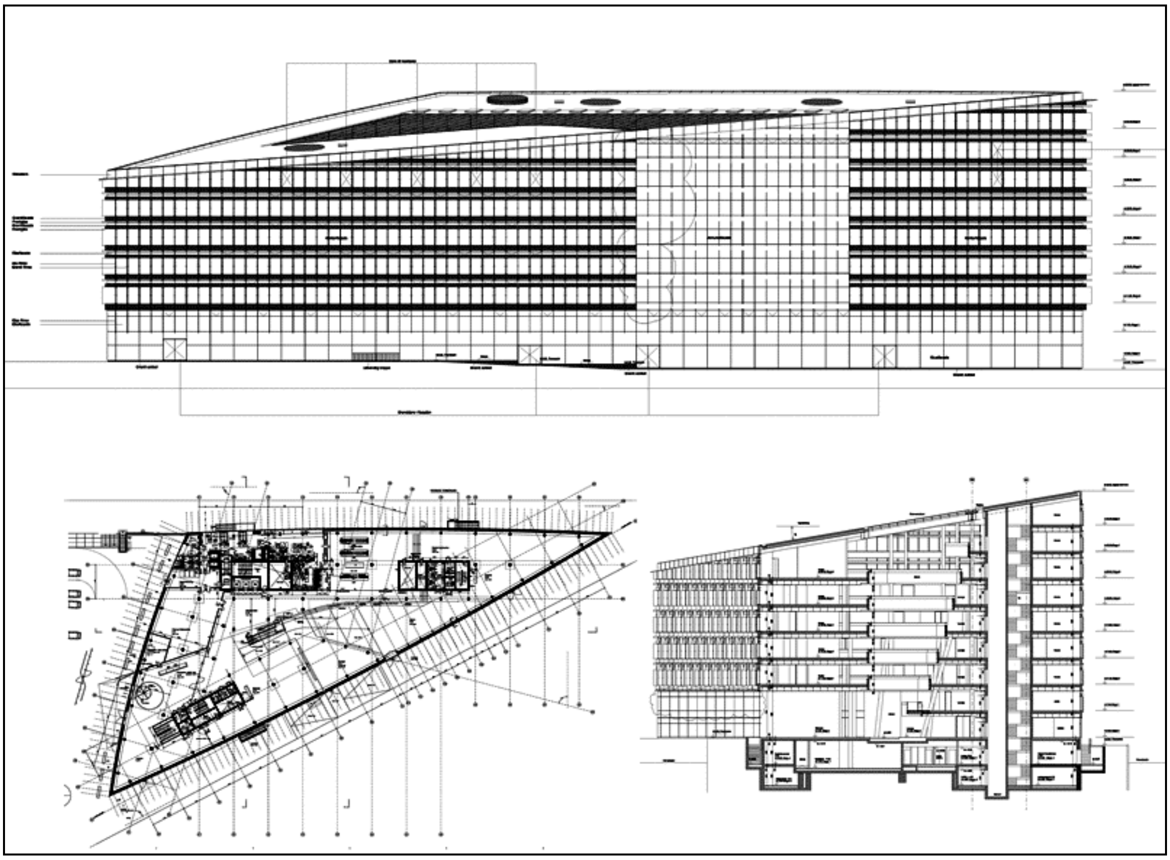

Figure 5: Collage of working plans.

Bearing in mind that the working plans are to be used for the accurate construction of the building, the engineers and architects at this juncture aim to represent the geometry of the building in its entirety and provide all the dimensions of the specific building elements that are involved in the construction process. This is most often a matter of the construction engineer or architect loading the relevant CAD model into his CAD application and picking up where he himself or others left off in the tendering stage. The working plans generated must include what is already shown in the tendering project. In addition for example the height, width and depth of every specific building element is provided.

From the elaborated three-dimensional CAD model a large number of plans are generated for the purpose of conveying to the contractor and builders precisely how every aspect of the building should be constructed. Based on the elaborated model, then, the building constructors turn out a large collection of highly detailed architectural plans of an almost all-encompassing scope and these are put into the hands of the men and women doing the actual construction work. In principle, every detail should be accounted for; in practice, however, that is not the case. It is assumed that the builders have the necessary skill and experience to fill in some blanks themselves.

In sum, the tasks of creating the working plans of the main architecture is mainly based on the model made in the tendering stage that is elaborated and further detailed for the benefit of the performance of construction work.

Working plans for building services

Parallel to the creation of the working plans for the architecture, the building services engineers are underway with models for their respective areas as well, namely electricity, heating, lighting, communication lines, ventilation, sanitation, lifts, alarms, fire detection, etc. These models have to be created and aligned with the each other and not least the general layout of the building. Note that building services may take up as much as fifteen percent of a contemporary building's volume (Hall and Greeno 2007), and can hardly be ignored.

The design of the building services is tightly coupled to the general design of the building. For example, when creating the model for the ventilation systems the engineer at every turn has to pay heed to the architect's model of the building in order to ensure that the system is a ‘fit’. That it is compatible with the building in terms of size, proper ventilation, humidity, air temperature, noise level, etc. In addition, building services design such as ventilation design must be integrated with the other building services e.g. electricity, sanitation, heating, lighting, communication lines, lifts, alarms, fire detection, etc. This is done in a process of aligning CAD models set in separate layers and having design meetings to coordinate (we shall return to this below).

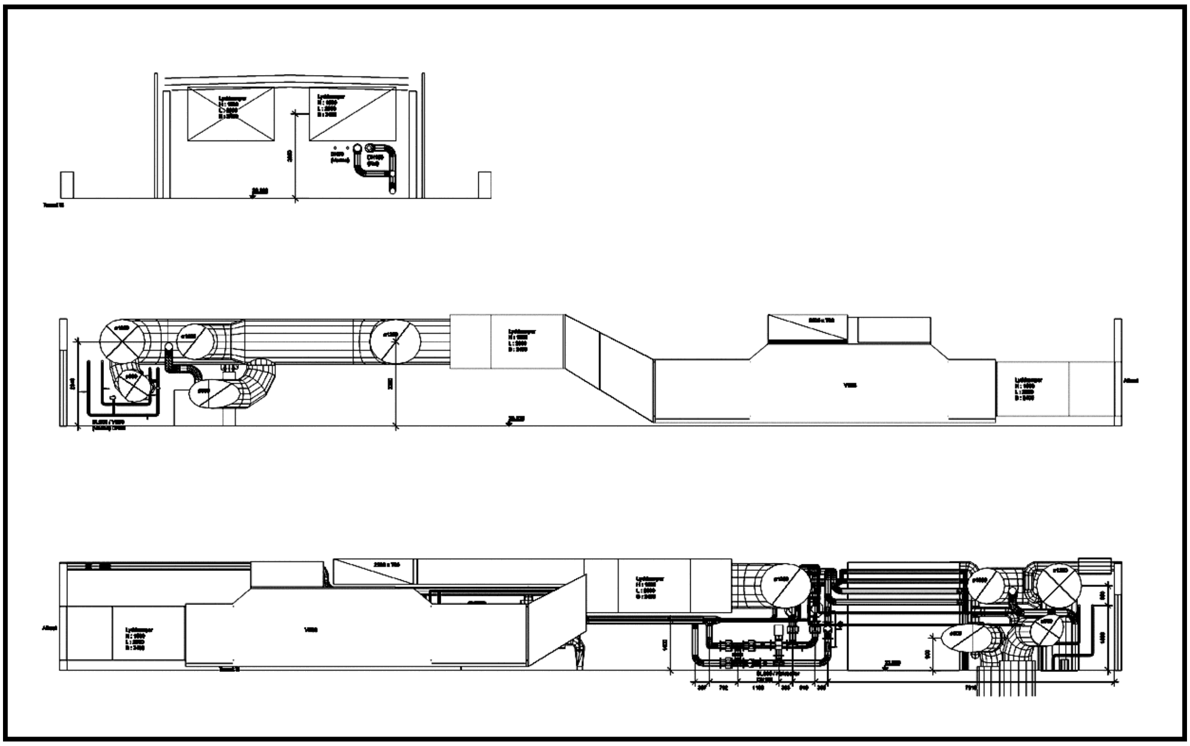

Figure 6: Two-dimensional plan of ventilation system as seen from different angles.

In sum, the tasks of creating the working plans for the building services pertains to creating submodels for services such as ventilation, electricity, sanitation, heating, lighting, communication lines, etc.

Perhaps the above descriptions will suffice as a brief overview of the design process in the sense that it gives a glimpse of what is involved as well as an impression of the distributed and complex nature of the endeavour. Next, we shall briefly consider an equally complex and distributed process, i.e. construction.

The taskscape of construction

Following design we now turn to describe the taskscape of construction. We will first consider the tasks of site investigations, secondly we will turn to the load bearing structure of the building, thirdly we will consider the building's exterior, and fourth we will give an impression of the tasks pertaining to the interior of the building.

In construction as in design, there are stages to the process (some are even legally defined), and generally speaking the progression follows what is known as 'the load bearing path'[6]. This means that the elements that are capable of bearing the load of others elements are built before the latter are. One obvious example is that the foundation is built before the walls and the walls are built before the roof. This is the general order of affairs, as we shall see below.

Site Investigations

A first step on the path of construction work is site investigations. Generally speaking, the site needs to be explored not least in order to determine the load bearing capacity of the soil. The soil on a building site is sometimes referred to as the 'natural foundation'. This language use emphasises that the soil is considered the ultimate or final foundation of the building. Hence the concerted interest in it. Site investigations are in fact comprised of several interrelated tasks, including a 'desktop' study and soil analysis.

The desktop study is an important element in the site investigations. The study is carried out by a consultant to the general-contractor and involves the collection and consideration of documents that may be obtained without having to visit the site. A considerable amount of documents pertaining to the site may be available from local and national authorities or private companies. The previous owner of the site may also have documents to share. Although the different site investigation operations often overlap, care is taken not to commence with for example expensive ground exploration before the desktop study has uncovered what may already be documented. This is partly to avoid unnecessary work and expenses (Emmit and Gorse 2004, p.16). The value of actually visiting the site, however, is easily recognized.

6 This is a member's concept, an expression used by the actors on the site.

Figure 7: The site of one of the buildings studied, i.e. the domicile.

Visiting the site allows a consultant-engineering firm retained by the general contractor to perform analysis pertaining to surface soil, subsoil, and ground water. Such analysis is carried out not least in order to ensure adequate ground support for the foundation of the anticipated building. To use Harré and Madden's (1975) term, the anticipation of 'causal powers' pertaining to the load of the proposed building is a distinct concern – can the soil support the load of an eight-storey building? In preparation to designing and constructing a foundation is necessary to calculate the loads of the building as well as determining the soils bearing capacity. Hard clay, for example, may carry more weight per square meter than loose sand, hence the interest in the qualities of the soil. Establishing the qualities of the subsoil may be carried out through methods such as digging trial pits or drilling bore holes. One feature of the site that may have a significant influence on the load bearing capacity of the soil is the existence of groundwater, or more precisely, the height of the water table. The water table is the level beneath which the soil is saturated with groundwater (Riley and Howard 2002, p.40). In the case of the domicile project mentioned above, the site was situated on the waterfront of the harbour, and deep bore holes were drilled only to find out that the subsoil's load bearing capacity was impaired by a high ground water table – measures were taken to counter this, as we shall see next.

In sum, site investigations include the tasks of performing a desktop study as well as soil analysis.

Foundation

We now turn to the foundation. The foundation it is the built base of the building. The foundation contributes an important element in handling the gravity and weather induced pressure from and on the building, it transfers these loads into the ground soil. In the case of the domicile project, as mentioned above, the subsoil had a poor bearing capacity and a high water table impaired the bearing capacity of the soil further. Consequently, a deep foundation was called for, and what is known as a pile foundation was constructed. The piles extend down through the unstable soil and transfer the load to a more appropriate stratum of the soil well below the surface. The piles where constructed by a crew from a subcontractor specialised in this endeavour. The crew drove steel casings into the ground, with a large pneumatic hammer mounted on a rig, until the casings meet the required resistance, at that point they were filled with concrete in order to obtain the qualities needed to withstand the crushing loads of an eight storey building. In addition to these piles the foundation also consists of a bottom slab cast on site by a concrete crew as well as load bearing walls made from prefabricated elements, readymade in a factory off site, transported to the site, and hoisted in place with cranes. The construction of the foundation serves as a prelude to the construction of the upper load bearing structure that rest on it.

In sum, the performance of the construction of the foundation involves several subcontractors engaged in tasks such as driving piles into the ground, casting decks and mounting walls.

Upper structure

We will now briefly consider the upper load bearing structure. In the case of the domicile project, that the task of constructing the upper load bearing structure amounted to forming a skeleton structure out of three types of structural elements: kernels, decks and columns (see figure 8.).

The three kernels provide the building with horizontal stability, housing stairwells and elevator shafts. They are constructed from prefabricated concrete elements made in an off site facility and are transported to the site on trucks and hoisted in place with cranes and bound together with irons. The execution of this task primarily involves the vendors producing the prefabricated elements and the crew of the subcontractor responsible for the montage.

Figure 8: The superstructure in the initial phases of construction. Note the three kernels.

As far as the decks are concerned, these horizontal surfaces serve to support the structural loads of the building's mass as well as the anticipated loads of people, furniture and equipment. That is, the decks must have adequate stiffness to remain stable under the load of fixtures as well as people moving about. The decks are cast on site by a concrete crew supplied with liquid cement from a truck by a vendor rather than made from prefabricated elements. This casting is supported with elaborate formwork (see figure 9).

The decks are supported by prefabricated columns that are set in place with cranes by a concrete crew. They are positioned directly beneath each other, and reinforced steel bars extend into and down through the columns for structural continuity. Continuity between columns is required in order to transfer the load of the superstructure safely into the foundation and subsequently into the ground.

Figure 9: The superstructure rises. Note how the columns are placed directly beneath each other in order to accommodate load bearing. Also, note the formwork supporting the casting of the upper decks as well as the cement truck used in the process.

In sum, the construction of the upper load bearing structure is comprised of tasks pertaining to the construction of kernels, decks and columns. Following this, the building can be provided with an exterior.

Exterior

Once the load bearing structure (i.e. soil, foundation, upper load bearing structure) is taken care of and in place the *non*-load bearing elements may be mounted. In the domicile project the latter includes prefabricated building elements such as roofing cassettes and façade elements (see figure 10).

The roof is an important element in providing protection from the weather, and has a significant role to play in the reduction of heat (or cold) loss from the building. In the case of the domicile the roof is constructed by a subcontractor associated with the vendor that has prefabricated the roofing cassettes that once placed adjacent to each other on steel beams make up the roof.

Figure 10: The domicile half -covered in façade panels and with some sections of the roof set in place.

The external façade elements also play a part not least in providing shelter from the weather. In the domicile, this external barrier has the form of numerous façade panels or curtain walls delivered on site as finished components that may be hoisted into place and mounted by the vendor's crew. These are prefabricated lightweight panels, bolted to the decks as a form of cladding that forms a complete envelope or sheath around the structural frame. The panels consist of aluminium-framed glass with a thin ribbon of granite. The panels only carry their own load.

In sum, closing the building to the elements may proceed as soon as the main load bearing elements are in place. This involves the tasks of putting up an external barrier in the form of roof and façade elements.

Interior

Once the building has been closed, once a barrier to protecting its interior from the weather outside has been erected, work on the inside of the building gain momentum. We unfold one example of construction work on the interior, i.e. the construction of walls that divide the interior into functional areas or rooms, namely, partition walls.

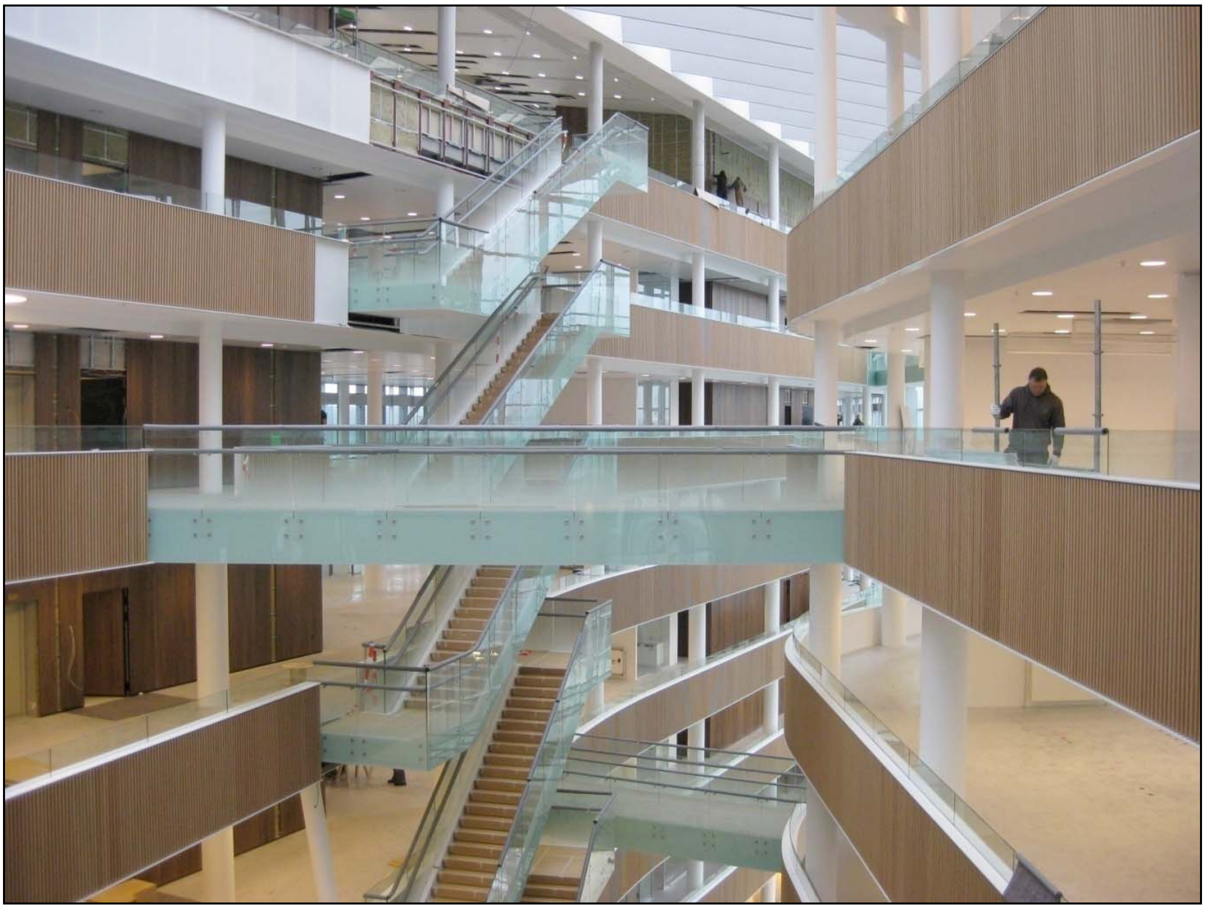

Figure 11: Inside the domicile building under construction.

Partitions walls are constructed to ensure areas of privacy, to provide visual division, to dampen noise or simply to allocate areas of activity to individuals (e.g. an office) or operational functions (e.g. a room for a photocopier) or for purposes of circulation (e.g. a corridor). In the domicile the partition walls were constructed by suspending plasterboards on steel frames or studs. The initial erection of the steel framing was undertaken by carpenters who also clad the first side of the walls with plasterboards. Subsequently, the electricians undertook electrical cabling within the frame of the wall in-the-making. In due course, the carpenters return to clad the second side of the steel frame with plasterboards, they may be said to 'close the wall'. Then follows the painters and their task of painting the walls. The construction of partition walls, then, involves several trades performing their allotted tasks.

In addition to the partition walls mentioned above there are doors, lighting, elevators, security systems, fire protection, telecommunication lines, etc. Moreover, above we have bypassed describing the construction of the building services including, heating, ventilation, sanitation, etc.

Generally speaking, the above descriptions of the taskscape of construction as well as the taskscape of design do not do justice to the vast scope and distributed nature of what is involved. However, the above descriptions may suffice as an impression, a glimpse, of the building process and its complexity.

CHAPTER TWO: THE RELATIONSHIP BETWEEN DESIGN AND CONSTRUCTION

Perhaps it would be prudent to explore the relationship between design and construction work. In this chapter we will start with the question of how design relates to construction and subsequently consider how construction relates to design.

Design in its relation to construction

A great deal of philosophizing may be done on how design relates to construction. However, perhaps one simple way to express the relationships is to assert that architectural design is partly a matter of designing spaces that will need to be realised during construction. Take static design, for example.

It is very rare for the architects to vouch for the stability of the building themselves. Although the architects may select and design the general appearance of the load bearing elements, it is structural engineers that perform the static calculations and make the final dimensioning of the elements in the load bearing structure such as columns and beams. Statics describe the distributed forces in a system such as a building at rest. Buildings and parts of building are usually motionless (if we disregard wind induced movement), and all the effective forces are calculated to balance each other out for the benefit of the stability of the building. Static calculations may include determining the assumed loads involved, calculating the forces that affect a particular structural element such as a column and the forces that it transmits to others, calculating the forces within structural elements themselves, determining the stability of the planned construction, etc.

The next working stage for the structural engineer involves crafting his or her own plans, placing particular emphasis on statically relevant elements (e.g. figure 12). Here it is also important to establish which structural elements load which others. For example, the roofing is not just supported by the roof structure, but also affects the beams, decks and columns, right down to the foundations. It must be established which structural elements absorb the loads of the upper stories.

The load bearing structure of the domicile building is a so-called skeleton construction made up of bar shaped elements forming a structure like scaffolding. Exterior façade panels and interior walls are then added to this structure. The load bearing structure and the elements that create the interior spaces are, in effect, two separate systems.

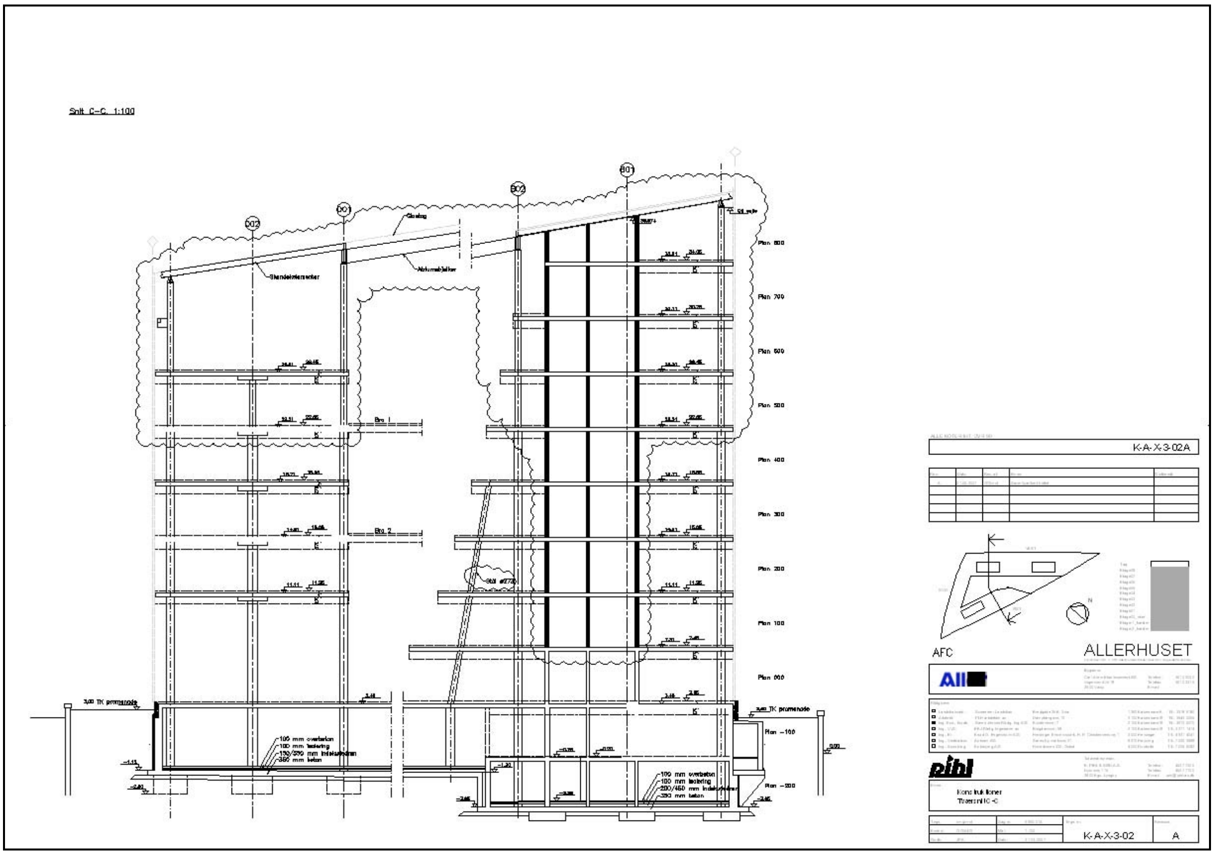

Figure 12: Plan pertaining to the load bearing 'skeleton' of the domicile.

Fundamentally, the skeleton structure of the domicile is made up of three kinds of structural elements: the columns and the decks that absorb vertical loads and the walls in the kernels that absorb horizontal forces. All the vertical forces from the floor slabs (decks) are transferred into the columns, and this means that the point of transition from columns to floor is very heavily loaded. There is a risk of the column punching through the floor. To avoid this, the columns must be evenly spread and appropriately dimensioned. The structural engineer distributes these structural elements appropriately as he or she designs the load bearing structure.

Of course, there are various approaches and options available in static design. However, the reality that structural integrity is called for is probably not debatable considering the ubiquitous presence of the forces of nature not least gravity. We could suggest that some form of load bearing structure is a 'natural necessity', if the structural integrity of the building is to be maintained and this is anticipated in design.

In addition, there are numerous other cases that we could mention in passing where causal phenomena are evident and may be anticipated in design. For example, the anticipation of temperature fluctuations may be related to the design of heating and cooling systems, the anticipation of the build up of air contamination may be related to the design of the ventilation system, the anticipation of wet weather conditions may be related to the design of the exterior of the building (i.e. roof, facade, windows and so on), etc.

Perhaps it is evident by now that that designing a building such as the domicile for the publishing house - a large and complex eight-storey building - involves anticipating casual powers (i.e. gravity, weather, temperature etc.). Perhaps we could assert that such design practice is conditioned by causal powers or natural necessity related to the construction of the material building. In order to give ourselves the opportunity to properly asses this assertion, perhaps we ought to take a closer look at one of the central concepts used, namely that of 'natural necessity'.

Harré and Madden (1975) coined the expression 'natural necessity' in their seminal work on causal powers. The notion captures the host of complex connections, actions and reactions that stem from the causal powers inherent not least to our natural world (Harré and Madden's 1975). In the context of the describing the building process using the notion of natural necessity may make us receptive to the assertion that in the building process there is no known option, but to act in accord with nature by anticipating the forces of nature - hence the expression natural *necessity*.

Furthermore, the notion of natural necessity may also be relevant in regard to the discussion of other types of design choices not least the choice of building materials. That is, perhaps the choice of some building materials is conditioned by natural necessity. Let us take a closer look.

According to Harré and Madden (1975, p.11), the notions 'natural necessity' and 'power' are intimately interwoven. Moreover, Harré and Madden (1975, p.85) report that under the influence of Ryle (1955) and others, a particular way of handling the ascription of power to material entities has become widespread. Ryle and others recommend that we treat power ascriptions *not* as the assertions of the presence of qualities, but analyse them as hypothetical or conditional statements. For example, the meaning of 'It is brittle' is supposed to mean 'If maltreated, it will break'. In a similar spirit, 'It is poisonous' is held to be identical with 'If taken, it will kill or make ill', and 'It can crush a car' is taken to mean 'If it presses a car, the car will be reduced to the size of a suitcase'. Following this approach, 'It is strong' may mean 'If placed under great pressure, it will hold'.

However, according to Harré and Madden (1975, p.86), the problem of what the ascription of a property or power to a thing means when it is *not* exercised is not really solved in this approach. To hold for example that to assert that a particular slab of concrete is strong is to make a prediction about how it *would* behave, if certain conditions of pressure were fulfilled is only part of it. That is, conditional statements are not enough when ascribing powers to things or materials. Things and materials *have* powers even when they are not exercising them, and this is a current fact about them manifest in our language about them, a way in which they are currently differentiated from other things or materials that lack these powers. Indeed, the reason why we believe that a certain disposition can be asserted of a thing or material is that we think or indeed know that it currently has such and such powers.

One of our reasons as actors, and sometimes our only reason, for believing that if certain conditions are met, then a material or individual thing will behave in a certain way is that the thing or material *now* has the power to behave in that way should the conditions obtain. The difference between something that has the power to behave in a certain way and something that does not have that power is a difference in what they themselves are now as material entities, rather than solely a difference between what they *will* do under certain conditions, since it is contingently or circumstantially the case that their powers are, in fact, ever manifested. It is a difference that may be ascribed to intrinsic nature, rather than only to extrinsic circumstances (Harré and Madden 1975). In this manner Harré and Madden refuse to base their characterisation of the powers of material entities solely on conditional circumstances, in addition to these relational parameters, they retain the notion of powers as internal or intrinsic to the particular thing or (composite) material such as the reinforced concrete used for the domicile.

Perhaps Harré and Maddens position could be understood in the context of a particular tradition of language philosophy concerned with the everyday or common use of language (e.g. Wittgenstein, Austin, Searle and Ryle). Arguably, it is in this tradition that Harré and Madden are asserting that when we *talk* about the powers of things and materials we routinely ascribe intrinsic powers to them as well as extrinsic conditions. "*In a sense the ascription of power is a schema for an explanation of the manifestation of the power*." (Harré and Madden 1975, p.87). That is, in explaining the powers of material entities both extrinsic conditions and intrinsic qualities may be invoked or referenced. This view may be corroborated if we consider, for example, how Hegger et al. (2007) describes the (compound) material concrete with reference to both intrinsic qualities and extrinsic conditions:

> "The mixture of cement, aggregates and water determines the properties of concrete. The cement acts as the binder, the water is present so that it can set, and the aggregates cut down the amount of cement needed and determine density, strength, thermal conductivity and heat storage capacity. Typical concrete has a high gross density, great surface hardness and great strength. The usual aggregate is gravel. The structure of large and small granules is calculated to create as few cavities as possible. The gravel will be completely enveloped by the cement and bound to it non-positively. The smaller granule sizes help the concrete to flow more easily. The properties of the concrete are determined by the aggregates. Normal concrete has high thermal conductivity and heat storage capacities. Thermal conductivity can be significantly reduced by changing the aggregates, for example by using expanded clay, particularly porous clay balls or wood chips. Thermal conductivity can be reduced further by introducing air pores as an insulation device. This is done by means of blowing agents, which make the concrete rise like a cake. The result is called aerated concrete. Chemical substances can also be added to make the fresh concrete easier to work; or colour pigments to dye the concrete." (Hegger et al. 2007, p.42).

In this paragraph Hegger and associates seems mostly to describe concrete with reference to what Harré and Madden (1975) call the intrinsic qualities of the material (e.g. '[...] concrete has a high gross density, great surface hardness and great strength'). However, they also refer to extrinsic conditions:

> "As a simple mixture, concrete has little tensile strength, so if it is used structurally it will always be reinforced concrete. Reinforcing steel is introduced into the concrete at the points where loads have to be absorbed." (Hegger et al. 2007, p.43).

In this paragraph Hegger and associates (2007) seem in part to refer to what Harré and Madden (1975) describe as extrinsic conditions (e.g. ' [...] if it is used structurally').

It is not uncommon, then, to explain the choice of building materials such as (reinforced) concrete with reference to the intrinsic nature of the compound, i.e. 'concrete has great strength' as well as by conditional statements such as 'if used structurally steel reinforced concrete will hold'. In a similar spirit, we could suggest that 'glass is transparent and wind breaking' and this makes it suitable, 'if used in windows or even sections of a roof'. Note how this allows for making a distinction between changes in the material itself and changes in extrinsic circumstances. We could argue that if a strict relational or conditional view were maintained as argued for by Ryle and others, changes in the material itself would be hard to express or speak of.

While on the subject of materials we could briefly return to the load bearing structure of the domicile. In principle, any material that has the properties of being both compression- and tension resistant can be used for the load bearing skeleton structures, for example timber, steel or concrete. Each of these has its own construction methods with a particular set of problems arising from the material and the methods used for joining it (we won't go into the details of this). The material chosen mainly for the domicile's skeleton structure is concrete, or more precisely, the compound steel reinforced concrete. We may note, then, that a strong rather than a brittle material is chosen for the load bearing structure of the domicile, a compound material that if placed under great pressure will hold rather than crumble. In this manner the designers anticipate the forces of nature in their choices of building materials. That is, choices are made partly out of natural necessity (and partly out of concerns for cost, aesthetics, etc.).

Furthermore, if perhaps a bit off subject, we may suggest that the phenomenon of natural necessity is apparent in the order in which the building is constructed as well.

The construction of the building follows the load bearing path, it is generally constructed from the foundation and up. For example, the substructure including the foundation must *necessarily* be constructed prior to the construction of the superstructure following that the latter rests its load on the former. An example on another level of granularity is that the concrete decks must be cast before the ventilation ducts or electrical cables can fitted or hung underneath them. This may be described as a matter of natural necessity considering that forces of gravity have a large part to play.

What this implies, then, is that natural necessity in part necessitates certain sequences of work, a certain ordering of the taskscape of construction. In combination with the specialised division of labour found among the network of actors, natural necessity influence the ordering of the taskscape. For example, the concrete crew necessarily must perform the work of constructing the foundation and load bearing superstructure of the building before the carpenters can do their part on the interior of the building. This implies that the carpenters (as well as electricians, plumbers and painters) must rely on the concrete crew and associated actors to literally lay the foundation for their subsequent work. *Note that there is nothing arbitrary about this specific ordering of the taskscape in this case*. For example, the work on the foundation must according to natural necessity be completed before any subsequent task literally resting on this can be performed.

This discussion implies that natural necessity in part necessitates the presence of a load bearing structure, the choice of building materials, and the order of the taskscape in construction. We could suggest that this is evident by the work task preformed by the structural engineer, the choice of building material with certain properties, and the order of the taskscape of construction. All this may be verging on the trivial; however, one point is perhaps worth making: *When designing or constructing a building, the cooperative work ensemble must adhere to natural necessity whether manifested in static calculation and design, the choice of materials or in the order of construction.* If they ignore or fail to do so at a critical juncture, the building simply will not rise let alone stand. This may be a trivial observation; however, it does underpin much of design and construction work.

In sum, if we return to the question of how design is related to construction, we are now in a position to answer that design is partly a matter of designing structures and spaces that will need to be realised during construction, and this is a process conditioned by natural necessity, or more precisely, the anticipation of causal powers. That is, the forces of nature, the phenomenon of 'natural necessity' that is constraining and enabling the construction of the physical building is anticipated in the design of it as well. This may be evident not least in the design of the load bearing structure and in the choice of building materials.

Construction in its relation to design

Perhaps it would be prudent to continue our exploration of the relationship between design and construction. In this section we will address the question of how construction relates to design, or more precisely, how the performance of construction work may involve using the representations of the building created in the design process. We will start with a general discussion of the status of formal constructs in work practice and in turn move on to discuss how a particular type of formal construct, namely architectural plans, are used in construction work.

In parts of the literature, the idea that formal constructs such as schedules, workflow charts and written office procedures may determine action in practice has been criticised (Schmidt and Simone 1996, p.166). These parts of the literature have convincingly showed that these formal constructs in relation to representing actual practice are not adequate and can even be considered misrepresentations of practice in a sense. In the words of Philip Selznick:

> "The formal administrative design can never adequately or fully reflect the concrete organization to which it refers, for the obvious reasons that no abstract plan or pattern can – or may, if it is to be considered useful – exhaustively describe an empirical totality" (Selznick 1948, p.25).

Years later Suchman and Wynn, studying office procedures, came to conclusions along similar lines: the effort involved in accomplishing office tasks is ignored in formal descriptions of the work. They stated that: "The point of this observation is not to critique procedural formulations, but to indicate *another domain of the work*, in which those formulations are brought to bear on the practical contingencies of actual tasks" (Suchman and Wynn 1984, p.139). Later Suchman in her influential book *Plans and Situated Action* (1987) proposed a metaphor for the way "these formulations are brought to bear on the actual tasks", namely that of a map:

> "Just as it would seem absurd to claim that a map in some strong sense controlled the traveller's movements through the world, it is wrong to imagine plans as controlling actions. On the other hand, the question of how a map is produced for specific purposes, how in any actual instance it is interpreted *vis-à-vis* the world, and how its use is a resource for traversing the world, is a reasonable and productive one" (Suchman 1987, p.188).

Suchman comes to the conclusion that constructs of a formal nature cannot determinate action causally. Instead they serve as maps that competent actors can use as guidelines and resources in their practice. However, in several places Suchman makes more general and radical suggestions: "the procedural structure of organizational activities is the *product* of the orderly work of the office, rather than the reflection of some enduring structure that stands behind that work" (Suchman 1987 p. 321). Suchman suggests that formal procedures are used by actors in their practice as a general reference of orientation and do not or cannot prescribe sequences of action. This interpretation of the status of formal constructs in cooperative practice is challenged by Schmidt in his article entitled "Of maps and scripts – the status of formal constructs in cooperative work" (Schmidt 1999). Schmidt criticizes Suchman for over-generalising on the basis of a single empirical study of office work and aims to bring more nuances into the debate on the status of formal constructs in cooperative work. He suggests that formal constructs may play differentiated roles in cooperative work:

> "They may, on one hand, as suggested by Suchman and others, play the weak role of the 'map' of the

> traveller that offers a codified representation of salient features of past and future actions which actors may consult as a referent. On the other hand, however, they may play the strong role of a 'script' that offers a precomputation of interdependencies among activities (options, required actions, sequential and temporal constraints, etc.) which, at critical points, provides instructions to actors of possible or required next steps" (Schmidt 1999, p.326).

Schmidt suggests considering formal constructs to be not casual determinants of practice (here he is in line with Suchman), but rather normative constructs that influence or mediate practice in a strong sense (as a script) or in a weaker sense (as a map) dependent on the circumstances (Schmidt 1999).[7] As an example of a formal construct that can be described as a script Schmidt offers the check list as it is used in safety critical situations, for instance in air traffic (Schmidt 1999, p.322).

On the basis of the discussion on the status of formal constructs in cooperative work, we can follow Schmidt (1999) and observe that formal constructs such as architectural plans do not determinate cooperative work such as construction work in a casual sense. Rather, they are used by and adhered to by the competent actor in a normative sense.

We may note that Bittner's (1965) in a critique of Selznick (1948), makes a call to consider what formal constructs inscribed in material artifacts "mean to, and how they are used by, persons who have to live with them from day to day" (Bittner 1965, p.242).

What is interesting for our purposes is that Bittner indicates that we have to consider and investigate how formal constructions are used by the actors who work with them on a daily basis, rather than limit ourselves to asserting that these constructs are not exhaustive descriptions of work. If we adopt this notion, how are we to approach this in relation to our interest in architectural plans as used in construction work? Perhaps we could start by taking a closer look at the nature of architectural plans.

[7] However, it is important that we do not allow ourselves to be caught up in the discourse of 'maps and scripts'. The metaphors of 'maps' and 'scripts' seems to be associated with the adjectives 'weak' and 'strong', and employing this as a dichotomy may ultimately bog us down. That is, what we are probably not interested in is creating a continuum between 'weak maps' and 'strong scripts' when describing how formal constructs condition action. Such a move may ultimately entrap our attempt to describe the role of formal constructs within a one-dimensional approach and use of language (I imagine that Schmidt and Suchman would concur with this point).

Figure 13: An engineer on site with an architectural plan in his hands.

In construction work architectural plans are most often used printed or plotted on paper, and consequently architectural plans in this format share, using Gibson’s (1986) concept, the general *affordances* of paper. On account of paper being light, thin, flexible and so on, these affordances include: grasping, carrying, folding, spreading out and ink absorption (Sellen and Harper 2003, p.17). These affordances allows several practices: jointly viewing and marking while in discussion, reading across many documents at the same time, and the physical presence of architectural plans printed on paper, placed on a desk in a conspicuous position, may be used as a reminder of some task or other to be performed.

In addition to the affordances associated with the material format of the architectural plans, these plans may be said to utilize a ‘writing system’ based on an inventory of graphic signs[8] (Harris 1995). Harris (1995, p.63) urges that writing systems should be explored on the

[8] According to Harris (1986, p.55), graphic signs may be used as referring to scriptorial signs (e.g. alphabetic letters), pictorial signs (e.g. icons), or both. Where the boundary between scriptorial and pictorial signs falls in the case of architectural plans will clearly be one of the issues to be resolved (we shall not address this issue here). Consequently, we will use the neutral terms of graphic signs.

basis of how they utilize the graphical space available (and not on the basis of a distinction such as glottic writing vs. non-glottic writing[9]). Every text (text understood in a broad sense) needs a graphic space in which to be situated for purposes of reading. According to Harris , the use of graphic space, in which graphic signs are situated, may be considered in terms of *syntagmatics* . Harris (1995, p.121) makes a distinction between internal syntagmatics on the one hand and on the other hand external syntagmatics where internal syntagmatics pertain to the disposition of graphic signs relative to one another within the same graphic space and external syntagmatics denotes the various relationships that may obtain between the graphical forms and items and events to which they are significantly connected in the space outside (i.e. the space outside the graphic space). Employing this distinction, we may ask: what is respectively the internal and external syntagmatics of architectural plans in construction work? We will start with the former and subsequently turn to the latter.

Internal syntagmatics

As mentioned above, internal syntagmatics pertain to the disposition of graphic signs relative to one another within the same graphic space (Harris 1995). In architectural plans the internal syntagmatics is partly guided by principles of proportionality. This entails that the various graphical elements representing different aspects of a building (e.g. walls, windows, doors, stairs, stairwells, etc.) correspond in size to one another. For example, a stair must 'fit' the stairwell. If they do fit, if they do in fact correspond in size, we may say that they are represented proportionally. One the other hand, if the stairs are larger than the stairwell, we may say that the elements are 'out of proportion'. In this manner there are certain norms of proportionality inherent in the internal syntagmatics of architectural plans.

Another part of the internal syntagmatics of architectural plans is related to positioning. The graphic sign's relational positioning within the graphic space must be in accord with certain norms. For example, if the graphical element representing a stair is positioned inside the graphical unit representing an elevator shaft, rather than at what is deemed correct, namely at the unit representing the stairwell, then we may say that it is 'out of place'. In this manner the internal syntagmatics of architectural plans is partly related to certain norms of positioning and proportionality.

[9] Glottic writing can be said to mirror the spoken language as opposed to mathematical notation or a music score.

Adhering to the norms of internal syntagmatics may be said to be important for the utility of a plan. Imagine an architectural plan characterised by elements out of proportion as well as a random positioning of graphical elements. Such a plan may be considered defective or even nonsensical, and consequently of no use in for instance construction work. That is, an architectural plan showing stairs that are larger than their stairwell or stairs positioned in the elevator shaft is considered defective rather than useful. In this manner proper internal syntagmatics may be considered to be a perquisite for the legibility of the representations, and as such it matters a great deal in the architectural office as well as on the building site.

Now we shall consider the phenomenon of external syntagmatics in relation to the use of architectural plans on a building site.

External syntagmatics

As mentioned above, external syntagmatics denotes the various significant relationships that may obtain between the graphic space and the space outside the graphic space. For example, a finger post road sign pointing in a particular direction may be said to be significantly connected to the space it is pointing towards - if the road sign was placed to point in the opposite direction for instance it would mean something else (Harris 1995). In a somewhat similar manner, the graphical space of an architectural plan used in construction work may be said to be significantly connected to the space of the building site. That is, actors in the building process may establish external syntagmatics between the architectural plan and the material objects of construction work. How is this done and what does it entail? First, we will suggest that there are certain techniques involved in establishing external syntagmatics between architectural plans and the objects of construction work. Secondly, we will suggest that establishing external syntagmatics in this context may amount to creating isomorphism i.e. a correspondence or similarity in form between the architectural plans and the building in-the-making.

The techniques used by the actors in establishing external syntagmatics include *projection*. That is, one method or technique for establishing external syntagmatics between the internal graphical space of the architectural plans and the actions and items of construction work is that of projection. Generally speaking, projection in the building process is a set of techniques pertaining to representing on a surface such as paper entities in the proposed built environment. Although we have not discussed projection until now, we have seen plenty of examples of projections above (e.g. figure 4, 5, 6). We will briefly consider the perhaps most common forms of projection in relation to architectural plans.

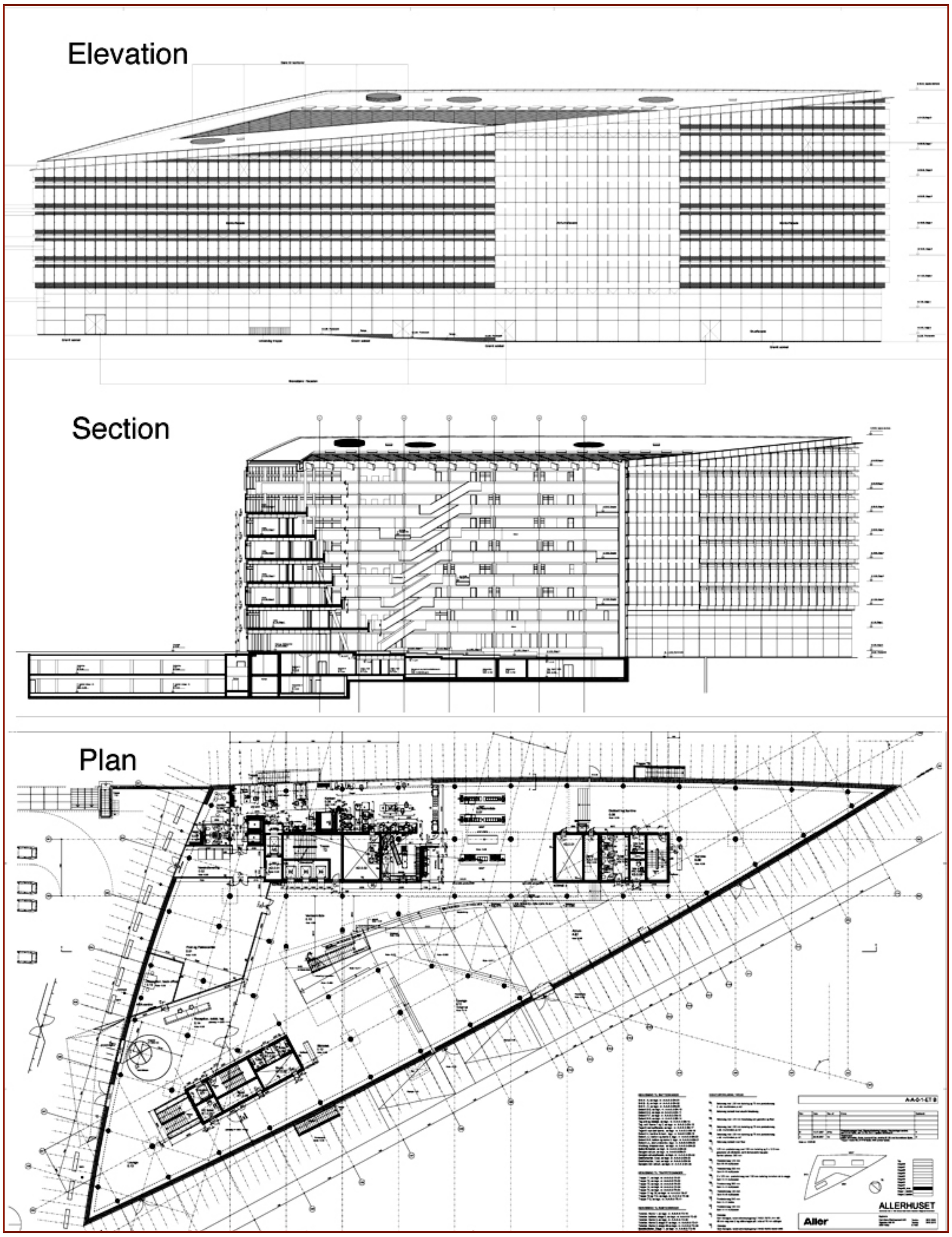

Figure 14: Elevation, section and plan projections juxtaposed.

A fundamental distinction may be made between top and elevation projection when representing the exterior, and between plan and section projection when representing the interior of the building (see figure 24). Top view representations present a projection of the building as seen from above. A top projection (also called a roof plan) is important for example for the positioning of the building on the plot. Elevations are parallel projections, as seen from the side, onto the building's façade. That is, they show the outside of the building with all its exterior features, and are important in for example establishing the general appearance of the building in relation to its immediate surroundings. A plan projection is made by making a virtual horizontal cut through the building at a height of about 1.5 m above the deck of any given single floor. It often represents apertures (doors, windows), their measurements and the measurements of significant structural sections (sill to floor height, ground level, floor height, etc.). Plan projections are generally designated according to the floor that they apply to, e.g. cellar floor plan, ground floor plan, 1st floor plan etc, and are important in for example showing the layout of any given floor. A section is a projection cutting vertically through a building. Important elements shown in a section include the structure of the roof, the floors and ceilings, and the walls with their apertures. The section may also represent the access to the building via stairs, lifts and ramps etc. These section projections are important not least in representing the vertically positioned elements of the building to the actors constructing the building.

In addition to projection (see e.g. figure 14), another and associated technique pertaining to the establishment of external syntagmatics with architectural plans is *scale*. Construction work with architectural plans also seems to require the actors to master the technique of scale in order to establish relation between the architectural plan and the material objects of construction work. Scale is a technique common to representations such as geographical maps and architectural plans and can be described as the ratio of a single unit or distance on the representation to the corresponding distance in the natural or built environment. For example, a 1:200 ratio is one in which it may be said that one unit within the internal graphical space is 200 times smaller than the unit in the external space that it represents. Common ratios in architectural plans are 1:20 or 1:5 for representations of details and 1:200 or 1:100 for representations of for example floor plans. Employing representation to scale in construction work makes it possible, for example, to calculate the proposed distance between two points on the building-in-the-making by measuring the corresponding distance on the architectural plan representing it. In this manner the techniques of representing to scale contributes to the possibility of establishing external syntagmatics, a connection between the internal graphical space of the representation and the events and items of the construction process in which it is employed.

Familiarity with the techniques of projection and scale, then, seems to be a prerequisite for establishing what Harris (1995) calls the external syntagmatics between the internal graphic space of an architectural representation and the material objects of the construction process. It is a prerequisite for using the architectural plans in construction work we may say. Of course mastering these techniques of projection and scale, establishing the external syntagmatics, is an *acquired* skill, rather than something *a priori* given.

In addition to being a prerequisite for using the architectural plans in construction work, the designers (architects, building engineers etc.) find themselves in a somewhat similar situation in that they also need to master these techniques in the performance of their allotted design tasks. That is, techniques of projection and scale are basic competences for any architect or building engineer as well as for actors engaged in the physical construction of the building. In fact, it is safe to say that almost any actor engaged in the building process practicing design, construction or even planning the process must be familiar with these techniques and able to put them to use in establishing the above mentioned external syntagmatics. Having said that, we may ask this: what does the external syntagmatics consist of?

We could suggest that in the building process external syntagmatics between the plans and the object of construction work may take the form of *isomorphism*. Establishing a connection between the internal graphic space of the representation and the objects of construction work, through techniques of projection and scale, allows the actor to see or establish *isomorphism* i.e. correspondence or similarity in form between the architectural representation and the (anticipated) building-in-the-making. This in turn allows the actors to pursue the aim of realising ‘that, which is represented’.

Perhaps we have now reached a point where we may return to, and attempt to answer, the question that opened this discussion, i.e. the question of how construction work relates to the use of architectural plans: In construction work, actors establish external syntagmatics in the form of isomorphism between the internal graphical space of architectural plans and the (anticipated) building in-the-making by virtue of their mastery of techniques such as scale and projection. The phenomenon of isomorphism, once established, allows the actors to pursue the aim of realising ‘that which is represented’. This assertion is not meant to create a deterministic impression of the actors' use of architectural plans in construction work. As discussed above, formal constructs such as architectural plans influence action in a normative sense, rather than in a causal sense. Furthermore, as Suchman (1987) insists, no plan can describe an empirical totality exhaustively, plans are underspecified with respect to that which is represented, and architectural plans for construction work is no exception. The actors have to 'fill in the blanks', so to speak, for themselves.

The discussion of internal- and external syntagmatics is merely meant to address the conundrum of how architectural plans may *become* a resource for construction work. How do the actors achieve turning 'a piece of paper with some marks on it' into a resource for construction work, what are the principles, methods and techniques involved?

In our investigation of the characteristics of using architectural plans for construction work, then, we have relied not least on the notions of internal- and external syntagmatics. The internal syntagmatics of architectural plans i.e. the disposition of graphical signs within the same graphic space was discussed in terms of proportionality and positioning. The external syntagmatics of architectural plans i.e. how the graphical space of a plan is brought into a relationship with the objects of construction work was discussed, and it was found that the techniques of projection and scale have a significant role to play.

This is only part of the story of course, there are other skills involved in using architectural plans, and of course there are other ways of describing what is involved. Henderson (1998) for example speaks of a 'visual culture' in relation to the use of representational artifacts.

In the next chapter, we shall consider (in another idiom) some of the (other) skills required to use architectural representations in the building process and not least how they may be acquired through apprenticeship.

CHAPTER THREE: APPRENTICESHIP AND VISUAL SKILLS

In this chapter we shall explore how skills pertaining to the use of architectural plans may be acquired through apprenticeship. The case presented below in based on an ethnographic study tracking an apprentice and an accomplished actor as they work with and annotate architectural plans in the process of planning construction work. We will explore how the apprentice struggles with this craft and is mentored by an accomplished actor in the process. The idea is that this investigative approach, this case, may highlight part of what an apprentice must learn in order to be able to engage in practices based on complex representational artifacts (an interest in apprenticeship shared partly with e.g. Ding 2008; Goodwin 1994; Oshri et al. 2006; Schulz 2008). In addition, the inquiry serves the purpose of underlining the phenomenon that working with complex representational artifacts such as architectural plans is an acquired skill.

We will proceed in the following manner. First, we will present our case, the study of two actors' planning of complex construction work annotating an architectural plan. Second, we will discuss issues of practice and apprenticeship that spring from the case description. Third, we will contrast the language myth with the insight that working with representational artifacts in the building process is an acquired skill. Finally, some of the study's implications will be outlined.

A case of apprenticeship

We will now turn to our case: the interactions between an accomplished practitioner and an apprentice engaged in coordinating building construction work on a large project advanced to the latter stages of construction work, more precisely, the construction of the roof. The physical location for the case studied is the site manager's trailer on a construction site.

Complex roof construction work requires the coordination of a diverse ensemble of actors (i.e. various contractors such as carpenters, plumbers, electricians, roofers etc.) each performing a range of specialised construction tasks.

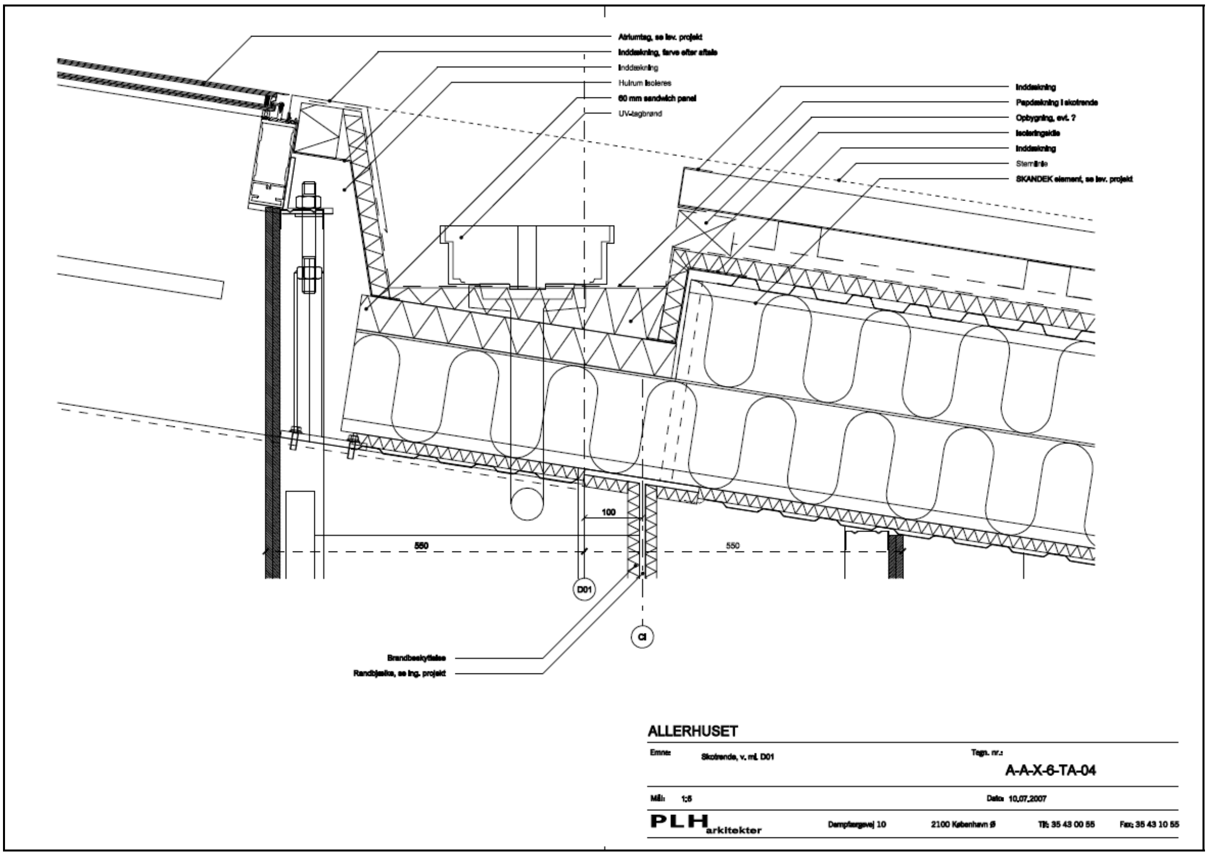

Figure 15: Detail architectural plan of roof construction *before* it is coloured with highlighters for coordinative purposes.

The particular representation, shown in figure 15, is of a *section view*, a view from the side virtually cut through the building. It shows the roof construction around a roof drainage. To demarcate what the team believes to be different areas of responsibility, the architectural plan is marked with highlighter pens in different colours. For example, blue marks the area that one particular subcontractor is responsible for, and yellow is the colour for another. This is a task that involves two people. One assesses the areas of responsibility, he reports the area out loud, e.g. “the roofing felt is going to cover the sandwich panels – KBK[10] should do this.” A second engineer marks the area in question. After finding the right area on the architectural plan he highlights it with the chosen colour. What we find here is a practice that encompasses talk, architectural plans and writing tools as the two actors collaborate on inscribing areas of responsibility onto the architectural plans (subsequently these plans are scanned and sent as PDF files to the various subcontractors involved in order to inform them of their

[10] KBK is the acronym for a subcontractor that was responsible for some elements of the roof construction.

responsibilities as seen by the manager). The action that we will now consider begins with a request from Peter, the caller, to Steen, the colourer (lines 1-2).

1 Peter:	The roofing felt is going to cover the sandwich panel
2	KBK should do this.
3	(Pause)
4	No, No. Not there.

However, before Steen, who is an apprentice, has coloured anything, indeed before he has said a word, Peter, who is his manager, challenges him, telling him what he is doing is wrong. How does he know that there is something wrong with what Steen hasn't even done yet? Here no talk has yet been produced by Steen, but talk is not the point. Providing an answer in this practice encompasses something other than talk. Steen must locate and colour the relevant part of the architectural plan in order to respond according to Peter's expectations. His movement of the highlighter to what Peter regards as the wrong place on the architectural plan is the visible event that prompts Peter's intervention (line 4). However, Steen's response to the correction calls this presupposition into question. Steen does not immediately colour the architectural plan but instead hesitates (line 5), before replying with an "hmm".

5 Steen:	(Pause) Hmm.
6 Peter:	Wherever the roofing felt goes.
7 Steen:	Ahh.

In line 6 Peter moves from request to coaching by talking to Steen and telling him what to look for in the architectural plan, i.e., "Wherever the roofing felt goes".[11] In the present case, in order to use what Peter has just said in their collaborative effort, Steen must be able to find the course of the roofing felt in the plan - knowing what 'roofing felt' means in the abstract is not enough. Wittgenstein notes: "If language is to be a means of communication there must be agreement not only in definitions but also (queer as it may sound) in judgments" (Wittgenstein 2001 p. 75, § 242). As the manager setting the task, Peter is in a position to evaluate Steen's practical judgment.

[11] 'Roofing felt' is also sometimes referred to as 'asphalt roofing'.

8 (Pause)
9 Peter: See, like right here, and down here.
10 (Tracks it with a pen across the architectural plan)
11 Steen: All right, yeah ok.

In line 10, instead of relying on talk alone to reveal the course of the material in question that Peter wants Steen to colour, Peter moves his pen onto the architectural plan and tracks the course of the roofing material. He shows it to him in the plan. What Steen is taught is not simply ‘definitions’ (he already knows what ‘roofing felt’ means in the abstract), but rather a practice, i.e. how to code the relevant perceptual field in terms of categories that are relevant for his work. The activity in progress, including the sequence of talk, provides a language game in which these judgments are taught, a language game about precisely which features of the complex perceptual field in question to attend to. Peter is instructing Steen how to ‘see’ the architectural plan.

As master and novice carry on planning the constructing of the roof, further tasks are delimited, pointed out and assigned to particular contractors.

12 Peter: Right (Pause)
13 Scandek is supposed to mount their elements.
14 Steen: The roof slab?
15 (Points to the architectural plan)
16 Peter: Yes.

In this manner the task continues until the result shown in figure 16 is reached. In line 12 – 16 yet another part of the roof construction is assigned to a particular contractor. That is, the responsibility for mounting the central reinforced concrete roof slab is assigned to a subcontractor named ‘Scandek’.

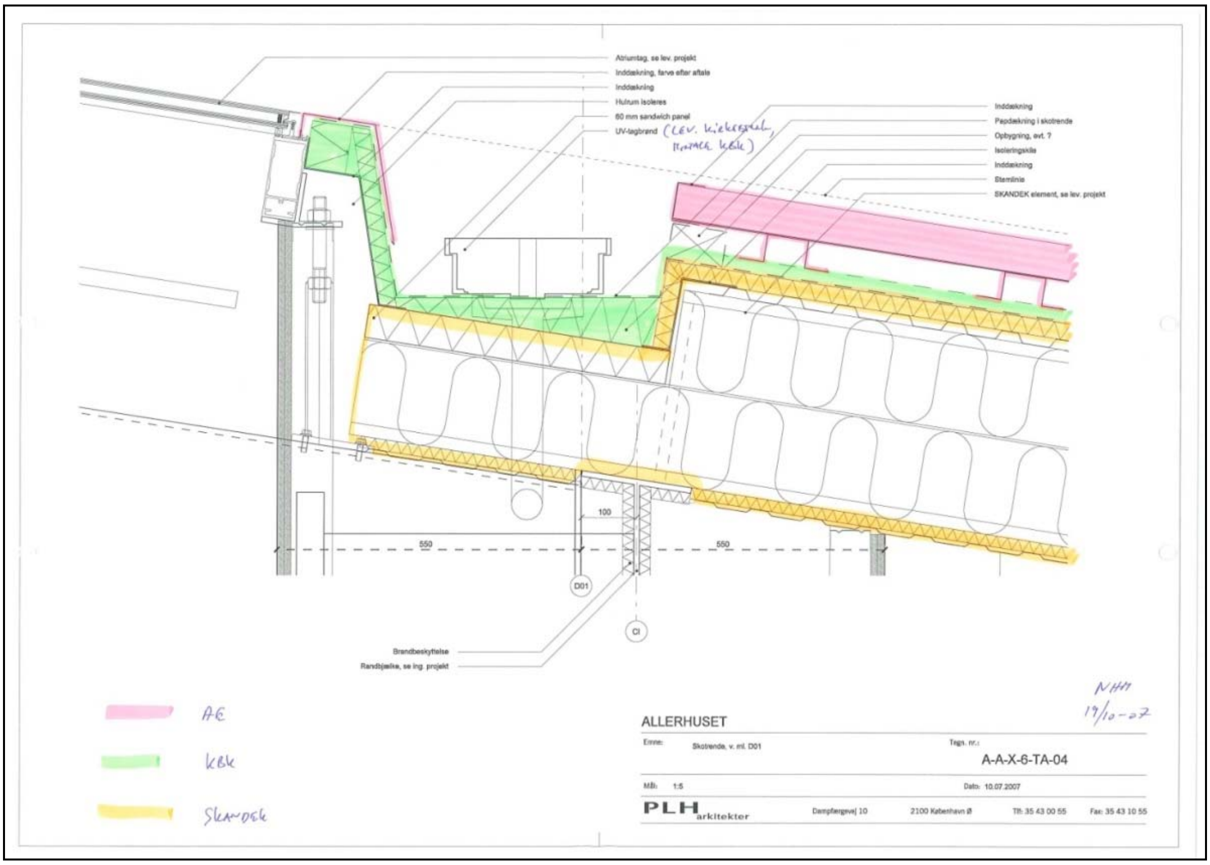

Figure 16: Detail architectural plan of roof construction *after* it has been coloured with highlighters for coordinative purposes.

As indicated above, we could suggest that what happens within this sequence is a not least a progressive expansion of Steen's ability to comprehend what he must do in order to carry out the task assigned to him as Peter explicates it. We could suggest that 'patches of ignorance' on the part of Steen are revealed and transformed into practical ability sufficient to get the job done, so that Steen is finally able to grasp what it is Peter wants him to do and how to see the architectural plan in order to do it.

However, it would be quite wrong to delimit the unit within which this is lodged as comprised of solely the two actors Steen and Peter. Instead the unit (with very soft boundaries) is the building process understood as a community of practice or set of related communities of practice within which the skills of building engineering and the task in question are lodged. The skill to handle the task, including the complex perceptual field of the architectural plans, and to see for instance 'where the roofing felt goes', is central to what it means to see the world through the eyes of a building engineer. Being able to highlight certain aspects of a representation of a building according to a specific task is part of what it means to be an accomplished building engineer, and it is these standards that Steen is being held accountable to – standards that also include mastery of techniques such as scale and projection discussed above. The relevant unit of analysis, then, is not these two individuals as an isolated entity, rather it is the wider building process where a community of competent practitioners are engaged, most of whom have never meet each other, but who nonetheless expect each other to categorise and act in this domain in ways that are relevant and predictable and pertain to the work, tools and artifacts that constitute the community of practice.

Perhaps we could interject that the task at hand is also dependent upon the nature of their common material field of work (i.e. the architectural plan) that in part constitutes the practice under consideration. Peter is able to show Steen, for example where the roofing felt goes. In addition, the representation allows the mapping of building elements as related to specific contractors. Furthermore, it is partly the affordances of the paper format of the architectural plan (its ability to absorb the ink) that enables Peter and Steen to stipulate (through colour-coding) that the roofing felt, for example, is the responsibility of KBK. Moreover, it is the stability, durability and transferability of the paper artifact that facilitate the practice. That is, the paper format allows for the visualization of the responsibilities in a stable medium that may be digitally scanned and digitally distributed in PDF format to the concerned parties. However, as noted above all this would not have been possible without the skills of the actors – not least the ability to read the architectural plan according to the techniques of scale and projection and to follow the 'rules' of construction work (that Peter masters and Steen is learning). Perhaps we could assert that the skills, the affordances of the material artifact (i.e. the architectural plan) and the tasks are all interrelated and interdependent components of the practice. Of course, the actions shown above are embedded in a community of practice of a much larger scope than glimpsed here.

Practice and apprenticeship

Bearing the case presented above in mind, we might suggest that practices found within a community can be seen as habitual patterns of behaviour that embody skills and techniques transmitted through education, training and apprenticeship. Many of these skills and techniques may elude representation (e.g. in a class room or in a text book) in the sense that they cannot be fully articulated, expressed in formulas or described in text. The notion of 'tacit knowledge', originating with Polanyi (1958), is often used to characterise this phenomenon. However, as Styhre (2004) points out the notion of tacit knowledge has acquired a position in contemporary social science where it is too often used as little more than an umbrella term for unrepresentable knowledge. Styhre cautions “the notion of tacit knowledge should be used with care and not considered a residual category of knowledge” (Styhre 2004, p.177). With this in mind we will limit ourselves to suggesting that the nature of a significant number of skills and techniques require them to be acquired over time through a process of apprenticeship and trial and error learning (as we have seen above). Furthermore, this may be said to be common in many work domains, and not only in the building process. For example, Collins' (1974) study of newcomers to building lasers reveals that even with access to accurate representations, documents and blueprints, they could not build lasers without consulting more experienced professionals. The newcomers or novices had to engage in relations of what amounts to informal apprenticeship to succeed - those whose lasers finally worked had made use of personal visits and extensive telephone calls.

Within a community of practice, to use Lave’s and Wenger’s (1991) term, we could suggest that techniques are largely ‘shared’ in the sense that the abilities and choices of an individual practitioner are shaped by the abilities of those with similar or equally important complementary skills. Although each practitioner may at times produce independently, all practitioners execute their routines in an environment created by other members of the community of practice (Langlois and Savage 2001). For example, a lawyer is constrained by the cumulative precedents of previous cases, most of which were decided long before the current generation entered the profession (Langlois & Savage 2001, p.154). We could argue that this is also holds for practitioners in the building process whose day-to-day decisions and actions are affected by for example the design and building methods used by other skilled actors (in some instances methods may date back numerous generations). This implies that the individual may rely on the fact that other actors within a certain community of practice, in our case the building process, have made decisions and performed actions in ways that may be retraced or reconstructed by virtue of the individual’s own training and experience (see also Feynman and Leighton 1988).

It seems to be specific to almost all the actors in the building process that they have ‘standards or routines of seeing’. This is related to what Henderson (1998) refers to as ‘the visual culture of engineers’. Henderson (1998, p.27) states that “the visual culture of engineers is not made up of school-learned drafting conventions but rather the everyday practices of sketching, drawing and drafting that constructs their visual culture - a visual culture that in turn constructs what and how design engineers see”. Henderson’s (1998) study of design practices among aerospace engineers describes that the visual culture of engineers is one in which actors turn to visual representations when asked a design question where representations are so central to design practice that meetings wait while individuals fetch them from their offices or sketch them on white boards. In the building process, actors continually create and use representational artifacts. For example, architects create representational artifacts as they design a building, and contractors use them as they construct it or as they plan for the construction as we have seen above. In this manner, representational skills are central to the routines, the regularities in being and doing, in perception and action found among accomplished actors in the building process.

The term ‘routine’ as it is employed here is not used in an effort to create a deterministic impression of the actors’ actions in the building process. Of course, individual judgment and choice plays a significant part. Practitioners must wield and apply a wide repertoire of skills and routines to work with widely varying concrete circumstances. In light of this, we may suggest that practitioners in for example the building process do not ‘standardise’ the application of their routines so much as standardise the ‘toolkit’ of routines from which they draw. The particular concrete application of routines requires on-the-spot professional judgment, a capability that may be thought essential in any situation with a measure of uncertainty. Like more specific routines, judgment is a skill that is cultivated in education, training and apprenticeship (Langlois and Cosgel 1993).

It would seem that the ability to work with representational artifacts is grounded in the actor’s training, skills and techniques that may be conceived of as acquired and in turn embodied in the accomplished actor through not least apprenticeship as a ‘feel for the task’.

As described in the case above, the accomplished engineer and the apprentice respectively comprehend and partly comprehend the representation that they are working on and annotating for coordinative purposes. That is, to a varying degree they are able to participate in a specific community of practice. A community of practice in the building process is *not* characterised by a random continuous flow, but displays recurrent patterns, regularities, characteristic ways of doing and being, acting and interacting. According to Bourdieu (1977, 1992) these regularities and characteristic ways of doing and being become embodied in the individual actor of the domain in the form of a *habitus*. Bourdieu (1992) on habitus:

> ‘The habitus […] it is a socialized body, a structured body, a body which has incorporated the immanent structures of a world or of a particular sector of that world - a field - and which structures the perception of that world as well as action in that world.’ (Bourdieu 1992, p.81)

The habitus is and acts as a set of 'pre-perceptive anticipations, a sort of practical induction based on previous experience' (Bourdieu 1992, p.80). We could suggest that the habitus of an accomplished building engineer acts as a disposition towards certain ways of understanding, doing and being, acting and interacting that are in accord with or reflects the nature of the field of construction work. Perhaps these dispositions are in play as the experienced building engineer tutors the apprentice as they articulate the construction process by annotating the architectural plans as described in the case above. Experience with the work domain of building design in part informs the accomplished engineer how to process the representation made by the architects, how to annotate it for coordinative purposes. According to Bourdieu (1992), the habitus amounts to a feel for the task or game:

> 'The actor, having deeply internalised the regularities of the game, does what he must do, at the moment it is necessary, without the need to ask [himself] explicitly what needs to be done. He does not need consciously to know what he does in order to do it and even less to raise explicitly the question (except in some critical situations) of knowing explicitly what others might do in return.' (Bourdieu 1992, p.98).

As mentioned, actors with a feel for the task who have embodied a host of practical schemes of perception and action that partly contribute to their practice are absorbed in their affairs (in their 'doing') which is inscribed in the presence of the task. This is the case for the experienced engineer, rather than for the apprentice.

Furthermore, according to Bourdieu (1992), the actors are *not* like subjects faced with an object that will be constituted as such by an intellectual act of cognition (Bourdieu 1992, p. 80). This is opposed to *intellectualism* which according to Bourdieu is "inscribed into the fact of introducing into the object the intellectual relation to the object, of substitution the observer's relation to the object for the practical relation to practice." (Bourdieu 1992, p.58).

In this context, Schutz' concept of the 'natural attitude' of the actor is of utmost importance. In the 'natural attitude' characteristic of everyday practice, the actor will not take the infinity of possible perspectives, points of view, or principles into consideration before acting.[12] Schutz writes:

> 'This world is to our natural attitude in the first place not an object of our thought but a field of domination. We have an eminently practical interest in it, caused by the necessity of complying with the basic requirements of our life. But we are not equally interested in all the strata of the world of working. The

[12] See also Schmidt 2002, p.453

> selective function of our interest organizes the world in both respects — as to space and time - in strata of major and minor relevance.' (Schutz 1990 p.227)

Alfred Schutz also observes:

> 'We normally have to act and not reflect in order to satisfy the demands of the moment, which it is our task to master, we are not interested in the `quest' for certainty. We are satisfied if we have a fair chance of realizing our purposes, and this chance, so we like to think, we have if we set in motion the same mechanisms of habits, rules and principles which formerly stood the test and which still stand the test.'(Schutz 1976 p.73)

Unless an actor has practical reasons for considering the situation in a different perspective, he or she will retain the previously obtained perspectives. Bittner (1973) argues a similar point[13] and relates it to fieldwork as he asserts that the urgencies with which the actors (in for example the building process) have to deal are not urgencies to the fieldworker, the observer who has deliberately undertaken to view the world 'as the world of others'. Bittner writes:

> '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. Slipping in and out of points of view, he cannot avoid appreciating meanings of objects as more or less freely conjured. […] Hence, without it ever becoming entirely clear, the accent of the field worker's interest shifts from the object to the subject. […] Moreover, since he finds the perceived features of social reality to be perceived as they are because of certain psychological dispositions people acquire as members of their cultures, he renders them in ways that far from being realistic are actually heavily intellectualized constructions that partake more of the character of theoretical formulation than of realistic description.' (Bittner 1973, p.121)

In this manner, Bittner convincingly points out the perils of intellectualism brought about by the very nature of fieldwork, the danger of missing the practical perspective by supplanting it with mentalist precepts springing from the freely chosen vantage point of the fieldworker. In this manner he also supports the notion of the natural attitude (Schmidt 2002).

Following Bourdieu, Schutz and Bittner, we could suggest that the *accomplished* actor engaged in practice may mostly have something quite different from explicit intention as a basis for their actions. What they do is rather grounded in acquired dispositions to perceive, comprehend and act in particular ways. It would be wrong to think that the actor in question

[13] Bittner's analysis of the observer's perspective is a development of Schutz' analysis of 'common-sense' and scientific perspectives (Schutz 1976; 1990)

needs to consciously explicate to himself or others what the practice entails (except in specific situations).

However, teaching and instruction may prompt the need for the explication of practice, as we have seen above. According to Wittgenstein (2001, e.g. §143-55, §179-81), the situation for the novice or apprentice is in stark contrast to that of the accomplished actor. Wittgenstein differentiates the role of the two participants (Williams 1999, p.204), and it is this that we may highlight with reference to our case. The accomplished actor momentarily acting in the capacity of teacher is the one whose judgment is unchallenged precisely because he has mastered the practice himself, and now he sets the standards for what is correct as far as the apprentice is concerned. The apprentice does not have and is not required to have all the skills or techniques that are necessary for the successful participation in practice. As indicated above, this differentiation enables the accomplished actor to extend a courtesy or show consideration for the shortcomings of the apprentice's performance. The stage setting, the background necessary for judgment, is within the domain of the accomplished practitioner. That is, the behaviour of the apprentice is shaped and made intelligible by the competences of the accomplished actor. In this manner, the background for judgment of the apprentice's actions is the competence of the accomplished actor who masters the practice, and in this process of 'judgement' or guidance the practice is explicated (albeit to a limited degree).

What are the wider implications of all this? Preliminarily, this suggests that one of the insights that we may take from the case described above, is that reading, comprehending, annotating and in general working with representational artifacts in the building process is an acquired skill, and consequently representational artifacts do *not* somehow speak for themselves. This assertion is incompatible with and in opposition to a popular myth, namely, *the language myth*. We shall investigate the implications of this.

The language myth

In this section we will argue that we must be careful not to confuse the signs (that are constituted by the actor at every encounter according to the context and the habitus of the actor) with the document (the stable material entity). We will attempt to do so following Harris' (1981) critique of *the language myth*.

The influential linguist Roy Harris has coined the term *the language myth* (Harris 1981). According to Harris, three assumptions are associated with the language myth - a myth Harris rejects. One is that in language actors somehow encapsulate their thoughts in the signs they use (and that these signs become information). Another is that the signs (or information) used have the property of containing thoughts in an invariant manner. Thirdly, when reading or listening, actors 'extract' the thoughts from the signs (or information) in which they are encoded (Harris 1981).

According to Harris (1981, p.14), the language myth is associated with the notion of 'somatic particularism', i.e. the thesis that individuals are differentiated from one another on the basis of each having a unique body. To begin with there is the assumption that human agents involved in communication are individuals with an independent and unique existence in the sense that we all believe ourselves to be creatures whose personal experience belongs to ourselves only. I cannot think your thoughts for you, I cannot see through your eyes and have your experiences, and I cannot be responsible for your decisions nor you for mine. In this sense, the assumption is that each of us is an island.

The whole problem of communication as constructed in Western philosophy is a problem about how somatic particularism – the natural state of the isolated individual – can be overcome. That is, the crux of Western thinking about communication has always been the belief that in order to escape from a natural state of isolation, the individual has no recourse except to other individuals (Harris 1981, p.15). Hence the problem, how can one isolated individual plus another isolated individual add up to more than two isolated individuals? What has to happen in order that the two cases of isolation are cancelled out, or at least reduced?

It is here that communication comes into play, however, often in the guise of the language myth (Harris 1981). In Toolan's (1997) description, the language myth essentially regards communication as the 'faxing' of thoughts from actor A to actor B. According to Harris, such an understanding of language and communication is *telementational* in nature and leads to the following account of how human actors communicate by the use of artifacts: Suppose actor A has a thought that he wishes to communicate to actor B, for example that 'glass is brittle'. His task is to search among the sentences of a language known to himself as well as to actor B, and select the sentence which has a meaning appropriate to the thought conveyed; for example 'glass is brittle'. He then encodes the sentence in its appropriate written form from which actor B is to decode it. By virtue of knowing what it means, actor B grasps the thought that actor A intended to convey to him, i.e. that 'glass is brittle' (Harris 1981, p.10).

Applied to the case of communication in general, what the telementation model yields is the notion that if only an idea in A's mind can be copied into B's mind, by whatever means, then the limitations of somatic particularism have been overcome. B will now have a replica of A's idea. The relevant thoughts will have been transferred from one person to another. Furthermore, other persons, C, D, E, F, - as many as you like – can also receive a replica of A's thoughts by multiple telementation – in principle by whatever means. This breaks the isolation of the individuals and reduces the problem of somatic particularism (Harris 1981). Stated in this manner, it sounds like common sense; sounding like common sense is one of the powerful sources of appeal of the language myth according to Harris.

Following Harris as well as our own case description, we could suggest that it is not tenable to maintain that meaning can take on a fixed form (of for example information) and migrate from head to head via artifacts or other means. That is to say, there is no *stable* meaningful entity encapsulated in the representations just waiting to be discovered in, for example, practices with representational artifacts.

In contrast to the assumptions of the language myth, Harris states that the sign (e.g. graphic signs on representations of buildings) does not exist outside the context which gives rise to it. Harris presents an example to clarify his position:

> 'In every day parlance the word sign often refers to a physical object, as for instance in the Highway Code to place a 'red warning sign' (a reflecting triangle) on the road at least 50 meters in front of a vehicle that has broken down14. This use of the word sign is a potential source of confusion. For the integrational theorist, the reflecting triangle does not become a sign until it is appropriately placed in a situation of the kind described. The same physical object – the red triangle – was not a sign during the time it remained in the boot of the motorist's car in readiness for such an emergency; nor having once functioned as a sign, will it continue to do so when the motorist eventually puts it back in the boot again and proceeds on the journey. The spatio-temporal continuity of the object is irrelevant to its semiological role' (Harris 1995, p.53)

In this approach, the sign is constituted in the situation that gives rise to it. No abstract invariant remains 'the same' from one context to another (Harris 1995, p.22). This is very much in line with his critique of the language myth including the notion of telementation, as far as it seeks to establish another understanding of what is involved in language use, an understanding that breaks with the language myth.

Furthermore, Harris (1995) urges us to distinguish between various semiologically relevant activities by separating out *forming* and *processing*. The difference between *forming* and *processing* partly corresponds to the implied contrast between the traditional terms

[14] *The Highway Code*, rev. ed. (London: HMSO, 1987), art. 133.

writing and *reading,* however it offers a broader scope. Forming is taken to include any activity or sequence of activities by means of which a written or pictorial form is produced, and processing is taken to include any activity or sequence of activity by means of which the written or pictorial form is examined for purposes of comprehension (Harris 1995, p.65). How does this apply to our case?

Following Harris' terminology, the team could be said to process the representation in order to form, or more precisely, reform it (i.e. annotate it with highlighters). Processing involves recognising certain units of pictorial and written form. For example, it involves the recognition of the pictorial forms of building elements such as roofing felt. Furthermore, it involves the recognition of the patterns into which these units are organised. For example, in conjuncture with other pictorial units such as roofing felt sandwich panels and drainage may form the impression of a roof section. Although processing anticipates comprehension, it does not automatically lead to it (Harris 1995). For example, an actor may 'scan' a representation without fully comprehending it, i.e. without knowing what to do, how to act on it, as we saw in the case of the apprentice. This opens up questions regarding the nature of comprehension. Perhaps we could suggest that comprehension may be said to involve a notion of what needs to be done (or not done). It involves a feel for the task or 'game'.

If we reject the notion of telementation, then the creator of a representational artefact is no more to be thought of as the 'sender' of a message than the reader is to be thought of as merely a 'receiver' (Harris 1995, p.64). The whole sender/receiver model is an untenable way to understand what is involved in, for example, work with representational artifacts. The meaning of, for example, a representational artefact depicting a section of a roof is not an independent fact that can be propelled back and forth between actors like a tennis ball in a game of tennis. We could argue that in practice there is no semiological tennis ball. This assertion could raise objections such as 'are the actors not precisely exchanging representational artifacts, are architects and building engineers not exchanging representations'. The answer is 'yes'; indeed they are, however, we must be careful not to confuse the signs (that are constituted by the actor at every encounter according to the context and the habitus of the actor) with the document (the stable material entity). The critique of the language myth and the notion of telementation seem to indicate that it would probably be wholly untenable to associate for example cooperative work performed with representational artifact with the language myth and the notion of telementation.

Perspectives and challenges

In sum, we have presented a case of articulation work and apprenticeship and attempted to emphasize the mundane insight that working with complex representational artifacts for coordinative purposes is an acquired skill. In addition, we have attempted to argue that such skills or techniques may be conceived of as lodged within a community of practice where they are passed on from accomplished actor to apprentice through education, training and apprenticeship. It is relevant to point to this state of affairs not least in the face of the 'language myth' where the learned skills that go into comprehension are presupposed.

Perhaps if we do not break with the language myth and take the insights that may spring from cases like the one presented above into account, we may be ill prepared to develop technologies and systems. We shall consider an example of this next relying on the work of Bansler and Havn (2003).

In their study of the development and adoption of a 'knowledge sharing system', Bansler and Havn (2003) report that the adoption of the system stalled and ultimately went awry as the documents placed in the systems repository by one group of actors were unintelligible to a large portion of their intended audience i.e. another group of actors. It seems that the developers of the system were presupposing the actors' ability to comprehend complex documents that were unfamiliar in content and style to a large group of them. That is, the documents in the system's repository turned out to be relevant and meaningful to very few people indeed (mostly those who had authored them), and significantly less meaningful to a broad range of readers gaining access to them via the system - readers were seemingly supposed to be able to comprehend the documents *untutored* and thus gain knowledge, but this was not the case (Bansler and Havn 2003).

Taking heed of the kind of apprenticeship described above, that seems to be a prerequisite for understanding many types of complex documents, is a step on the road to successful technology development and system design.

Furthermore, the study above gives us a glimpse into how cooperative work may be coordinated in the building process considering that the actors described in the case above are in fact stipulating the coordination of distributed construction work tasks as they colour code the architectural plan. In the following, we will elaborate and consider other coordinative practices.

CHAPTER FOUR: COORDINATIVE PRACTICES

One of the major research issues in CSCW is the understanding of how cooperative work is coordinated. This issue has often been cast as a question of exploring how articulation work is practiced and supported by way of artifacts. In the words of Strauss, articulation work is a kind of supra-type work in any division of labour, done by the various actors concerning the meshing and integration of interdependent cooperative work tasks (Strauss 1985, p.8). A series of focused, in-depth field studies have been undertaken with the specific purpose of investigating how the distributed activities of cooperative work arrangements are articulated and, in particular, how prescribed artifacts are devised, appropriated and used for these purposes (e.g. Bardram and Bossen 2005; Carstensen and Sørensen 1996; Schmidt and Bannon 1992; Schmidt and Simone 1996; Schmidt and Wagner 2004). In this chapter we will first follow in the footsteps of these studies and consider articulation work in the building process, i.e. in meetings, articulation work with coordinative artifacts such as Gantt charts, a file sharing system, and title blocks. Subsequently, within the context of design as well as construction we will consider a phenomenon that contributes to the integration of cooperative work, but perhaps cannot tenably be described as articulation work: We will consider how cooperative work task may be integrated by virtue of individuals acting on the material evidence of work previously accomplished by others.

Articulation work in meetings

Meetings could perhaps be considered the archetypical setting for articulation work. In this section we will briefly consider how distributed tasks may be coordinated in meetings.

The following excerpt from a meeting concerns design, that is, it concerns the coordination of the design of the ceiling with the design of the ventilation system in a large building project:

1 Engineer:	When we get past this then the ceiling become suspended, right?
2	(Points with a pen to a specific place on an architectural plan spread out on the meeting table).
3 Architect:	Yes, from that point and on we have a suspended ceiling.
4 Engineer:	Air ducts have to run above this ceiling.

5	(Pause)
6	It is hung pretty low.
7 Architect:	Yes, it is as low as 2.20. That cannot be a problem.
8 Engineer:	Is it in 2.20? If it is suspended that low then I can lay above it in 2.46?
9 Architect:	(Pause, looks at the architectural plan).
10	Ok that's fine.

According to Schmidt (1994), articulation work may take place in several dimensions; a tentative list could look like this:

> (a) Articulation in relation to actors, e.g. who is relevant and available in connection to a particular project. (b) Articulation in relation to responsibilities, e.g. who is accountable for what. (c) Articulation in relation to tasks, e.g. what is to be done and in what order. (d) Articulation in relation to activities, e.g. how far has the others come. (e) Articulation in relation to conceptual structures, e.g. how to classify. (f) Articulation in terms of resources, e.g. who has access to resources and to what extend (Schmidt 1994, p.15).

The excerpt above seems to amount to articulation work in relation to tasks (i.e. what is to be done). In line 1-6 a building services engineer draws attention to air ducts projected to run above a suspended ceiling. In line 7-10 the engineer and the architect settles that there is enough space to accommodate the air ducts for the ventilation systems underneath the suspended ceiling - in technical terms they settle the respective levels of their contributions. In this manner a particular issue related to the coordination of two interconnected tasks carried out by different actors working for different companies is articulated as they meet and talk. In this manner articulation work may simply be a matter of having a conversation.

However, note also how the actors continuously refer to and make gestures towards the architectural plans spread out on the table in front of them. The gestures involve pointing with a pen to particular places on the plan. This serves a variety of purposes including directing another meeting participant's attention to a specific area on the representation under discussion. The meeting participants, then, navigate a collection of representations and change which representations or part of representations that are visible on the table. This is especially important in relation to viewing design aspects represented over several printouts, such a floor plan relating to several detail views. Annotating the representations directly and making sketches on a blank piece or in the margins of a document occurred as well (not evident in the short excerpt presented above). These sketches often served as illustrations of new design ideas (see also Tory et al. 2008). In this manner the architectural plans themselves play a central role in the coordination of the design process - recall also the descriptions of how architectural plans may be colour-coded for coordinative purposes (see previous chapter).

In sum, the building process is partly articulated in meetings where the relationships between tasks are one of the dominating subjects of conversation, and in these conversations artifacts such as architectural plans are an important point of reference.

Articulation work with Gantt charts

In this section we shall describe articulation work with a set of coordinative artifacts.

Artifacts in general, and specialised coordinative artifacts in particular, play a crucial role in the coordination of the building process. According to Schmidt and Simone (1996), a coordination mechanism or coordinative artifact can be thought of as constituted by two parts. On the one hand, a coordinative protocol of a normative nature in the form of a set of agree-to-procedures and conventions stipulating to competent members of the cooperative ensemble the responsibility of the different roles in the cooperative work group. On the other hand, we have the persistent part of the artifact in which the protocol is imprinted (Schmidt and Simone, 1996 p.165).

The specific type of coordinative artifact that we will explore is often referred to as ‘time schedules’ or ‘Gantt charts’ (see e.g. figure 17). These coordinative artifacts may be used to stipulate ‘who does what’ within a certain time frame and depict an assessment of how far each member of the cooperative work ensemble have progressed towards completion of their tasks. Stipulation or negotiating such matters is at the heart of articulation work (Schmidt 1994). The charts stipulate by implication who is responsible for what tasks, how far the individual tasks have proceeded towards completion and what amount of resources (i.e. time) the completion of each task may consume. They are used as ‘time-schedules’ and in meetings whenever the topic of who-does-what-when is addressed. That is, the Gantt charts are instrumental in the articulation and ordering of the complex building process.

Herbert Simon, in his seminal paper entitled ‘The Architecture of Complexity’ (Simon 1962) proposes that complexity frequently takes the form of hierarchy where hierarchy refers to “all complex systems analyzable into successive sets of subsystems” (Simon 1962, p.468). Following Simon (1962), it seems that the Gantt charts, individually and as a whole, are indeed ordered into ‘successive sets of subsystems’. For example, we may note that the set of

Gantt charts involved in the construction process includes a main schedule with a low level of detail covering the whole construction process from start to finish, and another nine more detailed schedules that have been made out to each cover a particular subsection or phase of the overall process (e.g. the construction of elements such as the foundation, superstructure, interiors, exteriors etc). Internally, each of the individual charts is also ordered hierarchically. Perhaps it would be timely to take a closer look at a Gantt chart.

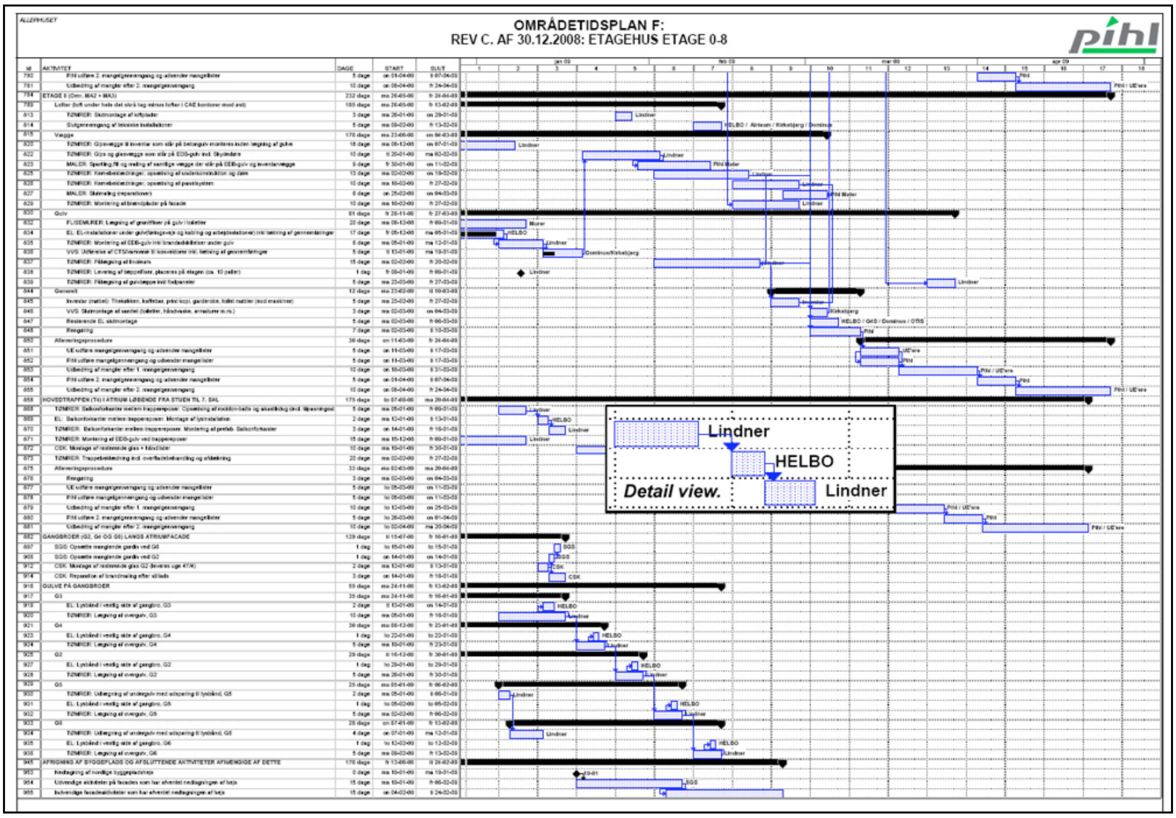

Figure 17: Gantt chart used and devised for the coordination of distributed tasks pertaining to the interior construction (note that the figure shown here is with a detail view). Read from the left the presentation shows the number and name given to the different tasks, the number of days each task is planned to last, start and finish dates, horizontal bars representing by length the duration of time each task or subtask is planned to last, the names of contractors that are part of each task (e.g. Lindner, Helbo, etc.), and finally graphical devises, i.e. arrows pointing to interdependencies between tasks.

Take for example the Gantt chart for the interior construction work (see figure 17); this chart is divided into a collection of tasks and is structured in a hierarchical manner. The top category on the chart is a particular ‘level’ of the building (i.e. level nr. 0-8), and each level is then further subdivided into four categories, ‘ceiling’, ‘floor’, ‘walls’ and the residual category of ‘all-purpose’. Each of these categories is again subdivided into a set of tasks where each task stipulates a particular relationship between the building in the making (i.e. the anticipated material field of work), actors and time. If we take a look for example at what is involved in constructing the interior walls on level 8, we find the following set of tasks: 'Walls - first side' scheduled to be carried out by the carpenters in three days from April 1st 2009 to April 3th 2009, 'cabling: electricity/sanitation/ventilation' to be carried out in three days by electricians, plumbers and ventilation specialists from April 13th 2009 to April 15th 2009, 'closing of walls' to be carried out by the carpenters in three days from April 16th 2009 to April 20th 2009, and finally there is the task of 'finish/painting' that is the responsibility of the painters to carry out in no more than four days from April 21st 2009 to April 24th 2009 (see figure 17).[15] In this manner the relationship between the cooperative work arrangement, the common field of work and time is ordered as tasks are formed and represented.

To see how closely connected the common field of work and the cooperative work arrangement are represented on the Gantt charts, consider that when planners delimit a task on a Gantt chart they are almost already always implying a particular type of member of the network to perform it. Even if they do not initially explicitly state which type of craftsman is needed, it is often implicit. For example, the task of 'painting' almost always implies some painter or other, not necessarily a named legal entity, but at least a painter in the general sense understood as a category of craftsmen. In the same manner delimiting the task of cabling electricity implies electricians, and putting up plasterboard implies carpenters. In this manner the notion of task in the building process is (very) hard, if not impossible, to separate from the notion of actor in the sense that at least a *type* of actor with certain skills is implied. By the same token, we may say that the notion of task in construction of course also implies a particular part of the building to be worked on. In this manner a task, and by implication whole taskscapes, may be said to be constituted not least by planners ordering (relating, meshing, delimiting, constituting) the mutual relations between the material field of work and the cooperative work arrangement.

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[15] By way of clarification, the subject of this particular stipulation of tasks is the construction of non-load bearing partition walls such as those found separating the interior of the building into office space. Such walls may be constructed by suspending plasterboards on steel frames or studs. The initial erection of the steel framing is undertaken by carpenters, what on the Gantt chart is referred to as 'walls - first side'. Following this the carpenters, electricians and plumbers undertake electrical cabling and plumbing pipe work respectively within the frame of the wall, these tasks are referred to as 'cabling: electricity/sanitation/ventilation' on the Gantt chart. In turn, the carpenters are designated to clad the steel frame in plasterboards and put up skirting boards, this is what is referred to as 'closing of walls' on the chart. Then follows the painters and their 'finish/painting' task also referred to on the chart. In this manner the construction of a partition wall involves several trades performing their crafts in an alternating sequence that is partly (and only partly) stipulated and represented on the Gantt Charts.

On a slightly different note we may return to the topic of causality discussed previously. It seems that the order of the taskscapes as represented on the Gantt charts are influenced in part by causal powers. Recall how the construction of the building follows the load bearing path, how it is generally constructed from the foundation and up. For example, the substructure including the foundation must *necessarily* be constructed prior to the construction of the superstructure, since the latter rests its load on the former. This is reflected on the main Gantt chart representing the overall construction process. For the planners, creating the sequence of tasks, i.e. the internal order of tasks on the charts, is partly a matter of taking into account causal powers such as gravity while studying the representations of the building and analyzing how the building may be constructed following the load bearing path. What this implies is that causal powers may influence the sequence of work tasks as represented on the charts for the construction process.

Furthermore, Gantt charts are used throughout the building process. That is, they are used in design (see e.g. figure 16) as well as in construction.

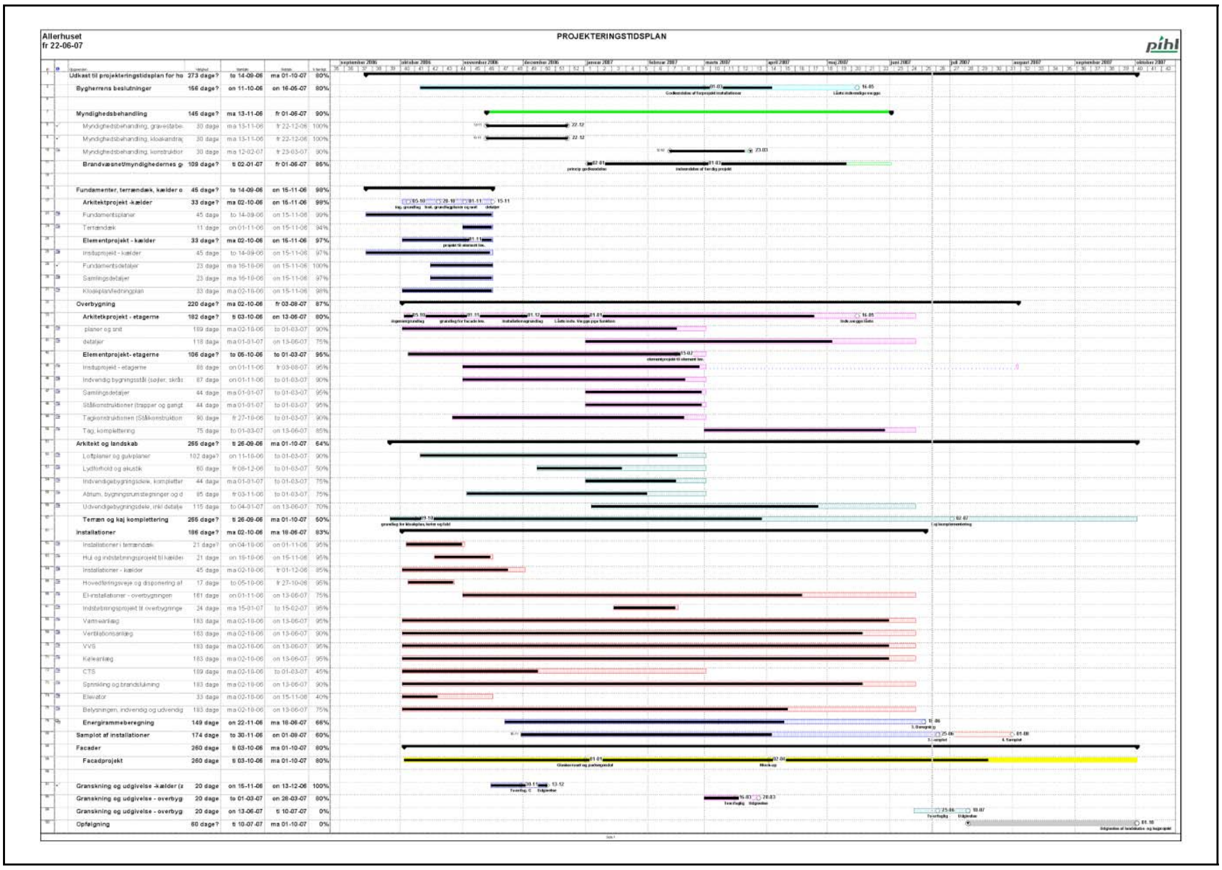

Figure 18: Time schedule for the design of the working plans with indications of progress.

The Gantt chart shown in figure 18 depicts the time schedule for a particular part of the design process related to the domicile project, i.e. the design of the working plans. It is reflected in the division of the graphical space on the chart that it is the responsibility of, for example, the architects to design the floor plans and it is the building engineer's task to design the ventilation system. Groups of tasks corresponding to the competences of a particular profession are grouped together and given the same colour on the horizontal bars. For example, all the tasks related to the building services are grouped together and given a colour distinct from that of the colour given to the architect's tasks in another grouping. It is possible to read for example that design of the architectural plans for the superstructure of the building is supposed to last 182 days, starting on October 10^{th} 2006 and finishing on July 13^{th} 2007, the plan also indicates that at the particular day of the meeting (November 11^{th} 2006) this task is 80 percent completed. This is indicated in written text as well as reflected graphically by the length of the black horizontal bars serving as progress indicators for each task. In addition, it is also possible to gauge that the engineering plans for the ventilation system are supposed to be carried out over a period of 183 days, starting on October 2^{nd} 2006 and finishing no later than July 13^{th} 2007, the progress indicator shows that November 11^{th} 2006 this task is 95% completed.

In this manner the Gantt chart may be said to reflect not only the time schedule for the process, as indicated it can also be said to reflect the division of the process into an array of interdependent tasks where each task is implicitly mapped to a specific member of the cooperative work arrangement. Simon (1962) speaks of "*nearly* decomposable systems" (Simon 1962, p.473, my emphasis). Following Simon (1962), it seems that the planning engineers are decomposing the building process into collections of tasks, or more precisely, they are *nearly* decomposing the process. That is, although a particular task may be stipulated as a discrete bounded entity (as we have seen above), the tasks remain interdependent and in this sense the process is only *nearly* decomposed by the planners. This is particularly evident on some of the Gantt charts where graphical devises such as arrows point from one task to the next (see detail view on figure 17), and in this way help underline the interdependencies between tasks.

Perhaps there is a family resemblance of sorts between the concept of 'nearly decoupled systems' (Simons 1962) and a concept that we have employed in previous chapters, namely, the concept of 'taskscape' (Ingold 2000). In the sense that nearly decoupled systems, or more precisely, the performance of such systems may amount to 'an ensemble of tasks, performed in series or in parallel, and usually by many people working together' as Ingold (2000) puts it characterising the notion of taskscape. Gantt charts may be described as representations of taskscapes. This is one way for us to grasp the role of Gantt charts in the building process.

Furthermore, perhaps we may consider the notion of taskscape not only a research construct, but a member's construct as well. According to Bittner (1965), sociology's third person descriptions are premised in and make unacknowledged use of the constructs which ordinary members have and use in daily practice. To see what Bittner has in mind here, we must first to understand the analytical backdrop against which this assertion is proposed. This is a general approach often associated with Garfinkel (1967). For Garfinkel the problem of social order in sociology is a problem of providing for the possibility that ordinary activities can be found to display an orderliness, a continuity, a predictability, a matter of factness, for those who are engaged in them. What precisely that orderliness might be is the outcome of the particular methods that members of that order use to establish it with (Garfinkel 1967). Garfinkel (1956) applies the same line of thinking to sociological constructs (as to members constructs), namely that the order is the outcome of the particular methods that members of that order use to establish it with (Anderson et al. 1989, p.62). One of the consequences of Garfinkel's approach is to put sociology and common sense constructs on the same footing. Furthermore, for Bittner (1965) and Garfinkel (1967), common sense accounts underpin sociological ones (Anderson et al, 1989, p.63). Perhaps this is also the case with the notion of 'taskscape'. We may follow Bittner (1965) and Garfinkel (1967) as far as pointing out that the notion that the ordering of activities or tasks in a process can be depicted, for example, in terms of taskscapes is simultaneously a sociological and a member's construct. If we, in addition to our own use of Ingold's (2000) notion of taskscape, consider that actors in the building process for planning purposes actually make representations of 'taskscapes', then perhaps it is safe to suggest that the phenomenon of 'taskscape' is a sociological notion as well as a common sense construct or members category. This state of affairs may provide the analytical use of the notion of taskscape with some empirical resonance, and it may point us towards investigating how the actors themselves use the Gantt charts as representations of the taskscapes.

In the next section we shall consider how the taskscapes are used, how they are reconfigured and policed on a regular basis.

Reconfiguring and policing the Gantt charts as representations of the taskscapes

The use of Gantt charts in the building process may be said to condition, in a normative manner, the actions and interactions of the actors in regard to the coordination of the interdependent tasks. For example, with reference to the Gantt chart, each member of the cooperative work ensemble, present at a given meeting, must give testimony to the progress of the task or set of tasks that they are each responsible for. In this way one of the main themes of such meetings is the calibration of construction work to its representation on the Gantt charts and vice versa. This is done under conditions of social accountability in the sense that the individual actor must live up to their assessments of how far they have come and when they are due to be finished.

The Gantt charts partly serve what could be called *practices of configuration,* that is the order of the taskscapes on the charts is continuously (re)configured. This is done partly in regard to anticipating or planning the taskscape of future construction work and partly in connection to updating the charts to represent the actual state of affairs on the building site. The composition of a task including its proposed starting date and completion date is stipulated on the chart as the taskscape is planned, and in turn these dates on the charts are continually reconfigured to the rhythm of the actual construction work as manifest in the state of the building observed and reported on. If for instance a task has been inspected and reported 100 percent completed, this status of the task is updated on the chart. Consider this excerpt from a meeting between on the one hand a planning engineer representing the general contractor and on the other hand foremen working for a large subcontractor responsible for parts of the construction work i.e. the carpentry work and the carpet work:

1 Planner:	Ok, then we have on level four, nr. 433, the core cladding.
2	(Points to a tasks id number on the Gantt chart spread out on the table in front of him).
3	Where are we in relation to that?
4 Foreman:	It is finished.
5 Planner:	Fine.
6	(Makes a note in the margins of his chart in regard to the status of task nr. 433)
7	Then we have nr. 448, the carpets, to be finished next Monday.
6 Foreman:	Should be ok.
7 Planner:	Then we have on level five, nr. 529, the core claddings adjustment panels.
8	Should have been finished last week.

9 Foreman: They *are* finished.
10 Planner: Ok - when did you finish that?
11 Foreman: Last week – Friday.
12 Planner: Ok, and you are sure because Marko says …
13 Foreman: Yes, I am sure.
14 Planner: Ok, if you are sure you are sure.
15 (Makes a note in the margins of his chart in regard to the status of task No.. 529).
16 Then we have here on level five, the carpets No. 547, the carpets on level five.
17 When will you start?
18 Foreman: The carpets?
19 Planner: Yes.
20 Foreman: Very soon I think, I think we will … (is interrupted)
21 Planner: I think that we can say here (makes a gesture towards the chart) that we can start on ...
22 (Pause)
23 Wednesday or Thursday, I think it will be Wednesday.
24 Because as far as I can see the people on level three can go up on level five. Is that correct?
25 Foreman: Yeah.
26 Planner: (Writes a note on the chart in regard to task No. 547)

In line 1-3, the planner draws attention to a task and inquires in regard to its present status. In line 4, a short status report is provided by the foreman, and in line 5-6, the planner acknowledges the status report and makes a note to updates the Gantt chart in accordance with the report. In line 7-26 this pattern of inquiry, report and chart update continues. In this manner construction work is calibrated to its representations of the Gantt charts and vice versa.

Perhaps we could describe this meeting as being akin an ‘interview’ where the planning engineer asks the foreman questions in accord with the ‘interview guide’ i.e. the Gantt chart, and where the answers subsequently are used in relation to updating the status indicators on the Gantt chart.

In addition to being reconfigured, the taskscape as represented on the Gantt charts may be said to be *policed*. We shall now turn to this *policing* of the Gantt charts: As stated above, the Gantt charts may be said to represent the taskscape of the building process. This particular order as represented is policed[16] in meetings i.e. it is enforced not least by the planning engineer. That is, the planners compare and adjust the state of the construction work on site with the state of construction work stipulated on the Gantt charts, and if a particular task is not completed according to schedule this is reprimanded by the planning engineer, and the date for completion is stressed to the foremen in the meetings. In this manner the rhythm of construction work is continually calibrated to the dates on the charts, or put more forcefully, the order of the taskscape as represented on the charts is continuously enforced or policed. Consider this excerpt from a progress meeting where a foreman is reprimanded by the planner for not completing a task according to the schedule stipulated on the Gantt chart (and note how the foreman engages in 'evasive' action):

1 Planner:	I have been down in the basement this morning. The doors are not finished as planned.
2	(Makes a gesture towards a Gantt chart in front of him on the table).
3	Door handles should have been installed by now.
3 Foreman:	Did we get informed that the doors where ready for the handles?
4	Did we get an update saying that the electrical locks had been installed?
5 Planner:	No, we cannot update the plans [i.e. Gantt charts] every hour.
6	You are down in the basement every day. You can use your eyes.
7 Foreman:	Yes, but you are asking us to keep an eye on everything.
8 Planner:	This is not the only thing that you have not completed.
9	The doorstoppers and the panels are also not installed.
10	We have talked about these items for three or four weeks now.
11 Foreman:	Yes, but I have only just heard that the locks were installed.

In line 1-2, the planner draws attention to the task of installing handles on the doors in the basement – something he has observed not to be completed as planned. In line 3-4, the foreman makes the argument that he did not proceed with the task, because the Gantt diagram had not been updated to state that the doors were ready for it. In line 5-6, the planner retorts that the foreman should look at the building in-the-making, and not rely solely on the Gantt charts for task status indicators, as the charts cannot be updated all the time. In line 7-11, the

16 The verb to 'police' fittingly has its origin in late 15th century in the sense of 'public order'. It is from medieval Latin (Oxford American Dictionary).

argument continues back and forth, ending with the foreman returning to the argument that he had not previously been made aware that the doors were ready for the montage of handles. In this manner the foreman attempts to shift the blame for the uncompleted task to the planner responsibility for updating the charts, and the planner is attempting to shift the blame back by insisting that the foreman could just look at the building for indications of the status of the taskscape. In this manner the Gantt charts as representations of the taskscapes may be said to be policed.

Furthermore, this mundane everyday episode highlights not least the two reference points that are in play in regard to the status of the taskscape of construction, namely, on the one hand the appearance of the building-in-the-making and on the other hand the appearance of the Gantt charts. Next, we will briefly explore how each of these respective reference points in this context may be said to represent different standards of time.

According to Sorokin and Merton (1937), it is possible to distinguish between astronomical time and social time. Astronomical time is the temporality of any perfect, repetitive system such as the rotation of a planet around its axis and its sun. Astronomical time is purely quantitative devoid of qualitative variations, and it is distinguished from social time, which is fundamentally qualitative and grounded in the 'rhythms' and 'pulsations' of the social sphere (Sorokin & Merton 1937, p.621).

Following Sorokin & Merton (1937) we may note that the Gantt charts seem to be drawn up in astronomical time or calendar time, whereas social time is manifest in the state of the construction work on site. Social time understood as the rhythm of cooperative work as a socio-material phenomenon is manifest in the progress of the construction work on site, whereas time understood as calendar time is part of the *representations* of the taskscape of the construction work. Going back and forth, between these reference points may be said to underpin or prompt much of the articulation work in the progress meetings. That is, the calibration of calendar time to social time and vice versa is one of the main themes of the progress meetings in the sense that dates on the charts are continually calibrated to social time as manifest in the state of the building observed and reported on, and the (socio-material) rhythm of construction work is continually calibrated to the dates on the charts.

We may further observe that although calendar time seems to be the chosen tool for the planners it is in fact social time as manifest in the state of the building that is often the final reference point. As indicated above, a look at the state of the construction work on site, not a look on the dates of the Gantt chart, will tell you when something is done.

One of the main themes of these meetings, then, is the calibration of construction work to its representation on the Gantt charts. This process may be described in terms of practices of configuration and policing. The charts may be said to be configured to anticipate the taskscape of future construction work as well as configured to represent the actual state of affairs on site and policed in the sense of being reinforced as the rhythm of construction work is calibrated to its representation on the charts.

The Gantt charts are attached as an appendix to the minutes at the end of each meeting and are brought forward in the next meeting, in this manner the charts facilitate the continuity of the articulation work not least by virtue of their durable form (i.e. in written form on paper and electronic document).

Of course, the use of Gantt charts as coordinative artifacts is only one element in the articulation of the building process. Between these weekly 'progress meetings'[17] the actors frequently employ for example emails and telephones in their articulation of the building process and of course *ad hoc* conversations on for instance the building site also play a part. In addition, coordinative practices centred on other types of coordinative artifacts such as file sharing systems also contribute as we shall see next.

Articulation work with a file repository

In this section we shall take a closer look at the role of a particular coordinative artifact, namely online repositories' role in providing infrastructure for the ordering of representation in the building process i.e. their distribution, identification and validation.

In the domicile project, an online file repository supports exchange and sharing of representational artifacts and other forms of documents pertaining to the building process. The repository is divided into several spaces or domains, including a design work area, an area for approved plans, and a distribution area with pigeonholes or folders for the firms and individual that are part of the project and are due to receive various documents including architectural plans (see figure 19). We will briefly describe the various parts of the system now.

[17] The actors themselves call them 'progress meetings'.

The work area is an area for the storing and exchanging CAD models as work-in-progress. Once the CAD models have been completed they are subject to approval (typically by the architects) and they leave the work area in the form of architectural plans and enter the area set aside for approved plans and furthermore they are distributed to the electronic pigeonholes of the firms and individuals they have been assigned to or that have declared an interest in them.

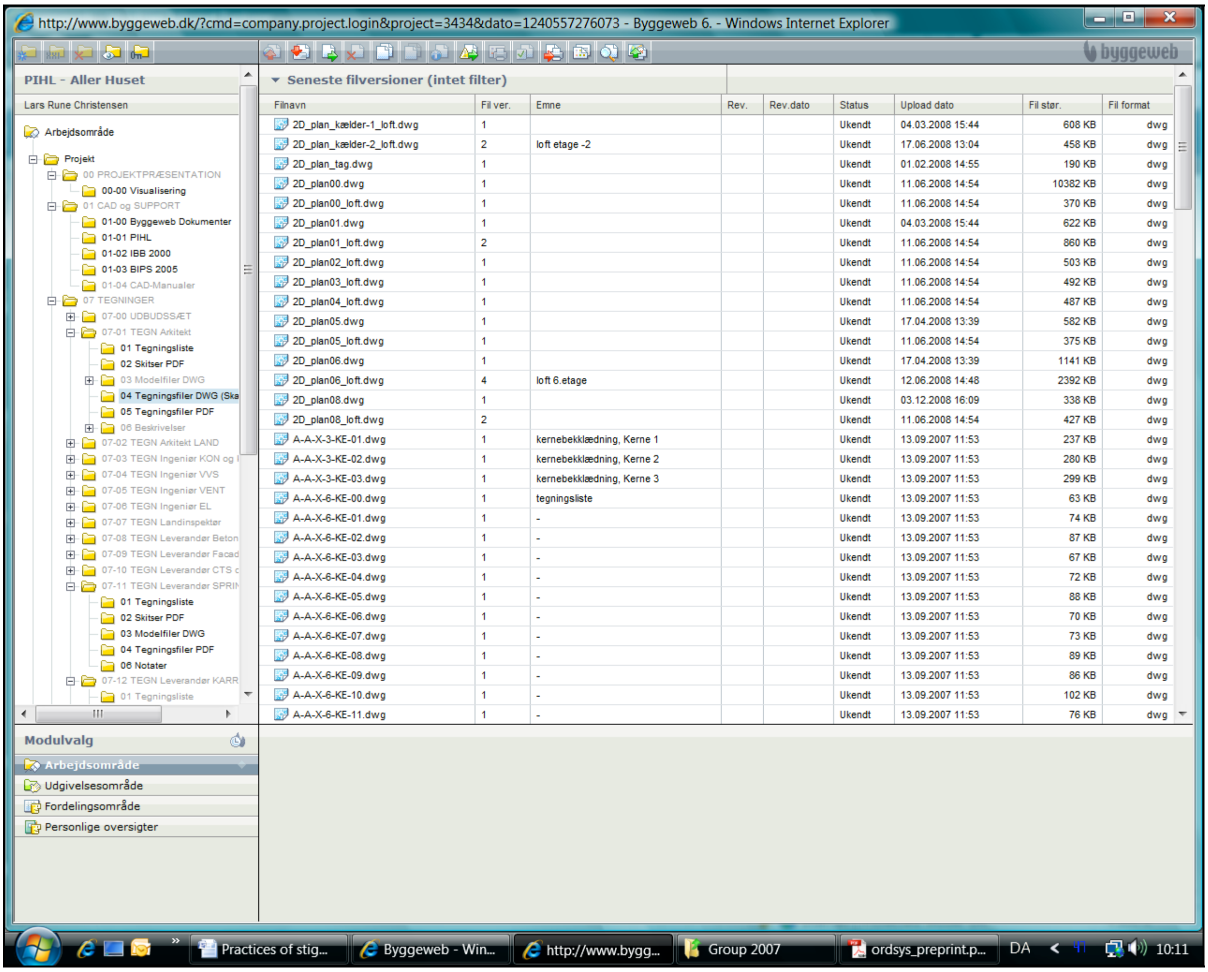

Figure 19: File repository shown in browser window with folder structure on the right and an open folder on the left.

The area of approved representations and documents will hold up to two thousand architectural plans in PDF format at its peak. In addition various documents and written description pertaining to the building design are also placed here. An inventory is made and maintained of the various plans and documents. That is, a list is made with descriptions of the files and the files are stored according to pre-defined naming conventions. By keeping the CAD models in development in the ‘work area’ and the approved architectural plans in another area the risk of mistakes pertaining to issues of file version and their validity is somewhat reduced, since it is relatively clear what is still being worked on and what has been approved.

The distribution area is as mentioned a cluster of folders or pigeonholes where the respective actors receive plans and documents deemed relevant for them. Perhaps we should mention that a fulltime employee retained by the general contractor is dedicated to the task of assessing what subset of the two thousand architectural plans and documents that are relevant for what actors and when. This ‘articulation worker’ is a key part of the system. In addition, the contractors and builders themselves can also act and ‘subscribe’ to a set of architectural plans pertaining to a specific building task. In this manner the plans are distributed to the subcontractors that print them out and put them in the hands of the men and women doing the actual construction work.

The repository is used, then, both in the design process and in the construction process. The work area is primarily used by the actors engaged in the design of the building, while the area for approved architectural plans, and the distribution area is accessed by the contractors and builders as well as the designers. The coordinative practices centred on the file sharing system may be described as pertaining to issues of identification and validation[18]:

Identification: In an effort to accommodate the orderly identification of the representations and documents the actors involved in the design project may identify a particular representation by its position in the repository, the repositories' version control, file history, and not least the pre-defined file naming conventions employed in the repository.

Validation: In addition to revealing the identity of a representation, the online repository also pertains to issues of validity. The version control of files in the work area is significant since it provides the actor with the most recent version of the file, if not the most valid. Furthermore, representations that are found in the publication area are valid in the sense that they have been approved by a trusted actor before being placed there, and the representations of the distribution area have also undergone scrutiny before being distributed to the various actors in the network.

Furthermore, the online repository is not alone in storing the plans representing the building. A parallel (legacy) system of binders supports the filing of the plans and documents in a paper format. Although, in principle, the online repository could be said to have the affordances to supplant the binder system this has not happened entirely and mainly for legal

18 See also Schmidt & Wagner (2004).

reasons and issues of thrust. In the words of one clerk ‘If the online repository fails, if the server crashes, we will still have the printouts in the binders’.

In sum, the ordering and orderly distribution of CAD models, architectural plans and other documents is performed with the support of coordinative artifacts i.e. the online repository.

Articulation work with title blocks

In this section we will se how title blocks on architectural plans serve as coordinative artifacts.

The identity and status of a particular representation is implied, as mentioned above, according to its position in the online repository and by its given file name there. However, once the plan it is printed, i.e. is outside the repository for example on a desk or in the hands of a craftsman or an engineer, another means of identification comes into prominence, namely the plan’s ‘title block’ (see figure 20). According to Schmidt and Wagner (Schmidt and Wagner 2004, p.371), the title block serves both identification and validation purposes (just as the online repository did):

Identification: In an effort to accommodate the orderly identification of the individual plans the actors involved in the design project may rely on the content of the title block. For example, when an actor navigates a stack of representations on a desk, she is able to identify the relevant plan by the title block, she is able to asses at a glance what it is, who made it when etc.

Validation: The title block will also reveal something about the status of the plan. That is, issues of validity are also addressed in the title block. For example, in figure 20 the field designated for initials signifying approval is filled out with ‘KR’, rather than left blank. This signifies that the plan has in fact been approved by someone with the initials ‘KR’. In addition it is possible to se, for example, that the plan is a revised version ‘B’ and read how this revision is different from revision ‘A’ (sometimes the number of revisions may prompt the use of the latter letters in the alphabet (e.g. X, Y, Z) indicating a large number of revisions). All this pertains to the validity of the architectural plan, and actors will have to draw on their knowledge of the validation procedures in order to access the status of a particular plan (Schmidt and Wagner 2004).

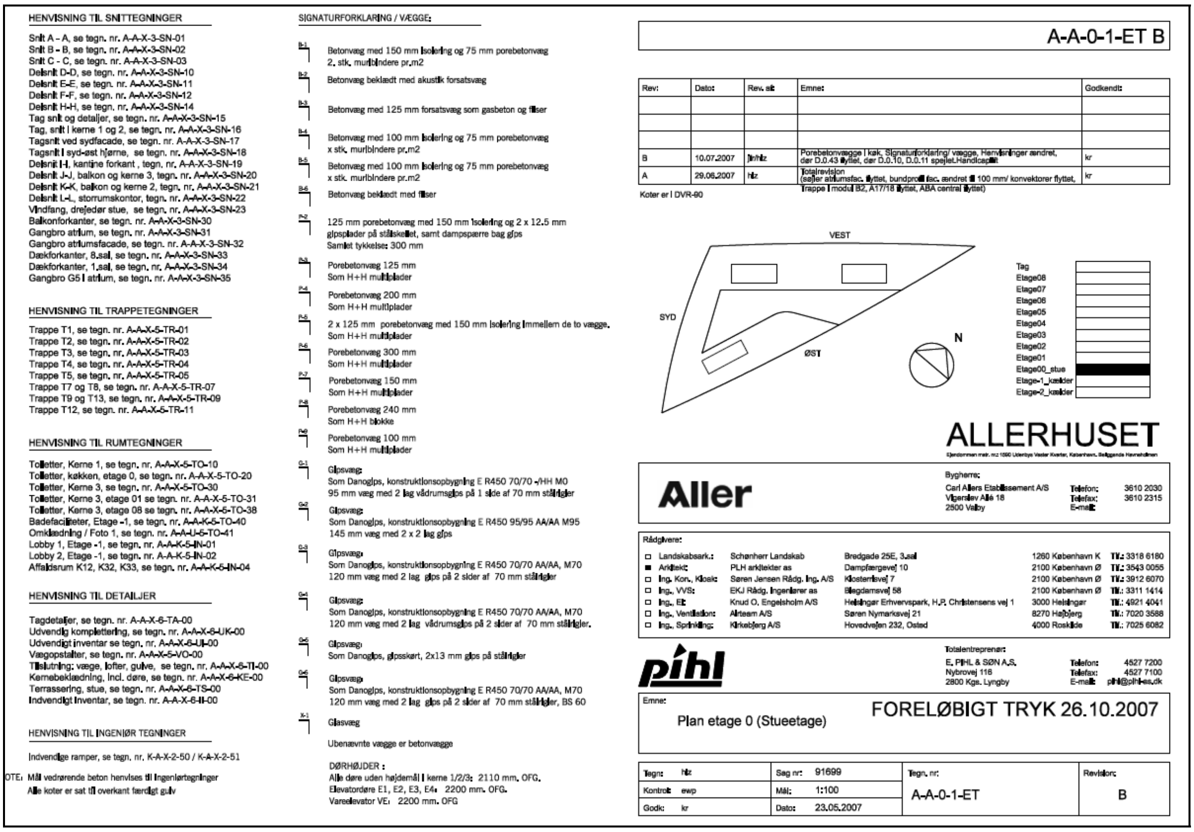

Figure 20: Title block with plan name, legend and more.

According to Schmidt and Wagner (2004) the title block is an ordering scheme based on what in CSCW has been termed a standardised format (Harper et al. 1989b, p.15). As indicated, each plan generated from the CAD models is provided with a title block, graphically, a bounded space divided into fields of different sizes (Schmidt and Wagner 2004, p.370). Each field is reserved for the display of a specific category of information including, date (e.g. 23.05.2007), case number (e.g. 91699), creator's firm (e.g. architects), creator's initials (e.g. HZ), initials signifying approval (e.g. KR), scale (e.g. 1:100), subject (e.g. plan view ground floor), revision (e.g. ‘B’), the cross section represented in the plan (graphically depicted), and last but not least a name or identification code for the individual plan which is identical with the file name in the repository (e.g. A-A-0-1-ET). Let us take a closer look at the naming scheme involved, i.e. what does for example ‘A-A-0-1-ET’ mean?

The naming scheme relies on a positional syntax where the first position stipulates who is responsible for the representation (e.g. A equals ‘architect’, B equals ‘client’, E equals ‘electrical engineer’, etc.), the second position indicates the location or building number (e.g. A equals ‘building nr. a’, B equals ‘building nr. b’, etc), the third position indicates the level (e.g. F equals ‘foundation’, K equals ‘basement’, 0 equals ‘ground floor’ etc), the fourth position stipulates the type of representation (e.g. 1 equals ‘plan view’, 2 equals ‘elevation view', 3 equals 'section view', etc.) and the last (double character) position is pertaining to the theme of the plan (e.g. TE equals 'terrain', ET equals 'floor', LO equals 'ceiling', etc.). This would make the file name A-A-0-1-ET stipulate the following about the representation: It is the responsibility of the architect, it concerns building 'a', it is of the ground floor, it is a plan view, and it is a floor plan.

In conjunction to the title block there may be a string of references to other plans. For example, in figure 20 there are references to, section views, stair plans, plans of the load bearing structure, and plans for spaces designated for human occupation (i.e. offices, toilets, bathrooms, dressing room, lobby, trash storage), and finally references to detailed architectural plans. These references could be seen as a means of integrating the representations, a way of putting the 'jigsaw' of representations together by pointing to relationships.

In sum, the descriptions above gives us a glimpse into how cooperative work in the building process may be coordinated through articulation work with coordinative artifacts. The meetings, the Gantt charts, the repository, the title blocks, and so on may be said to constitute parts of an 'ordering system', to use an expression from Schmidt & Wagner (2004). That is, these practices and artifacts are part and parcel of the articulation of the building process and may reduce the complexity of cooperative work there to a workable degree. Of course these practices and artifacts do *not* provide absolute order, only a workable order is strived for. As Schmidt and Wagner point out there is an economy to coordinative practices in the sense that no more order is created than is practically necessary (Schmidt and Wagner 2004). Moreover, articulation work and coordinative artifacts are not alone in integrating the distributed tasks of the building process, as we shall see next.

Acting on the state of the common field of work

In this section we shall consider, in the context of design as well as construction, how cooperative work tasks are integrated by virtue of individuals acting on the material evidence of work previously accomplished by others. This is a phenomenon that contributes to the integration of cooperative work. We shall consider this phenomenon first in the context of design and subsequently in the context of construction.

Acting on the state of the common field of work in design

As mentioned above, actors meet on a regular basis face-to-face at meetings, over the phone, via email, with coordinative artifacts such as Gantt charts, to discuss the 'big picture', the overall progress of the project, who does what when etc. However, when it comes to the coordination of 'the small things', the multitude of details involved in for example building design, this is *not* done exhaustively at meetings or over the phone (there is no time), this is also done through the material field of work. That is, on the detail level of concrete design tasks, work is very much coordinated through the performance of the work itself, rather than (solely) through for example meetings about it. We shall now turn to describe this phenomenon in more detail, and in the process of doing so we shall further familiarise ourselves with a technology and methodology commonly used in contemporary building design, namely CAD.

As indicated above, seen from the trajectory of a building project, design is primarily done by the use of CAD models. That is to say, in a modern architectural office, the central representational artifact is the system of CAD models. They incorporate, as an ensemble, a project's trajectory from draft to implementation; they absorb and reflect all decisions taken and changes made, as models are gradually modified and rendered more detailed.

Furthermore, the division of labour within the design project is facilitated by the subdivision of the system of CAD models into partial models or submodels. Someone responsible for a particular task such as for example 'ventilation system design' may work on the submodel for this building part, while others concurrently work on other submodels representing other parts of the building. There are for example submodels for static design, façade elements, roof, ventilation, electrical system, sanitation, and etc. The subdivision of the representation of the building into discrete yet interconnected entities (i.e. submodels) enable the actors, for long and short periods, to proceed concurrently, with only occasional communication, while still acting concertedly. That is, the division into submodels allows for a distributed work process. The distributed models are joined into a central model of the building (see figure 21.).[19]

[19] As a point of interest for the more technically inclined we could mention that in some projects (although not in all projects) model servers form the basis for cooperation in the design process in the sense that a model server acts as a shared container for the building model entities (on par with a project repository acting as a shared file container). Model serves are special databases dedicated to the handling of CAD models by which multiple users share their respective contributions. Users may be granted access rights to a model server and can then, as a basic functionality, upload models to a server and download models from a server. A special

We could interject that the central CAD model is a fine example of a boundary object (Star 1989; Star and Griesemer 1989) in as much as it is an integrated system of representations that provides an infrastructure that enables distributed actors to make their individual contributions to the overall design in a distributed, incremental, and yet concerted manner. The concept of 'boundary objects' highlights practices in which activities in distinct local settings are partially concerted by 'objects' on the 'boundary' between the settings. However, the question remains how exactly is cohesion or coordination of cooperative work obtained through such 'boundary objects'. We shall continue.

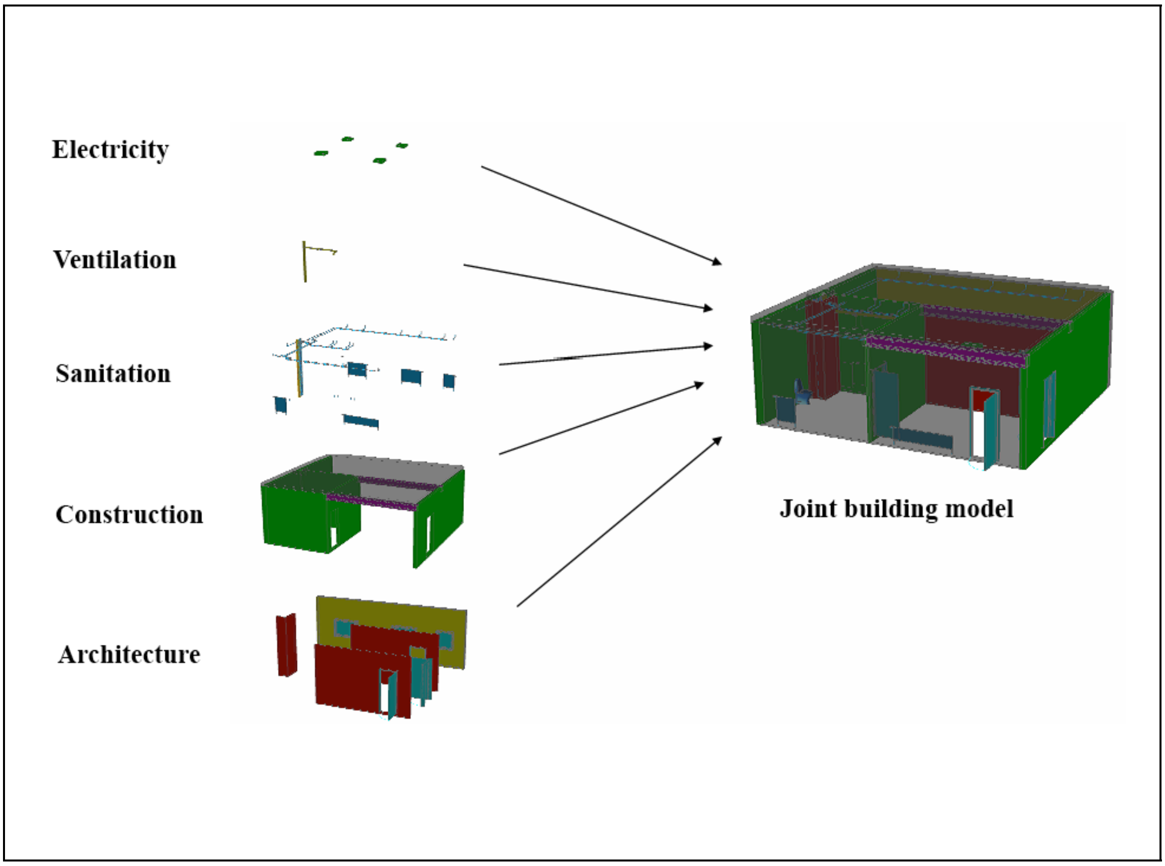

Figure 21: The principle of joining of a number of specialists CAD models into a joint model of a building.

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functionality of model servers is the check-out and check-in operations. Partial models can be checked out for external update and later checked in again. At check-out a special locking mechanism marks the checked out objects in the model server. Other users may still read these objects but only the user that performed the check-out, or the users administrator are allowed to make changes. Normally, the checked out model or partial model is modified by a modeling tool and then re-entered by check-in. During check-in, a merge operation is carried out. During this, re-entered objects will replace the excising objects, new objects will be added and missing objects will be removed automatically by the model server. A successful check-in will release all locks, created at check-out (Jørgensen et al. 2008, p.18).

The work ensemble including architects, engineers, specialists etc., all make distinct contributions in the form of CAD models covering their respective areas of expertise. The architect creates the outline of the building. On that basis the construction engineer creates the geometry of the concrete structure in a separate construction model. Subsequently, the sanitation specialist, for example, will take notice of the model for the concrete structure and seek to align the sanitation with it. In a similar manner, the electricity specialist, for example, will take notice of the previously created models and seek to align the wiring of the electricity with it. That is to say, the individual actor creates and changes the form of a CAD model, not for the purpose of conveying a message, but simply as a part of constructing a building; another actor takes notice and acts upon it. In this manner, components of the building such as concrete structure, sanitation, ventilation and electricity are brought into alignment with the overall design.

The actors are simply doing their job, going about their business while paying heed to the work previously accomplished by others and this has a coordinative effect on the cooperative design effort. That is to say, in addition to relying on meetings, plans and schedules, *actors coordinate their cooperative efforts by acting directly on the material evidence of work previously accomplished by others.* Let us look at a concrete instance of this. Take for example ventilation design.

When creating the model for the ventilation systems the engineer at every turn has to pay heed not least to the architects' model of the building in order to ensure that the systems is a 'fit', that it is in accord with the structural elements of the building as well as its layout. Perhaps we could take a closer look at how this unfolds.

Working with the CAD application the engineer juxtaposes what is to become the model of the ventilation system with the architects' model of the building already made. That is, the coming model for the ventilation system is placed in one 'layer'[20] and the model of the building is placed in another layer while ensuring that both are visible at the same time (see figure 22).

[20] Historically speaking, originally layers were pieces of paper with drawings of different building elements that could be placed on top of each other and looked through for inspection and alignment. Today the basis of this concept or idea persists in three-dimensional CAD designs, albeit in a somewhat different form. Today the term 'layer' in three-dimensional design refers to the divisions whereby a design may be broken into discrete and semi-autonomous entities each hosting specialised submodels.

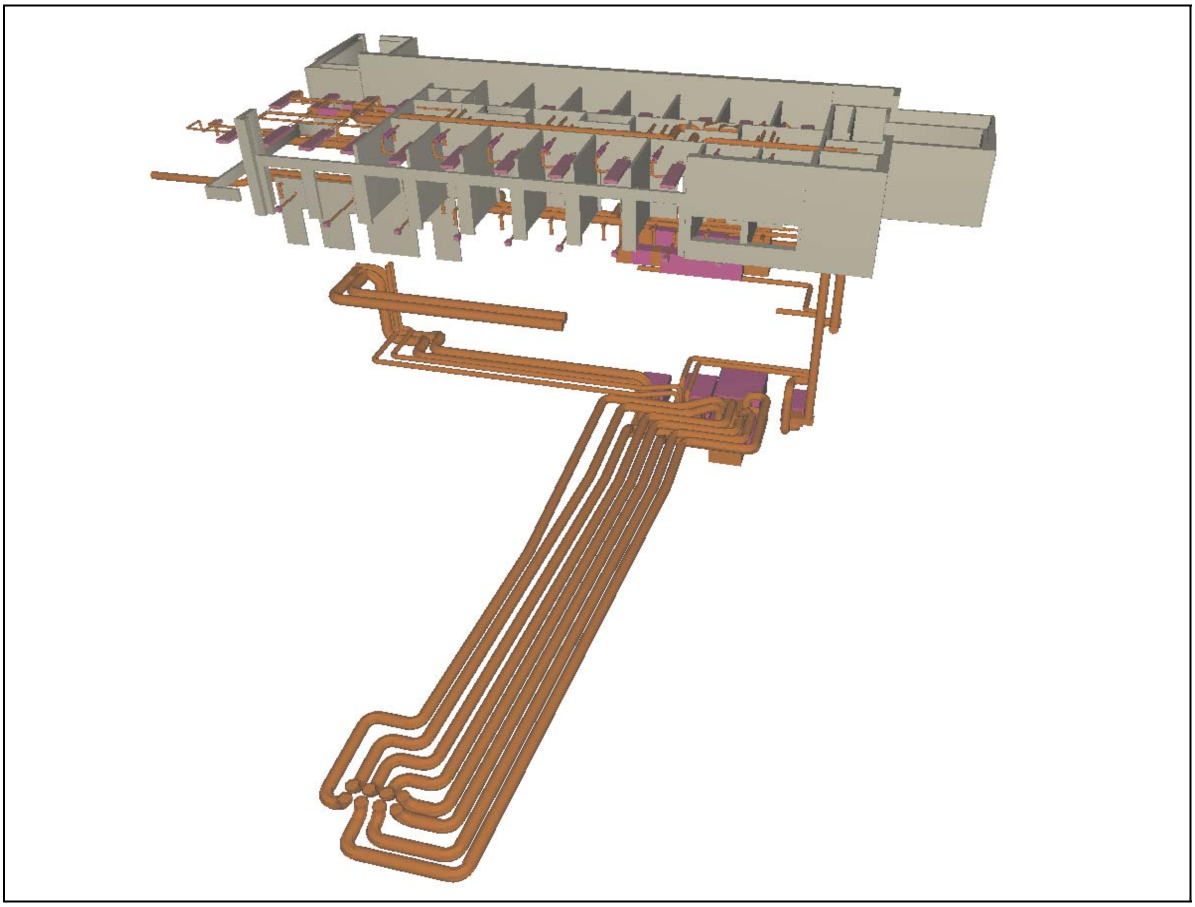

Figure 22: CAD model in three dimensions of ventilation system seen in conjunction with parts of the model for the buildings general architectures.

Panning and rotating the architects' model of the building the engineer is able to familiarize himself with the space constrains and possibilities that the model affords the engineer's design of ventilation system. The space allotted, for example, for the air ducts in the building layout is very limited due to the high cost of building construction, so space constraints is a concern. In extreme cases the engineer has to take such issues up at a meeting with the architects in an effort to have more space allotted for the ventilation system. However, meetings are time consuming and as a matter of routine the engineer will make every effort to make the system integrate with the architects' model of the building without having to meet, talk or otherwise correspond. That is, as a matter of routine the engineer acts on the representation previously made by the architects and in the process integrate his own task with theirs. This may involve for example positioning ventilation equipment such as air ducts, air dispensers and duct silencers in conjunction to the space made for building services in the architects' model.

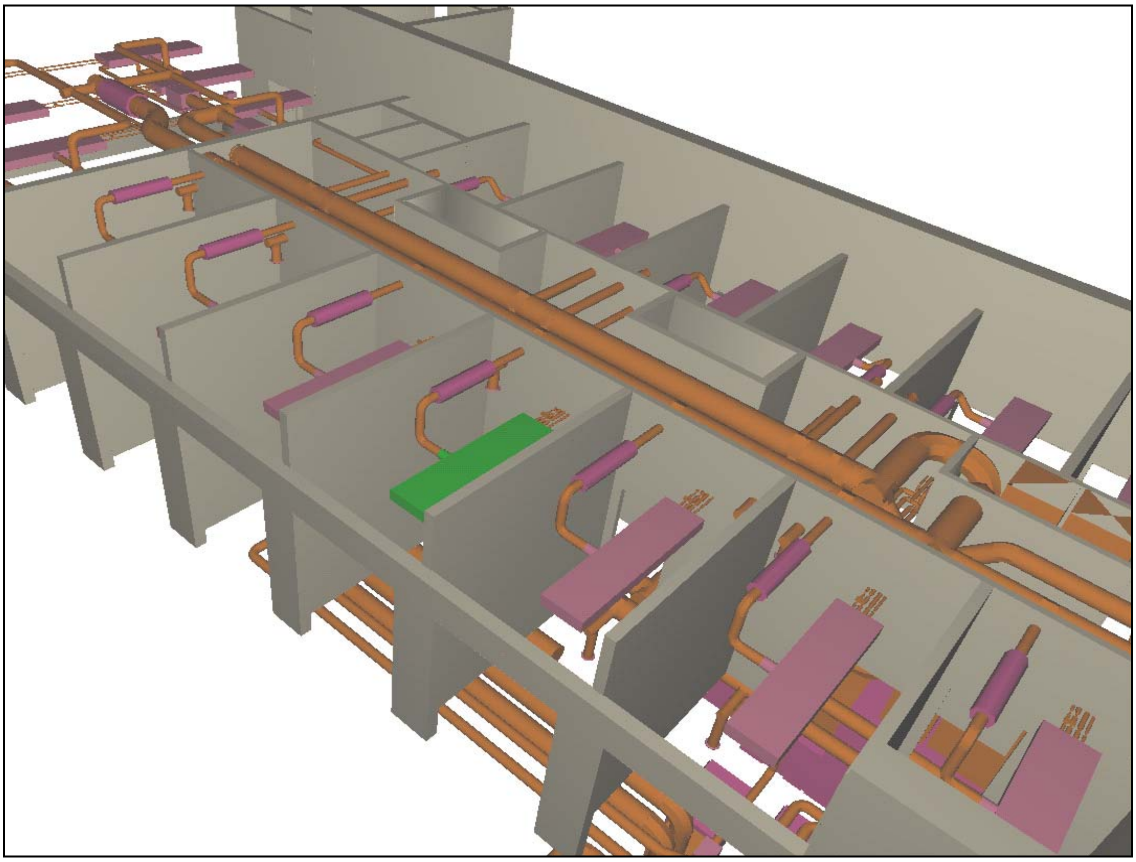

Figure 23: CAD model of ventilation system shown in connection with model depicting the spatial division of the building.

Part of the task of ventilation design, then, is to act on representations created previously by someone else. As mentioned, taking heed of the architects’ model in his own process of design, the engineer may integrate his own work with the architects' without resorting constantly to meetings, phone calls or emails.

In sum, we may say that actors in design partly coordinate their cooperative efforts by acting on the material evidence of work previously accomplished by others. This general phenomenon is not restricted to design, as we shall see next.

Acting on the state of the common field of work in construction

In construction work, as in design, interdependent tasks may be partly integrated by virtue of individuals acting on the material evidence of work previously accomplished by others. As a case in point we shall consider the integration of cooperative work tasks pertaining to the construction of interior walls.

In the interior construction stage a large number of partition walls are constructed. Partition walls are what divide the building into for instance units of office space. The construction of these walls is a cooperative work process involving a number of different trades such as carpenters, electricians and painters (see figure 24).

Figure 24: Interior wall in-the-making. The first and second frame shows the result of the carpenter's initial efforts. The third frame, including insert, shows the work of the electrician in progress. Finally, the fourth frame depicts the closed wall ready for painting.

The initial parts of a partition wall is constructed by a carpenter in the form of a frame made of light weight steel grinders fitted with plasterboards on the one side. At a later point in time, another actor, namely, an electrician will arrive and take notice of the work carried out and seek to align the wiring of the electrical circuits with it. That is, the electrician will drill holes in the plasterboard to accommodate the electrical instillations and he or she will pull electrical cables through little holes in the vertical steel grinders of the frame and connect them to the electrical system as a whole. When the electrician is done and has left the scene, the carpenter returns to close the wall i.e. clad the second side of the wall in plasterboards in accordance with the previous work done. That is, the carpenter must take notice of the work previously performed by himself and the electrician as he seeks to put up the second round of plasterboards. Subsequently, the painter shows up to paint what the others have erected. At this point the wall in-the-making will have been worked on to consist of a steel frame, plasterboards on the first side, electrical instillations inside, and plasterboards on the second side. Finding the wall in this state the painter paints the wall with several coats of paint.

In this manner the work ensemble including carpenter, electrician and painter all make distinct contributions towards the construction of the wall in accordance with their respective areas of expertise. We could say that the individual actor creates and changes the form of the wall in-the-making, not for the purpose of conveying a message, but simply as part of performing their individually allotted tasks, in turn another actor pays heed to and acts upon the material evidence of the work of others. This is partly how the cooperative work tasks pertaining to the construction of partition walls are integrated.

Perhaps to allow for full appreciation of the importance of this mode of coordination in building construction work, it would prudent to recall that no formal construct (e.g. architectural plan or Gantt charts) exhaustively stipulates a concrete practice. Plans are underspecified with respect to that which is represented (Suchman 1987), and architectural plans and Gantt charts for the construction of for example partition walls are no exception. The actors have to 'fill in the blanks' for themselves, so to speak, and acting on the evidence of work previously accomplished by others may be said to be one way of doing this. Furthermore, please bear in mind that architectural plans for specific building parts such as walls are *not* assembly manuals like those that come with for example IKEA furniture, rather architectural plans represent mainly how parts of the building it are supposed to look in the *final* state. Consequently, the *assembly* of for example partition walls is not covered in architectural plans.

In addition, the pace of contemporary construction work is such that as soon as one actor (e.g. carpenter) has completed a task, time does not allow for much standing around and talking to the next actor (e.g. electrician) even though their tasks are interdependent and there are numerous details that need to be integrated. Of course articulation work through talk on the building site may contribute to the integration of cooperative construction work tasks, but so may acting on the material evidence of work previously accomplished.

The point is that in addition to various kinds of articulation work with and without coordinative artifacts, cooperative construction work is coordinated by virtue of actors acting on the material evidence of work previously accomplished by others.

In sum, in construction as in design, cooperative work tasks are (partly) integrated by virtue of actors acting on the material evidence of work previously accomplished by others. How can we conceptualise this notion of coordination? Probably not in terms of articulation work as we shall see in the next chapter.

CHAPTER FIVE[21]: ON THE CONCEPT OF STIGMERGY

As indicated above, one of the main research issues in CSCW is the understanding of how cooperative work is coordinated and integrated by using artifacts. This issue has often been cast as a question of exploring how articulation work is practiced and supported by way of coordinative artifacts. A series of focused, in-depth field studies have been undertaken with the specific purpose of investigating how the distributed activities of cooperative work arrangements are articulated and, in particular, how prescribed artifacts are devised, appropriated and used for these purposes (e.g. Bardram and Bossen 2005; Carstensen and Sørensen 1996; Schmidt and Bannon 1992; Schmidt and Simone 1996; Schmidt and Wagner 2004).

These studies have provided invaluable insights (and large sways of the previous chapter are obviously inspired by the approach taken in these studies). But perhaps it could be fruitful to complement the concept of articulation work with a supplementary means of describing how cooperative work is coordinated and integrated.

In the words of Strauss (1985, p.8), articulation work is a kind of supra-type work in any division of labour, done by the various actors concerning the meshing and integration of interdependencies inherent in cooperative work. The prefix ‘supra’ is of key importance here.[22] In the context of cooperative work this could entail that articulation work comes before or stands in a meta-relationship to a work task or a set of work tasks performed. We could suggest that the distinction between the articulation work and the cooperative work articulated is an inherent feature of the concept of articulation work. As we have seen, articulation work in the context of the building process often revolves around time schedules and meetings where the progress of work is discussed, dates are settled, responsibilities cleared up, and work tasks are distributed and redistributed (if need be). These observations concerning the second order nature of articulation work are hardly controversial.

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[21] This chapter draws heavily on findings and analyses presented in articles published over the last couple of years (i.e. Christensen 2007; Christensen 2008).

[22] According to the Oxford dictionary ‘supra’ designates a prefix used in describing a phenomenon that is transcending, before or above something else. It originates in the Latin supra ‘above, beyond, before in time.’

Recall the coordinative practices described above where actors coordinate their cooperative efforts by acting directly on the evidence of work previously accomplished by others. Where an actor for example changes the form of a geometrical representation of a building in a CAD model, not for the purpose of conveying a message, but as a part of designing a building; another actor notices this, and in turn acts upon this change of state.

How could we describe practices of this nature? As indicated above, probably not in terms of articulation work, bearing in mind that articulation work refers to an activity that is transcending, comes before in time or is 'above' the cooperative work articulated (Strauss 1985). In the above example of the integration of CAD models no such supra–type relationship is apparent. The actors are doing their job, going about their business without making any supra-type efforts to coordinate anything, and yet coordination of the design of the building is taking place.

The concept of stigmergy

Perhaps we could use the concept of stigmergy to complement our descriptions of the coordination of cooperative work. The concept of stigmergy was not developed in order to describe human practice (Grassé 1959). Rather, it was developed to tackle problems pertaining to the field of entomology. Grassé coined the concept during his study of termite behaviour (Theraulaz and Bonabeau 1999, p.97). When looking at a group of termites, they all seem to cooperate in building nests etc., but when looking at single individuals, they seem to be working, as if they were alone and not involved in any collective behaviour. This appeared to be a paradox until Grassé introduced the concept of stigmergy[23]. Grassé showed that the regulation of building activities among social insects does not depend so much on the workers themselves as on the nest structure. A stimulating configuration triggers a building

[23] Grassé developed the concept of stigmergy during his study of termites. However, it has since been used and applied to other groups of social insects (e.g. Wilson 1975), not least in the study of ants (e.g. Hölldobler and Wilson 1994). Over the last decade or so the concept of stigmergy has been introduced to the field of telecommunication especially in connection with the development of algorithms for network traffic, these algorithms are sometimes termed 'ant algorithms' (e.g. White and Pagurek. 1998), and to the field of robotics (e.g. Dorigo et al. 2000).

action of a termite worker, transforming the configuration into another configuration that may in turn trigger another (possibly different) action performed by the same termite or any other worker in the colony (Grassé 1959). Thus, work in the termite colony is partly coordinated by virtue of the individual termites acting on evidence of work accomplished previously by themselves or others.

It can be instructive to consider nest construction in solitary species to get a feel for the ‘algorithm’ followed by the individual insect. The experiment performed by Smith on a solitary wasp shed some light on this issue (Smith 1978). The nest construction of the wasp *Eumenid Paralastor* takes place as a sequence of stimulus-response actions in which the completion of one stage provides the commencement of the next. A wasp begins its nest construction with the excavation of a narrow hole in the ground (approximately 8 mm wide and 8 cm deep). When the nest hole has been completed, the wasp begins to erect a large mud funnel above the hole. The funnel is built in five distinct stages from mud pellets applied in a stimulus-response sequence. Stage 1 involves the building up of the funnel until it reaches a certain height (approximately 3 cm). At stage 2 the wasp ceases to build straight upwards and applies more mud to one side of the funnel and in the process constructs a curve in the stem of the funnel. Once the curve has been completed, stage 3 begins with the formation of a bell like structure (approximately 2 cm in diameter). The flange of the bell is widened at stage 4 and at the final stage 5 the sides of the bell are formed (Smith 1978). At the end of each building stage, the stimuli for the responses that lead to the next stage are a consequence of the wasp’s earlier building activity. Smith chose to disrupt this sequence in his experiment. What happens if the stimuli triggering the start of a previous building stage are encountered by the wasp at a later building stage: if for instance the wasp after the work on stage 3 encounters the stimuli that started stage 1? Smith made an experiment to answer this question: A spherical hole located in the neck of the funnel (the stimuli for the start of stage 1 was a spherical hole) is made just after Stage 3 has been completed. After examining the hole several times, the wasp begins to construct a new funnel on top of the hole in the first funnel (Smith 1978). This result is instructive for anyone who wishes to understand the concept of stigmergy (Theraulaz and Bonabeau 1999, p.103).

There are two consequences of this behaviour. First, the order in which stimuli for the construction arises must follow a precise sequence for the orderly execution of the building activity. A non-orderly sequence of stimuli will lead to abnormal and redundant nest structure. Secondly, if one wasp does not distinguish the product of its own activity from the product of that of another wasp, the two wasps can in principle work at completing the same nest structure. One wasp could continue the work of another wasp at any stage of construction. Such behaviour may in turn be a step towards indirect cooperation between social insects. This is precisely the phenomenon that Grassé had in mind when he coined the concept of stigmergy[24] (Theraulaz and Bonabeau 1999, p.103).

As we have seen Grassé and others (e.g. Smith 1978; Wilson 1975) used a stimuli-response model of action characteristic of the field of entomology in their work. We must be careful not to transpose this model of action to the context of human practice. CSCW is obviously dealing with humans rather than insects, so we have to leave the stimuli-response model of action behind.

Stigmergy in a human context

What we are implying, then, is that when actors coordinate their cooperative efforts by acting directly on the evidence of work previously accomplished by others we may describe them as engaged in practices of stigmergy. However, it is important to note that before we are in a position to fully embrace this assertion, before we may be comfortable with it, we must exorcise or disassociate the concept of stigmergy from any stimuli-response model of action that may linger from the concept's origin in the field of entomology. In this section we will suggest that the stimuli-response mode of action is not characteristic of human practice in complex work domains such as the building process, including practices of stigmergy.

In chapter four, in the discussion of practice and apprenticeship, we argued that the ability to participate in practice in the building process and work with for example representational artifacts is grounded in skills and techniques that may be conceived of as acquired by the individual actor not least through apprenticeship as a ‘feel for the tasks’. The habitus, using Bourdieu’s (1992) concept, of for example an accomplished building services engineer acts as a set of dispositions towards certain ways of doing and being, acting and interacting that are in accord with or reflects the nature of the field of building design. Perhaps these dispositions are in play in practices of stigmergy as the actor acts directly on the evidence of design work previously accomplished by others. As such it is not simply a matter of stimuli-response.

[24] From the Greek *stigma* : outstanding sign, and *ergon*: work.

In addition, stigmergy may be described as performed mostly in the natural attitude. Recall Schutz (1990, p.227), ‘this world is to our natural attitude in the first place not an object of our thought but a field of domination’. According to Schutz (1976, p.73) we normally have to act and not reflect in order to satisfy the demands of the moment. Following our discussion in chapter four, including our discussion of Bourdieu and Schutz, we could suggest that the accomplished actor engaged in practices of stigmergy may mostly have as a basis for their actions something quite different from stimuli-response, namely acquired dispositions to perceive, comprehend and act that could be interpreted as oriented towards one task or another and performed most often in the natural attitude of the actor.

Of course this does *not* contradict the assertion that termites for their part engage in what may be described in terms of a sequence of stimuli-response action.[25] We are merely suggesting that the stimuli-response mode of action is not characteristic of human practice, including practices of stigmergy.

Furthermore, we may note that practices of stigmergy at least in a complex work domain such as the building process seem to be within the domain of the accomplished actor rather than the novice. It takes the habitus, the acquired skills and techniques of an accomplished actor to act directly on the evidence of work previously accomplished by others. In this manner the background for engagement in practices of stigmergy is the acquired competences of an accomplished actor, a novice may simply not have the skills. Of course, the distinction between master and novice is not binary; rather we could describe it as a continuum where and actors slowly acquire the skills necessary to participate, slowly moves from being a novice to being a master of a practice. Bearing this in mind, stigmergy as a way of integrating distributed tasks is obviously not fool proof since mistakes are made on a regular basis and the alignment of tasks may not always be successful, and this may partly be due to lack of skill on the part of inexperienced or semi-inexperienced actors.

In addition, recall also from our discussion in chapter four that the habitus of several actors may have similarities to the extent that their individual history and experience with a particular practice such as building design coincide. Perhaps these similarities in regard to the nature of their individual habitus, the mastery of the similar techniques related to representational artifacts, is what makes actors in the building process capable of engaging in

[25] This must be a discussion for the field of entomology, rather than the field of CSCW, and consequently we shall refrain from forming an opinion on the subject.

practices of stigmergy in a reciprocal manner. That is, building services engineers may act on the evidence of work previously accomplished by the architects and if need be the situation may be reversed and the architects may act directly on the evidence of work previously accomplished by the building services engineers. In this manner stigmergy within a community of practice may be facilitated by the similarity in acquired dispositions for action embodied in the actors within the same field of work.

With these considerations of stigmergy in mind, we may ask what kind of concept is stigmergy when used in a human context?

Stigmergy as a heed concept

In this section we will, based on the work of Ryle (1955), describe stigmergy as a ‘heed concept’.

According to Ryle (1955, p.135), the category of ‘heed concepts’ includes: noticing, taking care, attending, minding, applying one’s mind, concentrating, putting one’s heart into something, thinking what one is doing, alertness, interest, intentness, studying, trying. Perhaps stigmergy could also be considered a heed concept. Let us elaborate.

When a person hums as he walks, he is doing two things at once, either of which he might interrupt without interrupting the other. But when we speak of a person minding what he is doing e.g. when he is reading (or for example designing) we are not saying that he is doing two things at once. He could not stop his reading while continuing his attention to it (Ryle 1955, p.138). In a similar vein, we may add that he could not stop his designing while continuing to be engaged in stigmergy (i.e. acting on physical traces of the design of others). He could of course continue to read but cease to attend (Ryle 1955, p.138), or continue to design but cease to engage in stigmergy. The use of pairs of words such as ‘read’ and ‘attend’ or ‘design’ and ‘stigmergy’ suggests that there are two synchronous or perhaps coupled processes going on whenever both words are properly used, but that is not the case. This is a feature in the use of heed concepts (Ryle 1955, p.138).

If we accept at least preliminarily the notion of stigmergy as a heed concept, we may say that performing a task engaged in stigmergy is one, rather than two coupled activities. This may be easier to hear if we use stigmergy as a heed adverb e.g. ‘the engineer partly designed the ventilation system *stigmertively’*. We commonly speak of reading attentively, driving carefully (Ryle 1955, p.135), and now we could suggest speaking of doing something *stigmertively*. The adverb ‘stigmertively’ is not found in the dictionary. I have made it up.

The usage of such heed adverbs as attentively or stigmertively has the merits of suggesting that what is described is one operation with a special character, rather than two operations executed in different places with some relation between them (see Ryle 1955, p.135ff).

Perhaps we could pursue the notion of using stigmergy in the form of a heed adverb a little further and ask: what is the special character, then, of heed adverbs such as attentively or our new found stigmertively? According to Ryle (1955), the question is baffling since the ways in which heed adverbs qualify the active verb is unlike the ways in which other adverbs qualify their verbs. A horse may be described as running quickly or slowly, smoothly or jerkily, straight or crooked, and simple observations or films enable us to decide in which manner the horse was running (Ryle 1955). But when a person is described as reading attentively, driving carefully or now designing stigmertively the special character of the actor's activity may well elude the observer and the camera. Ryle (1955, p.138) considers that perhaps knitted brows and a fixed gaze may count as evidence of paying heed, but concludes that these postures may be simulated or they can be purely habitual. In any case, in describing someone as reading attentively or designing stigmertively we do not mean that this is how he or she looks and sounds when engaged in it. Consequently, we should not have to withdraw a statement saying that someone had be reading attentively merely on being told that his or her expressions and movements looked bored or distracted (Ryle 1955). How then may we find out if some has been reading attentively or more to the point integrating distributed design task by virtue of designing stigmertively?

Ryle (1955) tells us that if we want to find out if someone has been reading attentively, we are generally content to decide the question by cross-questioning him or her not long afterwards. If he or she cannot say anything about the gist of the chapter, if he or she finds not fault with other passages that contradict the original chapter, or if he expresses surprise on being informed of something already stated in the text, we are satisfied that he did *not* read attentively. To read attentively entails being prepared afterwards to satisfy some such test (Ryle 1955, p.139). In a somewhat similar manner we could suggest that if we are to find out whether or not someone has been e.g. designing stigmertively, we may generally be content to determine this by interviewing the designer not long afterwards. If he cannot say anything about the manner in which the design of others enable and constrain he own design task, if he finds no connections to the work of others, or if he expresses surprise on being informed of the state of the common field of work, we are satisfied that he did *not* design stigmertively (i.e. he did not design acting on the evidence of work previously accomplished by others).

To design stigmertively entails being able to satisfy some such test we may argue. In a similar way, certain kinds of accidents and near-accidents would satisfy us that the driver had not been driving carefully. To drive carefully entails being prepared for certain sorts of emergencies (Ryle 1955, p.139). Perhaps to design stigmertively entails being able to integrate or at least nearly-integrate one's own task with physical manifestations of the work of others. This could be the final test of whether someone is designing stigmertively or not.

Stigmergy, then, can be described as a heed concept and may be used in the form of a heed adverb. The point is not least that stigmergy or acting stigmertively cannot take place prior to the performance of a task or afterwards for that matter. It is part of the task, or more precisely, it is a characteristic way of performing the task. In this manner stigmergy shares the quality of other heed concepts.

However, there are a few features that set stigmergy apart from other more general heed concepts. For example, performing a task stigmertively is always part of cooperative work in the sense that stigmergy by definition is the integration of interdependent work task by virtue of individuals acting on the physical traces of work previously accomplished by others. In comparison, doing something *attentively* or doing it *carefully* is obviously not necessarily part of cooperative work and its integration. In this manner stigmergy is a specialised heed concept to be used only in the context of describing the coordination of cooperative work.

These considerations aside, the central question is this: does the concept of stigmergy add anything to our ability to account for the coordination of cooperative work? Perhaps this issue could be explored by explicitly comparing the concept of stigmergy to well-established concepts within CSCW, namely articulation work (e.g. Gerson and Star 1986; Schmidt 1994; Schmidt and Bannon 1992; Strauss 1985; Strauss 1988; Strauss et al. 1985) awareness (e.g. Heath and Luff 1992; Heath et al. 2002) and feedthrough (e.g. Dix 1996; Dix and Beale 1996). In addition we shall also discuss the notion of path dependency (e.g. Garud and Karnøe 2001) in relation to stigmergy.

Stigmergy compared to articulation work

In this section we shall compare the concept of stigmergy to the concept of articulation work in order to determine if they are interchangeable concepts or not.

Recall that according to Strauss (1985, p.8) articulation work is a kind of supra-type work in any division of labour, done by the various actors concerning the meshing and integration of the interdependent activities inherent to cooperative work . In a similar vein Schmidt describes articulation work as reflexive second order activities (Schmidt 2002, p.464). Perhaps it is safe to say, and this is meant to reiterate a point made above, that the distinction between the articulation work and the cooperative work articulated is an inherent feature of the concept of articulation work.

In comparison, using the concept of stigmergy does *not* entail making a distinction between the work and extra activities aimed solely at coordinating the work. That would be a contradiction in terms considering that stigmergy as we described it above is a heed concept. Recall that when we speak of someone performing a cooperative work task engaged in stigmergy we are not saying that he or she is doing two things at once. He or she could not stop the performance of the task and continue to be engaged in stigmergy. The usage of a heed concept such as stigmergy and especially a heed adverb such as stigmertively has the merits of suggesting that what is described is one activity with a special character, rather than two activities that are somehow interrelated in their execution (see Ryle 1955). In comparison, we may say that actors engaged in articulation work in relation to a set of cooperative work tasks, may stop performing the tasks and continue any articulation work in relation to their coordination. For example, two carpenters engaged in distributed cooperative work tasks on a rooftop may stop working on the roof and continue their conversation concerning how to coordinate their interdependent efforts - in fact this may often be the case. In this manner articulation work may be said to stand in a supra type relationship to the work tasks articulated, whereas stigmergy may not. That is, articulation work may be an activity separate from the performance of the cooperative work articulated, and in comparison stigmergy may not.

The point we are trying to make is that if stigmergy is a heed concept i.e. a characteristic way of performing a cooperative work task (to a coordinative effect) then it does *not* qualify to be described as an effort that may be said to stand in a supra-type relationship to the tasks performed. In this manner the concept of stigmergy is *not* interchangeable with the concept of articulation work.

Furthermore, we could suggest that stigmergy is *not* based on the use of specialised coordinative artifacts or coordination mechanisms. As mentioned above a coordination mechanism is a construct consisting of, one the one hand, a coordinative protocol (an integrated set of procedures and conventions stipulating the articulation of interdependent distributed activities) and on the other hand an artefact in which the protocol is objectified (Schmidt and Simone 1996, p.166). In contrast to articulation work, stigmergy does not rely on the use of coordination mechanisms – claiming so would be a contradiction in terms in the sense that there is no place for a discrete coordinative protocol when coordination is achieved by acting directly on the evidence of work previously accomplished. We could suggest that the use of a coordination mechanism is evidence of a supra-type effort to coordinate cooperative work, an effort unlike stigmergy.

Perhaps, then, we could rest the distinction between the concepts of articulation work and stigmergy on a distinction between coordination done through supra-type activities or second order activities (articulation work) and integration achieved by virtue of individuals acting on the material evidence of work previously accomplished by others (stigmergy). This seems to be a tenable position to take, since it makes it possible to distinguish with relative clarity between two forms of coordination of cooperative work. It speaks in favour of the distinction between articulation work and stigmergy that, without it, we would be compelled to place two different modes of coordination in the same category (as far as I can see). Seemingly, this could be avoided by upholding the distinction between articulation work and stigmergy.

In sum, we have argued that the concept of stigmergy is *not* interchangeable with the concept of articulation work (although it may complement it).

Stigmergy compared to awareness

In this section we will compare the concept of stigmergy to the concept of awareness in order to determine if they are interchangeable concepts or not.

The idea of awareness, at least in CSCW, originally emerged in a number of work place studies by not least Heath and Luff (1992; 1996) of Line Control Rooms on the London Underground as well as the studies of air traffic control work by the Lancaster group (Harper and Hughes 1993; Harper et al. 1989a; Harper et al. 1989b). In these studies it was noted how collaborative activity in complex organizational environments rests on the individuals' abilities to create awareness through bodily conduct whilst engaged in their respective activities. That is, it was described how actors produce awareness by rendering a feature of their conduct or a feature in the environment *selectively* available to others. We shall elaborate.

According to Heath and associates (Heath et al. 2002, p.318), the ways in which actors produce awareness is inextricably embedded in the activities in which they are engaged, and the ways in which those activities unfold. Simply put, what individuals are aware of depends upon the activities they and others are engaged in. Awareness, then, is a practical accomplishment that arises in and through action and activity. This feature of awareness is shared by stigmergy in the sense that both awareness and stigmergy are inextricably part of performing the work. However, there are also important differences between awareness and stigmergy, as we shall see.

In the course of their work performance actors may find that the activity in which they are engaged becomes potentially relevant for others within the domain and yet their colleagues are seemingly involved in something else. In such circumstances, an actor may modulate an activity (e.g. speak louder, stare in an obvious manner, or overtly move an object about), to enable others to gain awareness of some matter at hand, without demanding that anybody should respond. Heath and Luff (1992) gives a fine example of this as they describe how the operators in a control room coordinate train traffic and movement of passengers on a particular line. The control room can house several staff, including the Line Controller who coordinates the day-to-day running of the railway and the Divisional Information Assistant (DIA) who, amongst other things, provides information to passengers and to Station Managers (Heath and Luff 1992). In this setting awareness is produced through very delicate bodily practices:

> "On occasions, it may be necessary for the Controller to draw the DIA's attention to particular events or activities, even as they emerge within the management of a certain task or problem. For example, as he is speaking to an operator or signalman, the Controller may laugh or produce an exclamation and thereby encourage the DIA to monitor the call more carefully. Or, as he turns to his timetable or glances at the fixed line diagram, the Controller will swear, feign momentary illness or even sing a couple of bars of a song to draw the DIA's attention to an emergent problem within the operation of the service. The various objects used by the Controller and DIA to gain a more explicit orientation from the other(s) towards a particular event or activity, are carefully designed to encourage a particular form of co-participation from a colleague, but rarely demand the other's attention. They allow the individual to continue with an activity in which they might be engaged, whilst simultaneously inviting them to carefully monitor a concurrent event." (Heath and Luff 1992, p.81).

In this manner actors in the underground control room create awareness of their activities through modulation of their activities with bodily conduct directed at co-located colleagues in an unobtrusive way. That is, as Heath and associates (Heath et al 2002, p.321) express it 'actors may render activities selectively available' to their colleagues. How does this feature of awareness compare to stigmergy? We could suggest that stigmergy does not involve individuals rendering activities *deliberately* or *selectively* available to others through bodily conduct (e.g. modulations in voice, gesture, pose, stance, gaze, glance, etc.). Stigmergy does not rely on this sort of selective rendering of activities in the sense that stigmergy merely refers to actors in cooperative work acting on the physical evidence of work previously accomplished by others to a coordinative effect.

Furthermore, unlike much production of awareness through bodily conduct, stigmergy does not rely on co-location, as we shall see now. Within CSCW, awareness is commonly associated with a particular type of workplace. In part, this association derives from the fieldwork settings of the studies that contributed to the recognition and understanding of the phenomenon in the first place. These settings have certain characteristics that make awareness pertinent and have been described by Suchman (1997) as 'centres of coordination'. These include such settings as subway control rooms, air traffic control rooms, newsrooms, trading rooms, and the like. According to Heath and associates (Heath et al. 2002, p.320), one of the important characteristics of such work places is that personnel is co-located in the 'same' physical domain (through continually interact with others outside that domain). As indicated, co-location enables not least the production of awareness through bodily conduct such as modulations in voice, gesture, pose, stance, gaze and glance whereby actors render a feature in their actions or in the environment selectively available to others (Heath et al. 2002). How does the notion of co-location relate to stigmergy? We could suggest that in contrast to awareness, co-location is irrelevant for stigmergy in the sense that for an individual acting of the physical evidence of work previously accomplished by others the co-presence of these 'others' is irrelevant or unnecessary. That is, in respect to the notion of co-location awareness and stigmergy seem to differ.

Compared to awareness, then, stigmergy does not involve rendering activities selectively available to co-located colleagues through bodily conduct or otherwise. That is, co-location is irrelevant in stigmergy just as there is no place or need in stigmergy for bodily gestures. Furthermore, stigmergy is in no way confined to specific domains such as centres of coordination in the sense that stigmergy may transgress several settings - think of how stigmergy with CAD models transgress several physical settings (i.e. architectural office, static engineers office, building services office, etc.).

We could suggest that the difference between stigmergy and awareness is (partly) the difference between heeding the material evidence of work previously accomplished by others (stigmergy) and rendering activities selectively available to co-located others through bodily conduct that these others in turn may take heed of (awareness). Note that one of the differences is related to the object that is paid heed to. Acting stigmertively involves paying heed to the physical traces of work previously accomplished by others, whereas producing awareness involves bodily conduct that co-present others may take heed of subsequently. That is, in stigmergy it is the state of the material field of work that is heeded, and in awareness the heeded object is mainly bodily conduct.

In sum, we have argued that the concept of stigmergy is *not* interchangeable with the concept of awareness (although it may complement it).

Stigmergy compared to feedthrough

Leaving the distinctions between the concepts of articulation work, awareness and stigmergy for now, another concern appears. Perhaps other, more established concepts within CSCW and related research fields are already doing what stigmergy does. Are *stigmergy* and *feedthrough*, for example, interchangeable concepts? In addition to contrasting stigmergy with articulation work and awareness, perhaps it could also be helpful to contrast the concept of stigmergy with Dix's concept of feedthrough (Dix 1997; Dix and Beale. 1996). We shall do so in this section.

According to Dix in some cases cooperative work is coordinated through the artifact rather than by direct face-to-face interaction or by other forms of verbal interaction. Dix states that:

> 'In a cooperative setting not only is it important to see one's own updates, but also to see the effects of other people's actions. This is feedthrough. The presence of feedthrough effectively creates an additional channel of communication through the artefacts themselves' (Dix 1997, p.38).

According to Dix, this form of coordination is often more important than direct verbal communication. It is effective, partly because it is tied so closely to the work itself, and partly because it is implicit, unconsciously noted and acted upon. So far Dix is describing a coordinative practice akin to stigmergy. Consider, however, Ramduny & Dix (Ramduny-Ellis and Dix 2002) in a discussion of awareness of user activity in a collaborative environment:

> 'Delivering feedthrough at the wrong pace can be problematic. If it is too slow, users may have to act without up to-date knowledge of one another's actions. If it is too fast, users may be distracted by irrelevant changes. Some feedthrough is very goal-directed - information directly used by users in their tasks' (Ramduny-Ellis and Dix 2002, p.122).

The notion that feedthrough can be delivered at the ‘wrong pace’ seems to indicate that in some instances the ‘information’ that feed through the artifacts is distinct from the efforts that are being coordinated. How else could it be delivered at the ‘wrong pace’? It seems that, at least in some instances, the concept of feedthrough is concerned with ‘meta-information’ used to coordinate collaborative work.

Furthermore, the concept of feedthrough seems to rely on the notion that ‘people's actions’ feed through the artifacts from actor A to actor B in the form of ‘information’. Dix and Beale:

> ‘The sharing of information comes because of feedthrough, when people are aware of and respond to the effects of one another's actions. In the sales situation the information from the factory floor must be timely, that is feedthrough of the factory staff's actions to the sales force.’ (Dix and Beale. 1996, p.6).

Perhaps a closer look at the concept of information is warranted. The scientific formulation of the concept of ‘information’ can be traced back to the ‘mathematical theory of communication’ developed shortly after WWII by Claude E. Shannon for the purpose of measuring the transportation capacities of communication networks (Shannon 1948, p.379). Of course, the word ‘information’ was in common usage for many years before its scientific conceptualisation. It was recorded in print in 1390 to mean ‘communication’ or ‘knowledge’ or ‘news’ of some fact or occurrence (Oxford English Dictionary). However, as a part of his mathematical theory of communication, Shannon coined a definition of information that transformed it into a physical parameter capable of quantification. He accomplished this by separating information and meaning. He applied ‘meaning’ to the semantic part of a message and used ‘information’ to refer to the quantity of different possible messages that could be carried along a channel of communication at any one time depending on the length of the message and on the number of choices of symbols for transmission at each point in time (Aspray 1986). For his purpose, this was quite appropriate, because semantic aspects of communication are irrelevant to the engineering problem (Shannon 1948). Shannon had coined a quantitative concept to be used for measuring and emphasized that ‘information’ should not be confused with ‘meaning’ (Shannon and Weaver 1949, p.8).

In relation to the concept of feedthrough, does the term ‘information’ refer to a quantitative measure, to meaning or both? Perhaps the very idea that information or some other fixed correlation between ideas and symbols migrate through the artifact is untenable. Recall our discussion of *telementation* in chapter four. Is the concept of feedthrough associated with the notion of telementation? Perhaps, to the extent that it suggests that information is fed from actor A to actor B through the conduit of artifacts. Harris (1981) holds that it is not tenable to maintain that meaning can take a fixed form (of for example information) and migrate from head to head via artifacts or other means. That is to say, there is no stable entity of for example information that may be propelled back and forth between actors like a tennis ball in a game of tennis. Consequently, in practice there is no semiological tennis ball that may be feed through form actor A to actor B. It seems that we have no other recourse but to suggest that the concept of feedthrough is associated with the notion of telementation. In addition, we could suggest that there is a kinship of sorts between Harris' (1981) notion of *telementation* and what Reddy (1979) has dubbed *the conduit metaphor*. Perhaps the concept of feedthrough is a form of the conduit metaphor.

According to Reddy, the English language alone hosts more than a hundred expressions based on what he calls 'the conduit metaphor' (Reddy 1979). Reddy calls it 'the conduit metaphor', because it implies that thoughts are transferred from actor A to actor B through some conduit or other. Reddy argues that it is almost impossible for an English speaker to discuss communication without committing to some form or other of that metaphor. Is the concept of feedthrough a commitment to a form of conduit metaphor? Perhaps, to the extent that it suggests that information is fed from actor A to actor B through the conduit of artifacts (e.g. Dix and Beale. 1996, p.6; Ramduny-Ellis and Dix 2002, p.122). If we accept this, the analytical use of the concept of feedthrough is, in some instances, a commitment to a form of the conduit metaphor as well as the notion of telementation.

In contrast to the concept of feedthrough, the concept of stigmergy, as we are attempting to cast it, does not rely on the notion of information, does not commit to the idea of telementation and is not a form of the conduit metaphor (as far as I can see). That is, actors engaged in practices of stigmergy may have as a basis for their actions something quite different from e.g. telementation, namely, acquired dispositions to perceive, comprehend and act that could be interpreted as oriented towards one task or another and performed most often in the natural attitude of the actor (as mentioned above). In sum, the concept of stigmergy and the concept of feedthrough are not interchangeable concepts.

Stigmergy compared to path dependency

The concept of path dependency has been used to underline the phenomenon that prior events may condition or influence unfolding or future ones (Garud and Karnøe 2001, p.4). In comparison, we say that actors engage in practices of stigmergy when acting on previously accomplished tasks to a coordinative effect. Even at this initial stage we may glimpse a kinship of sorts between the notion of path dependency and the concept of stigmergy. What does this kinship consist of? What relationship may we create between the concept of path dependency and the concept of stigmergy? We shall address this question in this section. However, first we will take a closer look at the notion of path dependency on its own terms in order to get a better feel for the concept.

The concept of path dependency, originating in David (1985), broadly speaking alludes to a sequence of events where prior events have significant implications for unfolding and future events (Garud and Karnøe 2001, p.4).

However, with a reference to Marx one could ask: When is this *not* the case? Marx holds that:

> "Men make their own history, but they do not make it just as they please; they do not make it under circumstances chosen by themselves, but under circumstances directly encountered, given and transmitted from the past." (Marx 1852).[26]

In this manner Marx assert that we are always already under the influence of the circumstances of history. This may be perfectly accurate, indeed we may adopt this view of Man's relationship to history, however, we could also suggest that solely being embedded in history at large does not make the performance of a task 'path dependant' in the sense that we wish to understand and apply the concept of 'path dependency' here. This would amount to stretching the notion of path dependency too far in the sense that all action would fall under the category of path dependency, and this could render the concept analytically useless.[27] This raised the issue of how we may distinguish between the influences of history in general on the one hand and on the other hand path dependency.

Perhaps we could suggest placing the notion of *interdependence* at the core of the conception of path dependency: the performance of a task within a certain taskscape (e.g. building design) may be described as path dependant when the performance of the individual tasks is enabled and constrained by the performance of prior tasks to an extent where the

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[26] Karl Marx in a letter to Joseph Wedemeyer, March 5, 1852.

[27] That is, the notion of 'path dependency' for analytical use relies partly on its antonym 'path independency' for meaning.

tasks are required to be integrated or coordinated in order to be performed. What does this (revised) notion of path dependency do for our understanding of the building process? We could suggest that many tasks in the building process are path dependant in this sense. Take for example the design process. The design process could be described as a path dependent phenomenon in the sense that many design tasks are coupled or dependant on prior task performances. Recall, that the field of work for the cooperative work ensemble in the design phase consists of a series of representations of the building; each representation in the series is created at different stages (e.g. conceptual design, tendering, working plans) where the individual representation is coupled to the representations that may have preceded it and to those that may follow. That is, the intermediate architectural models made in the tendering stage may be seen as an elaboration of the sketches made in the initial conceptual design phase. The final models for the working plans are an elaboration of the models previously made for tendering. In this manner one representation may be created as an elaboration or extension of those that preceded it. This entails that the individual actor involved in the design process may often find herself elaborating on a representation created previously by someone else and in this manner the actors are involved in a path dependant process where the nature of previously created representation have significant implications for the creation of new ones.

What we are arguing for, then, is that ‘path dependency’ in the building process is associated, or put forcefully, a consequence of the interdependencies among the tasks. This qualification of path dependency is conceived of in order to make a distinction between on the one hand the influences of history in general and on the other hand path dependency as a consequence of coupled tasks.

Furthermore, and a bit off subject, we may note that according to Schmidt & Bannon (1992) coupled or interdependent tasks are the fabric of cooperative work. Work is understood as cooperative when the involved actors are mutually interdependent in their work and therefore are required to cooperate (and coordinate) in order to get the work done (Schmidt & Bannon 1992). What we see here is that the notion of interdependency is crucial to the notion of cooperative work as well as the notion of path dependency, at least in the form that we have given path dependency here.

Moreover, perhaps we are now in a position to address the question that we started with: What relationship may we create between the concept of path dependency and the concept of stigmergy? What are the relation and the difference between these concepts? We could suggest that path dependency alludes to the general phenomenon of a sequence of coupled tasks where the performance of prior tasks has significant implications for unfolding and future tasks. In comparison, stigmergy is a more specialised concept that points to a specific manner in which path dependent tasks may be integrated. That is, stigmergy is the integration of path dependant tasks achieved by virtue of actors acting on the evidence of work previously accomplished by others. Or put in another idiom, stigmergy is the enactment or achievement of path dependency in the sense that acting stigmertively in for example design is part of what establishes the 'path' that we may observe between for example the various stages of design in a building project. In this manner stigmergy is a concept that differs from path dependency although it may be associated with this notion.

In addition, we may note that path dependant tasks need not necessarily be coordinated through stigmergy. For example, path dependant tasks may also be coordinated through articulation work. In this manner path dependency may be associated with articulation work as well as stigmergy.

In sum, the concept of stigmergy and the concept of path dependency are not interchangeable concepts.

Gothic cathedrals and steel rolling mills

It seems that we have been unable to point to concepts that are interchangeable to stigmergy. That is, the concepts of articulation work, awareness, feedthrough and path dependency all differ from our notion of stigmergy. However, we may be able to point to (empirical) descriptions of practice that may, in our perspective, be described as stigmergy. We will now turn to investigate this matter. In this section we shall investigate how on the one hand James (1981, 1985) and on the other hand Popitz and associates (1957) have described practices that may, in our perspective, be described as stigmergy.

Our first case is a historical study concerned with the creation of the cathedral of Chartres, a study conducted by James (James 1981, 1985). We will suggest that over forty distinct building campaigns leading to the construction of one of the most renowned pieces of Gothic architecture was integrated through what we describe as stigmergy.

After a disastrous fire Notre Dame de Chartres was rebuild between the year 1194 and the year 1230. According to James (James 1981, 1985), the appearance of the cathedral today cannot be explained as the result of a coherent master plan or even the presence of a master designer (what we today would call an architect). Altogether it took between 25 and 30 years for nine different master masons to build the cathedral in 30 distinct campaigns. Masons built Chartres; there was no overall designer or architect, just a succession of builders (James 1981, 1985; Turnbull 1993). That is, large mobile teams of masons build the cathedral. Such teams were highly mobile (out of necessity) and moved around the countryside from job to job working for as long as a particular building campaign lasted. That is, when the funds for a particular building campaign ran out they would leave the site in a body, the crews still intact under their master, to find another project, in a sense they were like the circuses of today which roam the country settling for their allotted time and then, complete with their tents and tools, departing for other places' (James 1981, p.9). Until funds and a new master mason and crew were found the building site of the cathedral of Chartres was inactive for months even years at a time. This entails that the cathedral seems to have been build in distinct campaigns by discrete crews of actors.

James describes that one of the most important social rules governing the relationship between successive crews and their distinct building campaigns seems to have been that when a the master of a crew took over and started a new campaign, he did not move or alter what had already been built: 'He might change the shape of the next stone, but what had already been put down was sacrosanct (…) the stones of Chartres show that, once placed, they were not touched again' (James 1985, p.125). Furthermore, James (James 1985, p.146) states that 'for most of the time the master's freedom was heavily constrained by what had already been built, so his major training lay in learning how to adapt himself to circumstances.' In this manner James seems to indicate that the master masons were committed to the state of the cathedral in-the-making as they found it at any given point in the process, and from this basis they had to elaborate on the building.

The absence of a master planner or plan coupled with the distributed nature of the work organization and the discontinuous building process begs an explanation as to how the interdependencies between campaigns were managed or coordinated. James describes the building of Chartres as 'the *ad hoc* accumulation of the work of many men' (James 1985, p.122), and in a way it seems to underscore the absence of formal architectural design and planning as we know it today. Perhaps we could suggest that, in our perspective, it sounds as if the distributed building campaigns were integrated partly through practices of stigmergy. If we accept this suggestion, it seems that over forty distinct building campaigns leading to the construction of one of the most renowned pieces of Gothic architecture[28] was integrated partly through what we describe as stigmergy.

Of course the activities of a particular building campaign was coordinated though articulation work as well. According to Turnbull (1993) actors resorted to the use of string for measuring, templates for the prolific production of stone, and talk for coordination. In addition to stigmergy, then, other modes of coordination have played a part here as well.

We now turn to our second example of distributed cooperative work activities that, in our perspective, can be described as integrated through stigmergy. The case study was conducted by Popitz and associates (Popitz et al. 1957) and is concerned with cooperative work in the German steel industry where manually controlled steel rolling mills shaped hot steel ingots into strips of varying forms and dimensions. We will suggest that the distributed task involved in operating the steel rolling mills were mainly integrated through practices of stigmergy.

Popitz and associates (Popitz et al. 1957) describe how the cooperative work ensemble running the mill is – for all practical purposes – unable to coordinate their individual activities by talking to each other. The noise level of the mill prevents them from talking and some of them cannot even see each other. It is not uncommon that operators do not talk to each other during the operation of the rolling mill for the length of an eight hour day.[29] Furthermore, Popitz and associates (Popitz et al. 1957) informs us that operators are so intensely occupied with controlling the rolling mill, a process with a strict temporal order, that they do not have time to talk and cannot be attentive to for example the hand gestures of each other. Each operator is on his own in doing his work, albeit in a manner where activity at any time fits closely into and continues the steel transformation process in the mill where every variation in the work of another actor that is of importance to the process must be immediately adhered to often by performing a variation in his own work. The steel rolling mill crew nevertheless manages to act in a concerted way without verbal communication and without gestures. They are able to integrate their distributed cooperative effort by appreciating the state of their common material field of work, by paying attention to the vibrations of the mill and the glowing strip of metal rolling through (Popitz et al. 1957,

[28] We could note that today the cathedral is considered one of the most beautiful examples of gothic architecture (Turnbull 1993).

[29] Not considering socialising in the for example the lunch room or outside work.

p.187). In this manner the distributed activities associated with operating the rolling mill are integrated by acting directly on the state of the material field of work.

Furthermore, in discussing this case, Schmidt (1994, p.23) puts forward the apt proposition that cooperative work may be ‘solely mediated by changes to the common field of work’. Schmidt holds that cooperative work involves interaction through the changing state of the field of work - what one actor is doing is of importance to another actor and perhaps in turn another actor as changes propagate through the common material field of work (Schmidt 1994, p.23).

Perhaps we could suggest that, in our perspective, it sounds as if the distributed tasks involved in operating the steel rolling mills were integrated through practices of stigmergy. We could also remark that the concept of stigmergy seems to be akin to the notion that cooperative work may be ‘solely mediated by changes to the common field of work’ as argued by Schmidt (1994b).

In sum, the case of Chartres (James 1981, 1985) as well as the case of the steel rolling mill (Popitz et al. 1957), suggest that others describe phenomenon that in our perspective may be described as practices of stigmergy. Consequently, the concept of stigmergy amounts to a notion, a shorthand, or more precisely, a conceptualization of the phenomenon or insight that cooperative work can be integrated by acting on the state of the common material field of work. As such the concept of stigmergy does not point to a ‘newly discovered’ empirical phenomenon. Rather, the preoccupation with the concept of stigmergy in this dissertation amounts to an attempt to conceptualize the phenomenon and in turn explore how this concept (i.e. stigmergy) relates and compares to other established concepts within CSCW such as articulation work, awareness, and feedthrough.

The logic of stigmergy

At this point we could ask: Why do the various actors in cooperative work such as building design engage in practices of stigmergy and in the process relate to or continue the work performed by other actors – what is the logic of this, why not begin from scratch?

Recall how the design of the working plans was carried out as direct elaborations of the previously created tendering plans, and how the tendering plans stem from the representations created in the conceptual design phase. One (obvious) answer is that from the point of view of the individual actor involved in design, it is more practical to continue the work on representations made by other actors, because it mostly requires less effort than the alternative, beginning from scratch.

However, we could argue that there is more to it than that. These practices also have an integrating effect as described above. Perhaps beginning from scratch is not a real option, because it risks breaking the continuity of the design process. That is, if the previous work was not taken into account, it would probably be entirely impossible to create the working plans, for example: the complexities of creating the highly detailed working plans would be overwhelming without less complex representations to build on. We could suggest that the gradual increase in the complexity of the representations makes the design process more manageable in the sense that it reduces the overall complexity of representing the building by allocating the process to a series of interrelated steps or stages.

In addition, in relation to design the affordances of a particular type of artifact mostly seem to meet the demands of a particular position in the taskscape. For example, the open and imaginative nature of sketches meets the demands internal to the task of making up the conceptual design of the building. To architects, their sketchy and informal representations capture the mixture of symbolic richness and abstraction, which allows them to express qualities of space, light, atmosphere, and materials (Schmidt and Wagner 2004, p.12). The sketches are highly theatrical; they use the language of ‘artistic impurity, hybridity, and heterogeneity’ for communicating certain ideas and qualities of an object. As mentioned, one feature of these informal representational artifacts is their openness to extensions, modifications, and novel interpretations (Schmidt and Wagner 2004).

Compared to sketches, the more accurate and generally less ambiguous CAD models are better suited to the task of creating the tendering material or the working plans. According to Harris (Harris 1995), architectural plans of a technical nature often rely on having the space divided in a predetermined way so as to make the significance of a graphical form depend partly on the absolute position it occupies within that space (Harris 1995, p.123). Architectural plans of scale such as CAD architectural plans are based on this principle. That is what makes it possible to calculate, for example, the exact size of a room measured in square feet or the distance from pavement to roof. CAD plans made for construction purposes are mapped to a coordination system referred to as ‘module lines’. Moving a particular graphical element, for example the representation of a wall, in relation to these module lines will have an alternating effect - for example changing the size of a room. Perhaps we could suggest that the same commitment to scale and precision is not found in what is described above as informal imaginative and open sketches.

Following this discussion of the affordances of various types of representational artifacts we could suggest that different affordances are required of representations at different positions in the taskscape. For example, the requirements of conceptual design prompt the employment of sketchpads on the part of the architects creating the design concept; analogue to this, the requirements of the tendering project or the working plans induce the actors to rely on CAD applications rather than sketches, for example. The sketches and CAD models, described above, are not interchangeable at a given position in the taskscape due to their vastly different affordances. This may be part of the reason why certain types of representation are employed at certain positions in the taskscape and part of the reason why actors are compelled to permutate the representational artifacts through practices of stigmergy involving the characteristic inheritance of content from one type of artifact to another and the derived coordinative effects.

As progress is made, then, from one position in the taskscape to another, representational artifacts are created, elaborated and merged through practices of stigmergy. These practices are partly prompted by the discrepancies between the affordances required of representations at different positions in the taskscape, and partly in order to reduce the complexity of the design process by allocating the process to a series of interrelated stages. This could be dubbed the 'logic of stigmergy' in relation to architectural design.

Stigmergy, awareness and articulation work

For the sake of clarity, perhaps it would be prudent to pause at this juncture and briefly take stock. We shall do so not least in regard to the relationship between stigmergy, awareness and articulation work.

Above, the notion that cooperative work may be coordinated by virtue of individuals acting on the material evidence of work previously accomplished by others was conceptualised as stigmergy. We traced the origins of the concept of stigmergy to the field of entomology. In relation to this we noted that a stimuli-response model of action was associated with the use of the concept of stigmergy in this research field.

In relation to transposing the concept of stigmergy to the field of CSCW, i.e. to the analysis of the coordination of cooperative work, we found a need to supplant this stimuli-response model of action. We argued that stigmergy in a human context may be conceived of as practice based on acquired skills and techniques that may be described as embodied in the habitus of the individual actors, rather than in terms of stimuli-response.

Subsequently, we suggested that stigmergy could be described as a heed concept and that it may be used as a heed adverb. The notion that stigmergy is a heed concept has the merit of suggesting that stigmergy is a characteristic manner in which cooperative work may be performed, rather than a separate activity. Following this, we asked if the concept of stigmergy would add anything to our ability to account for the coordination of cooperative work? In order to address this question we compared the concept of stigmergy to not least the concepts of articulation work and awareness. We found that none of these concept where interchangeable to the concept of stigmergy, although it was suggested in passing that they may complement it.

We indicated that articulation work, stigmergy and awareness may act in concert as distinct yet interconnected modes of coordination in cooperative work. The constitution and articulation of the taskscapes in advance of their performance may be handled through articulation work with coordinative artifacts. Recall for example how actors such as planners partly constitute the taskscapes of the building process through articulation work with for example Gantt charts or by colour coding architectural plans. When the distributed tasks in turn are to be actually performed and integrated on a concrete level, stigmergy may complement articulation work. Recall for example how cooperative work tasks in the building process are integrated stigmertively i.e. on the level of the concrete material performance of the tasks by virtue of actors acting on the material evidence of work previously accomplished by others. On par with stigmergy, awareness practices may also play their part in regard to the integration of cooperative work tasks in the concrete i.e. as they are performed. Recall the awareness practices described by Heath and Luff (1992) and Heath and associates (2002) in relation to centres of coordination such as control rooms where coordination is partly achieved by virtue of actors rendering activities selectively available to co-located others through bodily conduct that these others in turn may take heed of. Finally, articulation work may take on the character of an evaluation or ordering process after the tasks have been performed. For example, recall the meetings where the representations of the taskscapes on the Gantt charts are calibrated to reflect the progress of the tasks on the building site.

It seems that articulation work may be performed prior, in parallel to, and after the performance of the tasks articulated (articulation work may be described as a ‘supra-type’ or 'second order' activity precisely because it may be performed separately from the tasks - even in instances where articulation work is performed in parallel to the tasks, articulation work may as mentioned be considered a supra-type activity). Note also how stigmergy may *not* be performed prior, in parallel to, and after the performance of the tasks articulated in that stigmergy is a characteristic manner in which cooperative work may be performed to a coordinative effect, rather than a separate activity. As mentioned above, stigmergy (and possibly awareness) are heed concepts.

Perhaps the three concepts of articulation work, stigmergy and awareness could amount to a trinity in the CSCW toolbox for the description and analysis of the coordination of cooperative work. Of course more analytical and empirical work needs to be in order to establish this firmly, and an interesting question for further empirical research is how exactly does articulation work, stigmergy and awareness practices complement each other as distinct yet interconnected modes of coordination in cooperative work.

CHAPTER SIX: IMPLICATIONS FOR CSCW

In this, the last chapter of the thesis, we shall consider the implications of our study for the field of CSCW.

CSCW research has often aimed to marry work place studies with technology design and interventions into the operation of those settings. However, field studies and design activities are often reported to sit uncomfortably together. Despite many attempts to cross ‘the great divide’ (Bowker et al. 1997), combining the two apparently remains a challenge, as we shall discuss.

In the context of discussing a number of interdisciplinary research projects, Dourish (2001 p.155) holds that despite the premise that the fieldwork setting is an incomparably rich source of insights – often the only one that matters – it seems a rare occurrence for the design partners in collaborative research projects to actually visit the field. Most often technology designers, learn of the field through the reports of their fieldworker colleagues. In such cases, the success of the project often hinges on the fieldworkers’ ability to communicate and translate their understandings in terms of what is meaningful to the constructive activities of design. In many cases, though, even this level of communication is more than can be achieved, and instead communication takes place though journals and discussions at conferences. The different perspectives, concerns and training of the participants result in each partner feeling that the others fail to understand the complexity of his or her position. Researchers on both sides of the debate grumble about what commonly appear under the title of ‘Implications for Design’ at the close of CSCW papers reporting on ethnographic fieldwork. In a technology design perspective, these implications often seems obvious, insubstantial and or vague, and from a sociological perspective, they deny the richness of the settings to which they refer (Dourish 2001).

As well as a practical concern this is a research issue. Plowman and associates (1995) analysed an array of CSCW papers with a particular focus on the role of workplace studies in the design process. They argue that the design implications of such studies should be uncovered or arise through direct dialogue between researchers from different disciplines, rather than require for example social scientists to be able to engage in design (or computer scientists to engage in fieldwork). In addition, Hughes and associates (1995), drawing on their experience with a number of interdisciplinary research projects, present a framework for presenting ethnographic material or results to audiences that are unfamiliar with the approach and interested in understanding fieldwork for design, rather than as purely ethnography. The framework addresses the tension involved in 'translating' the analytical findings of social science into specific proposals for design. Furthermore, Bellotti (1988) notes two particular problems with using theoretical design models. First, the approaches were often laborious and time-consuming to apply, especially because they often operated on a micro level of analysis. Second, the models tended to be so 'theory laden' that, in practice, only their developers (who were very well versed in the theories that they were based on) could apply them effectively, putting them beyond the reach of many practicing designers.

Despite the apparent difficulties inherent in forging connections between analytical findings based on ethnographically informed accounts and design practice, there may be good reason for not giving up on making this connection. We could suggest that theory or conceptual frameworks may ground design practice by providing a framework within which design may be explored, compared, discussed, analysed and evaluated. That is, we may say that the connection between analytical findings based on ethnography and design practice is conceptual as well as direct or concrete. Perhaps we should expect work place studies to provide a vocabulary that may be applied to the discussion of design, rather than expect every CSCW book or article based on fieldwork to make concrete design recommendations. From this perceptive, conceptual frameworks may contribute to design in placing design in a context where it may be discussed in an overt and systematic manner.

Keep in mind that the alternative to an analytical conceptual framework based on ethnography is a common-sense conceptual framework, rather than no framework at all (Bourdieu et al 1991). That is, if conceptual frameworks based on ethnography are not positioned to provide a context and a vocabulary for the discussion of design, common-sense frameworks will step in and provide that context. Why is this problematic? This is unfortunate considering that 'common sense' conceptual frameworks may be said to be if not closed then at least less open to explicit and systematic critique that their ethnographically and analytically produced counterparts. That is, the schemes used in ethnographically produced explanations are (ideally) tested by being made completely explicit in for example articles and books where they are (ideally) scrutinised in a tradition of methodical and systematic critique. In contrast, the spontaneous sociology of everyday life is not open to the same measure of systematic critique. This is related not least to the lesser degree of explication in relation to many common-sense schemas of understanding (Bourdieu et al. 1991). Consequently, analytical findings based on ethnography may provide design practice with a *tested* and *critiqued* conceptual framework (one that spontaneous sociology cannot fully provide) within which design may be explored, compared, analysed and evaluated.

Furthermore, and this is meant to reiterate a point made above, data generated in 'naturally occurring situations' through e.g. ethnography may give us an insight into things that we could never imagine (Sacks 1992), and these insights may be a great resource in the design process.

None of these points deny that common sense can ever be useful in the design process. However, they do suggest that it is design based on common sense alone that should be justified, rather than design related to analytical findings based on ethnography. That is, the question is not why should we carry out design informed by analytical findings based on ethnography, but why should we not?

Furthermore, according to Bourdieu and associates (1991), social scientific theory is an apparatus of the mind, a technique of perception and reflection, which helps its processors see, discuss and ultimately act on phenomena. In this sprit, the conceptual explorations of the previous chapters are partly intended to ground the design process within a context that may make designers sensible to phenomena such as stigmergy and provide a vocabulary or conceptual apparatus for thinking about design opportunities and design features.

Perhaps it could be interesting to carry out this exercise ourselves, that is, we could use the notion of stigmergy to think about design opportunities and design features. This may be worthwhile considering that computer support for practices of stigmergy does *not* appear to be well explored within the field of CSCW.

Computer technologies for the support of practices of stigmergy

We will now turn to focus on computer support for practices of stigmergy. We will do this by setting out and exploring a set of principles. Given the variety of ways in which technologies can be configured to comprise concrete systems in regard to concrete settings (even within the confines of the building process) it would be beyond the scope of this dissertation to offer concrete systems design recommendations. Instead, we will attempt to discuss computer technology for the support of practices of stigmergy in more general terms. We shall start with a few general requirements for computer support of stigmergy.

First of all, stigmergy is based on direct engagement with the objects in the common field of work and as such any computational support of stigmergy must ideally allow for unmediated engagement with the objects in the common field of work. This entails, for example, that showing a *representation* of the common field of work does not qualify as support of stigmergy in the sense that a representation does not allow direct engagement with the field of work (it is merely a *representation* after all).

Of course this does not imply that computer representations of the state of the common field of work is not worth making, it only implies that coordination supported in this manner at the end of the day probably cannot be described as stigmergy. As a case in point, consider Sørensen and associates' project of 'linking virtual models with physical objects in construction using radio frequency identification (RFID[30]) technology' (Sørensen et al. 2008). The approach of Sørensen and associates is to graphically represent the state of construction work in an online application that tracks the status of physical construction components such as concrete elements for walls and decks through RFID technology. The idea is to make it possible for the actors in the construction process (e.g. architects, engineers, contractors, vendors and builders) to follow the progress of a project via an online representation of the building in-the-making. RFID tags are cast into the prefabricated concrete elements as they are produced at a plant allowing for the tracking of the elements as they leave the plant, arrive at the building site, and as they are finally installed into the building in-the-making. At each of these discrete steps the RFID tags are read with handheld devices and the status of the individual elements are passed on to an online viewer. For example, when the elements are installed into the building their new status is updated through the handheld tag readers and

[30] RFID is an acronym for Radio Frequency Identification and denotes any identification system in which electronic devices occur that use radio waves or pulsating magnetic fields to communicate with identification units fastened to objects. In the 1970's and 1980's RFID was first introduced in the industrial sector to keep track of railway wagons, dairy cattle and auto chassis in production lines. Since then it has spread to other areas such as identification of animals, clothing in laundries, billeting systems, admittance control etc. From the beginning of this century there has been an increasing focus on the employment of RFID. This is, among other things, because of recommendations from the U.S. Department of Defence and the U.S. Food and Drug Administration about using the technology. Furthermore, since 2005 the world's largest retail chain, the Wal-Mart Stores, Inc., has required its largest suppliers to use RFID on all their produce pallets and larger units. The most referenced components in RFID systems are tags, readers and middleware. Tags, also termed transponders, are identification units that are attached to the objects to be localised. The interrogator, the transceiver or the RFID reader, as they are often called, is that component which via the antenna is used for scanning the data contents of the tag. The middleware is the software component which ties the RFID reader together with the other software components in an IT system and, if necessary, also filters the data before it is relayed (Sørensen et al. 2008).

the results are passed on to the online viewer that represents installed elements in a model of the building with the colour green and uninstalled objects are shown in red (see figure 27). In this manner the state of the common field of work i.e. the building in-the-making is represented to the cooperative work ensemble via a model of the building showing the status of individual building elements through RFID technology - albeit at a rather coarse level of granularity where only large elements such as whole walls section or decks are represented as either installed or not.

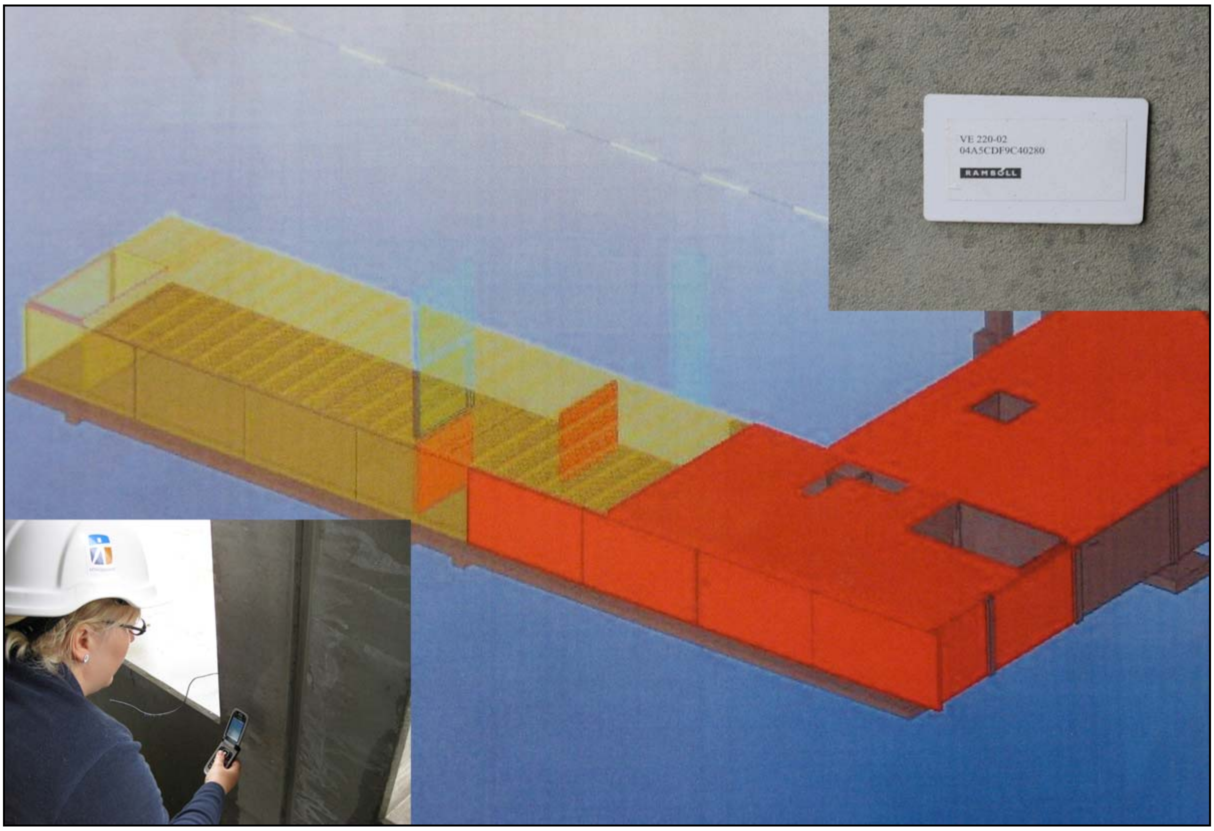

Figure 27: Representation of a building-in-the-making showing the progress of construction work updated through RFID technology. Top right insert shows a RFID tag and the bottom left insert shows an engineer using a handheld device to read a tag lodged inside a concrete element.

This approach to creating representations of the field of work e.g. through RFID tags logged in material building elements that must be read with handheld devises by the users can be said to entail articulation work in the sense that the actors need to engage in supra type activities (i.e. reading tags, navigating the model of the building, etc) in order to articulate their activities. Furthermore, the system does *not* afford the users with unmediated engagement with the field of work in the sense that the central feature of the system is a model of that is *showing* the field of work, rather than *being* the field of work. Considering this, the whole enterprise cannot be described as supporting stigmergy - although the approach may of course hold great merit anyhow.[31]

The approach of Sørensen and associates (2008) may perhaps be described as rather elaborate. Could a less elaborate solution *representing* the state of the common field of work be considered to support stigmergy? Imagine setting up a simple video system broadcasting the state common field of work (e.g. showing video of a building in-the-making) to each member of the cooperative work ensemble so that each individual could react to changes to the state of the field of work visible on a monitor – would that qualify as support of stigmergy? Again, we have to say 'no' considering that such a system does *not* allow for direct engagement with the field of work (i.e. the monitor is *showing* the field of work, rather than *being* the field of work). In the field of CSCW, such visibility is often addressed in terms of 'awareness' in collaborative systems.

As mentioned above, the role of awareness as an element in the coordination of work emerged first from field studies of cooperative work, most markedly in the studies of co-present work in settings such as control rooms (e.g. Heath and Luff 1992). The notion of awareness subsequently served as an analytical tool for laboratory studies of collaborative technologies (e.g. Dourish and Bellotti 1992) and inspired the design of technologies and systems explicitly aimed at providing awareness among the members of a group (e.g. Borning and Travers 1991; Gutwin and Greenberg 1998). These technologies provided group members with views or representations of each other and their work to help coordinate action. For example in collaborative systems such as Portholes (Dourish and Bly 1992) in which video images of offices and public spaces are provided to the members of distributed work groups in order to give them the opportunity to glance at other group members' immediate activities. Portholes, for example, are arranged as a series of adjacent video feeds (of a somewhat grainy quality), that gives an overview of the group members as they for example sit at their desks or walk the corridors of the office building. The somewhat grainy quality of the video feeds gives an impression of 'what is going on', while making it hard to make out details. In this manner the low-resolution of the video images gives an overview without invading what may be considered personal or private. In addition to Portholes, a number other systems have provided a direct view of others and their immediate activities,

[31] Furthermore, it is only fair to mention that Sørensen and associates (2008) never intended to support stigmergy. They do not refer to or use this concept in any way. The case is used here, as an example of what computer support of stigmergy cannot look like.

these system include e.g. Peepholes (Greenberg 1996), Postcards (Narine et al. 1997) and ArgoHalls (Gajewska et al. 1995). As indicated above, such technologies cannot be considered to support stigmergy, as described they rather support awareness through various representational technologies. At this juncture we may again ask ourselves what sort of computer technology could support stigmergy and how?

We could suggest that *shared feedback* may qualify as support of stigmergy. Shared feedback is an extension of the conventional feedback loop in any graphical interface. For example, as text is entered in a normal single-user word processor, the application will give the user feedback on the user's actions. The user sees the letter that he or she types displayed on the monitor, sees the cursor move along and sees the text move up or down as the scroll bar is used. Similarly, other sorts of applications such as web browsers, spreadsheets and CAD applications will reflect the user's actions. According to (Dourish 2001, p.176), there are at least two ways to think about this sort of feedback. One way is to think about it as part of the *interface*; it's a way that the system displays the application's responses to the user's actions. The second is to think about it in terms of the *artifact*; the user's actions transform the artifact (e.g. word document, CAD model, etc.) to which the application is giving the user access, and these transformations or state changes are visible to the user that can see them taking place. Thinking of feedback in terms of showing the transformation or changing state of the artifact may lead to the 'shared feedback' approach; in for example a multiuser application in which the artifact (e.g. word document, CAD model, etc.) is shared, all users will see the effects of each other's actions as a consequence of seeing the same artifact. What are the implications of this for the support of practices of stigmergy?

We could suggest that a shared feedback approach supports practices of stigmergy; the members of the cooperative work ensemble will see the effects of each other's actions, will see the evidence of work previously accomplished, as a consequence of seeing the same central artifact. That is, to the members of the cooperative work ensemble the (changing) state of the common field of work may become evident or visible through shared feedback showing the effects of the distributed ensembles actions, and this may in turn facilitate acting on the evidence of work previously accomplished to a coordinative effect (i.e. stigmergy). For example, to the members of a cooperative work ensemble engaged in building design, the state of the common field of work may become evident through shared feedback on the effects of action taken on central artifacts (e.g. CAD models) within the common field of work[32], and this may in turn support practices of stigmergy.

Shared feedback may be considered internal to the common field of work in the sense that, from the user's point of view, it appears as unmediated feedback on the effects of action taken on objects in the common field of work, and it allows for direct engagement with the objects in the common field of work. In this manner it is in accord with the requirements for computer support of stigmergy posted above.

Shared feedback may be worthwhile to consider in regard to supporting stigmergy, then, although the important question of how exactly to implement such feedback in for example CAD applications remains to be explored, such exploration may ideally involve designing prototypes of applications with the feature of shared feedback that can be hands on evolved, evaluated and tested in work practice using methods from for example the tradition of participatory design (see e.g. Bødker et al. 2004; Greenbaum and Kyng 1991). Alas, we are not in a position to engage in participatory design and experimental computer science at this juncture (mainly due to time- and other resource constrains), and in lieu of such prototype development we shall make a few remarks.

The shared feedback approach may have the potential to support practices of stigmergy; however, there are several issues to be considered. First, perhaps being able to see the effects of other people's actions all the time may be too distracting. Hence there is a need for careful consideration as to how and when shared feedback is called for. Perhaps the simplest solution is to make it up to the user to decide when he or she wishes to receive shared feedback; the application should probably allow the user to shift this sort of feedback 'on' and 'off'. Second, shared feedback imposes some technical challenges not least in regard to issues of what in software design is known as *concurrency control*. Concurrency control is the set of problems related to giving for example two users access to the same resource or artifact at the

[32] Keep in mind that to the extent representational artifacts such as CAD models constitute the field of work, they may be the locus of practices of stigmergy, and consequently the locus of what is supported through computer technology such as shared feedback. Recall that for the architects the representational artifacts (e.g. sketches, CAD models, etc.) may constitute the field of work. They serve as objectifications of the building-in-the-making and are, as such, the immediate object of their work, they are what is looked upon, inspected, gestured at, discussed, modified, annotated, etc. (Schmidt and Wagner 2004, p.366).

same time (i.e. concurrently) while controlling the consistency and integrity of the resource.[33] Concurrency control may become an issue considering that shared feedback may imply concurrent access to an artifact.[34] One approach to such issues, for example, could be to have independent action over *copies* of an artifact that the system will later integrate. However, by separating the artifacts that the actors work on, this approach may interfere with shared feedback in the sense that the feedback will be given in regard to multiple copies of an artifact instead of one instance of the same digital artifact such as a CAD model.

Furthermore, it is perhaps prudent to mention that the notion of shared feedback seems to bear at least a family resemblance to what in the CSCW litterateur (e.g. Greenberg et al. 1996; Stefik et al. 1987) is referred to as 'what-you-see-is-what-I-see' (WYSIWIS). Where the general idea is, as the name suggests, that the members of a collaborative group may all have visible access to a common entity such as a computer workspace. In its strictest interpretation WYSIWIS means that everyone should have the same view of the workspace and see what everyone else is doing e.g. where they are moving their cursor and so on (Stefik et al. 1987, p.147). However, we may note that it was found that WYSIWIS should be enforced in a relaxed manner in the sense that the implementation of WYSIWIS should take into account that cooperative work ensembles continually form and dissolve, that individuals may shift their focus of activity from cooperative work tasks to individual work tasks and back again (Stefik et al. 1987). We could suggest that these issues also seem relevant for the design of shared feedback in support of stigmergy. That is, such issues should probably be taken into account when designing computer technology in support of stigmergy. It is safe to say that there is certainly more work to be done here.

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[33] According to Celko (1999), there are three fundamental ways that two activities can interfere with one another: (1) Dirty read: Activity 1 (A1) reads an entity from the system of record and then updates the system of record but does not commit the change (for example, the change hasn't been finalized). Activity 2 (A2) reads the entity, unknowingly making a copy of the uncommitted version. A1 rolls back (aborts) the changes, restoring the entity to the original state that A1 found it in. A2 now has a version of the entity that was never committed and therefore is not considered to have actually existed. (2) Non-repeatable read: A1 reads an entity from the system of record, making a copy of it. A2 deletes the entity from the system of record. A1 now has a copy of an entity that does not officially exist. (3): Phantom read: A1 retrieves a collection of entities from the system of record, making copies of them, based on some sort of search criteria such as "all CAD files pertaining to the roof design". A2 then creates new entities, which would have met the search criteria (for example, inserts a new file representing parts of the roof construction into the database), saving them to the system of record. If A1 reapplies the search criteria it gets a different result set.

[34] We may say that it is hard to see the effects of other people's actions on an artifact if others do not have 'write and read' access to that artifact.

Furthermore, although useful in the discussion above, we could interject that the notion of *shared* feedback is somewhat dubious. That is, there are reasons why we should not take an undoubted faith in *shared* feedback too far: First of all, we have to consider the question of what, when and how an entity in the common field of work is *shared?* When a cooperative work ensemble engages in for example building design tasks they will probably most often be working on coupled entities in the common field of work, rather than on entities that are shared in the sense of being viewed and worked on at the exact same time. That is, the actors are probably most often dealing with, at least in building design, coupled rather than shared (i.e. concurrently viewed or worked on) entities of the common field of work. Consequently, we should perhaps talk of *coupled* feedback rather than *shared* feedback, considering that the former seems to be a broader term that does not entail the notion that objects in the field of work necessarily have to be viewed or worked on at the same time.

These consideration aside, there is something to be said in favour of shared or coupled feedback, not least that to the members of the cooperative work ensemble the (changing) state of entities in the common field of work may become evident or visible through coupled feedback conveying the effects of the distributed ensembles actions, and this may in turn facilitate stigmergy.

In closing we could raise the question of relevance in regard to the distinctions between stigmergy, articulation work and awareness. Are the distinctions important in relation to the design of computer support for cooperative work? Perhaps they are, we could argue. The notion of stigmergy seems to underline unobtrusive support of cooperative work including direct access to manipulate object in the common field of work. For example, well-implemented shared or coupled feedback may ideally be perfectly unobtrusive in the sense that it need not involve the user in any supra type activities directed solely at the coordination and it may give the users access to manipulate object in the common field of work. For instance computer support of articulation work may be quite the opposite. Elaborate computational coordinative measures such as the RFID augmented coordination of construction work discussed above seem to have a tendency to draw the user into spending considerable time and effort working with representations and performing supra type activities directed solely at the coordination. This need not be a bad thing - although it does make a difference.

In sum, stigmergy is internal to the common field of work in the sense that it is based on direct engagement with the objects in the common field of work and as such any computational support of stigmergy must allow for unmediated engagement with the objects in the common field of work. An example of a technology that may support stigmergy is shared feedback. That is, shared feedback in computer applications to the members of the cooperative work ensemble on the effects of individual action taken on entities in the common field of work could be described as in support of stigmergy.

The main propositions of the study

As the thesis draws to a close we will reflect on the study, and consider it in terms of its core arguments and main propositions. In preparation to this we will first familiarise ourselves with the distinction between empirical propositions and grammatical propositions. Secondly, we will attempt to condense the study into a series of respectively empirical and grammatical propositions.

According to Hacker (2008) there is a distinction to be made between empirical propositions and grammatical propositions. Hacker, drawing on Wittgenstein, writes:

> "For an empirical proposition to be true is for things to be as it says they are. But for a grammatical proposition to be true just is for the proposition to express a constitutive rule for the use of the constitutive terms. A false empirical proposition is intelligible – it describes a possible state of affairs that does not actually obtain. What we call a 'false' grammatical proposition (e.g. that pink is darker than red) does not describe a possibility that does not happen to obtain. It does not describe anything [...] so one might say that it is a particular form of nonsense." (Hacker 2008, p.21).

In this manner Hacker distinguishes between different roles and uses of propositions. Such differences of roles are connected with differences in grounds for assertion, understanding, misunderstanding and not understanding (Hacker 2008, p.18). Where empirical propositions may be assessed according to external (empirical) observations, grammatical propositions are assessed according to internal relations of grammar (Hacker 2008). Employing this distinction we will attempt to account for the main propositions brought forward the study.

A significant proposition brought forward in this study is the proposition that cooperative work tasks in the building process tasks are partly integrated through articulation work with coordinative artifacts and partly through stigmergy. This could be critiqued as an empirical proposition. That is, the question of whether this is in accord with what is or could be observed through fieldwork may be brought forward. Of course the argument upheld here is that the descriptions made above are in accord with fieldwork observations. However, should anyone wish to, such propositions may be contested as empirical propositions by claiming for example that building designers in fact do *not* coordinate and integrate their distributed tasks in ways that may persuasively be described as stigmergy. The manner in which some propositions open up to empirically laden critique makes them distinct from purely conceptual propositions, the latter type of propositions may as mentioned be critiqued with reference to internal relations of grammar, rather than external observations.

A significant grammatical proposition brought forward in the study is the proposition that that the concept of stigmergy is distinct for the concept of articulation work as well as the concept of awareness. We have argued that the concept of stigmergy is distinct from the concept of articulation work in the sense that, articulation work is a supra-type coordinative effort that for example may come before the cooperative work tasks performed, whereas stigmergy is internal to the work performed, it is an integrative effect that may be achieved by virtue of individuals acting on the evidence tasks previously accomplished by others - it is a heed concept. In addition, we have argued that the concept of stigmergy is distinct from the concept of awareness in the sense that awareness refers to actors making activities selectively available to co-located others through bodily conduct, whereas stigmergy refers to actors heeding the material evidence of work previously accomplished by others to a coordinate effect. This proposition or set of propositions may be critiqued as conceptual or grammatical propositions, that is, according to internal relations of grammar. For example, questions may be asked if the concepts and their relationship as proposed are free of inconsistencies and self-contradicting delimitations. Of course the argument upheld here is that the conceptual propositions make sense.

Furthermore, this is not the only manner in which to assess the concepts brought forward above. Certain concepts may be said to heighten particular analytical sensibilities. The concept of articulation work for example may be said to heighten awareness of how actors engaged in cooperative work practice perform specialised coordinative practices in order to integrate their respective tasks. What analytical sensibility may the concept of stigmergy afford? Perhaps the concept of stigmergy makes us sensible and aware of the integrating effect that acting on the physical evidence of tasks previously accomplished can have on cooperative work. Of course, the final assessment of any analytical concept, including stigmergy, is whether or not it serves well as an analytical tool.

In sum, the study can be condensed into a series of propositions that may be critiqued as empirical and conceptual propositions respectively. The distinction between the different roles and uses of propositions is connected to differences in grounds for understanding and evaluation that may come in handy as the arguments of this dissertation are critically assessed. On an optimistic note, we may say that if the propositions are generally assessed favourably, we may be said to have gained some insight into how cooperative work tasks are integrated in the building process as well as gained a concept that may complement the concepts of articulation work and awareness, namely that of stigmergy.

Summary

For the sake of clarity we will now summarise the thesis.

In chapter one, an attempt was made to provide an introduction to the building process. It was described as a complex cooperative endeavour, constituted by numerous distributed and interdependent tasks carried out by a diverse network of actors. The term taskscape was adopted in order to capture or describe this state of affairs, and subsequently the taskscape of design as well as the taskscape of construction were briefly accounted for.

In chapter two, the question of how design related to construction and vice versa was discussed. It was noted how design and construction are overlapping and highly interconnected endeavours. Design was found to be connected to construction in the sense that design is partly a matter of designing spaces that must be realised during construction, and it was discussed how this is partly a matter of anticipating natural necessity or causal powers. In the discussion of how construction relates to design the focus was on the role of architectural plans in construction work. Initially, architectural plans were discussed on par with other formal constructs, and the general insight that formal constructs influence work practice in a normative sense, rather than in a causal sense, was highlighted. Subsequently, the specific characteristic of using architectural plans for construction work was investigated relying not least on the notions of internal and external syntagmatics. The internal syntagmatics of architectural plans i.e. the disposition of graphical signs within the same graphic space was discussed in terms of proportionality and positioning. The external syntagmatics of architectural plans i.e. how the graphical space of a plan is brought into a relationship with the objects of construction work was discussed, and it was found that the techniques of projection and scale have a significant role to play.

In chapter three, it was explored how skills pertaining to the use of architectural plans may be acquired through apprenticeship. This was investigated tracking an apprentice and an accomplished actor as they work with and annotate architectural plans in the process of planning construction work. It was highlighted how the apprentice struggled with this craft and was mentored by the accomplished actor in the process. Subsequently, issues of practice and apprenticeships that sprung from the case description were discussed. It was not least discussed how the visual skills required of someone working with architectural plans may be conceived of as part of their habitus and something that must be acquired through for example apprenticeship. Following this discussion, the insight that working with representational artifacts in the building process requires a set of particular skills that must be acquired through training, education and apprenticeship was contrasted with the language myth and the notion of telementation i.e. the idea that in signs (e.g. on an architectural plan) actors somehow encapsulate their thoughts or ideas in an invariant manner that others in turn may simply 'extract'. The language myth and the associated idea of telementation presuppose the skills that go into working with representations and decontextualise the process - the myth was presented as a cautionary tale and rejected.

In chapter four, the focus was on coordinative practices inherent to the building process. Initially, these practices were discussed in terms of articulation work with coordinative artifacts. It was discussed how Gantt charts serve as representations of the taskscapes of the building process, and it was noted how they are reconfigured and policed in meetings. It was also discussed how a file repository and title blocks on the representations are employed in practices pertaining to the identification, validation and distribution of representational artifacts. At the end of the chapter we were presented with the phenomenon that actors partly coordinate their cooperative efforts by acting directly on the evidence of work previously accomplished by others, this was evident in design as well as in construction. It was indicated that this phenomenon cannot be described in terms of articulation work, and the question of how to conceptualise it was raised.

In chapter five, the notion that actors coordinate their cooperative efforts by acting directly on the evidence of work previously accomplished by others was conceptualised as stigmergy. We traced the origins of the concept of stigmergy to the field of entomology. In relation to this we noted that a stimuli-response model of action was associated with the use of the concept of stigmergy in this research field. In relation to transposing the concept of stigmergy to the field of CSCW, i.e. to the analysis of the coordination of cooperative work, we found a need to supplant this stimuli-response model of action. We argued that stigmergy in a human context may be conceived of as practice based on acquired skills and techniques that may be described as embodied in the habitus of the individual actors, rather than in terms of stimuli-response. Subsequently, we suggested that stigmergy could be described as a heed concept and that it may be used as a heed adverb. The notion that stigmergy is a heed concept has the merit of suggesting that stigmergy is a characteristic manner in which cooperative work may be performed, rather than a separate activity. Following this, we asked if the concept of stigmergy would add anything to our ability to account for the coordination of cooperative work. In order to address this question we compared the concept of stigmergy to the concepts of articulation work, awareness, feedthrough and path dependency. We found that none of these concepts were interchangeable with the concept of stigmergy. Articulation work may be an activity separate from the performance of the cooperative work articulated, in comparison we found that stigmergy may not. The concept of awareness pertains to actors rendering activities selectively available to others through mainly bodily conduct, and stigmergy does not. Feedthrough is a concept that seems to be associated with the notion of telementation, and stigmergy is not. Path dependency for its part alludes to the general idea that prior events may have significant implications for unfolding or future events, whereas stigmergy is a more specialised concept that points to a specific manner in which cooperative work task may be integrated. Following the comparison, it was suggested that the concepts of articulation work, awareness and stigmergy could complement each other in the description and analysis of the coordination of cooperative work.

In chapter six, the study's implications for the field of CSCW were explored. The initial discussion focused on computer support for practice of stigmergy. In terms of requirements it was found that, considering that stigmergy is based on direct engagement with objects in the field of work, any computational support for practices of stigmergy must allow for direct or unmediated engagement with the field of work. It was found that shared feedback, i.e. technology that allows a multiuser application to show the effects of all the users actions on shared artifacts (e.g. CAD models), may meet these requirements. That is, to the members of the cooperative work ensemble the (changing) state of the common field of work may become evident or visible through shared feedback showing the effects of the ensemble's actions on object in the field of work, and this may in turn facilitate individuals acting on the evidence of work previously accomplished by others. At the end of the chapter, the main propositions of the study were brought forward and described as either empirical or grammatical propositions. It was found that one significant proposition of the study is the proposition that cooperative work tasks in the building process are partly coordinated through articulation work and partly through stigmergy. This could be critiqued as an empirical proposition. That is, the question whether this is in accord with what is or could be observed through fieldwork may be raised. Another significant proposition brought forward in the study is the proposition that stigmergy is a concept distinct from the concepts of not least articulation work and awareness. This proposition or set of propositions may be critiqued as grammatical propositions e.g. questions may be raised as to whether or not the conceptual distinctions are consistent and without self-contradicting delimitations. Finally, it was found that if the propositions are generally assessed favourably, we may be said to have gained some insight into how cooperative work tasks are integrated in the building process as well as gained a concept that may complement the concepts of articulation work and awareness, namely that of stigmergy.

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