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Scalability through Cultivation:

Jens Bergqvist
The Viktoria Research Institute, jens@viktoria.informatik.gu.se

Per Dahlberg
Viktoria Institute, Sweden, dahlberg@viktoria.informatik.gu.se

Scalability through Cultivation

Using Co-ordination Theory in Design

Jens Bergqvist & Per Dahlberg
jens@viktoria.informatik.gu.se
dahlberg@viktoria.informatik.gu.se
The Viktoria Research Institute, Gothenburg, Sweden

Abstract

The objective of this paper is to discuss how to use Information Technology to enable the staff at a mission-critical order packaging department to cope with a drastically increasing scale of operation. To reduce the risk of interrupting the production, a cultivation approach is adopted. We use co-ordination theory to analyse the current work setting and present a design proposal. The basic building blocks of the analysis and the design are co-ordination mechanisms. This facilitates the understanding of today's way of working, as well as the design of a new setting, enabling the department to cope with the larger scale of operation. The underlying approach for the change process is cultivation, which is a softer, less disruptive approach compared to more radical methods for organisational change. Based on the results, we argue that it is the co-ordination work that is lacking, not the actual productive work performed. Even though co-ordination theory has been criticised for being difficult to apply in practice, we find that it is indeed fruitful to use in this real-world case. The cultivation approach facilitates a design that allows implementation of changes without disrupting the throughput at the department.

Keywords: CSCW, Co-ordination mechanisms, Cultivation, Design

1. Introduction

What happens when a small-scale department suddenly has to deal with an annual growth in production of well over fifty per cent? Is it at all possible to preserve the way of working that has developed over the years? If so, is it possible to use Information Technology (IT) to do this?

We have conducted qualitative research at a mission critical packaging department of a large Swedish company that is experiencing a growth rate of this magnitude. In this paper we will discuss how to enable the staff to cope with the increasing scale of operation. In particular, we will explore the important aspect of scaling up the current work setting and present a design strategy that makes it possible to transform non-scalable work into scalable work. The objective is interesting from a business perspective as well as a research perspective, since the company is in need of an evaluation of today's work practice and design suggestions for a future work practice capable of coping with the growing scale of operation.

The department has been, and still is working very well. However, the production is growing rapidly e.g. the anticipated growth in 1999 alone is 100%. The growing throughput in the factory is giving the order packaging department two kinds of problems: (1) the number of important events that must be monitored and controlled has grown and they are becoming difficult to track. (2) The old way of working is not efficient enough: they are already working at full capacity and are unable to increase the throughput.

The workers as well as the management find today's way of working satisfactory, but they fear that the rapid growth will cause severe problems and realise that it is time to “do something” in order to prevent a total breakdown in delivery precision and packaging

quality. We use the term “scalability” to denote the ability of a work practice to cope with an increasing workload.

Because the work practice today is satisfactory we choose to base our analysis and design on the cultivation approach (Dahlbom and Mathiasen 1993). This approach views the organisation as a living organism, constantly changing and evolving. By changing some of the computational tools and procedures in the current work practice we attempt to guide the evolution of the department in a beneficial direction. This approach contrasts against radical approaches, e.g., BPR (Hammer 1990), where you re-design the entire work practice.

Since we will change only parts of the work, we are interested in the interfaces between different parts of the work practice. We use co-ordination theory (Malone and Crowston 1994), as described in the CSCW field to investigate these interfaces. Furthermore, according to Schmidt (1994) a means of articulating work is not provided via the work itself; it must be explicitly communicated. If a work setting is small enough, the articulation may be handled in an ad-hoc fashion, but as the work setting grows, and therefore becomes increasingly complex, it is essential to provide adequate support for the co-ordination of activities. In order to enable scalability we must supply that support.

Thus, our objectives are to investigate to what extent the use of co-ordination theory, in conjunction with a cultivation approach, supports (1) the understanding of a work setting and (2) the design of work practices capable of coping with a higher scale of operation.

The paper is organised as follows. First, we discuss the concepts of cultivation and co-ordination. After a brief discussion of the site and method we report the results from the field study and present our design proposal. Finally, we discuss the results leading up to the conclusion.

2. Cultivation

The nature and importance of cultivation in organisational change and IT development are best described in the words of two of the authors who have introduced cultivation into the Informatics community:

> “Construction and cultivation give us two different versions of systems thinking. Construction is a radical belief in our power to, once and for all, shape the world in accordance with our rationally founded goals. Cultivation is a conservative belief in the power of natural systems to withstand our effort at design, either by disarming them or by ruining them by breakdown.” (Dahlbom and Janlert 1997, p 7)

> “To the extent that organizations have a life of their own, as long as they evolve, grow and learn by their own power, then organizations have to be cultivated rather than constructed, and the development of computer technology use in organizations will be a matter of cultivation rather than construction.” (Dahlbom and Janlert 1997, p 111).

At its most basic level, cultivation states the following: do not change, and thereby upset, an organisation more than what is absolutely necessary to accomplish the task at hand (Dahlbom and Mathiassen 1993, Dahlbom and Janlert 1997). Construction on the other hand assumes that a new well functioning organisation can be designed and implemented without taking the current situation into account. A prominent example of this approach is Business Process Reengineering where the old organisation should be obliterated in favour of the new (Hammer, 1990).

How would cultivation apply to the situation we have studied as opposed to construction? Consider this simple metaphor of a gardener nursing a young tree. As the tree grows ever bigger it evolves features that are undesirable. Unless these features are untreatable the gardener does not cut down the tree and plant a new one (that is construction). Instead he prunes it, eliminating the defects and allows the tree to continue to grow and

evolve. Alternately, he ties up branches to make then grow in the preferred direction. If the gardener's judgements were right the tree will be healthy and display the desired features. What the gardener does is cultivate the tree, that is, he trusts the innate abilities of the tree and allows it to grow on its own, only taking on a guiding role rather than a more controlling one.

Viewing a work place from this perspective implies that the complex interactions of the current situation must be well understood in order to judge which parts are working and which parts are not. Only the badly functioning (here: non-scalable) parts should be addressed with new ways of working. It is much akin to how the evolutionary approaches (Dahlbom and Mathiassen 1993) work, but in a more controlled fashion. Cultivation means to promote guided evolution in the work place. The guidance is needed to prevent the organisation from "growing the wrong way" and make sure that, for instance, a single department does not evolve into a state that is counterproductive to the organisation as a whole.

This approach contrasts rather sharply with more radical theories of organisational change, which state that organisations should be reshaped completely, top to bottom, in order to meet new demands (Hammer 1990). The point of using the cultivation approach is to keep well functioning parts and (within reason) build upon those parts. Basically it is a way of making sure you do not throw the baby out with the bath water, which, according to Gallier (1997), is more likely to happen using a radical approach such as BPR as presented by Hammer.

To accomplish the identification and separation of well working parts from badly working parts, a means of analysing the interdependencies between different aspects the work setting is needed. Thus we turn to co-ordination theory.

3. Co-ordination

We are constantly co-ordinating our day-to-day life. This is done in different fashions ranging from the casual "I put the keys on the table, honey!" to formally filling out papers. This is clearly an interesting phenomenon and it is comprehensively investigated in the literature. Coordination is a central issue in the organization of people and tasks (cf., Mintzberg 1983, Thompson 1967). It is therefore a central issue in CSCW (e.g., Schmidt and Simone 1996, Malone and Crowstone 1994).

A simple definition of co-ordination is "…managing dependencies between activities" (Malone and Crowston, 1994, p. 87), i.e. if two or more activities are dependent upon each other they must be co-ordinated in order to manage the interdependency between them. According to several studies (e.g., Schmidt 1993, Carstensen and Sørensen 1996) the resources needed to co-ordinate the work increases when the work setting grows. In smaller settings a more ad-hoc means of co-ordinating the work might be sufficient, but when it grows the need to support co-ordination increases. Thus, to investigate co-ordination, we will focus on the interfaces between the work activities rather than on the activities as such. We now discuss the concepts and terminology used in the analysis.

3.1 Articulation Work

In a co-operative work setting the actors share the same resources, that is, they are mutually dependent on each other when carrying out their activities. The co-ordination of these interdependencies can be managed through the work itself or through explicitly communicating the current state of the work to all affected parties.

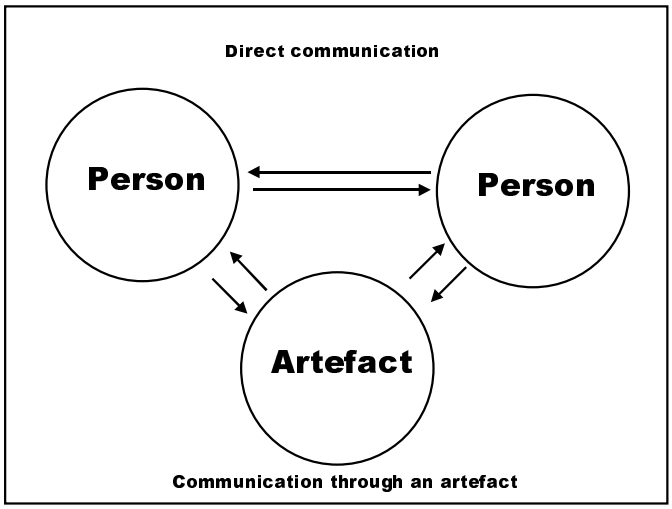
Strauss (1988) introduced the concept of articulation of work. In the CSCW field, Schmidt and Simone (1996) use the terms articulation work and co-operative work to make the distinction between co-ordination work and "all other" work. In a work setting the workers manipulate, control and monitor objects according to certain rules. These rules are

the procedures of work. This set of objects and procedures is denoted the workers field of work. Some co-ordination of activities can be managed indirectly through the field of work and in other cases it must be explicitly communicated.

Dix and Beale (1996) introduce a framework for CSCW (figure 1) where they make a distinction between direct communication and communication through an artefact. Direct communication is when two persons are communicating with or without the use of technology, e.g. face-to-face, e-mail or telephone. Communication through an artefact is a more indirect way of communicating as information is mediated through an artefact.

The framework for CSCW complements that of Schmidt and Simone. Co-operative work is work performed by several individuals in a common field of work. Some co-ordination is achieved by the feed-through when manipulating artefacts in that field of work, e.g., a paper in an in-tray signals the initiation of a different action than the same paper placed in an out-tray. Articulation work is the direct communication used to enhance that co-ordination, e.g., a colleague telling another that a certain paper in the in-tray should in fact be treated as if it were in the out-tray.

Figure 1: The Dix and Beale framework for CSCW.



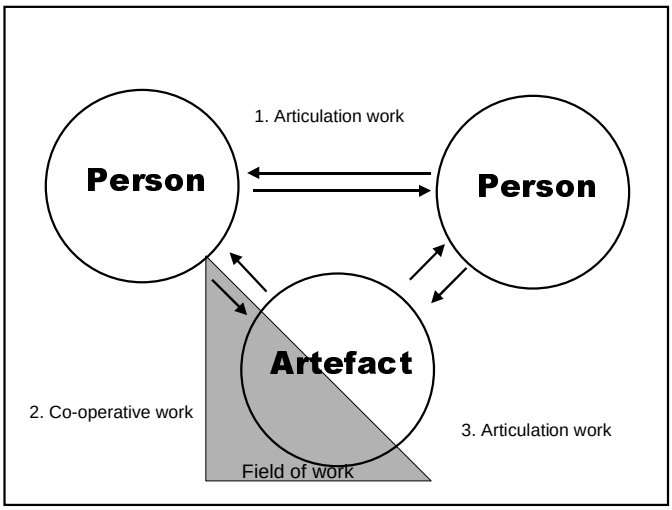
3.2 Co-ordination Mechanisms

When a work setting becomes more complex some form of support is needed to facilitate the co-ordination of work (Schmidt 1993, Carstensen and Sørensen 1996). One way of reducing the complexity of articulation work is to employ Co-ordination Mechanisms (Schmidt and Simone 1996, Carstensen 1996). A co-ordination mechanism is an artefact that is used to help actors to co-ordinate their work. It provides a protocol that defines the possible means of articulating the work, and it also makes the actors less dependent on direct communication, since the co-ordination mechanism can serve as mediator of the articulation. It follows that by using co-ordination mechanisms we are able to articulate the state of work by communicating through an artefact. This possibility is not obvious in the Dix and Beale framework. However, it is possible to extend it to accommodate this (figure 2).

In figure 2 the first notion of articulation work is still direct communication, explaining the state of work to others (1). The co-ordination achieved by manipulating objects in the common field of work is denoted “co-operative work” (2). However, by using co-ordination mechanisms, objects existing outside the common field of work are introduced to reduce the complexity of articulation work (3). Hence, the Dix and Beale notion of commu-

nication through artefacts is either co-operative work, or articulation work depending on the function of a specific artefact.

Figure 2: Extended framework for CSCW to understand co-ordination mechanisms



4. Research Site and Method

The packaging department where we conducted the study is part of a modern manufacturing site for high technology equipment. The total number of employees at the manufacturing site is approaching 1400 and roughly 25 are working at the department in focus. The site is part of a global enterprise with manufacturing sites and customers worldwide.

The personnel work in two shifts, sometimes even three, and also weekend shifts during workload peaks. The shifts overlap one hour, meaning that the first shift always has time to transfer ongoing tasks to the new shift and discuss problems and tasks and events out of the ordinary.

4.1 Method

We began the project by doing a field study to gain knowledge of the current work practice at the department. The study lasted for two weeks, and we spent approximately 70 man-hours at the site. The field study was conducted using "Quick-and-Dirty Ethnography" (Hughes et al. 1994), which "…provide[s] a general but informed sense of the setting for designers." (ibid) The use of ethnography to gain knowledge of the work practice has been extensive in the CSCW field (c.f., Button and Harper 1996, Bowers et al. 1995). Ethnography for the purpose of designing IT, rather than solely for the purpose of understanding the current work practice has been explored by, for instance Bly (1997), Blythin et al. (1997), Hughes et al. (1994, 1997) and Belotti and Bly (1994). It has also been combined with an iterative intervention approach (e.g., Kensing et al. 1998).

At the beginning we conducted semi-structured interviews (Patton 1990) with administrators, such as order-clerks, as well as with some of the managers at the department. Our objective was to get a quick overview of the tasks conducted within the department, as well as an overview of the organization of work. A total of six interviews were conducted, each ranging from fifteen to sixty minutes in length. Subsequently, we shadowed workers with different roles and tasks and asked questions about what they were doing and why. Detailed notes were taken during the study.

We applied the co-ordination mechanisms framework to the field data to identify issues for further study. More issues became apparent when we analysed the field data, using a grounded theory approach (Glaser and Strauss 1967). The analysis started during the second week of the study and was continuously refined for several weeks during multiple sessions.

In order to arrive at a design proposal, we further analysed the identified issues from a co-ordination theory perspective in search of similarities and common problem causes. When this was accomplished we broadened our view is somewhat to investigate the relationships between the issues and how a change in one issue would affect another. In this theoretical experimental fashion we arrived at a well-rounded and consistent set of design issues that compose a design satisfactorily supporting the scalability of the work practice.

The cultivation approach was used throughout the process, in conjunction with previously described methods. The choice of methods and theory is based on the cultivation approach. The co-ordination mechanisms framework helped us focus on the interfaces between work activities and develop new IT support.

The design proposal was evaluated in a workshop where we presented and discussed the results. The participants also filled out a qualitative feedback-form. Nine months after the project, we conducted a semi-structured interview with a department manager. The objective was to establish whether the design suggestions had been implemented and if a cultivation approach had been applied during the change process.

5. The Work Practice

Figure 3: A view of the order packaging department.

The department consists of three distinct areas. The administrative area (not shown in Figure 3) where all the clerks and other administrative personnel reside, the product packaging area where the first stage of the packaging takes place and the order packaging area where the second and final stage of the process is conducted. There are also several external plants, where some products are manufactured and stored.

In order to structure the description of work at the order packaging department we have divided this section into two parts. First, we describe important co-ordination mecha-

nisms in use and second we show how a single order moves through the department, describing the main processes and highlighting important issues.

5.1 Co-ordination Mechanisms

During our study we have identified two artefacts central for supporting co-ordination work, the work order and the board. The importance of these artefacts will become evident in the description of work below and in the discussion following it.

5.1.1 The Work Order as a Co-ordination Mechanism

A work order is a set of papers stapled together representing the customer's order throughout the packaging process. It consists of two E-orders, one of which is the actual delivery note and the other is an administrative tool. Furthermore, there is a T-order, which is a bar code version of the E-order for internal use and finally a map of the work floor. The work order is a co-ordination mechanism that supplies the operative information a worker needs to perform his work. By existing as only one copy, it insures that only one worker handles an order at any given time, making the processes sequential. Thereby the constraints of the packaging process are enforced. In conjunction with the board it also regulates the transfer between the product packaging process and the order packaging process as elaborated on in section 5.2.

5.1.2 The Board as a Co-ordination Mechanism

Figure 4: The board, without order lists. On the left-hand and right-hand sides are the paper tray columns used both by order packaging and product packaging for storing work orders.

The board consists of four different parts: a large notice board and three columns of paper trays. The notice board contains listings of all current orders. These are posted to make the workload and the status of each individual order visible to all. This is an example of what Dourish and Belotti (1992) refer to as explicitly generated information for facilitating awareness. This list supplies the workers with enough information to set the pace of work during the week. The board is a co-ordination mechanism that facilitates awareness. The awareness function must be supported in the future work practice. A few weeks after

the field study was completed, we returned to the order packaging department for other reasons, and discovered that there were no longer any listings posted on the board. The number of orders had grown so much in those few weeks that the lists no longer fitted on the board (figure 4). The awareness function of the board had already been diminished due to the lack of scalability of this particular co-ordination mechanism.

The first column of paper trays is where work orders are placed when first issued from the planner, the second column is where the work order is placed when the product packaging process is completed and the third column contains faxes of E-orders with stock information from external plants. The placement of a work order informs the workers as to whether the product packaging department or the order packaging department should process the order. The board is a co-ordination mechanism that (in conjunction with the work order) co-ordinates the transfer of products between processes, as well as enforces the prerequisite constraints (Malone and Crowston 1994) of the packaging process.

5.2 A Work Order's Journey

We will now describe how a work order moves through the order packaging department. We focus on the work order for the purpose of making the different processes explicit in order to make the co-ordination mechanisms visible and thereby making it possible to identify the co-ordination work associated with them. The main processes are the product packaging process and the order packaging process.

5.2.1 Product packaging

A clerk receives orders from customers and enters these orders into a central computer system, registering delivery date, customer information, etc. Every week another clerk, the planner, sorts the orders in the system by giving priority to the most urgent orders and orders from the most important customers, to ensure that these are processed and shipped quickly. This results in a chronological list of what orders to package each day of the week. Another clerk prints the list, and for each item (i.e., order) in the list, a separate work order is compiled and printed.

The journey of a work order begins when the clerk places it in the product packaging tray column. Product packaging is where the individual products are wrapped in carton, together with cables and other standard accessories. The work orders are stored in chronological order, with the one with the closest delivery date in the top-most tray. When a product packager does not have any task to perform, he goes to the board and checks the tray column to obtain a new task, i.e., a work order to process. He takes a work order from the top tray and checks what kinds of order items are listed on it. The product packaging department is split into two parts, each responsible for packaging one of two different product families (A and B). If the worker finds any order items that should be packaged by his department he takes the work order to his work desk and starts to package the products. For each order item there is an index number, indicating what kind of accessories should be enclosed with the product. Some clients want manuals, some just need a set of cables and some want no accessories at all. Each carton is labelled with bar codes representing the product number and index number.

The packaged products are stored in an interim storage area. The location is marked on the map included in the work order, and the order items packaged are marked as well. Because there is a large number of combinations of accessories there is also a correspondingly large number of indices. The products are therefore stored in the interim storage area as per order and not as per product number and index number. The growing throughput in the department has made it difficult for the product packaging personnel to fit all the processed products ready for order packaging into the area reserved for interim storage. Often they place the products in an adjacent floor area instead. They mark the spot on the work order map with an “X” and jot down a nearby shelf number next to the mark. It is clear that

this work practice will not be able to cope with the growing workload. This is a key scalability issue.

Depending on whether there are any products from the other product family to package, the product packager puts the work order back in the product package tray or in a tray in the next column. If he chooses the second option the work order is passed on to order packaging. This choice is an indication of both the transfer co-ordination function and the prerequisite constraints enforcing function of the board.

5.2.2 Order packaging

At the order packaging department, the assignment of tasks works in a similar way. An idle order packager goes to the board and checks the order packaging trays for work orders to handle. First he checks the list of order items to make sure everything is ready (i.e., that everything requiring product packaging has in fact been processed). If there are any products handled at another plant (members of product family C), he checks the E-order faxes in the third tray column. An E-order fax contains a parcel number for each order item packaged at another site. If he cannot find any such fax he puts the work order in a special tray with a post-it sticker showing what product is missing. The order will not be order packaged until all order items from product family C are packaged. (Another example of enforcing the prerequisite constraints) The management has decided that the product packaging should be completed, but not the order packaging if there are order items missing from the external sites. It sometimes happens that products are stored in the interim storage area for weeks. The process of co-ordinating the packaging when there are products manufactured and packaged at external plants is a problem. This is an issue we identify as important for making the work practice scalable.

To facilitate the order package work and ensure good quality a small handheld computer is used. The device works very well, and has increased the quality dramatically, i.e. the number of packaging errors decreased. However, the functionality of the handheld computer as well as the connection to the central computer systems is very limited. The bar codes on the T-order are used to scan all order items, quantities and other order information into the handheld computer. There are two bar codes for each order item (item number and quantity) and also bar codes for the order as such (date, order number, customer number etc).

The packager examines the order items and tries to estimate whether the order is to be shipped in one or more parcels. If the order turns out to result in more than one parcel he should try to split it up with the sequence of the order items on the E-order in mind. However, this is not always the case, since he also needs to optimise the space available in each parcel. It is common practice that products that formally should be shipped in parcel number two are in fact packaged in the first parcel and vice versa in order to save space. The rules regulating this matter are flexible and the order packager uses his acquired knowledge of “how things are done” to find a satisfactory compromise between the rules and the need for saving space.

He decides what order items to package first and checks the enclosed map to find out where the products are stored. He selects a free space on the floor area reserved for order packaging, and there he gathers enough products to assemble a parcel. For each product he scans the product number bar code. The handheld computer warns the packager if he forgets to package a piece of an order item. It is possible since both what products to package and their quantities are stored in the computer. However, if the packagers accidentally package too few items, the handheld computer will not sound the warning until the packager tries to dock the handheld computer.

The order packaging personnel spend very much of their time searching for the items to package. This is due to the fact that the interim storage area is no longer large enough to accommodate all the products that should be stored in it. This has two negative effects: First, all products are not stored in their appropriate shelves, but are instead placed

in an adjacent floor area and its approximate position is marked on the map that is included in the work order. Second, it means that the floor area available for the actual order packaging process is diminished. To sum it up, we discovered that not only does the increase in interim stored products make it more difficult to find the products listed in an order, but it also hampers the order packaging process itself by reducing the available floor area usually reserved for this process. Both factors contribute to lower work efficiency. This is a very important issue from our scalability perspective. The co-ordination mechanism supporting the transfer of products between the product packaging and the order packaging is the map in the work order depicting the interim storage and the product's location within it. This co-ordination mechanism is not working well even today. When the workload increases the transfer between the processes will most likely break down.

In addition to the two product families that are interim stored, there are a number of standard products stored in another storage area called the Backflush storage. The products in Backflush storage are not stored according to any system at all. When they arrive they are simply placed in a convenient empty space. In order to find the items to be packaged the order packager either has to remember where the products are or has to confer with a colleague. Usually there is someone around who knows where they are. If this is not the case the packager has to search the Backflush storage in order to find them, and since it is rather large it may take quite a while. Spending fifteen minutes searching for a specific product is not unheard of. The Backflush storage is an issue that must be addressed. This is not functioning efficiently today, and it will become even more difficult to find packagers that have knowledge about where products are stored when the scale of operation increases. This means that it will take even longer to find the right products unless the situation is remedied. IT-support is needed to co-ordinate storage and retrieval from the storage.

Some packagers use the handheld computer to count standard products to be sure they get the number right. If the packager tries to scan too many products the handheld computer sounds a warning.

Sometime during the process the order packager also has to mark the cables (if included in the order) with the appropriate parcel number. To do this he has to leave the building and walk some hundred meters to a tent, which houses the cable drums. The cable drums are not stored there according to any system what so ever. He has to search through the entire tent in order to locate the drum marked with the correct order number. This can sometimes take up to half an hour according to the workers. Once the correct drums are located, a note with a parcel number is attached to each of them. When the order is to be shipped the forklift driver has to locate the cable drums again causing the whole process to slow down even more.

When a parcel is fully assembled the packager prints out a number of labels at the label printing station. The parcel is labelled with bar codes representing the parcel number and order number and a label with delivery address. Depending on the destination, a label with content information and another label with customer specified markings may be attached to the parcel as well. The order packager then measures the height of the parcel (due to the standard size of a pallet he does not have to measure the width and length of the parcel) and writes down the figure on the parcel. He uses a special pallet truck with built-in scales to weigh the parcel and jots down the figure next to the dimensions. These figures are then copied onto a weight list. If necessary, the packager also uses a special machine to wrap the parcel in order to make it sturdier during transport. He then separates one of the E-orders from the work order, stamps the parcel number on it and puts it in a small plastic bag together with a quality report form, also stamped with the parcel number, and attaches it to the parcel. The remaining E-order is given to an administrator. If it is an international shipment, the administrator faxes information about the consignment to the company shipping agent. If the parcel is to be shipped within the country a consignment note is written using an ordinary typewriter. The note contains the following information: address, order number, number of parcels, volume and weight. The adhesive consignment note is then attached to the parcel. The parcel is placed directly in the loading bay by the packager himself. If it is

an international shipment the forklift will collect it and place it in final storage, where it will remain until the freight company arrives to collect it.

The packager docks his handheld computer and downloads the packaging data into the central computer system. He walks over to the board and marks the packaged order items on the order listings with a magic marker. When all order items of a given order are marked, the packaging process is completed. The packager takes a new order from the board and the process begins again…

5.3 Key Issues

We now summarise the identified key issues that must be addressed in order to achieve a scalable work practice. Our proposed solutions to the issues will then be discussed in the design proposal section below.

The issues are:

- The overview function of the board: An overview of the current workload is important for setting the work pace. Until now the board has been working well, but it can no longer display the large number of orders in a useful and productive manner. Another solution with better capacity is needed due to the high rate of growth. This is a matter of high priority.
- The interim storage area: It is already impossible to store all products in the small interim storage area and due to the growth this problem will become even more severe as time progress. This also applies to the observed difficulties in finding the right products stored in the area. Finding a solution is imperative since the interim storage area is a crucial element in the work practice, not only does it take time to search for products, it also takes up valuable working space needed by the order packagers.
- External site co-ordination: The co-ordination with external sites is barely functional today. The lack of information of the state of an order is affecting the throughput since an order cannot proceed to order packaging unless all items are available. With an increasing scale of operation far too much time will be spent on deciding whether all products have arrived so that the order packaging process can begin.
- The work order: It happens that work orders simply disappear. Sometimes they are packaged into a parcel, sometimes they are dropped under a shelf. As the number of orders, and thereby the number of work orders increase, it is very likely that the numbers of disappearing work orders will increase as well. The current incarnation of the work order is not suitable for large volumes of orders, since papers are difficult to handle in large quantities and are easily lost or misplaced.
- The work activities: Our observations show that the workers are very efficient when performing each work operation. With better co-ordination support, they will be able to cope with the increasing scale of operation.
- Stop orders: If it is discovered that something is wrong with an order that has entered the packaging process, the clerks have to find the individual work order to stop it. This means finding the right worker on the shop floor. It still works since the department is rather small, but when it grows larger it will take longer time to find the person in possession of the work order.
- The Backflush storage area: The storage area is not well functioning today. It is uncoordinated and confusing. Often the workers must find and ask the right person in order to find the sought after item. As the workload increases it will become even more chaotic. This is an urgent matter to attend to.

- The final storage area: This works very well today due to the IT-support. When the scale of operation increases problems will arise due to the limitations built into the current system.
- The cable handling: The handling of cables is not well functioning today. It takes a very long time to find the right cables, and there are two persons that have to find the cables at different times: the order packager and the forklift driver.

6. The Design Proposal

Here we present our design suggestions, beginning with a description of the revised co-ordination mechanisms. Changing the co-ordination mechanisms affects the two main processes, product packaging and order packaging. We discuss the effects of this and present new ways of handling the storage areas.

6.1 Co-ordination Mechanisms: The Board and the Work Order

We suggest that the board is replaced in its entirety by a computer system consisting of one or several large computer screens and a large number of handheld computers connected to a central server via a radio based LAN. The screens will display awareness information, such as the number of order to process during the day, how far along in the process orders are and so forth. Basically it is replacing the listings function of the board and since it displays statistics generated from the central computer system it is possible to display this in new and interesting ways.

The work orders information will be downloaded directly into a more sophisticated version of the workers handheld computer and is displayed as lists of items to package. This way the paper-based co-ordination would be removed. The T-order will disappear, since the functionality of the T-order is to provide data for the handheld computer used today. This solution does not only eliminate the need for a cumbersome paper based work order, but also the need for scanning every single order item of each order into the handheld computer before the actual packaging work can begin. If a handheld computer with a large graphical display is used, the map previously included in the work order could be shown graphically on the handheld computer. It is also possible to use a system of co-ordinates to store information on where different products are located. Since all the order information is stored on the server there is no need to print the E-order until it should be attached to the parcel at the very end of the packaging process. Using this system all the information, both co-ordinating and awareness generating, can be accessed and displayed electronically eliminating the paper based co-ordinating mechanisms causing problems today.

Since all events are registered and reported electronically to the server, it is also possible for the administrative staff to access the system and see whether the handling of an order has begun and how far along in the packaging processes it has come. If necessary, the staff can send out stop orders directly to the packager via the handheld computer and tell him to stop working on the specific order. It also rids the packager of the paper handling at the end of the process where he checked off the packaged order on the notice board and turned the work order over to an administrator. This is automatically handled by the computer system. The new system eliminates many of the problems arising in the order packaging process today. It not only allows the packagers to work more autonomously but also to be more efficient since much of the searching conducted today is eliminated. The operative information needed to perform the packaging process is immediately available in an updated form.

6.2 Product packaging

The reason for having a separate product packaging process is that some customers want their products configured in a special ways. They may also want different sets of accessories. We have identified no serious problems with the product packaging process per se, but how the process is conducted has a serious impact on the interim storage area, where the processed items are placed until they can be handled by the order packagers. Until now it has been easier to interim store the products according to which order they belong to, as opposed to what product number and index they have. This system worked very well as long as the number of orders was relatively low and the number of different configurations was large. Today the number of orders is ever increasing and storing order specific products gives a much more complex storage system than if only standard products where stored in the interim storage area. The space available in the interim storage is limited and it has currently spread out into adjacent areas, stealing workspace from the order packagers. The location of products not placed on reserved shelves is not covered in the E-order, thus the need for ad hoc markings on the enclosed map. As a consequence, it takes the order packagers a long time to find the products, and since each product is tied to a specific order it is essential to find the exact item, not just one with the right product type and index number. It is vital to find a solution where interim storage of large quantities of order specific products is not needed. Some products must still be manufactured and configured for specific customers, but our ambition is to remove the direct relationship between the product packaging process and work order.

We suggest a change in the product packaging process, which will result in an interim storage with standard products. The products will not be stored as per order, but rather as per product type and index number. When the order packager needs a product he only has to locate the right product type, not a specific item. According to the product packagers non-standard orders make up less than 20% of all products passing through the department. A proportional part of the interim storage area will be dedicated to storing these special items as per order.

The product packagers will get their tasks directly from the computer system, as opposed to the indirect route by work orders taken today. The product packagers' assignments will be based on stock information and on what orders are to be shipped in the near future. This way the interim storage will be both simply ordered and kept as small as possible, yet always have just enough products in stock for the order packaging department. The new design does not affect the current work activities as to how products are packaged but only as to what products are packaged. This way as much as possible of the product packaging competence is preserved.

The design suggestions allow the product packaging process and the order packaging process to become more loosely coupled, thus decreasing the need for co-ordination. They do however place great demands on the information systems supplying the product packaging process with tasks to perform.

6.3 Order packaging

The new order packaging process we are proposing begin when a packager turns on his handheld computer connected to the department's server by a wireless LAN. He enters a request for a new order and receives one automatically. From now on he is the person responsible for this specific order. He immediately gains an overview of the order size and composition. He is also notified as to whom the customer is.

At a push of a button the order is displayed as a list of items to package. The handheld computer can sort the list depending on different criteria of the order items, perhaps he wants them ordered by product number or by what storage area he is to collect them from. Each order item has up to date location information supplied by the server over the wireless LAN. As the listed products are picked up they are scanned using the scanner on the hand-

held computer. The packager can choose whether he wants to collect all the order items first and then assemble the parcels or if he prefers to collect the items as per parcel. The handheld computer must therefore be able to handle other functions while the task of collecting order items is still unfinished. It shall however clearly tell the packager that the entire order is not yet finished so that the packager does not risk missing items.

We also suggest that label printing can be initiated from the handheld computer. The software controlling the label writer must be connected to the other systems. That way the packager can be notified as to special cases, such as a certain customer wants a label of contents on a particular parcel. When the packager wraps the parcel, he should be able to estimate the height of the parcel from markings on the wrapping machine. Both height and weight is noted in the digitised version of the weight list using the handheld computer. Once a parcel is fully assembled the packager makes a note of this on his handheld computer. A message is immediately sent to the forklift driver who collects the parcel and places it in a suitable position in the final storage area.

The design suggestion lead to reductions in the amount of co-ordination work the individual order packager has to perform, allowing him to concentrate on the work activities. With better co-ordination mechanisms and higher quality operative information he can accomplish his productive tasks much easier and more efficiently as well.

6.4 Storage Areas

Only the final storage area works satisfactorily today, much due to the truck computer system. We propose a more extensive computer system, which is integrated into the overall information system by a wireless LAN. There are two reasons for this. First, the current fork lift computer has all storage information on its hard drive and this data is not available unless you interact directly with this isolated computer. Should the department purchase a second forklift this system breaks down since there is no way to keep the storage information consistent. With the connection to the department server this information can be stored in a common database and accessed and maintained from any number of computers. Second, the forklift computer will also be able to send and receive messages, just like the handheld computers.

There are three other storage areas, which are not working well. These are the Backflush storage area, the storage area for product family C and the cable storage. They all suffer from lack of structure and are all entirely without computer support. This we intend to amend by using the system from the final storage area here as well. Thus we make all the storage areas in the department accessible for stationary computers as well as handheld computers. By increasing the quality and availability of the storage information we reduce the time spent searching for products.

7. Discussion

In this section we reflect on our findings, starting off with reporting on what happened after the study was finished. We then discuss the chosen theory, and argue that it facilitated analysis and design in this case.

7.1 Implementation

Important measures of the validity of the design proposal are how well it is received, to what extent our suggestions are implemented and how well those changes work. During a workshop, which we held after the design proposal was finished, many issues concerning the implementation of our proposal were discussed. These issues where mainly on a practical level, for instance security issues. The suggested changes were appreciated and the com-

pany representatives claimed that they would work on solving the practical problems in order to implement the suggestions. Consequently, the design proposal was well received.

Eight months later we contacted the company to find out what changes have been made. The packaging department has grown, and now has 40 employees, as opposed to 25 when we conducted the study. As predicted the throughput has almost doubled, i.e., they are packaging twice as many units each day. Our interviewee claimed that many of our design suggestion have been implemented in small steps due to economic and organisational constraints. In fact, due to the cultivation approach, the different parts of the design proposal are possible to implement at different times. This allows the company to focus their resources on making each redesigned part mature before moving on to the next implementation. Our recommendation to increase and develop the use of mobile IT-support has also been implemented, but in a slightly different fashion. Instead of using PDAs, they use laptop computers attached to carts, supporting both the mobility and carrying capacity of the individual worker. There are far-along plans to introduce a wireless network, which was one of our main points. Initially, there was some resistance to this due to the problems of electrical interference and security. These problems have been solved. The proposed solutions for finding products in the storage areas have been implemented, except for the Backflush storage area where static places for all products are now used. Our suggestion was a dynamic storage system, but otherwise the solutions are similar. The interim storage area is now indexed by product type, in accordance with our suggestion.

Based on this feedback we draw the conclusion that the company believes that the design proposal was valid and improves the department's performance. A major part of the proposal has been validated in the day-to-day operations. The implemented changes, together with a larger work force, allow them to cope with the increased throughput.

7.2 Co-ordination

Using co-ordination theory in a real world case is not a trivial thing. It has been argued that it is difficult to make the distinctions used in co-ordination theory (e.g., Heath and Luff 1992, Rouncefield et al. 1994). It can be cumbersome to understand what objects are within the field-of-work, if tasks and actions are articulation work or co-operative work, to mention but a few problems. These problems become obvious in a situation where work consists mainly of communication, such as in the vision of the Talk Society (Dahlbom 1997). If all you ever do is talk to people in your personal network, at work as well as in private, does this not make such distinctions as co-operative work and articulation work useless?

Be that as it may, we argue that there are still situations and settings where they prove useful. In the case described in this paper it is clear that the use of co-ordination theory is fruitful. Co-ordination theory and in particular the notion of co-ordination mechanisms became valuable tools for understanding as well as design. By using the distinction between co-operative work and articulation work we where able to better understand the complex work practice with its constant need for co-ordinating activities. Consider for instance workers calling out for the forklift driver when they need products from the top shelves of the Backflush storage. They use direct communication to co-ordinate, i.e. articulate, their activities.

But, as mentioned, there are situations where this concept is not clear enough to provide guidance. For instance the workers co-ordinate the entire packaging process using the work order. This is clearly a form of co-ordination, but the manipulated object is not part of the common field of work. It has been introduced for the soul purpose of co-ordinating activities. Is this still articulation work? In this example we where able to apply the notion of co-ordination mechanisms, which facilitated our aim to investigate the interfaces and interrelationships between the activities. Once these were identified and analysed the design for specific issues became viable. The exact implementation addressing the identified issues maybe discussed, e.g. the company's choice of using laptop computers, instead of handheld

PDAs. However, the both designs are fundamentally the same, i.e. they aim to support the required co-ordination of activities with information technology.

Therefore, we believe that co-ordination theory is helpful for both analysis and design in such industrial work settings.

7.3 Cultivation

The idea of using cultivation rather than construction influenced us throughout this project. It has helped us decide on using co-ordination mechanisms as framework for analysis, as well as on how we were to structure the resulting design proposal in order to make the proposed changes possible to implement.

Studying the department from a cultivation perspective, the initial constraints of non-disruptive changes due to the mission critical nature of the work, made us realize that it would be much more costly and disruptive to actively change the work rather than the technology supporting it. In order to change the way of working, the company would have to retrain the personnel as great cost and performance loss. Information technology on the other hand is relatively cheap and can be introduced gradually to make the disruption minimal. Analysing the field data using the co-ordination mechanisms framework we were able to isolate the interfaces between tasks and study how well those interfaces were functioning. This way we can introduce new IT, performing the co-ordination mechanism functions without greatly affecting the work activities it co-ordinates. The workers would then adapt (evolve) their own work practice using the new IT support.

This contrasts quite sharply to the findings presented in Hanseth (1996) where it is suggested that it is the information infrastructure (i.e. the technology) that must be cultivated. We believe that this is due to the difference in scale between the cases. While we are looking at the organisation of a department, Hanseth investigates large information infrastructures, such as the Internet. Large infrastructures, Hanseth argues, are not possible to change using a construction approach. They must be cultivated. In our case, on the other hand, it is the way of working that we cultivate, not the infrastructure.

8. Conclusion

Our objectives were to investigate to what extent the use of co-ordination theory, in conjunction with a cultivation approach, supports (1) the understanding of a work setting and (2) the design of work practices capable of coping with a higher scale of operation.

Co-ordination theory provided the conceptual framework for studying and analysing the work setting. It made it possible for us to identify interfaces and mechanisms important for co-ordinating the work activities. The cultivation approach provided a much-needed perspective on how to implement the changes without disrupting the work and what the design must be like to allow the organisation to continue to operate during implementation. This case serves as a good example of how co-ordination theory and a cultivation approach can be applied in an industrial context when scaling up a work setting.

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