Chapter 4. TASK AND DOMAIN: THE PLANNING TASKS

4.1. Introduction
Chapter 2 provided an overview of the entire order flow process within Cabofa, the cardboard company, while Chapter 3 justified the choice of methodology for defining tasks and domains within Cabofa, methods for gaining the required information and the appliances used to analyze the data. The main theoretical framework we use, called commonKADS, comes from the knowledge engineering field.

The three important types of knowledge within commonKADS are task knowledge, inference knowledge and domain knowledge. In this chapter, we focus on the planning tasks, which are narrowly related to task and inference knowledge. We describe the planning tasks from a system-oriented view. Planning problems may occur in several of the stages during which the tasks are planned and these will have to be resolved. One problem may be a lack of lining paper, another lateness of a subset of orders, and so on.

Problems within the planning and scheduling domain have been described in the preceding chapter as well as the general procedures for resolving them. No attention will be paid in this chapter to the individual differences between the planners; this issue will be discussed in Chapter 5. The description in this chapter will provide a conceptual framework for the way planners act. It will be used as input in the prototyping phase that is discussed in Chapter 6.

This chapter will be structured as follows. The planning tasks within the Commercial Department will firstly be discussed, then those within the Logistics Department. The main focus, however, will be on planning activities within the Logistics Department.

The Logistics Department has two divisions that provide support by constructing production plans in respect of mill planning and converting planning. Each planning task will be analyzed in considerable detail in order to provide an overview of the most important procedures for executing the planning tasks. Interdependencies exist between the planning tasks at the mill and converting planning. There are also
interdependencies within the mill planning department. In the first place, there is some interdependency between the cardboard machine and the paper machine; this is related to the lining paper that is used as input for the cardboard machine. Another type of interdependency within the Mill Planning Department is that between rough and fine planning. We will discuss the links between the rough and fine planning levels in this chapter.

Finally, this chapter will conclude with an overview of the various elements of the conceptual framework and identified procedures. All these elements constitute input for the prototyping stage of the research, which will be discussed in Chapter 6.

4.2. Planning Tasks within the Commercial and Logistics Departments

Production planning and control within Cabofa has already been discussed in the previous chapter. Here the analysis continues at a more detailed level, focusing on the planning tasks. The Logistics (I) and Commercial departments (II) both perform planning tasks. A planning task consists of identifying activities in the planning and scheduling domain in order to satisfy the customer’s requirements.

In this section we describe the order flow through the Commercial and Logistics departments. Sections 4.2.1, 4.2.2 and 4.2.3 provide a detailed analysis of all planning tasks within the Mill Planning and Converting Planning departments respectively. Figure 15 shows in diagram form how the system as a whole operates.

A customer order arrives at the Commercial Department (1). If the order data is not already in the logistical information system, an employee enters the new order data (2). If all data is valid, the customer order is directed to the small format module. In the small format module (3) a decision is made as to whether the order can be processed immediately on the cardboard machines, or whether the required format is such that additional converting is necessary. In the event of a large format order, the order flows through the large format bucket system (4a); otherwise it flows to the small format bucket system (4b). The Commercial Department manages both bucket systems. The bucket system assigns the capacity available in the production week to several commercial regions. A commercial region consists of either one important customer, or a collection of customers within a geographical area. If capacity is available for the customer order, it is directed to the fixed allocation system (5a), or rough converting planning (6b). In the case of a large format order, it flows into the fixed allocation system (5a). The fixed allocation system assigns the customer order to a particular cardboard machine based on particular properties of the order. In the case of a small format order, the next stage is rough converting planning (6b). (This flow shall be discussed after the analysis of large format customer order flow.)
The large format order flows into rough planning (6a). If the cardboard machine is at the Sand Site, the order flows to rough planning for this mill, otherwise to rough planning at the Lake Site. During the rough planning stage (6a) two checks will have been performed. Firstly, the order will have been checked against order data feasibility to determine whether there are any technical reasons for not being able to manufacture it. This involves such factors as sheet dimensions and pallet heights being checked for feasibility.
Secondly, the machine load will have been balanced. During the previous stage – the fixed allocation stage – customer orders are assigned to a particular cardboard machine. It may happen that distribution over the product types and calipers differs from the usual pattern. This may lead to over and under-capacity at the individual production machines. An exchange of collection of orders with the same characteristics from the one cardboard machine to the other may redress the lack of balance.

The fine planning stage (7a) consists of combining the customer orders such that the total output is maximized. After this stage the production plan is ready and the order will be waiting to be processed.

Let us return to the flow for a small format order. A small format order arrives at rough converting planning (7a). The customer demands a small sheet with specific dimensions. In order to cut the sheets to the sizes required, a large format is used as input. The dimensions of the large sheet are specified first. If the large format is not in stock, the large format will be produced on the cardboard machine. It will flow automatically to the fine planning stage; it does not need checks at the rough planning stage of mill planning.

Converting fine planning (7b) involves deciding the line-up of orders for a particular converting machine. Once the order is determined, the production plan for the converting machine will be made ready and the customer order planned.

To this point, the order flow has been described in broad lines. Two flows have been distinguished, namely a flow for managing large format orders, and a flow for managing small format orders. A detailed analysis of the flows may provide additional knowledge about the planning tasks that can be used in the prototyping phase.

4.2.1. The Commercial Department

In section 4.2 we described the entire customer order flow within the Commercial and Logistics departments. Planning tasks in the Commercial Department will now be analyzed.

One might well think that it is only the Logistics Department that performs planning tasks. However, within Cabofa, the Commercial Department also manages some stages of the planning process. The main reason for planning tasks being done within the Commercial Department is related to irregular entry of orders and the unfair First In First Out (FIFO) system. FIFO means that a customer claims a specific capacity, resulting in no capacity for other customers being available, and their not being able to be served. The Commercial Department did not want to discriminate in any way between market segments or customers. As a result, more profitable orders being knocked back in favor of another customer order was always a possibility.

It was because of this that the bucket system was introduced. This system enabled more promising market segments and more important customers to be given priority, with the potential for higher profits for the company as a whole. It also meant that the Commercial Department created a new planning task for itself, one that has the potential for having a big impact on the planning tasks within the Logistics Department.
The Commercial Department manages two bucket systems, one for the mill production and one for converting production. Both systems function in the same way; the only difference is the type of order handled by the system.

### 4.2.1.1. Bucket system (4a, 4b)

<table>
<thead>
<tr>
<th>Input:</th>
<th>new order entry</th>
</tr>
</thead>
<tbody>
<tr>
<td>Process:</td>
<td>check if customer order can be accepted commercially</td>
</tr>
<tr>
<td>Output:</td>
<td>accepted or refused customer order</td>
</tr>
</tbody>
</table>

The first step taken within the bucket system is determining which commercial region applies for the new customer order. It will be recalled that a commercial region consists of either one important customer, or a collection of customers within a geographical area. If no capacity is available in the particular commercial region for the required production week, the customer order cannot be accepted.

However, if the customer order is too important to reject, the order can still be accepted in the following way. Either capacity is exchanged between commercial regions, or the customer order will use a particular capacity called “pool” capacity. The pool is the amount of reserve capacity that is available within a production week but not assigned to any commercial region. It makes it possible to accept orders that would normally not be accepted because of lack of capacity in the required production week. Example 5 explains how the bucket system functions.

**Example 5: The bucket system**

*Assume the Converting Department has a cutting capacity of 800 tons (both rotary cut and die cut machines). The Commercial Department assigns 90% of this capacity to the commercial regions. The other 10% is the so-called pool. It is used to reduce deviations in production capacity and customer demand. Suppose we have three commercial regions, A, B, and C. Each region has a particular capacity to be used. The total budget of A, B, and C is equal to 720 tons (90% of 800 tons). The other 10% can be claimed from the pool. Assignment of the claims takes place according to circumstances that will be described later.*

<table>
<thead>
<tr>
<th>Region</th>
<th>Budget</th>
<th>Booked</th>
<th>+ / -</th>
<th>Budget</th>
<th>Booked</th>
<th>+ / -</th>
<th>Budget</th>
<th>Booked</th>
<th>+ / -</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>300</td>
<td>320</td>
<td>-20</td>
<td>300</td>
<td>200</td>
<td>+100</td>
<td>300</td>
<td>50</td>
<td>+250</td>
</tr>
<tr>
<td>B</td>
<td>320</td>
<td>370</td>
<td>-50</td>
<td>250</td>
<td>100</td>
<td>+150</td>
<td>250</td>
<td>-50</td>
<td></td>
</tr>
<tr>
<td>C</td>
<td>100</td>
<td>90</td>
<td>+10</td>
<td>170</td>
<td>210</td>
<td>-40</td>
<td>170</td>
<td>90</td>
<td>+80</td>
</tr>
<tr>
<td>Total</td>
<td>720</td>
<td>780</td>
<td>-60</td>
<td>720</td>
<td>510</td>
<td>+210</td>
<td>720</td>
<td>440</td>
<td>+280</td>
</tr>
</tbody>
</table>

Available pool: 10, 40, 30

To be booked: 20, 290, 360
In the table, the current week is denoted by week 0, the consecutive weeks are denoted by week 1 and week 2 respectively. The column ‘+/−’ denotes the available budget for a particular region for a particular production week. Customers in region A have already booked 20 tons more than is in the budget; 10 tons of the pool are still available in week 1. The 20 tons above the budget comes from the pool. It is assigned to the commercial region. The same holds for region B. The current week is already using 50 tons from the pool. Thus, from the 80 tons of available pool, 70, 30, and 40 tons have already been assigned to customers in one of the commercial regions in the respective weeks.

The bucket system streamlines order entry and enables strategic discrimination between customers in several commercial regions. However, it does not use any production machine property, except for the aggregated capacities.

4.2.2. Mill Planning (IA.)

The Mill Planning Department manages planning for the cardboard and paper machine. Figure 16 shows in detail how mill planning takes place.

After commercial acceptance (2), a customer order flows into the allocation system (5a). The fixed allocation system (5a) determines which default cardboard machine the customer order should be manufactured on. Note that the assignment can always be overruled.

At each production site, Cabofa has two cardboard machines and one paper machine. Generally, each cardboard machine carries out both rough (6a1a, 6a1b, 6a2c, 6a2d) and fine planning (7a1a, 7a1b, 7a2c, 7a2d). On the other hand, the paper machine only carries out fine planning (8a1, 8a2).
Cardboard and paper machine planning is performed in a decentralized way. The Lake Site plans its allocated orders, and so does the Sand Site. Entry of converting orders will tend to disrupt allocation.

It may happen that the company needs greater capacity for manufacturing the cardboard sheets. If such is the case, it is able to claim some of the capacity that Specabo, Cabofa’s sister company, has. This is called external production (6a3). The same holds for external lining paper (8a3). If the available capacity on the paper machine is too low or the lining paper cannot be manufactured at Cabofa, external lining paper is ordered. Existing due dates have to be taken into account.

In the rest of this section, each task mentioned above will be discussed in detail, starting with the allocation system.

### 4.2.2.2. Allocation system (5a)

| Input: | new customer orders, product type, caliper |
| Process: | assign customer orders to a default cardboard machine |
| Output: | mapping of customer order to cardboard machine |

The allocation system is determined on a yearly basis. It shows the combination of product type and caliper assigned to a particular cardboard machine. The labels CM-1, CM-2, CM-6, and CM-8 denote the cardboard machines. It will be recalled that the abbreviation for a cardboard machine is CM. The allocation system operates as follows:

- unlaminated cardboard, and the product types “mono” and “duo” are outsourced to a subcontractor, the sister company Specabo,
- the thinnest cardboard of the product type “board” is produced on the CM-1,
- the middle area and the thicker calipers are produced on the CM-2,
- the special types (“print”, “screen”, “puzzle green”, and “deluxe”) are produced on the CM-6, and
- the thicker types of board are produced on the CM-8.

Table 2 shows the overall pattern. The last column shows the percentage of product type in the total range. The most important product type is the so-called laminated board, which accounts for more than 80% of the total volume. This allocation system is not strict in the sense that if another cardboard machine is more suitable, these values cannot be exchanged.

The actual situation may thus disrupt the intentional allocation system. This matter will be dealt with in greater detail when the production planner protocols are analyzed.
### Table 2: Pattern of an allocation system

<table>
<thead>
<tr>
<th>Product type / Caliper range</th>
<th>Lake Site</th>
<th>Sand Site</th>
<th>External Specabo</th>
<th>Share</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>CM-1</td>
<td>CM-2</td>
<td>CM-6</td>
<td>CM-8</td>
</tr>
<tr>
<td>Unlaminated “board” 0.8-1.5 mm</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Laminated “board” 1.5-2.0 mm</td>
<td>✓</td>
<td></td>
<td></td>
<td>✓</td>
</tr>
<tr>
<td>2.0-2.3 mm</td>
<td>✓</td>
<td>✓</td>
<td></td>
<td>✓</td>
</tr>
<tr>
<td>2.3-2.5 mm</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td></td>
</tr>
<tr>
<td>2.3-3.0 mm</td>
<td>✓</td>
<td>✓</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3.0-4.0 mm</td>
<td>✓</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>“Mono” / “duo”</td>
<td></td>
<td>✓</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Special types (0.8-3.0 mm)</td>
<td></td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>“print”</td>
<td>✓</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>“screen”</td>
<td>✓</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>“puzzle green”</td>
<td>✓</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>“deluxe”</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

The allocation system works merely with the initial assignment. Suppose that there are some manufacturing problems at one particular machine. The orders assigned to this machine will be manually assigned to another cardboard machine. Converting orders may constitute another disruptive factor. The due dates for converting orders are relatively short. Consequently, manufacturing of the large formats should take place at the same production site, thus reducing additional handling and transportation.

These are actions performed manually; in general terms, orders converted at the rough planning stage are assigned to a cardboard machine at the Sand Site, also the site of the Converting Department.

The allocation system is based on an average order entry. Normally, distribution over the product types and calipers will exhibit weekly fluctuation. This may result in unbalanced machine loads, which then need to be corrected.

4.2.2.3. Rough planning (6a)

| Input: | orders assigned to machines, unbalanced machine loads, some orders with extensive trim losses have to be combined with other orders |
| Process: | shift orders such that machine loads are balanced, trim losses already minimized (preprocessing) |
| Output: | leveled orders, fewer combination problems at fine planning level |

In the rough planning stage, two targets are aimed for: balancing of the capacity across the machines, and preprocessing the orders such that it is not hard to make good combinations at the fine planning level.
Figure 17 shows the rough planning process in diagram form.

Balancing the capacity works in the same way as discussed in relation to the fixed allocation system (5a). Preprocessing activities are executed to make the planning problem at the fine planning level easier, especially for orders that show high trim losses.

The first stage consists of checking whether the customer order is technically producible (6a.1). An order is technically producible if the product specifications are valid. This means that the properties of the machines are such that they can do what is required of them, and the order quantity is above a minimum level. Internal guidelines may also determine minimum order quantities and minimum run sizes. A run consists of all customer orders with the same caliper, the same liquid percentage, and the same
recipe in the same production week. If these parameters have disallowed values, the 
order will not be accepted.

Suppose the order is accepted. The next stage is to analyze the cardboard 
machines’ loads in the required production week (6a.2). If the preferred cardboard 
machine has too many orders, one way of removing this imbalance is to shift a partial 
set of orders to a machine with available capacity. The company regards the card-
board machine’s lower and upper limits as being an acceptable workload.

If the workload is acceptable for the production machine, the next stage is to 
consider what combination of options is best for each specific order. Options combi-
nations show whether it is easy or not to plan the customer order so that there is an 
acceptable trim loss. As well as the dimensions, due dates are also taken into account. 
The way in which the orders are labeled is explained in the task “partitioning in sets” 
(PS). It will be discussed later. It uses a similar structure to the one used by the pro-
duction planners.

Partitioning into sets is a simplified way of separating jobs into the classes of 
“good”, “bad”, and “worse” orders. The results are used for specific orders. If an 
order cannot be run independently (6a.3), a suitable customer order for side-by-side 
planning is retrieved from the system.

If there are insufficient orders for acceptable trim loss, the next stage is look-
ing at the proposed production week for that particular order (6a.5). If it is in the cur-
rent production week, a solution will have to be found at the fine planning level 
(6a.6). The order will then flow into the fine planning system (7a). If a solution is 
found, the order will be accepted (6a.b). If the order has a proposed production week 
that is not the current one, the order is conditionally accepted (6a.b) and given addi-
tional attention together with the caliper where the customer order belongs.

If the order book shows sufficient orders in the specific caliper of the customer 
order (6a.4), the next stage is to do a so-called pre-trim. This means that the available 
order set is checked for possibilities of combination. The deckle shows the amount of 
cardboard that is not used for any order. If no deckle bench problems exist (6a.6), 
then the order is accepted. Otherwise, additional orders from consecutive weeks may 
be necessary; these orders are shifted to an earlier planning and production week 
(6a.c).

4.2.2.4. Partitioning in sets (PS)

<table>
<thead>
<tr>
<th>Input:</th>
<th>customer order</th>
</tr>
</thead>
<tbody>
<tr>
<td>Process:</td>
<td>classify orders with respect to due date and trim loss</td>
</tr>
<tr>
<td>Output:</td>
<td>order that belongs to one or more of the following classes: urgent order/non-urgent order, orders on call, independent running order, dependent orders with/without combination</td>
</tr>
</tbody>
</table>

The construction of partitioned sets is on the basis of a pattern-recognition structure. 
The task depends on the experience of the production planner and the orders in a spe-
cific caliper. It is used at both the rough and fine planning levels to classify the orders 
with respect to:

- urgency of orders (tight deadlines)
order dimensions that, together with the distribution of the orders within a caliper, depend on whether the customer order will be processed with high or low trim losses.

Figure 18 shows the criteria that have been used to classify a customer order. In order to have a complete overview, a combined set of criteria has been used. Each item triggers the subsequent processes. At the start of the process there is a set of orders that is unsorted. The first process is examining the delivery date (PS.a). The sets are partitioned into three groups (PS.b): orders with and orders without tight deadlines, and orders on call. Set A denotes orders with dominant due dates, which means that the restriction on the due date is tight. Set B denotes orders with non-dominated due dates, and set C shows all orders on call that have not been called off.

Note that the order set as a whole is equal to \( A \cup B \cup C \). A distinction will now be made between planning week and production week. The production week is equal to the week in which the order runs on a production machine (normally the cardboard machine) in order to keep to the deadline. A planning week is the week in which the production plan that assigns the order to a production machine is constructed. A planning week is generally earlier than the production week. If a customer order is split, things will become more difficult.

The next stage is assigning the value of the current planning week to variable \( k \) (PS.c). The first condition is to split the set into two separable sets: one of orders that run independently and one that needs an additional order for an acceptable trim loss. (PS.d and PS.e). If the order needs an additional order – a judgment about the difficulty of planning the particular order – it is labeled “easy” or “hard” (PS.f).

The other alternatives for the next two weeks are examined, and the classification repeated again for one of the consecutive weeks (PS.f). If \( k \) is larger than the planning week +2 (PS.1), an appropriately partitioned set will have been obtained or this procedure will stop.

Set \( D_k \) includes the orders of planning week \( k \) that do not need any other order during production, because the trim loss that belongs to this order is considered acceptable. Set \( E_{k,1} \) shows the orders of planning week \( k \) with dimensions for which it is hard to find any alternative, and set \( E_{k,2} \) shows those orders of planning week \( k \) that need another order, though for these orders alternatives will be easy to find. Note that the whole order set is equal to \( D_k \cup E_{k,1} \cup E_{k,2} \).
Figure 18: Construction of various sets

Suppose that a particular customer order has the following characteristics:

- it has an urgent delivery date
- it is hard to find other orders to combine it with

This order will belong to both set $A$ and $E_{k,1}$. 

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The notion of whether it is easy to find one order to combine with another depends on circumstances at a particular moment; for example, the order book for the consecutive weeks in a particular caliper. It is difficult to give hard guidelines for separating orders that are difficult to plan from those that are easy to plan. As a rule of thumb, the interval from dimensions with maximal trim loss to a trim loss of 20% generally covers the class of orders that are “hard” ones.

Example 6: Construct the partitioned sets

Suppose we have an order entry with preference machine CM-2. The CM-2 has a planning width of 2.760mm. Suppose we already have the following set of orders in a particular grade, say 2.25 mm. The data lists as follows.

<table>
<thead>
<tr>
<th>Label</th>
<th>Order no.</th>
<th>Accepted weight</th>
<th>To be produced (tonnes)</th>
<th>Dimensions</th>
<th>Direction</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>63264-1</td>
<td>4200</td>
<td>4200</td>
<td>553 x 1082</td>
<td>LG</td>
</tr>
<tr>
<td>2</td>
<td>62435-1</td>
<td>26924</td>
<td>26924</td>
<td>635 x 970</td>
<td>SG</td>
</tr>
<tr>
<td>3</td>
<td>63328-1</td>
<td>62979</td>
<td>62979</td>
<td>663 x 718</td>
<td>LG</td>
</tr>
<tr>
<td>4</td>
<td>64224-1</td>
<td>3500</td>
<td>3500</td>
<td>663 x 874</td>
<td>LG</td>
</tr>
<tr>
<td>5</td>
<td>63967-1</td>
<td>45533</td>
<td>45533</td>
<td>663 x 969</td>
<td>LG</td>
</tr>
<tr>
<td>6</td>
<td>62896-1</td>
<td>9300</td>
<td>9300</td>
<td>669 x 979</td>
<td>LG</td>
</tr>
<tr>
<td>7</td>
<td>63744-1</td>
<td>21939</td>
<td>21939</td>
<td>889 x 914</td>
<td>LG</td>
</tr>
<tr>
<td>8</td>
<td>61907-1</td>
<td>3212</td>
<td>3212</td>
<td>920 x 1065</td>
<td>LG</td>
</tr>
<tr>
<td>9</td>
<td>63745-1</td>
<td>25312</td>
<td>25312</td>
<td>946 x 991</td>
<td>LG</td>
</tr>
<tr>
<td>10</td>
<td>64064-1</td>
<td>3600</td>
<td>3600</td>
<td>973 x 688</td>
<td>SG</td>
</tr>
<tr>
<td>11</td>
<td>64062-1</td>
<td>5900</td>
<td>5900</td>
<td>979 x 629</td>
<td>SG</td>
</tr>
<tr>
<td>12</td>
<td>64083-1</td>
<td>3600</td>
<td>3600</td>
<td>979 x 706</td>
<td>SG</td>
</tr>
<tr>
<td>13</td>
<td>63737-1</td>
<td>20707</td>
<td>20707</td>
<td>1245 x 1232</td>
<td>SG</td>
</tr>
<tr>
<td>14</td>
<td>62911-1</td>
<td>25500</td>
<td>25500</td>
<td>1318 x 975</td>
<td>SG</td>
</tr>
</tbody>
</table>

Dimensions
Extracted from order data of 01-07-1997
This set of data shows how a feasible plan is constructed. This example will not give the planner any real problems. However, with respect to the trim loss, he will construct the following three sets (the numbers in the sets refer to their corre-

\[
D_k = \{7, 8, 13, 14\}
\]

\[
E_{1,1} = \{9, 10, 11, 12\}
\]

\[
E_{2,2} = \{1, 2, 3, 4, 5, 6\}
\]

In general, the orders that run independently with a trim loss of less than 10% are considered ones that need to be combined with another order. In this instance, two types can be identified: those orders that are difficult to run, and those that are easy. The degree of difficulty is not particularly great in this particular example; in general, problem jobs will register at just above the 920mm. This corresponds to set \(E_{1,1}\). Finally, set \(E_{2,2}\) denotes the “easy” to plan orders.

The sets are used to place a customer order in the “correct” production week so that there is maximum machine output. During the fine planning stage, the pattern recognition structure is again used to make decisions relating to that level.
4.2.2.5. Fine planning stage (7a)

| Input:  | set of orders with the same product characteristics |
| Process: | construct production plan by combining customer orders, determine the sequence in and between the runs |
| Output: | production plan, sequenced runs, the runs have assigned customer orders |

After rough planning the order flows to the fine planning stage. In the fine planning stage the orders are assigned to runs, the sequence of the orders in the run determined, and the sequence of the runs in between determined. This stage is far more complex than the previous one. Figure 19 shows the sequence of subtasks in the fine planning for headlines.

![Diagram of fine planning stages](image)

**Figure 19: Fine planning in diagram form**

It will be seen that fine planning consists of the following subtasks. Firstly, the available capacity on the preferred cardboard machine is checked (7.a.1). Note that the balance is controlled at the rough planning level, but adjustments at the fine planning level may cause unbalanced workloads across the production machines in a particular production week. The workload thus needs to be checked again at the fine planning level and, if necessary, batches of orders rearranged (7.a.2).

If everything is satisfactory, the next task is to arrange the order of the calipers (7.a.3). In a particular caliper, one or more runs may take place. After that, the positions within the run (7.a.4) are determined. This particular subtask can be modeled as a cutting stock problem, a problem which has been studied intensively in the literature (see e.g. Goulimis, 1990 and Dyckhoff & Finke, 1992).

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As soon as the positions have been determined, the sequence can be arranged (7.a.6). Upon completion of all these stages, the production plan is ready and can be approved (7.a.7) to be sent to the production department (PD). However, the design of the information system is such that the production plan can only be sent to the PD (7.a.8) if the orders in the particular run have already determined pallet sizes and number of pallets (PN). This is thus the next task that has to be performed.

Having shown the broad lines of the fine planning stages, they will now be analyzed in greater detail.

*Check on available capacity (7a.1)*

<table>
<thead>
<tr>
<th>Input:</th>
<th>aggregated order data with capacity load</th>
</tr>
</thead>
<tbody>
<tr>
<td>Process:</td>
<td>take over some orders if there is an imbalance</td>
</tr>
<tr>
<td>Output:</td>
<td>balanced output over the particular production machine</td>
</tr>
</tbody>
</table>

If the load on a cardboard machine is very high, the planning is sensitive to disruption of production and demand. In order to avoid these effects, the load on the machines needs to be balanced. Each order has a machine of initial preference; this is determined by the allocation system. However, in practice, the allocation will not balance the load on the machines effectively enough.

The imbalance may already have been noticed at the rough planning level, but it now takes on greater significance since it is at this stage that production plans have to be released to the work floor for mill production.

Figure 20 shows the aspects relevant for determining the machine load for the CMs and whether or not to shift orders from one machine to another.

If the machine load is very high (7a.1.1), some customer orders should be shifted to one of the consecutive weeks, or to another cardboard machine (7a.2). If all machine loads are balanced (7a.1.2) the next subtask can be started, *determining the arrangement of the calipers* (7a.1.3). If not, the cardboard machine can take some customer orders over from another cardboard machine. There must be a request to take a collection of orders over (7a.1.3).

A cardboard machine can adopt an order if:

- there are no technical reasons for not being able to manufacture this order (7a.1.4)
- lining paper supplies are sufficient to manufacture this additional order (7a.1.5)

Rush orders from the Converting Department (CD) need special attention. If no CD rush orders are in the order batch, the cardboard machine can take a part of the batch over (7a.1.6). If there are rush orders in the batch (7a.1.6), then the following considerations are important. If the due dates are tight, the cardboard cannot be produced at the Lake Site because too much handling time is needed to have everything ready on time (7a.1.7). These orders should be manufactured at the Sand Site, the production site where the CD is located.
Check on available capacity (7a.1)

Acceptable CM load for the planning week (7a.1.1)

Is there too great a load on the other CM? (7a.1.2)

Yes

Determine arrangement calipers (7a.3)

Is there too great a load on the other CM? (7a.1.2)

No

Shifting orders (7a.2)

Is there too great a load on the other CM? (7a.1.2)

Yes

Is there a request to take over a part of another CM's batch? (7a.1.3)

No

Is CM technically capable of taking over part of another CM's batch? (7a.1.4)

No

Is there sufficient lining paper to take over the batch? (7a.1.5)

No

Is there a request to take over a part of another CM's batch? (7a.1.3)

Yes

Is CM technically capable of taking over part of another CM's batch? (7a.1.4)

Yes

Is there sufficient lining paper to take over the batch? (7a.1.5)

Yes

Rush CD order so that the batch can be taken over? (7a.1.6)

Yes

Location CM = Lake site (7a.1.7)

Yes

Sufficient orders if rush orders are left out? (7a.1.8)

Yes

Take over part of the batch without rush CD orders (7a.1.c)

No

Take over part of the batch (7a.1.b)

Do not take over part of the batch (7a.1.a)

Figure 20: Capacity check
If these requirements are satisfied, the cardboard machine can take some production orders over (7a.1.8). These orders will flow into the respective run. The next stage is determining of the caliper sequence (7a.1.3).

*Shifting the orders (7a.2)*

| Input: | set of customer orders assigned to a specific cardboard machine, to be produced in a specific production week |
| Process: | shift set of orders with respect to the cardboard machine and the production week |
| Output: | new distribution of customer orders across the cardboard machines to be produced in a specific production week |

In the event of too great a machine load, some orders will be shifted to either another cardboard machine, or to the same cardboard machine, but be produced in one of the following weeks. Figure 21 shows the stages in this subtask.

If another cardboard machine has some capacity available to take over a part of the order batch, the *capacity check module* (7a.1) is used.

Shifting orders is necessary if any of the cardboard machines has under- or over-capacity. It starts to initialize some parameter values (7a.2.a). If another cardboard machine has some capacity available (7a.2.1) to take over the order batch, a request to take over the order batch is made (7a.2.b).

At this point, the other cardboard machine initiates the capacity check module (7a.1), and the request intervenes at (7a.1.3). It continues to check the feasibility of fitting in the order batch on the other machine. If the takeover is granted (7a.2.2), the order batch or a part of it is contracted out to the order cardboard machine (7a.2.c). If the takeover is refused, the capacity problems should be resolved in respect of that particular cardboard machine only. If the orders on call can be shifted to one of the following weeks (7a.2.3 and 7a.2.4), the order production week is changed (7a.2.d). If the orders on call cannot be shifted, consultation with the Commercial Department is necessary (7a.2.a).

As already mentioned, orders at buyers’ option do not have a specified delivery date. Estimations about the risk of delivering late to the customer are based on acceptability. If the risk of being too late is acceptable, the orders are shifted to one of the following weeks.

The next check is whether the available capacity on the particular cardboard machine is sufficient (7a.2.5). If this is the case, the fine planning flows into the next stage of determining the arrangement of the calipers (7a.3). If not, the module runs again.
Figure 21: Shifting orders

Determine arrangement of the calipers (7a.3)

<table>
<thead>
<tr>
<th>Input:</th>
<th>orders sorted on caliper</th>
</tr>
</thead>
<tbody>
<tr>
<td>Process:</td>
<td>determine a provisional arrangement of calipers</td>
</tr>
<tr>
<td>Output:</td>
<td>provisional arrangement of calipers</td>
</tr>
</tbody>
</table>

Theoretically, the caliper sequence is very simple: manufacture from thin to thick cardboard and vice versa. The tight delivery dates of some customer orders (including those manufactured for the CD) disturb this ideal pattern and cause extra setup costs.
Based on the available information, a provisional arrangement of calipers is determined for each week. New rush orders may mean that the arrangement has to be changed around.

Figure 22 shows in diagram form on what basis decisions relating to the caliper sequence are made.

**Figure 22: Arrangement of the calipers**

The most important conditions determining the caliper sequence for customer orders are:
- How urgent deadlines are (7a.3.1); and
- Availability of lining paper (7a.3.2).

Where there are no lining paper problems, calipers for customer orders which have urgent delivery dates should be manufactured at the beginning of a production week (7a.3.a). If both conditions hold, the arrangement is determined by both the delivery dates and the amount of lining paper that is available (7a.3.b). If these two conditions are not strict, the sequence can follow pattern for optimal results(7a.3.c). If lining paper availability is the only impediment, the particular run might be split into two pieces (7a.3.d). If that is the case, orders with urgent delivery dates are produced first, followed by another run and a return to the rest of the run as soon as the lining paper is finished on the paper machine and ready to be used as input.
A customer order delivery date will be regarded as urgent if the delivery date falls in the production week, and thus the time available to both manufacture and load the order is very short. Urgent delivery dates influence both the sequence of the calipers and the sequence of positions within a particular run.

The issue of whether there is sufficient lining paper for a particular caliper can be decided as follows. First, calculate the lining paper needed for each run. Do the same for the available supplies of lining paper for each weight that is in stock. Estimate the starting date and time of the run on the cardboard machine and determine the gap between available and required amount of lining paper.

**Determine separate runs (7a.4)**

<table>
<thead>
<tr>
<th>Input:</th>
<th>orders sorted according to caliper, liquid percentage and assigned cardboard machines</th>
</tr>
</thead>
<tbody>
<tr>
<td>Process:</td>
<td>select a set of orders with the same characteristics to form a run</td>
</tr>
<tr>
<td>Output:</td>
<td>one or more runs</td>
</tr>
</tbody>
</table>

After the caliper sequence has been determined, the next step is to decide which orders should be included in a particular run. A run is a collection of orders with the same product specifications, produced on the same cardboard machine in a particular production week. The size of a run is an important issue. It should not be too small, otherwise the cardboard machine will need too many setups. On the other hand, it should not be too large, because this can result in exceeding the deadlines for other customer orders, or problems in later planning. If a production plan is entirely made up of orders of a particular product type in a particular caliper, and a new rush order enters the planning system, combination problems may be encountered. In order to avoid such situations, orders for “popular” caliper product types are split into two or more runs; normally one run at the start and one run at the end of a production week. This gives some flexibility for relatively easy resolving of combination problems relating to new rush orders.

Figure 23 shows the way in which the runs are constructed.

Both the planning week and the production week will now be considered (7a.4.a), and the total amount of orders in a particular caliper examined (7a.4.b). If the size of the run is too small (7a.4.1), additional orders will be inserted. The first candidates for insertion are the orders for the next two weeks. The production week counter is increased by 1 (7a.4.c), and orders with the same requirements are added to the run (7a.4.d). If the size of the run is still too small, and the liquid percentage of the run is equal to 7% (7a.4.9), then orders of the same product type and caliper but with a liquid percentage of 8% may be added to the 7% run (7a.4.e). The size of the run will hopefully be above the lower limits. If not, this may create problems.
Determine separate runs (7a.4)

Initialization

1. Determine separate runs (7a.4)
2. Initialization
   - h:=current planning week
   - k:=current production week

Sufficient orders to construct a run?

1. Examine total amount of orders in particular caliper (7a.4.1)
   - yes
   - no
   - Sufficient lining paper available?
     - yes
     - no
     - Sufficient "own" lining paper for all orders in run?
       - yes
       - no
       - Sufficient orders to divide run into two runs?
         - yes
         - no
         - Construct two runs: plan one now, the second at the end of the week (7a.4.1)

Sufficient lining paper available?

1. Assign orders or partial orders production week k that have the same requirements as those in production week h (7a.4.2)
   - yes
   - no
   - Order with EAO instruction with respect to smoothness of the product?
     - yes
     - no
     - Assign these orders in "own" lining paper run (7a.4.3)

Liquid percentage of run equal to 7%?

1. yes
   - Assign partial orders production week h with liquid percentage of 8% to run of 7% (7a.4.4)
2. no
   - yes
   - no
   - Exchange some orders between two runs (7a.4.5)

Determine separate positions (7a.5)

Figure 23: Determine the separate runs

The second stage consists of checking lining paper supplies (7a.4.2). Most lining paper is produced on the firm’s own paper machines. If the capacity is too low, Cabofa purchases lining paper from outside the firm. Some customers will specify cardboard with properties that can only be satisfied by using the firm’s own lining
paper. These orders should not be manufactured using lining paper from an external source.

If the need for lining paper cannot be met by what is currently available, one of the following can be done:

- Reduce the run size (7a.4.i), or
- Change the sequence of the runs such that runs in calipers with available lining paper are manufactured first (7a.4.3), and / or
- Revise paper machine planning (8)

It may also happen that the supplies are adequate, but the customer imposes additional requirements such as manufacturing the cardboard with a particular type of lining paper. The effect may thus be that the firm’s own lining paper supplies are insufficient (7a.4.3). The run will then be split into two separate runs, one using the firm’s own lining paper, and one using lining paper from an external source (7a.4.f). Special attention is given to the so-called Extra Attention Orders (EAO orders). These orders (7a.4.4) are generally manufactured with the firm’s own lining paper (7a.4.g). If the run lengths are acceptable for both runs (7a.4.5), all that will then remain for construction of the run is determination of the sequencing of the runs: which run should come first. This is the only decision to be made at this stage (7a.4.1). After determining this, fine planning will shift to the next stage of determining the separate positions (7a.5). If the run lengths are not acceptable, an exchange between the two runs takes place (7a.4.h) and the production circuit will return to the EAO level (7a.4.4).

If the order can be manufactured from the firm’s own lining paper (7a.4.3), then a split of the run is considered in order to create flexibility for the rest of the week (7a.4.6). Two runs will then be constructed, one at the beginning and one at the end of the production week (7a.4.1). After each has been constructed, the next stage is to determine separate positions.

*The flow from determining separate positions to an approved production plan (7a.5), (7a.6), (7a.7), and (7a.8)*

| Input: | run that consists of a set of orders of the same product type, the same caliper, and the same liquid percentage |
| Process: | production plan construction |
| Output: | a production plan stating which orders are in the run and how the orders are manufactured on the cardboard machines |

Both a provisional arrangement of the calipers and a selection of which orders are in which run have already been determined. The orders now need to be analyzed in order to ensure minimal trim losses. Orders generally run together on the cardboard machine, resulting in a deckle not being used.

Figure 24 shows the way a run consisting a selection of orders becomes a production plan.
Figure 24: Outline of how the separate positions are determined

The first stage consists of determining the positions of the orders to ensure minimal trim loss. This process is also called trimming (7a.5.1). Normally, the next stage consists of determining the arrangement of positions (7a.6) within the run. The production plan will have been finalized after this is done, and is then approved (7a.7) and sent to the production department (PD).

In some cases the orders in the run cannot be combined so that there are acceptable trim losses (7a.5.2). A way of solving this problem is to add or remove some of the orders on the run (7a.2). Internal orders may be created in dimensions that can be sold in the near future. These orders are then stored.

The creation of internal orders need not always provide an acceptable production plan. The poor production plan will then just have to be accepted; the agreed-upon due dates will make this necessary (7a.5.3).

TRIMMING THE ORDERS IN THE RUN

| Input:       | run with orders |
| Process:     | assign one or more orders to a position, which will give a specified trim loss |
| Output:      | positions such that all orders in the run will be processed with an acceptable (minimal) trim loss |
The main task here is to combine orders so that their run on the cardboard machine has a minimal trim loss. It is one of the most important elements of the fine planning stage. This problem has already been studied intensively at the theoretical level in the field of Operations Research. The problem is termed the “cutting stock problem.” Among other writers, Goulimis (1990) and Dyckhoff & Finke (1992) have proposed algorithms to solve this problem.

The standard way of determining combinations of orders will now be analyzed. Figure 25 shows the order trimming process in diagram form.

Figure 25: Trimming customer orders

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The first stage is initialization of the parameters to ensure sound results (7a.5.1.a). The partitioned sets (PS) constructed previously will be used again. A customer order that is difficult to plan – it will have a high trim loss if it runs alone – is selected from the partitioned sets (7a.5.1.b). This order is combined with other orders, preferably from the same set \( E_k \). If this set does not contain orders that give good combinations, a customer order from set \( D \) is selected.

If the order produces a solution (7a.5.1.1) the position is added to the production plan (7a.5.1.c). A new order from the set \( E \) (7a.5.1.2) is then selected and the process continues.

If the orders cannot be combined, the planning for one or more weeks ahead (7a.5.1.e) is considered. If no options are available in these weeks (7a.5.1.3), then a new internal order may be constructed if it is commercially acceptable (7a.5.1.4, 7a.5.1.e). This sideline order is simply an internal order that runs side-by-side with the selected customer order and with sheet dimensions such that the trim losses are acceptable.

A sideline order with unsaleable sheet dimensions is a problem (7a.5.2). One option is to create a sideline order that is thrown away after production.

After selection of the combination, the production plan construction process continues. If all orders that belong to the set \( E \) can be planned (7a.5.1.2), the planning problems in this stage will have been evaded. Orders from the set \( D \), which have to be planned for the current week, will not produce any planning problems. These orders will simply run alone, or two or more orders from this set combined if this results in a trim loss decrease (7a.5.1.d).

After constructing all positions such that all orders that are in the run can go through all the manufacturing processes, the next stage is determining the arrangement of the positions in the run (7a.6).

Now that the trimming stage has been described, the following simple example may make it more concrete.

**Example 7: combining two customer orders**

If customer order \( A \) has a width of 1,000 mm, and customer \( B \) a width of 700 mm, these orders might be combined such that order \( A \) runs in two strips, and order \( B \) in one strip. This will result in a trim loss of \((2,760-(2\times1,000+700)=60\) mm.

Customer order \( A \) belongs to the set \( E_k \) with a trim loss of 27.5% if it runs alone. In order to have an acceptable trim loss, order \( B \) is combined with order \( A \).

All of the sets of orders to be planned are analyzed in this way until all orders have been planned. The next step is determining the position sequence.
THE POSITION SEQUENCE

<table>
<thead>
<tr>
<th>Input:</th>
<th>positions in a run</th>
</tr>
</thead>
<tbody>
<tr>
<td>Process:</td>
<td>determine arrangement of positions in a run</td>
</tr>
<tr>
<td>Output:</td>
<td>sequence of positions in a run</td>
</tr>
</tbody>
</table>

Now that all orders in the run have been selected and have a combination such that the trim loss is minimal, the next thing to do is to rearrange the sequence of the positions so that the due dates are met. The selection of the sequence depends on three notions:

- Urgency of the deadline;
- How independently a particular customer order can be run; and
- The extent to which orders may have to be divided up across the positions.

The production plan is constructed in such a way that customer orders with an urgent delivery deadline are manufactured first. For technical reasons, orders that have to be run independently are produced in the last part of the sequence. Logistically, it is preferable to reduce the number of split orders. By this is meant that if order A runs in position 1, then it is preferable for position 2 to also contain order A. In this way the orders can be located at one place in the warehouse. If order A runs in one of the first positions of the run as well as in one of the last, it could well be that the pallets with cardboard sheets are at two different locations in the warehouse.

To give an example, if the machine breaks down, or there are other problems involving, for example, the knives or the slitters (the knives that face the reverse direction of the production flow), the run will be constructed in such a way that the independent orders can be manufactured first and the combined order part produced later. In this way the replanning process is reduced to the combined orders that have not been manufactured.

The production plan is now ready. However, before it can be sent to the PD, pallet requirements have to be determined. From a theoretical point of view, this is a new and independent task.

**Link between rough and fine planning**

Rough and fine planning are closely connected. A production planner performs both tasks. Although the differences are difficult to detect in practice, the tasks differ in the entities that are tuned. These tasks occupy the same position on the planning hierarchy.

From a theoretical point of view, rough and fine planning represent different stages in which the production planner is coordinating different objects. Reducing the overall complexity or at least making it manageable by various projections within a particular solution space is the way to resolve the problem. In the fine planning stage the planner decides when to run each order on the cardboard machine. For each site, the fine planning mode will be different. The planners at the Lake Site use a computer program to fine-tune the combinations of orders in a particular run, while the planners at the Sand Site make the production plan by hand.
The time available for the rough planning stage has been increased at the Lake Site. Because they have more time available, they use this time to make more adjustments at the rough planning level in such a way that the complexity of the problem of combinations at the fine planning level is reduced. The improved input goes to the computer program and the production plan proposal has a higher quality and needs fewer adjustments in comparison to the “original” input. In the final analysis, there is very little difference in the overall quality of the production plans at both sites, but the time spent on the overall planning task is less at the Lake Site because there are fewer areas in which man and machine need to interact.

Section 6.3 discusses the use of Paperclip and which planning tasks are supported. The changes in planning tasks that have taken place suggest that the best results can be obtained by extended and revised support at the rough planning stage. Some important considerations are the planning week and the production week. These have been defined above (see page 69).

The planner constructs a production plan for a particular run in a planning week (normally the current week, or next week). He analyzes the combination possibilities in respect of the orders that are in the run. If there are some problems, the run may be extended by:

- Adding orders that are to be made to the same recipe and in the same planning week but are not in the run yet, or
- Adding orders with the same caliper, the same planning week, but a different liquid percentage (and thus a different recipe), or
- Adding orders with the same characteristics as the two types discussed above, but in one of the consecutive weeks

The extended run is evaluated again, and the production planner examines the average trim loss of the constructed run. If the trim loss has an acceptable value, the production planner continues his search for alternatives, or will delete a “bad” order whose deadline is not yet urgent. The process continues until the trim loss has an acceptable value, or improvements are not acceptable if weighed up against other costs such as higher storage costs for orders that will have to stay for a longer time than usual in the warehouse.

4.2.2.6. Pallet need (PN)

<table>
<thead>
<tr>
<th>Input:</th>
<th>production plan, strips of order in a run</th>
</tr>
</thead>
<tbody>
<tr>
<td>Process:</td>
<td>determine pallet need and pallet height for a customer order</td>
</tr>
<tr>
<td>Output:</td>
<td>pallet need and pallet height</td>
</tr>
</tbody>
</table>

After the production plan has been prepared, the number of pallets is determined. How many are needed will depend on the cardboard machine’s properties as well as the particular shipping instructions. Figure 26 shows the stages in this process in diagram form.
Figure 26: Pallet needs for a particular customer order
The pallets needed are determined in the following way. Firstly, the variables are initialized (PN.a). We shall define \( v \) as being the number of required sheets, \( w \) the number of sheets per pallet, \( x \) the number of pallets, \( y \) the pallet height, and \( z \) the number of strips in a production plan.

The current Logistical Information System shows five proposals for pallet height and the number of pallets available to fill a customer order. Manual entry of the variables is also possible. From the alternatives, one is selected (PN.b), meaning that \( x \) pallets have been selected with a pallet height of \( y \) millimeters; each pallet has \( w \) sheets (PN.1). The theoretical number of pallets, the pallet height, and the number of sheets per pallet give the total amount of sheets. This will usually not be enough for the order. If the difference is acceptable (PN.2), the next stage is to look at the most efficient way of piling the pallets onto the truck (PN.b). If it is not acceptable, another alternative is selected (PN.d).

Transport restrictions are then checked. Certain countries in Europe do not allow lorries with a load higher than a particular value (PN.4). If these restrictions are likely to be violated, the pallet height or number of pallets is decreased (PN.f). This might result in an underdelivery for this particular customer order.

The next issue to evaluate is the number of strokes on the machine. If the order runs in two strokes, the number of pallets should be even; if it is three, the number of pallets is a multiple of three (PN.5). If this gives problems, the number of pallets should be adjusted (PN.g). Converting of orders may mean that two different pallet sizes are needed, one for internal use and one to deliver to the customer. If the dimensions are different, two types of pallet requirements have to be determined (PN.h). The “internal” pallets are delivered to the cardboard machine; the “external” pallets to the converting machine. If the dimensions of the “internal” and “external” pallets are equal, but the number of pallets is different (PN.8), and production needs more “external” than “internal” pallets (PN.9), then the additional “external” pallets are delivered to the converting machine; the “internal” pallets to the cardboard machine.

The end result is that pallet need and pallet height will have been determined (PN.k). The pallet order is then directed to the pallet supplier (PN.2).

4.2.2.7. Paper machine planning (8a)

<table>
<thead>
<tr>
<th>Input:</th>
<th>lining paper need for each run on the cardboard machine</th>
</tr>
</thead>
<tbody>
<tr>
<td>Process:</td>
<td>determine size of the lining paper runs and the queues on the paper machine</td>
</tr>
<tr>
<td>Output:</td>
<td>arrangement of lining paper runs on the paper machines, including the sizes of the lining paper runs</td>
</tr>
</tbody>
</table>

Paper machine planning is the second type of planning that is carried out within the Mill Planning Department. It will be recalled that there was an overview of this in Figure 16.

The most important factors determining the sequencing of lining paper runs are:

- available lining paper stock in particular weights
- urgent customer order deadlines.
If a particular caliper on the cardboard machine requires a lining paper weight of 200 g/m² and this is not available, a decision may be made to use thinner or thicker lining paper, for example 225 g/m² if supplies of this weight are sufficient.

Stock levels and expected supply of orders will have an effect on both the paper machine and the cardboard machine. If stock levels are too low, the paper runs will have to be changed to smaller paper runs. However, longer paper runs are preferred. Figure 27 shows the subtasks of the paper machine planning task.

**Figure 27: Paper machine planning**

Production plans include cardboard machine planning for the next 4 or 5 days (8a.1). The first stage is determining the lining paper required for each run on the cardboard machines. Lining paper need has to be calculated for runs requiring the same type of lining paper for that particular grade.

Given the available lining paper stock (8a.3), the amount of lining paper to be produced is estimated. Throughput times on both the cardboard machine and the paper machines are estimated (8a.4, 8a.5). If the lining paper is not available in time, sharing supplies among the paper machines (8a.6) is an option, or else splitting the runs on the cardboard machine.

The definitive lining paper production plan is determined (8a.7). If it is approved (8a.8), the paper production plan is sent to the production department (8a.9).

**4.2.3. Converting Planning (IB.)**

Converting planning is less formalized in comparison to the other planning subtasks. Figure 28 shows the converting process.
After commercial acceptance, a small format order flows to the small format decision module (3). If the order needs die cutting it is processed on the die cutting machine, otherwise on the rotary cutting machine. Besides technical restrictions, the capacity also determines the type of machine that is used. If the capacity on the rotary cutting machines is too low to manufacture all rotary cut orders, some of these orders can be produced on the die cutting machine; the other way around is not possible.

The difference between a rotary and a die cut format has already been shown in Figure 7. Rotary cut activities are the most important ones in the Converting Department. The policy of the company is to manufacture all small sheets in-house in order to reduce the outsourcing of customer orders.

As with mill planning, there is an allocation system (5b1, 5b2), and rough (6b1, 6b2) and fine planning (7b1a, 7b1b, 7b2a, 7b2b, 7b2c, 7b2d, 7b2e). Converting of rough planning directly influences rough planning for the CMs because accepted orders automatically flow into the rough planning customer order list. This is one of the reasons for the capacity check of the cardboard machine taking place at both the rough and the fine planning level.

This brief sketch of the main converting planning processes will now be followed by a detailed description of each type of converting planning.
4.2.3.8. Rough converting planning (6b)

<table>
<thead>
<tr>
<th>Input:</th>
<th>customer order entry</th>
</tr>
</thead>
<tbody>
<tr>
<td>Process:</td>
<td>accept small format orders and assign an associated large sheet</td>
</tr>
<tr>
<td>Output:</td>
<td>large sheets associated with small format order</td>
</tr>
</tbody>
</table>

Rough converting planning takes place for two types of orders: rotary cut and die cut orders. The two types are treated differently during the rough planning stage. For each particular customer order, there will be considerable time pressure between this stage and the delivery date. As a rush order is always likely, the large format should be in stock. How to determine an efficient large format stock is discussed in Wanders et al (to appear).

If the deadline is not tight, a large sheet is applied with dimensions such that the trim loss with respect to the converting machines is minimized. The total trim loss should be kept to a minimum.

4.2.3.9. Allocation system for the rotary cut machine (5b2)

<table>
<thead>
<tr>
<th>Input:</th>
<th>small format orders</th>
</tr>
</thead>
<tbody>
<tr>
<td>Process:</td>
<td>assign order to a rotary cut machine</td>
</tr>
<tr>
<td>Output:</td>
<td>small format orders assigned to rotary cut machine</td>
</tr>
</tbody>
</table>

At this stage, choice of rotary cut machine is made. The knives necessary to cut the orders and the type of order will determine to which rotary cut machine the order is assigned. The available machines have been labeled RCM 2, 3, 4, and 6. There is no formalized system, as is the case with the cardboard machine. However, Table 3 shows how the allocation system works when it is used for initial assignment.

Table 3: Allocation system for the rotary cut machine

<table>
<thead>
<tr>
<th>Rotary cut machine</th>
<th>Order type</th>
<th>Arrangement at machine</th>
</tr>
</thead>
<tbody>
<tr>
<td>RCM-2</td>
<td>Binder sheets</td>
<td>2x3 and 3x4</td>
</tr>
<tr>
<td>RCM-3</td>
<td>Sizes in between</td>
<td>3x4, 4x4 and 5x3</td>
</tr>
<tr>
<td>RCM-4</td>
<td>Binder sheets</td>
<td>2x3 and 2x4</td>
</tr>
<tr>
<td>RCM-6</td>
<td>Small orders, small sheets</td>
<td>several</td>
</tr>
</tbody>
</table>

All customer orders that will be applied in binders are assigned to RCM 2 and RCM 4. The main difference is in the arrangement of the small sheets within the large sheet. Orders of small size and orders with small dimensions are assigned to the RCM 6. Orders that have not been assigned yet are assigned to the RCM 3. In this way the number of setups on a particular machine is reduced. This increases the maximum output of the converting machines.

Although Table 3 gives guidelines for the assignment of small format orders to the rotary cut machines, in practice this system is subject to many alterations. As with

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cardboard machine planning, the order book will have a considerable impact on the assignment of orders to machines.

4.2.3.10.  **Fine converting planning (7b)**

<table>
<thead>
<tr>
<th>Input:</th>
<th>small format orders on converting machine</th>
</tr>
</thead>
<tbody>
<tr>
<td>Process:</td>
<td>determine arrangement of orders</td>
</tr>
<tr>
<td>Output:</td>
<td>queue of small format orders on converting machine</td>
</tr>
</tbody>
</table>

Fine planning consists of determining the sequence in which the orders are processed on a converting machine. At the rough planning stage, a preferred machine is assigned to an order. Now the suitability of the machine preferred for the order is checked and the delivery date will more or less determine the sequence of orders on the converting machines.

4.3.  **Conclusions**

This chapter has given an overall view of the planning tasks in both the Commercial and Logistics departments. A system-oriented approach has been taken in order to detect those elements that play a prominent role in planning of the tasks.

The Commercial Department performs some planning tasks to reduce the complexity of order entry. The tool used is the so-called bucket system. The bucket system balances the machine load and accepts the orders that are “attractive” in a commercial sense (in terms of profitability, due dates, future expectations, and strategic decisions).

The Logistics Department performs a whole range of planning tasks. Although all of the planning tasks within the planning and scheduling domain have been analyzed, the focus has been on the mill planning tasks. The most important of these tasks is rough and fine planning for the cardboard machine. Both rough and fine planning contain a great many subtasks. These subtasks will be different for each production planner, although in general terms, each performs the same sequence of subtasks to achieve the desired goals. The broad similarities were a factor behind the choice of a system-oriented view.

The planners use their experience and knowledge to make decisions. Reasoning mechanisms and guidelines on which to base decisions may simplify the decisions to be made. Experience refines and improves these methods and guidelines. One of these mechanisms, often applied at both the rough and fine planning stages is **partitioning in sets**. It is one mechanism that depends heavily on the experience of the production planner. With this mechanism, orders are directed to a particular set that shows planning complexity based on dimensions and the current order book. The next stage is to start the planning process with the most difficult set. The partitioning in sets reasoning mechanism reflects the way the planner constructs a production plan.

Another aspect that has been discussed is the interdependency between several tasks and sub-tasks. It complicates the whole planning task because the planner
has to be aware of the effect of particular decisions in one stage on another stage within the planning process. The following example demonstrates this.

The Converting Department cuts small sheets from a large sheet. The converting planner determines the large format that is used as input. The large format is then usually manufactured on the cardboard machine. A decision (in this case, the dimensions of the large format) made at the converting planning level will thus have a considerable impact on some of the planning tasks carried out by the converting planner.

The same holds for the cardboard machine and paper machine. Laminated cardboard uses lining paper that is manufactured on the paper machine. Lateness of a lining paper run may disturb the planning for the cardboard machine.

These interdependencies make it necessary to perform the various planning tasks simultaneously. This means that during fine planning for the cardboard machine, restrictions relating to the paper machines are already under consideration, and vice versa. These elements make a thorough understanding of the planning process difficult. This analysis of the dynamics in the domain makes it clear that there is still good reason for breaking each planning process down into individual tasks, if only to enable careful analysis of the planning tasks. From a theoretical point of view, the planning tasks can be analyzed in an isolated fashion. The prototyping stage uses these analyses. However, before the prototyping stage gets underway, additional information is needed. The next chapter provides this information. Important entities within the planning and scheduling domain are analyzed. These analyses are based on verbal reports resulting from ‘thinking aloud’ sessions. After a description of the important entities, they will be shown within an object-oriented framework.

This chapter has focused on the task and inference knowledge level, a choice made on the basis of the commonKADS framework presented in the previous chapter. The next chapter, however, will have a domain knowledge level focus.