The Selection of Distribution Control Techniques

Sander de Leeuw  
Babson College

Ad R. van Goor  
Free University Amsterdam and Nyenrode University

Rien Ploos van Amstel  
Eindhoven University of Technology

Due to changes in the company and its environment, distribution control requirements will change. Knowledge of the criteria influencing the successful application of distribution control techniques is needed in order to make these changes. This article investigates these criteria. After a description of redesign of distribution systems, a framework of control decisions is introduced and explained. It is then shown how each of the decisions depends on the characteristics of the products distributed, the markets served and the processes used.

It has been frequently suggested that the company environment is constantly changing. Often quoted aspects are that customers are becoming more demanding, and that availability of timely information is key to efficient operation of supply chains (see for example [11], [2]). These industry trends have an impact on the way companies need to operate their distribution systems. For example, forecasting demand may become more difficult due to lumpiness of demand and the growing obsolescence risk of inventory. New opportunities are also arising through information technology capabilities that enable the application of more sophisticated distribution control techniques and faster information processing in supply chains.

Due to the changing environment, changes in distribution systems may be necessary. In stable environments, simple distribution systems and simple distribution control techniques can be applied. However, the volatility of the current company environment will force management to review distribution systems frequently. To keep pace with market trends and developments, managers will need to have instruments to enable them to judge the state of their companies’ distribution systems in a relatively short period. Furthermore, more complex control techniques must be applied to cope with the complexity of the environment. Knowledge of the criteria influencing the successful application of such techniques is needed.

Redesigning Distribution Systems

This article is concerned with the selection of distribution control techniques. Distribution control may be defined as:

“All activities taking place to coordinate the place and timing of demand over a finite horizon with the supply of products and capacities, in such a way that the objectives of the distribution process are met, given the characteristics of the product and the requirements of the market”[3].

In a era of rapid environmental changes and increasing complexity, the limitations of control techniques must be known. However, literature introducing new control techniques for distribution systems generally omits consideration of application criteria. Often, these techniques are introduced as a panacea for all distribution control problems (see for
an example [4]). Theoretical and practical evidence clearly shows that the successful application of a specific distribution control technique is limited to particular situations [5].

Research in production logistics has shown that control techniques have limited application areas. For example, the value of materials requirements planning (MRP) is confined to specific circumstances [6]. A major point of criticism is that these production control techniques do not justify the richness of variety in production control practice [7]. In line with this, Thomas and McClain [8] state that:

"...Research on the best way to develop a set of models including production planning can proceed in several ways. In limited situations, an optimal set of models may be developed... In most situations, how to choose an appropriate set of models will be an empirical question. Simulation studies can study the issue in particular situations, and perhaps, eventually, some large empirical study can ascertain the best among a few alternative ways of breaking up the task..."

Distribution control in the mathematically oriented literature is often confined to descriptions of mathematical models or to the setting of specific parameters. The book by Graves, et. al. [9] for example, contains models and parameter settings, but the evaluation of when to apply a specific model is omitted in most cases.

The design of new control techniques as a panacea for problems that cannot be solved with the usual techniques is not expected to solve all of the aforementioned problems. Rather, an instrument that can be used to select a distribution control technique in a specific situation is desirable. We investigate which characteristics of a company and its relevant environment are crucial for the selection of distribution control techniques and in which way they influence distribution control.

We will first describe the breakdown of distribution control techniques in a set of distribution control decisions. Then the characteristics that influence these control decisions will be investigated.

### Framework of Control Decisions

Several classifications of distribution control techniques have been presented in the past. A frequently used discriminatory parameter to explain differences between distribution control techniques is "push" versus "pull" [10], [11]. However, there is a wide variety of associations commonly linked to the terms "push" and "pull" [12]. Silver [13] gives a classification of inventory models, which has been elaborated by Prasad [14]. Both classifications are set up to classify inventory control theory by means of theoretically oriented aspects such as the type of demand processes assumed or the stock out policy. Only the theoretical capabilities of mathematical inventory control models are considered and therefore, they are omitted from this evaluation.

A more practically oriented classification is the one provided by Rosenthal and Pendock [15]. They use a differentiation between coupled and independent systems with centralized or decentralized control. However, their classification is only oriented at a specific part of distribution control.

In the following sections, a framework of distribution control decisions is presented, which uses elements of the classifications mentioned above. These control decisions are summarized in Table 1 and are described in the next sections.

<table>
<thead>
<tr>
<th>Control decision</th>
<th>Deals with...</th>
</tr>
</thead>
<tbody>
<tr>
<td>Type of reorder planning</td>
<td>The ability to incorporate a pattern in the planning of independent demand and dependent demand</td>
</tr>
<tr>
<td>Status information</td>
<td>The use of local or integral information for reorder purposes</td>
</tr>
<tr>
<td>Central stock function</td>
<td>Having both central stock and local stock or only local stock</td>
</tr>
<tr>
<td>Allocation coordination</td>
<td>Having a centrally or a locally (i.e., in the local DCs) coordinated allocation</td>
</tr>
</tbody>
</table>
The control decisions can be differentiated into stock replenishment decisions and stock allocation decisions. Stock replenishment in a distribution system means to fill a distribution system with inventory irrespective of the future location of the stock. The question "where to distribute the inventory" is thus not answered. The decision, where to put the inventory in the system is called stock allocation. Van Donkelaar and Wijngaard [10] and Diks and De Kok [17] further discuss the effect of different types of stock allocation rules in detail. Figure 1 depicts the difference between stock replenishment and stock allocation.

In a multi-echelon system, the allocation decision for the higher echelon might constrain the replenishment decision for the lower echelons and vice versa. This implies that the relationship between the replenishment and the allocation decision needs to be considered.

Type of Reorder Planning

The type of reorder planning can be categorized as the planning of independent and dependent demand. Independent demand concerns the demand of the final customer, dependent demand consists of the net requirements from the local DCs as paced by the central DC.

Independent demand planning deals with the question of which technique should be used to forecast demand. A difference is made between two types of techniques. The first type can incorporate patterns in demand and is referred to as a forecasting technique with a pattern. The forecast \( \hat{F}_{t+i} \), which is the forecast made at time \( t \) for period \( t+i \), may be different for each \( i \) at a specific moment \( t \). The second type is a technique that cannot incorporate patterns, called a forecasting technique without a pattern. As a result, all \( \hat{F}_{t+i} \) are the same for all values of \( i \) at a specific moment \( t \).

There are two possibilities to deal with dependent demand from the local DCs. In a time phased planning technique, it is attempted to predict the moment which a new order is generated by the lower echelon. The order is planned in such a way that the stock is available only just before it is needed. The other possibility is to discard the pattern of orders from the local DCs over time and to replenish up to a specific level based on the reorder of the local DCs. The effect on central stock levels for both time phased and non-time phased planning is shown in Figure 2.

Status Information

Status information is information about demand and stock levels in the distribution system. This applies to the replenishment of goods only. The status information that is used in the replenishment calculation can be either local or integral.

Local status information refers to information about stock norms for the inventory of one DC only - also called installation stock norms - and about local demand, the demand of the link next downstream. Integral information is information about stock norms for the
inventory of a complete system and about integral demand information, information about the demand of the independent customer (see Figure 3).

**Central Stock Function**

The central stock decision deals with the question whether a central depot function is needed for storing the replenished items or whether it is possible to use a central DC as a cross docking point only. At a cross-docking point, goods are not stored but are immediately shipped to the local DCs after receipt at the central DC. Figure 4 depicts a situation with a central stock function and one with only a cross docking point.

For simplicity reasons, this article is confined to distribution control in two-echelon inventory systems. We assume that the local DCs always carry some inventory (but not necessarily of all products).
Coordination of the Allocation Process

The coordination of the allocation process refers to the degree of centralized control [15], [18]. Locally coordinated allocation means that the local DCs order goods at the central facility on their own initiative. The frequency of allocation is dependent on the review frequency of the local stock.

Centrally coordinated allocation implies that the decision on the timing and the amount of the shipments of goods to the local DCs is not made by the local DCs, but by a central department. The replenishment batch may be completely allocated in one time to the local DCs or it may be allocated in fractions. The \( \alpha \)-policy [19] is a technique according to which the replenishment batch is allocated at two times. According to this policy, a fraction \( \alpha \) is allocated to the local DCs and a fraction \( 1 - \alpha \) retained at the central depot each time a new replenishment batch is received. As soon as there is a local need for a shipment, the remaining fraction \( 1 - \alpha \) is allocated to the local DCs in a centrally coordinated way. It is also possible that only the initial allocation is centrally coordinated and that the remaining stock is allocated to the local DCs in a locally coordinated way. In that situation, it should be determined when the next allocation will take place.

The terms centrally coordinated and locally coordinated allocation could be related to the terms “push” and “pull”. Push is generally related to central control of inventory [11]. Pull, on the other hand, is related to local control of inventory [11]. Brown [10] uses a similar differentiation between push and pull. There seems to be a certain disagreement or misunderstanding about what push and pull really means. Pyke and Cohen [12] argue that it is not possible to label an entire production or distribution system as push or pull. They introduced a framework to differentiate between elements in distribution and production that are push and that are pull.

The Use of the Classification

For each of the four decisions described, two options have been defined. For example, status information can either be local or integral. The options can be combined into a graph of nodes and branches. Going from the left to the right, a control decision needs to be made at each of the nodes.

The decision tree is first split into two sub-groups: replenishment and allocation decisions. Distribution control always consists of both replenishment and allocation decisions. The replenishment decisions can be discriminated into decisions on the type of status information and the type of reorder planning. The allocation coordination and the central stock function are not relevant as they do not influence the replenishment decision.

The allocation decisions consist of the central stock function, the allocation coordination, the status information and the type of reorder planning (Figure 5).

Each standard distribution control technique available can be defined in terms of the framework. DRP for example is a technique where the allocation is done with central stock, the allocation coordination is done locally, the status information is local and the type of reorder planning is time-phased. Distribution control can thus be defined by going through the graph from the left to the right. As a result, if we can make a
decision at each node of the tree we are able to make a grounded decision on distribution control. We can determine for example whether DRP is applicable or whether this technique needs to be implemented in a slightly adapted form. We are thus able to determine which standard control technique is the most appropriate.

In the next sections, we will describe which company and environmental characteristics influence the control decisions. We will present a general literature overview on characteristics influencing the four distribution control decisions. Subsequently, a case study analysis of three different companies is presented in which the reason for making particular distribution control decisions is analyzed. Last, the results of the literature review and the case studies are compared.

Characteristics Influencing Distribution Control: The Literature

Products are obtained from suppliers, either an internal production department or third-party supplier, and are delivered to the market. Information that is obtained from the market is sent back in the opposite direction (see Figure 6).

As the distribution system is located between these two entities, its functioning will be influenced by both. The market imposes requirements on the distribution process and the physical supply side only has a limited flexibility to react to these requirements. The design of a distribution control technique is dependent on the characteristics of the physical supply process and on the requirements of the market. Characteristics of the physical supply processes, the products distributed and the requirements of the market are the

The design of a distribution control technique is dependent on the characteristics of the physical supply process and on the requirements of the market.
characteristics that will be used for the selection of distribution control techniques.

Other authors use similar characteristics or a subset of them. Picard [20] uses product factors in the design of distribution systems. Hoekstra and Romme [21] indicate that the position of the customer order decoupling point—also referred to as the order penetration point—in production systems is influenced by characteristics of the processes used, the products distributed, and the markets served.

Below, we identify which of the characteristics of processes, products and markets are relevant for distribution control in the next section, the results of the literature search are summarized and then described for each of the distribution control decisions.

Reorder Planning

The question of how to deal with dependent demand has been researched extensively by Van Donkelaar [6]. Time phased dependent demand calculation is beneficial if there are strong and stable patterns in the dependent demand from the local DC at the central DC. These patterns may be the result of large distribution batch sizes or of large customer orders. If there are stable patterns, for example spikes, in the dependent demand from the local DCs at the central DC, time phased dependent demand planning is able to calculate the future dates a replenishment is needed to satisfy these dependent demand spikes, while accounting for lead times (see Figure 2 for a graphical explanation). In the remainder of this article, we will omit dependent demand planning since this has been thoroughly researched in an application oriented way by Van Donkelaar [6]. We will focus on independent demand planning (i.e., demand forecasting).

Assuming that there is enough data available for forecasting purposes, the possibility to forecast will generally become a problem if demand gets non-stationary, that is the mean and standard deviation of demand are changing in the course of time [22]. According to Makridakis [22], more sophisticated forecasting techniques do not necessarily lead to a better forecasting accuracy. This is supported by Alstrom and Madsen [23], who have investigated the logistics effect of different types of exponential smoothing forecasting techniques by means of simulation.

Silve and Peterson [24] argue that for cheap items and slow moving items, forecasts are not useful. The reason for this is that it is hard to achieve any sizeable absolute savings in the costs of these items. The guideline for these types of items should therefore be to keep procedures simple.

Status Information

The question whether integral or local information should be used in the replenishment of items is closely related to the topic of stock imbalance. Stock imbalance is related to demand uncertainty and lot sizing. Stock imbalance influences the performance in the following cases [25]:

- In a system with a central warehouse: if the variance of imbalance is considerable due to a long time between orders (i.e., large lot sizes) and the variation of demand (forecast error) is small, safety stock is relatively small due to the small variation in demand, while the imbalance is significant due to the lot sizes.
- In a system without a central warehouse (i.e., everything is allocated to the local DCs as soon as it arrives at a central cross.
docking facility; if there are large lot sizes and a large variation in the forecast error on demand.

The question whether imbalance is a problem is also influenced by the possibility of making transshipments between the local DCs. According to Rosenfield and Pendrock [15], transshipments to resolve imbalance problems are beneficial if it is relatively inexpensive to transship items. This implies that transshipments are worthwhile if the costs of capital tied up in inventory are relatively high and/or if the products are characterized by a high obsolescence risk.

Stock Position

Zinn and Bowersox [26] conclude that demand uncertainty is the most important reason to keep both central and local inventory instead of keeping stock only in the local DCs. According to their analysis, keeping central stock—thus postponing the allocation of items—is beneficial in case of products with a high value and a distribution network with many local DCs and highly fluctuating demand. Arnold [27] argues that central stock is not necessary in cases of low variation in demand and a small number of DCs. If the demand variability or the number of DCs increases, more shipments are needed to the local DCs. As a result, central stock becomes necessary. Supply lead times are long, central stock is needed as well due to higher uncertainty.

The question of having central stock is closely related to the imbalance problem. If the imbalance risk is high, it will be beneficial to have central stock to correct the inventory imbalance from central stock [25]. Imbalance can also be resolved by means of transshipments. Transshipments can be economically justified in case of high product value density [15].

Allocation Coordination

The degree of centralization of the allocation coordination in distribution systems is related to the question whether the allocation quantities need to be determined by the local DCs (e.g., locally coordinated allocation) or by a central authority (i.e., centrally coordinated allocation). Reid [28] has done a simulation study on the effects of different distribution control strategies. He shows that central control has advantages in terms of service and in terms of costs, but does not draw other conclusions than that central control provides more inventory at the local level, in addition to providing good customer service with minimal total system inventory. A major drawback of a centrally coordinated system is that it is inherently more difficult to apply [29].

Yu So [30] analyzed the difference between a centralized and a decentralized order policy. His conclusion is that a centralized policy nearly always outperforms the decentralized policy in terms of inventory costs. If the number of local DCs is large and the demand variation is considerable, the benefits of a central policy diminish if central stock is reviewed only at the moment on which the local DCs place an order at the central DC. This is probably due to the stock imbalance. If stock is reviewed continuously, the centralized policy always outperforms the decentralized policy.

Overall Summary of Literature

Table 2 summarizes the characteristics of product, process, and market (PPM) that have an influence on the distribution control decisions according to literature.

Distribution Control in Practice

The literature has been used to create a preliminary theory on the characteristics that influence distribution control decisions. In the second phase of the research, this theory base has been applied to three case studies. It should be emphasized that it is not the objective to strive for a complete, but for an expanded theory on distribution control.

A large-scale survey of companies that are successful in distribution logistics, has been considered as well. In the survey, managers were asked about relevant company and environmental characteristics and their respective control techniques. The survey can be used to statistically relate these relevant characteristics to control techniques. This approach assumes that all relevant characteristics are known and that success in logistics is correlated with good distribution control. However, factors other than those captured in the survey might be responsible for the success.
For viable survey results, the investigator should be able to define clearly what it is that he or she wants to measure and to set up appropriate and specific means for measuring it [31]. However, the total collection of relevant company and environmental characteristics in this area is not yet established. So called pilot surveys or experience surveys, which consist of a small number of unstructured interviews on the research topic, can instead be used as a basis for explorative research (see [31], [32]).

**Methodology**

Case studies were conducted through multiple interviews and discussions with the logistics managers of three different companies. The reason for selecting a particular distribution control technique has been assessed in each case study. Feedback has been generated from each of the case studies and is consequently used to improve the theory on distribution control decisions. As a result, a consistent set of selection rules is developed and company feedback is given on the selection method.

The research involved Masters thesis assignments in two of the three companies. The research also contained some quantitative analysis of improvements in distribution control, by means of either spreadsheet simulation models or qualitative decision-making tools. Case research in each company lasted about six months. The companies have been selected so that both retail and manufacturing were covered and that the types of products were different.

**The Three Case Study Companies**

The first company researched was Walkers Europe. This company manufactures and distributes exhaust systems for the after market through five plants and DCs in Europe. The assortment of 6,500 items are kept in most of the DCs, but manufactured in only a limited number of plants. There is a large difference in demand between the products (this may vary between around 100 per year up to 70,000 per year). Inventory costs are low, but transportation is a big cost factor (and not very flexible due to the fixed shipping schedules used).

The second company, Vroom and Dreesmann (V&D), is a Dutch department store chain with 63 stores nation-wide and five regional distribution centers. The assortment contains 500,000 different products, which are categorized into three types of products (from a distribution point of view): normal products, promotional products and fashion products. The bigger part of the assortment is replenished to the stores based on a pull strategy with a weekly automatic review of the inventory levels. Push
strategies are used for the initial allocation of products at the beginning of a selling season or promotional period.

The third company, EMI Compact Discs, manufactures and distributes CDs from plants in Europe to several warehouses throughout the world. A primary characteristic of the market is the high uncertainty of demand. Because of the required short reaction times to market demand, the high value density of CDs and the high contribution margin of CDs, capacity costs for distribution of CDs are of secondary importance. Transportation costs are relatively fixed because of the fixed truck schedule between the DCs. Handling costs are limited due to the small size of the product and the simple processes used for it. The local marketing departments are responsible for inventory control, which complicates inventory reduction oriented actions.

Case Study Findings: Independent Demand Planning

In the Walker case study, the relatively low demand uncertainty together with the presence of a seasonal demand pattern are key factors for the selection of a forecasting technique, which can incorporate demand patterns. A forecasting technique with a pattern is also preferred for the new items as they have a relatively stable demand pattern. For the B-items, the less stable demand and the relatively high amount of stock keeping units (SKUs) lead to the selection of a forecasting technique without a pattern. For C-items, the use of dynamic forecasts is less useful due to the relatively large production batch size, which results in a large batch size stock. As a result, improved accuracy of forecasting techniques and hence lower safety stock levels only has a minor effect on the total stock level. A technique without a pattern is thus preferred [3].

Within V&D, the number of SKUs is relatively high. For this reason, a forecast without a pattern is preferred for the allocation decision. For the suitcase replenishment decision, the decision to select a forecasting technique without a pattern is predominantly determined by the large supply batch size. Also during promotional action periods, such a forecasting technique is preferred for both the replenishment and the allocation decision. Due to the short time of an action period, it is often not meaningful to take demand patterns in an action period into account in the replenishment decision. If the supply lead time is short - in this case about one week or shorter - it is preferred to use a constant forecasting technique. The ability to incorporate demand patterns during these short lead times is not expected to add value, as it is difficult to discern a pattern during such a short time period.

The sales pattern of new items at EMI appeared to be too unpredictable to use a forecasting technique that can incorporate patterns. For this reason, a forecast without a pattern has been selected. For mature items, a simple technique is preferred, as well due to the unpredictable sales pattern. For old items, the large production batch size is an important reason to select a forecast without a pattern. The high value density and the low demand rate enables the use of small distribution batches for the old items. As a result, the local stock norms can be low and the allocation can simply equal the quantity sold.

The relevant PPM-characteristics and their effect on the forecasting decision are summarized in Table 3.

Case Study Findings: The Location of Stock

In the Walker case, central inventory is not kept for the A-items due to the stable demand and the high production frequency. Furthermore, abolishing central stock implies a reduction in handling activities since products now need to be handled only once at the local DC instead of twice - both at the central and the local DC. This reduction is significant for products with a low value density and a high product volume such as exhaust systems. B and C-items, on the contrary, are faced with much less stable demand and less frequent production and a relatively high production batch size. As a result, central stock is needed for these items. Furthermore, capacity stock is made for B-items, because of a seasonality in demand. This stock should be kept centrally. For new items, but also for B-items some form of capacity stock is needed, which is best retained centrally to have it available for all local DCs.

The large number of outlets within V&D necessitates central stock. Central stock can only be abolished if the supply lead time is
Table 3
PPM-Characteristics and Their Effect on the Type of Reorder Planning (only the type of forecasting technique is discussed; W=Walker, V=Vroom and Dreesmann, E=EMI)

<table>
<thead>
<tr>
<th>PPM-characteristic</th>
<th>Effect on forecasting</th>
<th>Type of forecast</th>
<th>Case study</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lead time</td>
<td>Short lead times</td>
<td>Without a pattern</td>
<td>V</td>
</tr>
<tr>
<td>Production batch size</td>
<td>Large batch sizes</td>
<td>Without a pattern</td>
<td>W,E</td>
</tr>
<tr>
<td>Amount of SKUs's</td>
<td>Large amount of SKUs's</td>
<td>Without a pattern</td>
<td>V,E</td>
</tr>
<tr>
<td>Demand uncertainty</td>
<td>Low uncertainty</td>
<td>With a pattern</td>
<td>W</td>
</tr>
<tr>
<td>Demand rate</td>
<td>Low demand rate</td>
<td>Without a pattern</td>
<td>E</td>
</tr>
<tr>
<td>Demand pattern</td>
<td>Seasonal demand pattern</td>
<td>With a pattern</td>
<td>W</td>
</tr>
</tbody>
</table>

relatively short. The supply lead time must be short to ensure a quick reaction to the market. Demand needs to be low to ensure that the local stock levels do not rise significantly. The total lead time increase for the outlet resulting from abolishing the central stock raises the outlet inventory. If the central inventory is eliminated, the outlet stock needs to cover the demand during the total supply lead time instead of during the lead time from the DC to the outlet. This may entail more local stock. As the local storage space is small, which prohibits the local storage of a large amount of items, central stock is needed. Short lasting promotional action periods necessitate central stock to avoid a large return flow of products by the end of the action period.

For EMI, central stock is needed for all items, except for the unique items that are produced for one country only. A main reason for keeping central stock is the large number of local DCs. Furthermore, for new items, capacity stock is needed, which should be stored centrally because of organizational restrictions and high customer service requirements. The uncertain demand necessitates central stock for the mature and the old items. For old items, the batch size stock is large. The batch size stock needs to be kept centrally to minimize the obsolescence risk. The infrequent production of old items furthermore necessitates the use of central stock.

Table 4 summarizes the PPM-characteristics and the influence on the central stock decision.

Case Study Findings:
The Type of Status Information

In the Walker case, integral information is preferred for all items. The stock reduction that may be attained by using integral information is particularly relevant for exhaust systems because of their high product volume. Storage space reduction can be considerable. The imbalance risk is limited either because of the low demand uncertainty or because of the use of central allocation coordination. In the EMI case, integral information is recommended for the old items. The local stock norms can be relatively low, resulting in a small absolute imbalance risk. Table 5 summarizes the considerations for a decision on the type of status information.

Case Study Findings:
The Type of Allocation Coordination

In the Walker case, central allocation coordination is applied to the A items to avoid stock in the central DC. Because no central stock is kept for A items, demand uncertainty is low and the production frequency high, a production batch should be completely allocated to the local DCs. This is best attained by means of centrally coordinated allocation. If locally coordinated allocation is applied, it would be a coincidence if the local reorders exactly match the supply batch. The B-items are allocated by means of local allocation coordination. Distribution capacity costs can hardly be influenced by centrally coordinating the allocation of B items. The imbalance risk is relatively low as distribution batch sizes are not extremely high. The B items are also kept in central stock because their stock serves as production capacity stock. As this stock is made because of
production constraints, it should be located at the plant until it is needed locally. C items, on the contrary, need to be allocated by means of central allocation coordination. Distribution batch sizes of C items are relatively high, which may increase the imbalance risk. To avoid imbalance, central allocation coordination is preferred because of the lack of fixed batch sizes.

In the V&D case, the initial allocation is centrally coordinated in the case of promotional actions. Promotional actions are characterized by a relatively short period of sales in which large amounts of items are sold. Good planning of the handling activities in the DC by smoothing the use of order pick capacity and of the transportation capacity by planning round trips is crucial because of the high goods flow volumes that need to be shipped. Later allocations in a promotional action period are locally coordinated to ensure that an item is only reordered when sales have been generated for this item. This avoids high return flows by the end of the
action period. Also during the normal selling season, the allocation is locally coordinated. The local storage space is small due to the objective of maximizing the turnover per square meter. Local stock levels can be kept low by only allocating stock for an item if sales have been generated for that item. The use of locally coordinated allocation in the normal selling season would furthermore imply much effort to coordinate every allocation because of the large amount of stock keeping units involved. The allocation should be locally coordinated in case of very short supply lead times. The time between ordering and receipt is too short to generate additional demand information that may improve the allocation. It is easier to put outlet orders directly through to suppliers.

At EMI, the allocation is locally coordinated for all items. The number of SKUs is large because of the high local variation. This makes it difficult to follow every market centrally. Market demand is strongly influenced by for example local actions. Furthermore, production has a short lead time. The reaction time to market changes is therefore short. Besides, the market is very uncertain which necessitates the use of relatively small distribution batch sizes and frequent allocations to follow market changes. For the old items, the local stock levels are low and distribution batch sizes small. It is possible to allocate items to the local DCs each time they have been sold. The PPM characteristics are summarized in Table 6.

**Conclusions**

The problem researched dealt with the investigation of the characteristics that influence the selection of distribution control techniques. For this reason, distribution control has first been decomposed into four major control decisions. For each of the decisions characteristics that influence that decision have been investigated. We have investigated both literature and case study findings. Table 7 consolidates the findings of both literature and case study analyses. Dependent demand planning is not incorporated in the reorder planning decision in Table 7 as this has not been researched in great detail in the case studies. Differences between case study and literature findings or additions are printed in italics.

The case studies are used to identify the characteristics for the selection of distribution control decisions. The way in which these characteristics influence the control decisions has also been indicated in Table 7. All relevant PPM characteristics and their effects as found in the literature were also found in the case studies, except for the product value. Product value has been taken into account indirectly in the case studies, since it has been incorporated in the characteristic “value density of products” which is defined as the product value per cubic measure [33].

Table 7 can be used to assess which type of distribution control technique can be best for a particular group of products. Based on the characteristics of products, processes, and markets of the particular group of products,

![Table 6](image)

<table>
<thead>
<tr>
<th>PPM-characteristic</th>
<th>Value of characteristic(s)</th>
<th>Direction of decision</th>
<th>Case study</th>
</tr>
</thead>
<tbody>
<tr>
<td>Type of sales period</td>
<td>Promotional action (initial allocation)</td>
<td>Central coordination</td>
<td>V</td>
</tr>
<tr>
<td>Type of sales period</td>
<td>Promotional action (subsequent allocations)</td>
<td>Local coordination</td>
<td>V</td>
</tr>
<tr>
<td>Local storage space</td>
<td>Small local storage space</td>
<td>Local coordination</td>
<td>V</td>
</tr>
<tr>
<td>Distribution batch size</td>
<td>Large distribution batches</td>
<td>Central coordination</td>
<td>W</td>
</tr>
<tr>
<td>Supply lead time</td>
<td>Long lead time</td>
<td>Central coordination</td>
<td>V</td>
</tr>
<tr>
<td>Amount of SKU's</td>
<td>Large number of SKU's</td>
<td>Local coordination</td>
<td>V, E</td>
</tr>
<tr>
<td>Demand uncertainty</td>
<td>High demand uncertainty</td>
<td>Local coordination</td>
<td>W, E</td>
</tr>
</tbody>
</table>
Table 7 can be used to determine the type of reorder planning/forecasting, the need for central and/or local stock, the type of status information needed and the type of allocation coordination.

These findings can be used to select distribution control techniques such as statistical inventory control or distribution requirements planning. Each of these techniques can be expressed in terms of our decision framework. Since the research gives information on how to make each of the control decisions dependent on characteristics of products, processes and markets, this information can be used to evaluate the application restrictions of standard distribution control techniques. It can also be used to select a distribution control technique.

However, the effect of the interaction between different characteristics could not be investigated in the cases. It has been indicated for example, that large production or supply batch sizes decrease the need for forecasts with a pattern due to the large size of the batch size stock. A simple forecast without a pattern is then sufficient. It was not possible, though, to indicate the effect of having both large batch sizes and seasonal demand. Further analysis on this has been conducted and a description of this analysis can be found in De Leeuw et al. [34].

These findings can be used to select distribution control techniques such as statistical inventory control or distribution requirements planning.

<table>
<thead>
<tr>
<th>PPM-characteristic</th>
<th>Type of reorder planning</th>
<th>Central stock function</th>
<th>Status information</th>
<th>Allocation co-ordination</th>
</tr>
</thead>
<tbody>
<tr>
<td>High product volume</td>
<td>Forecast without pattern</td>
<td>Yes</td>
<td>Integral</td>
<td></td>
</tr>
<tr>
<td>Unique product</td>
<td>No</td>
<td>No</td>
<td>Integral</td>
<td></td>
</tr>
<tr>
<td>High obsolescence risk</td>
<td>Yes</td>
<td>Yes</td>
<td>Integral</td>
<td></td>
</tr>
<tr>
<td>High value density</td>
<td>Yes</td>
<td>Yes</td>
<td>Integral</td>
<td></td>
</tr>
<tr>
<td>Low product value</td>
<td>No</td>
<td>Yes</td>
<td>Integral</td>
<td></td>
</tr>
<tr>
<td>Promotional action</td>
<td>Forecast without pattern</td>
<td>Yes</td>
<td>Central (initial allocation)</td>
<td></td>
</tr>
<tr>
<td>sales period</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Restricted local storage</td>
<td>Yes</td>
<td>Yes</td>
<td>Local</td>
<td></td>
</tr>
<tr>
<td>space</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>High supply frequency</td>
<td>No</td>
<td>No</td>
<td>Local (if no central stock)</td>
<td></td>
</tr>
<tr>
<td>Large distribution batch</td>
<td>Forecast without pattern</td>
<td>Yes</td>
<td>Central</td>
<td></td>
</tr>
<tr>
<td>size</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Short supply lead time</td>
<td>Forecast without pattern</td>
<td>No</td>
<td>Local</td>
<td></td>
</tr>
<tr>
<td>Large supply batch size</td>
<td>Forecast without pattern</td>
<td>Yes</td>
<td>Local</td>
<td></td>
</tr>
<tr>
<td>Large amount of local DCs</td>
<td>Forecast without pattern</td>
<td>Yes</td>
<td>Local</td>
<td></td>
</tr>
<tr>
<td>Large amount of SKU's</td>
<td>Forecast without pattern</td>
<td>Yes</td>
<td>Local</td>
<td></td>
</tr>
<tr>
<td>High customer service</td>
<td>Forecast without pattern</td>
<td>Yes</td>
<td>Central</td>
<td></td>
</tr>
<tr>
<td>required</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>High demand uncertainty</td>
<td>Forecast without pattern</td>
<td>Yes</td>
<td>Local</td>
<td></td>
</tr>
<tr>
<td>Low demand rate</td>
<td>Forecast without pattern</td>
<td>Yes</td>
<td>Local</td>
<td></td>
</tr>
<tr>
<td>Seasonal demand</td>
<td>Forecast with pattern</td>
<td>Yes</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
References


Sander de Leeuw was at the time of writing this article a visiting Assistant Professor of Management at Babson College, U.S.A. At the same time, he was also a research associate at the Massachusetts Institute of Technology, doing research for the International Car Distribution Program. He holds a MSc and a PhD in Industrial Engineering and Management Science from Eindhoven University of Technology in The Netherlands. He currently works for KPMG Management Consulting and can be reached at phone number: +31 30 2724243.

Ad R. van Goor is Professor of Logistics at the Faculty of Business Administration of the Free University Amsterdam and Professor of Supply Chain Management at Nyenrode University. During more than 25 years, he conducted research in marketing, retailing and logistics. Since 1984, he has been a management consultant in the areas of logistics and supply chain management, including efficient consumer response. He can be reached at Nyenrode University, Straatweg 25, 3621 BG Breukelen, The Netherlands. Phone: 31 346 29 1306. Fax: 31 346 29 1250. E-mail: a.goor@nyenrode.nl

Rien Ploos van Amstel was Physical Distribution Manager for Philips International and is Professor of International Distribution and Logistics at the Eindhoven University of Technology. He has over 20 years managerial and consultancy experience in industries and is an established author.