The Flow Type Selection Model

by

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Abstract
This report describes the design of the flow type selection model, which can be used to select the economically optimal logistic structure for any given non-perishable product. The three logistic structures under consideration include: central warehousing, break-bulk cross docking and pre-allocated cross docking. A decision framework is presented that incorporates all relevant logistic factors and supports the flow type selection decision. Furthermore, the report identifies the most significant factors affecting the flow type selection problem.
Preface and acknowledgements

This master thesis report is the result of the final assignment for my master Operations Management and Logistics at the Technical University of Eindhoven. This graduation project was performed at the Logistic department within V&D and was supervised by the sub department Operations Planning and Control (OPAC).

First of all, I would like to thank my university supervisors. I thank Rob Broekmeulen for his guidance and support during the past 1.5 year of my master’s. It is fantastic to have a supervisor as Rob who shows so much attention and involvement whether it meets his planning or not. The frequent, short meetings and his flexibility in making these appointments have continually helped me to stay focused and follow the right direction. Furthermore, I would like to thank my second supervisor from the university, Hajo Reijers. I have gratefully accepted your constructive comments.

I also would like to thank my company supervisor, Robert-Frans Niers. I sincerely appreciate that you made continuation of my project possible after Joke’s departure. Furthermore, I want to thank you for your clear vision on the assignment and for keeping me sharp and motivated throughout the project. Furthermore, I would like to thank Pim de Boer, Olav Vissers and Joke Vink-Goudriaan for their suggestions and feedback on my ideas.

Obviously, I also would like to thank my colleagues of the logistic department: Bob, Max, Fred, Aafke, Agnes, Ymke, Iwan, Ron, Albert, Peter and Annelies. Thank you all for the pleasant working environment. I really have enjoyed working with you.

Finally, I would like to thank my family and in particular my parents for their unconditional support and encouragement throughout my period as a student at the TU/e. Furthermore I would like to thank my friends and in particular my girlfriend for their support throughout this final stage of my study. Thank you all for the encouragements.
Management Summary

Retail companies operate in a volatile and highly competitive market and often offer a wide variety of products to their customers. The availability of these products is fundamental to the increase of sales and satisfying customer demand. However, offering high product availability for such a wide variety of products whilst minimizing logistic costs at the same time is a tremendous challenge. The distribution process of products from the supplier to the stores is a crucial component of the operations that enables the successful fulfilment of customer demand. Therefore it can be concluded that the method of product distribution is relative to the success of a retail company.

The subject of this research project, relates to the challenges outlined above. The problem considers the selection of the most economical optimal flow type. A flow type is defined as the way products flow from the supplier to the stores (Van den Heijkant, 2006). Previous research (Van den Heijkant, 2006) has defined the three flow types that are considered in this report including:

F 1. Central Warehouse (CW): The suppliers deliver the goods to a central warehouse, where the goods are stored, and shipped to a store as and when the store requires these products.

F 2. Break-Bulk Cross-Docking (BB-XD): The orders for the different stores are combined into one order. The supplier delivers this order to a cross docking point, where the goods are sorted by destination and shipped directly (without storing them in a central warehouse) to the stores.

F 3. Pre-Allocated Cross Docking (PA-XD): The orders for the different stores are picked separately at the supplier. Then, the different orders are loaded in one truck and shipped from the supplier to the cross docking point, where the shipment can be easily split and transported to the different stores. In comparison to the break bulk cross docking, the goods do not need any further handling at the platform of the DC.

Based on this description it becomes clear that the flow type selection is defined as selecting one of these three flow types as the most beneficial distribution process.

Problem definition

V&D’s logistics department operates as a budget centre and is responsible for the execution and coordination of the distribution of purchased goods from the supplier to the stores. The execution refers to the logistic activities (e.g. transportation, sorting, loading, picking etc) and the planning refers to the scheduling of activities in order to meet specified delivery dates. The control of the flow of goods is the responsibility of the Buying and Merchandise department. The decision of selecting the most economical optimal flow type is regarded as an important challenge (in which it is important for the logistics department to recognize whether the flow type applied at present is the most beneficial. Based on this challenge the following research question is formulated:

Which tangible and intangible factors affect the flow type selection and how do these factors affect the selection of the most beneficial flow type?

- The tangible factors refer to the factors that can measured by the logistic costs of transportation, inventory and handling.
- The intangible factors refer to the factors other than the logistic costs that affect the flow type selection. (e.g. a product’s shelf availability, supplier delivery performance, a supplier’s response time etc).
Analysis
The analysis phase shows that the flow type selection problem has to be separated into a single flow and recurring flow problem. Single flow products are defined as products for which the forecasted demand for a specific period is purchased at once, and therefore these products only flow once from the supplier to the stores. The recurring flow products are defined as products for which the demand forecast does not equal the purchased quantity. Orders are triggered by an inventory control policy that is determined by actual customer demand. As a result six different flow types arise (see table 1).

<table>
<thead>
<tr>
<th>Single flow of goods (S)</th>
<th>Recurring flow of goods (R)</th>
</tr>
</thead>
<tbody>
<tr>
<td>CWS</td>
<td>CWR</td>
</tr>
<tr>
<td>BB-XDS</td>
<td>BB-XDR</td>
</tr>
<tr>
<td>PA-XDS</td>
<td>PA-XDR</td>
</tr>
</tbody>
</table>

Table 1: flow types

The distinction between the two types of products results in two different types of problems. Both have different relevant tangible and intangible factors (see table 2). Furthermore the relevant factors relate differently to both problems. For example, product availability for a recurring flow can be expressed by the fill rate, whilst for the single flow product availability refers to the optimal allocation of the purchased quantity.

<table>
<thead>
<tr>
<th>Tangible factor</th>
<th>Single</th>
<th>Recurring</th>
<th>Intangible factor</th>
<th>Single</th>
<th>Recurring</th>
</tr>
</thead>
<tbody>
<tr>
<td>Inbound transportation</td>
<td>No</td>
<td>Yes</td>
<td>Product availability</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Outbound transportation</td>
<td>No</td>
<td>No</td>
<td>Incomplete or wrong delivery</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Storage costs</td>
<td>Yes</td>
<td>Yes</td>
<td>On-time delivery performance</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Carrying costs</td>
<td>No</td>
<td>Yes</td>
<td>Technology (EDI)</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Handling</td>
<td>Yes</td>
<td>Yes</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 2: relevant tangible and intangible factors

From this point forward the single flow and recurring flow problem are discussed separately. Firstly, the single flow problem is discussed and secondly the recurring flow problem.

Single Flow
The single flow problem is put into perspective of the entire planning process to demarcate the problem and analyse the characteristics of each flow type. As can be shown in figure 1 the three single flow types differ with respect to how the order is allocated. Imbalance of purchased quantity in the divergent network would result in a loss of sales or costs of transhipment, which will be referred to as costs of wrong allocation.

Figure 1: planning horizon single flow
From the single flow planning horizon, the following general conclusions can be drawn with respect to characteristics of the three flow types:

C.1 The PA-XD flow type is the flow type with the least flexibility since the allocation decision has to be made the moment an order is placed at the supplier.

C.2 The BB-XD has the capability to postpone the allocation decision to the moment an order arrives at the distribution centre.

C.3 The CW has the capability to postpone the allocation decision and pool risk by keeping stock at the distribution centre.

C.4 The assigned available store space / shelf capacity can constrain the flow type selection.

C.5 Allocation accuracy is only relevant if the aggregated forecast is fairly similar to the actual sales.

Furthermore the costs of the three flow types differ with respect to the handling activities. CWS has the highest costs with respect to logistics followed by the BB-XD and PA-XD. However, the latter two carry a higher risk of allocating products to the wrong store. As a result the trade-off that has to be made is whether the more expensive logistics outweigh the risk of wrong allocation. Wrong allocation might result in lost sales or cost of transhipment.

A significant observation is that the costs of wrong allocation only play a role when the purchased quantity is approximately equal to the actual demand. If the purchased quantity is significantly larger or smaller than the actual demand, all stores will experience shortages and overshoots, and therefore costs of wrong allocation are not relevant. Consequently the model developed assumes that V&D’s purchasers order the expected average demand (Bolton, 2008), which is reasonable since they do no use any news boy related order methods.

Finally, the BB-XD and PA-XD differ with respect to the moment at which the allocation decision has to be taken. PA-XD requires that the allocation decision is made when the order is placed, while BB-XD enables this decision to be postponed till the order arrives at the distribution centre. Therefore, the model restricts the use of PA-XD by requiring that the data used for making the allocation decision is available.

**Recurring Flow**

To demarcate the problem and analyse the logistic variables the recurring flow problem is also put into perspective of the entire planning process.

![Diagram of decisions taken before the flow type selection](image)

From figure 2 it can be concluded that based on the variables on the left side of the flow type selection decision, the model should determine which flow type is selected. The key input parameter is the shelf availability measure. This parameter is determined by the management and reflects the trade-off between going out-of-stock and costs of keeping stock. The three flow types differ in their ability to quickly replenish the stores. The model therefore should determine which flow type is responsive enough to achieve the required shelf availability measure. It can be concluded that the following logistic characteristics are the most relevant factors for the flow type selection model:

F.1 A product’s average demand and variation in demand
The main trade-off for the recurring flow type is whether the set product availability can be obtained by the different flow types. Each flow type has its own response time to the stores. The response time of the CWR can be adjusted to three replenishment frequency levels, namely daily, twice a week or weekly. In general, CWR has the highest response time followed by the PA-XDR and BB-XDR, respectively. When the pre-determined product availability is met, the logistics costs are evaluated per flow type. Finally, if from a commercial perspective the required minimum inventory level plays are role in the product’s exposure the flow types should be evaluated according to it.

**Conceptual model**

Based on this analysis, a conceptual model (see figure 3) is developed that incorporates all identified tangible and intangible factors into a decision tree. The conceptual model presents three constraints, four different decisions and the six flow types (and the replenishment frequencies for CW). The constraints lead a product to the right decision (D1, D2 or D3). For D1, D2 and D3 an analytical model needs to be developed. D4 represents the relevant factors that are not taken further into account in the analytical model, which includes the technology requirement (i.e. EDI), the supplier performance and the supplier’s price for delivering to pre-allocated standards.

The following example shows how the decision tree works. A product that is purchased for a single period and in which the forecasted demand is purchased at once (C1), would fall in the category of the single flow product. Next, the second constraint evaluates whether the available shelf capacity is sufficient to fit the entire order at once. If the order does not fit, a CWS flow type is selected. The question that remains is how frequent the product should be replenished, which is determined by decision model 2. If the entire order does fit in the stores, one still wonders if it is beneficial to use CWS, as a result of the higher costs.

**Figure 3: conceptual model**

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F.2 A product’s available shelf capacity / store space
F.3 A supplier’s response time and the DC-store lead time
Analytical model and results

For each of the three decisions presented in the conceptual model, an analytical model is developed. These analytical models have incorporated the key input parameters and are applied to V&D's data.

From the model’s application, a general conclusion regarding single flow products and recurring flow products can be deduced. First the conclusions for the single flow are discussed and then for the recurring flow.

The flow type selection model for the single flow has shown that CWS (i.e. an alpha policy) becomes more beneficial or necessary when:

- A product has a high cost of inaccurate allocation.
- Demand uncertainty of a store is high which results in shortages and overshoots of products.
- The difference in the logistic costs of a pushed flow and that of a pulled flow is small
- A product’s ordered quantity is large, in which case the minimal required inventory level can be obtained and at the same time a fraction can be retained at the DC.
- A product’s required minimal store exposure is low
- A product’s maximum shelf capacity is smaller than the ordered quantity.

Both cross dock flow types become more beneficial in the opposite situations. The PA-XDS and BB-XDS differ with respect to the availability of sales data, the required technology (i.e. EDI) and the complementary price for the supplier’s extra handling activities. These factors are described in the conceptual model but are not incorporated into the analytical models since the application of these factors in practice is straightforward.

Secondly, the flow type selection model for the recurring flow has shown that CWR becomes more beneficial or necessary, when:

- A supplier's response time is low
- A product's shelf capacity is low
- A product's demand highly fluctuates over time
- A product's value is high

Both the cross docking flow types become more beneficial in opposite situations. Similarly to the single flow, the PA-XDR and BB-XDR differ with respect to the availability of the sales data, the required technology (i.e. EDI) and the complementary price for the supplier’s extra handling activities. Note that in the case of V&D, the availability of sales data is not relevant for the recurring flow since the BB-XDR and PA-XDR are controlled by the same method.

Recommendation

The presented guidelines apply to V&D’s situation since their data was used. However, the general results are not specific enough to advise the Buying and Merchandise department on selecting the economical optimal flow type. In order to enable this support the tool should be embedded into the decision process. Furthermore the research showed that the recurring flow model can only provide insights on a product level, while the single flow model also enables to draw more general conclusion about V&D's single flow products. As a result of this, the results in this research support V&D’s predominant use of the CWS flow type.
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<th>Definition</th>
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<tr>
<td>3PL</td>
<td>Third Party Logistics</td>
</tr>
<tr>
<td>ABC</td>
<td>Activity Based Costing</td>
</tr>
<tr>
<td>BB-XD</td>
<td>Break Bulk cross docking</td>
</tr>
<tr>
<td>BPS</td>
<td>Business Problem Solving</td>
</tr>
<tr>
<td>B&amp;M</td>
<td>Buying &amp; Merchandising</td>
</tr>
<tr>
<td>CW</td>
<td>Central Warehousing</td>
</tr>
<tr>
<td>DC</td>
<td>Distribution Centre</td>
</tr>
<tr>
<td>DOS</td>
<td>Days of Supply</td>
</tr>
<tr>
<td>DPP</td>
<td>Direct Product Profitability</td>
</tr>
<tr>
<td>DSD</td>
<td>Direct Store Delivery</td>
</tr>
<tr>
<td>EDI</td>
<td>Electronic Data Interchange</td>
</tr>
<tr>
<td>KPI</td>
<td>Key Performance Indicator</td>
</tr>
<tr>
<td>MANOVA</td>
<td>Multivariate analysis of variance</td>
</tr>
<tr>
<td>MOQ</td>
<td>Minimum Order Quantity</td>
</tr>
<tr>
<td>MOA</td>
<td>Minimum Order Amount</td>
</tr>
<tr>
<td>LSP</td>
<td>Logistic Service Provider</td>
</tr>
<tr>
<td>O&amp;C</td>
<td>Open &amp; Check</td>
</tr>
<tr>
<td>OR</td>
<td>Operations Research</td>
</tr>
<tr>
<td>PA-XD</td>
<td>Pre-Allocated cross docking</td>
</tr>
<tr>
<td>PVD</td>
<td>Product Value Density</td>
</tr>
<tr>
<td>TRC</td>
<td>Total Relevant Cost</td>
</tr>
<tr>
<td>V&amp;D</td>
<td>Vroom &amp; Dreesmann</td>
</tr>
<tr>
<td>VMI</td>
<td>Vendor Managed Inventory</td>
</tr>
<tr>
<td>VRP</td>
<td>Vehicle Routing Problem</td>
</tr>
<tr>
<td>XDS</td>
<td>Cross-Docking Single Flow</td>
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Introduction

Retail companies operate in a volatile and highly competitive market and often offer a wide variety of products to their customers. The availability of these products is crucial to increase sales and satisfying the customer demand. However, offering high product availability for a wide variety of products and minimizing costs at the same time is a tremendous challenge. Over the past two decades this challenge went hand in hand with an increased technology support, which enabled companies to register point of sales data and electronically interchange this data with all stages of the supply chain. Also many new concepts have been introduced to apply the new technology and thereby improve performance. Nonetheless, many companies still struggle with their supply chain performance. The following example given by Fisher (1997) points out this struggle: “One department store chain that regularly had to resort to markdowns to clear unwanted merchandise found in exit interviews that one-quarter of its customers left its stores empty-handed because the specific items they had wanted to buy were out of stock”.

The example illustrates the importance of the product availability in the retail industry. The department store V&D also needs to cope with this challenge in order to achieve their goal of becoming the most respectful and profitable department store of the Netherlands. Achieving high supply chain performance depends on selecting the appropriate supply chain for a product (Fisher, 1997). This research focuses on a product’s flow type selection, which relates to selecting the appropriate supply chain. Therefore, it can be concluded that the flow type selection is relevant for being a successful retailer.

As we will see, the flow type selection decision should be based on a product’s characteristics, and the associated logistic process characteristics of a flow type. In this thesis a mathematical model is presented that determines, given a number of product characteristics, the expected optimal flow type.
CHAPTER 1: INTRODUCTION INTO THE RESEARCH PROJECT

This chapter describes the business environment in which this master thesis project has been executed, namely the retail company V&D. Firstly, V&D is described in section 1.1. The flow type selection problem is introduced in section 1.2. Then, the problem definition is given in section 1.3. Next, the research design and methodology is presented (section 1.4), followed by the project’s scope in section 1.5. Finally, this chapter ends with a conclusion and the structure of the report in section 1.6.

1.1 COMPANY DESCRIPTION

The Maxeda Group is a large Dutch retail group and is the parent company of V&D. V&D, which is headquartered in Amsterdam, was founded in 1887 by Willem Vroom and Anton Dreesmann. Initially the two business men only collaborated in purchasing, but after founding the company V&D together, V&D opened many establishments nationwide. Nowadays, V&D is part of the Dutch retail company Maxeda, in the past known as Vendex KBB. Maxeda is active in many European countries. They own nine other retail chains:

<table>
<thead>
<tr>
<th>Do-it-yourself</th>
<th>Department store</th>
<th>Fashion</th>
<th>Restaurants</th>
</tr>
</thead>
<tbody>
<tr>
<td>Brico</td>
<td>Bijenkorf</td>
<td>Hunkemöller</td>
<td>La Place</td>
</tr>
<tr>
<td>Formido</td>
<td>Vroom &amp; Dreesmann</td>
<td>M&amp;S Mode</td>
<td></td>
</tr>
<tr>
<td>Praxis</td>
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<td></td>
</tr>
</tbody>
</table>

Table 1: Retail formats owned by Maxeda

All the retail formats keep their own identity and approach to the market. V&D, which is one of the two department stores, comprises 62 branch stores and 1 web shop. In total V&D employs approximately 12,000 employees. The subdivision of V&D is visualized in the organization chart, presented by figure 1. The most relevant departments for this assignment are further elaborated.

![Organizational chart V&D](image)

1.1.1 Product assortment and market position

As a department store, V&D is a retail establishment that specializes in satisfying a wide range of consumer’s personal and residential durable product needs. Moreover, V&D offers the consumer a choice of multiple product lines at variable price points, in all product categories. V&D’s stores sell products including apparel, furniture, small appliances, electronics, office supplies, books, luggage, cosmetics, jewelry, entertainment, toys and sporting goods.
V&D positions itself as a mid-range department store with some characteristics of a high range department store. The type of products sold at V&D can be roughly distinguished into two groups, namely staple and fashion merchandise. Staple merchandise can be typified as predictable sales with lower margins. On the contrary, fashion merchandise has hardly any product history, however higher margins can be obtained (Ayers & Odegaard, 2008). Besides the predictability of sales, a product's obsolescence and the length of the selling season are also important aspects of these two types of products.

### 1.1.2 V&D’s supply chain

This subsection describes V&D’s supply chain. First, some recent developments within V&D are discussed. Then, the logistic network is briefly described and finally the research topic of this thesis is introduced.

**Supply Chain Developments**

Before 1990, V&D operated in a regional structure. The Netherlands was divided into fourteen regions each with its own operations, including purchase, sales, logistics etc. During the nineties V&D centralised all these regional headquarters and its operations in Amsterdam. The logistic structure, which was also highly decentralised, started to centralise as well. Gradually, V&D reduced its number of distribution centres (DC) from fourteen to three DCs.

Besides the change in logistic strategy in the recent past, V&D also changed its retail concept drastically in the last few years. In the past V&D operated only as a wholesaler. In essence this meant that V&D purchased products at its suppliers and distributed and sold those products accordingly. The latter automatically meant that all goods flowed through one of V&D’s DCs. Around 2006, V&D started to introduce three new types of partnerships, all related to the shop-in-shop concept, namely:

- **P 1. Concession partner**
- **P 2. Consignment partner**
- **P 3. Wholesale partner**

The types of collaboration differ in the amount of responsibility that the supplier has with respect to store personnel, inventory and transportation to the store. The concession partner is the most far reaching collaboration. A brand hires store space from V&D. The shop is set-up in the style of the brand. The supplier is responsible for the assortment decisions, the inventory registration and replenishment, and delivers directly to the stores. The same holds for the consignment partnerships, the only difference is that V&D is responsible for the personnel. The wholesale partnership is similar to traditional wholesale but differs since the supplier is responsible for the shop set up and training of V&D personnel. The logistics and inventory management are the responsibility of V&D. As a consequence of the concession and consignment partnerships, suppliers started to deliver their products directly to the stores.

**Logistic Structure**

For the products that are offered through the wholesale concept the logistic activities can be partitioned into the inbound, the distribution and the outbound process. The inbound logistics are partly controlled by V&D. In general, the goods from suppliers located outside the Netherlands are controlled by V&D. The transportation and consolidation of this flow is outsourced to a third party logistic (3PL) service provider. The goods flow from the suppliers located close by (e.g. The Netherlands, Belgium, Germany) is often executed by a supplier’s 3PL service provider. All wholesale goods are transported to one of V&D’s three DC. These DCs have two logistic functions:

1. Cross docking
2. Warehousing
Cross docking relates to bringing goods from different origins to a single location where they are sorted, loaded onto other vehicles, and taken to different destinations (Hall, 1987). The warehouse function relates to keeping inventory. From now on these facilities will be referred to as distribution centres. The three DCs are located in Aduard, Amsterdam and Utrecht. Each DC is assigned to a specific type of products. In the figures 2 and 3, the logistic network is graphically illustrated.

Finally, the outbound process is controlled, planned and executed by V&D. V&D owns and operates a private carrier fleet. This fleet ships all products from the DC’s to the stores. According to a more or less fixed routing schedule the carriers visit the 63 stores during the week. The general guideline is that large stores are visited each day and the smaller stores only once every two days.

1.2 THE FLOW TYPE SELECTION PROBLEM

In the next section the problem definition of this research project is introduced. However, in order to understand the problem definition, some background knowledge is required with respect to the flow type selection problem. Before the flow type selection problem is introduced, a definition of a flow type needs to be established. Van den Heijkant (2006) has defined a flow type as follows: “A flow type is the way that a product flows from the supplier to the store(s)”. Based on this definition he has identified the following four basic flow types:

F 1. Direct Store Delivery (DSD): The goods are delivered directly from the supplier to the different stores.

F 2. Central Warehouse (CW): The suppliers deliver the goods to a central warehouse, where the goods are stored, and shipped to a store when the store requires these products.

F 3. Break-Bulk Cross-Docking (BB-XD): The orders for the different stores are combined into one order. The supplier delivers this order to a cross docking point, where the goods are sorted by destination and shipped directly (without storing them in a central warehouse) to the stores.

F 4. Pre-Allocated Cross Docking (PA-XD): The orders for the different stores are picked separately at the supplier. Then, the different orders are loaded in one truck and shipped from the supplier to the cross docking point, where the shipment can be easily split and transported to the different stores. In comparison to the break bulk cross docking, the goods do not need any further handling at the platform of the DC.

Without going into detail it can be concluded from the descriptions above that each flow has different logistic characteristics with respect to the logistic costs (e.g. transportation, handling and inventory costs) and the supply chain responsiveness (time between the moment of ordering and the moment a product is
available in the store). The flow type selection problem refers to the challenge of selecting the appropriate flow type for a supplier, a product or a range of products. Besides the intention of solving this problem, this research also shows how the flow type selection problem applies to V&D’s situation. The next section will introduce the problem definition with respect to the flow type selection at V&D.

1.3 PROBLEM DEFINITION

This section will first describe the current situation at V&D followed by the logistic challenge they face. Based on this challenge the research question is formulated in section 1.3.3.

1.3.1 Current situation

V&D’s logistics department operates as a budget centre and is responsible for the execution and coordination of the distribution of the purchased goods from the supplier to the stores. The execution refers to the logistic activities (e.g. transportation, sorting, loading, picking etc) and the planning refers to the scheduling of activities in order to meet specified delivery dates. The control of the flow of goods is the responsibility of the Buying and Merchandise (B&M) department. De Leeuw et al. (1999) define distribution control 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”

As a result of this division of responsibilities a situation occurs in which close collaboration between the B&M and logistics department is required. In practice the logistics department gives advise about the logistic costs and constraints to the B&M department, and based on this information the B&M department takes the distribution control decisions.

In the recent past the logistic costs were allocated to the B&M department based on the sales turnover and the number of products purchased. This method of cost allocation is inaccurate and does not take product characteristics (e.g. volume, weight and replenishment quantities) into account which are the actual cause of the logistic costs. As a response, the logistics department recently introduced the activity based costing (ABC) method in order to assign logistic costs more accurately.

A second aim of the logistics department is to extent the ongoing professionalization of the department and changing its role from being a budget centre to serving as a logistic service provider (LSP). As a result of this aim the logistics department should be able to advise the B&M department on logistic decisions. This advising role should not only incorporate the logistics considerations (e.g. costs, scheduling etc) but also factors that are crucial for the B&M department (e.g. quick response, high product availability and increasing sales).

The incentive for the logistics department to increasingly serve as a LSP is caused by the limited incentive for the B&M department to optimize the logistics costs. This limited incentive is the result of the following three causes:

1. Performance evaluation of the B&M department focuses on key performance indicators that do not include logistics costs (e.g. gross margin, gross margin percentage).
2. The logistics costs incorporated in the ABC-method are just a small portion of the total costs.
3. Despite the ABC-method logistic costs are still difficult to trace back to an actual decision maker within the B&M department.

As result of this situation it can be concluded that the logistics department increasingly wants to advise the B&M department in order to optimize their logistics efforts. The first step of making the logistics costs
more transparent is taken. Based on this transparency and insight, logistics decisions should be optimized. The next section will discuss these logistics decisions into more detail.

### 1.3.2 Logistic decisions

Section 1.3.1 describes the current role of the logistics department and its aim to increasingly operate as a LSP instead of a budget centre. As a result the logistics department provides the B&M department with information on the logistics costs (e.g. inbound transportation costs, inventory storage costs, costs of value added services etc). The insight in these costs can support the B&M department in making better purchase decisions and distribution control decisions. Some of these decisions are straightforward and can be evaluated based on a simple comparison of the logistics costs of V&D and that of the supplier (e.g. executing the value added service, holding inventory at supplier or at own DC). However, the decision of choosing the most appropriate flow type is regarded as a challenge and the logistics department wants to gain insight into whether the flow type decision is taken in the most beneficial way. The flow type selection problem described in section 1.2 therefore remains an area where logistics opportunities might hold. The logistics department, which initiated this assignment, wants to gain insight into this decision based on the logistics costs and the factors that are considered by the B&M department.

---

<table>
<thead>
<tr>
<th>This situation leads to the following challenge:</th>
</tr>
</thead>
<tbody>
<tr>
<td>The logistics department requires a more thorough understanding of which factors affect the flow type selection and furthermore on how these factors affect the flow type decision.</td>
</tr>
</tbody>
</table>

---

### 1.3.3 Research definition

As indicated in section 1.3.1 the logistics department of V&D needs to enhance its knowledge concerning the flow type selection problem. This challenge is the subject of this master thesis and results into the following research question:

---

<table>
<thead>
<tr>
<th>The main research question is:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Which tangible and intangible factors affect the flow type selection and how do these factors affect the selection of the most beneficial flow type?</td>
</tr>
</tbody>
</table>

- The tangible factors refer to the factors that can measured by the logistic costs of transportation, inventory and handling.
- The intangible factors refer to the factors other than the logistic costs that affect the flow type selection. (e.g. a product's shelf availability, supplier delivery performance, a supplier's response time etc).

In order to answer the main research question the following five sub questions need to be answered. Furthermore the sub questions will serve as a guideline throughout this report:

S.1 Which logistic processes hide behind the three flow types?
S.2 Which control mechanisms are used to manage the product flow?
S.3 Which factors affect the decision between the flow types?
S.4 How is the flow type selection decision related to the entire planning process?
S.5 How do the identified factors affect the flow type selection?
1.4 RESEARCH DESIGN AND METHODOLOGY

This section presents the approach to answer the stated research question. Within the field of Operations Research (OR), studies often tend to be either research-oriented or design-oriented. The former mainly aims at developing scientific knowledge and is based on rigorous work. However, this knowledge is often difficult to implement in a company specific situation. The latter, on the other hand, is oriented on solving real-life problems (Bertrand & Fransoo, 2002). The challenge therefore in every OR study is combine relevance and rigour. According to the classification types described by Bertrand & Fransoo (2002) this research project can be classified as an empirical normative research project. Empirical research focuses on finding a fit between reality and the developed model. Normative refers to developing policies, strategies and actions to enhance the solution of a defined problem.

Mitroff et al. (1974) created a research methodology for doing quantitative empirical normative research. This methodology consists of four phases and these phases form appropriate project steps. The model is presented in figure 4. A researcher must conduct all four phases to complete a research project.

![Figure 4 – Mitroff’s model for an empirical normative research](image)

1. Conceptualization phase
   In the conceptualization phase, a conceptual model is made of the defined problem. All the factors that are related to the problem are analyzed. This means that decisions have to be made about the included factors. Also the scope of the problem and the model need to be determined (Bertrand & Fransoo, 2002). This phase, which is presented in chapter two, defines a research area by means of a literature review and an analysis of the problem at V&D.

2. Modelling phase
   The second phase defines the causal relationship between the variables and based on this relationship a quantitative model is built. The identified input variables should be translated by the quantitative model into an estimation of the decision variables (i.e. the flow type selection).

3. Model solving phase
   Mathematics and economics play a dominant role in the model solving phase. Using the developed model, cases will be evaluated and compared with the flow type chosen in practise. The model is also validated by subjecting the variables to a sensitivity analysis. In this way the robustness of the model is checked.
4. Implementation phase
The last phase consists of the implementation of the model/solution. Normally, after the implementation phase a new cycle starts. However, due to time limitations the actual implementation is not executed in this research. Nonetheless, the research is concluded by given a reflection of the developed solution. The limitation of the research and the future research possibilities are discussed.

1.5 SCOPE
The flow type selection problem is defined as the flow of finished goods from the supplier to the store(s). However, optimizing this selection could be influenced by the operations and costs of the supplier, for example by synchronizing a supplier's production/activities with V&D's operations. To limit the complexity of this project, its scope is limited to factors and processes that are within V&D's span of control.

Furthermore, only the three indirect flow types are examined. The reason for eliminating the direct-to-store flow type from the research is due to the fact that this flow is not controlled nor executed by V&D.

1.6 CONCLUSION AND OUTLINE
Based on the previous sections the aim of this research can be summarized as follows:

| Determine the tangible and intangible logistic factors related to flow type selection and develop an analytical method that enables the logistic department to support the B&M department in selecting the most beneficial flow type. |

Further explanation:

Purpose: The purpose of the model is to serve as a decision support tool. The model will be used in the flow type decision process.

Method: The method should be structured and documented in such a way that someone with access to the required information can use it and will use it in the right way.

Relevant factors: Both the tangible and intangible factors should be incorporated into the model.

User: The decision support tool will be used by the logistics department and therefore serves as a tool to support and negotiate with the B&M department about flow type selection.

The outline of this thesis follows the presented methodology of Mitroff et al. (1974). The second chapter presents the problem analysis and the resulting conceptual model. From this model the analytical model is derived and described in chapter three. Chapter four will apply the model in V&D's situation and present the results of the model. Finally, in chapter five the conclusion of this thesis is drawn and furthermore the implementation phase, recommendations and future research possibilities for V&D are discussed.

Figure 5: Outline of this Master Thesis
CHAPTER 2: THE CONCEPTUAL MODEL

Chapter one introduced the research question and the five sub questions relating to it (1.3.3). This chapter presents the analysis of the first four sub questions and based on the answers a conceptual model of the flow type selection problem at V&D is built. First, an overview of the relevant processes and participants is presented by using the SCOR model. Following on from these processes the second section (2.2) discusses the control of the three flow types by analysing the flow type characteristics and control variables. Next, section three discusses the identified tangible and intangible factors. Then, the distribution decision process within V&D is described. Section, 2.5 discusses research related to the flow type selection problem. Finally, section 2.6 presents the conceptual model of the flow type selection problem.

2.1 PROCESS DESCRIPTION

A flow type is the way that the products flow from the supplier to the store(s) (Van den Heijkant, 2006). This project concentrates on three flow types, which are already mentioned in section 1.2.
1. Central Warehousing (CW)
2. Break Bulk Cross-Docking (BB-XD)
3. Pre-Allocated Cross-Docking (PA-XD)
The aim of this section is to provide a thorough analysis of the flow type’s logistic processes and answer the first sub question.

2.1.1 Description of the logistic processes

In order to identify the relevant factors for the flow type selection the business activities associated with satisfying customer demand have to evaluated. The SCOR model (SCOR, 2000) identifies three process types: planning, execution and enabling. Planning refers to aligning aggregate demand with resources, execution refers to a process that is triggered by planned or actual demand that changes the state of goods, and finally enabling refers to the process that prepares, maintains, or manages information or relationships on which planning and execution rely. The logistic processes correspond with the execution process since the logistic processes are triggered by planned or actual demand. Therefore the process type execution relates to sub question one. To identify the relevant logistic processes the SCOR model describes five basic management processes.

![Supply Chain Operations Reference Model](image)

Figure 6: Supply Chain Operations Reference Model (2000)

The SCOR model in figure 6 shows five basic management processes.

- **Plan**: Processes that balance aggregate demand and supply to develop a course of action that best meets sourcing, production and delivery requirements.
- **Source**: The procurement, receipt and transfer of raw material items, subassemblies, or finished products.
Flow type selection concentrates on the primary ‘source’ and ‘deliver’ process. The primary process ‘plan’ is excluded since this project forms an input for the planning process. Besides, the primary process ‘make’ is excluded too as a result of the fact that V&D does not transform products. Finally, the return process is also excluded since the flow type selection refers to the flow of products from a supplier to stores. Appendix B gives an elaboration of the ‘source’ and ‘deliver’ execution processes. The descriptions illustrate the difference in the logistic execution of the three flow types since they differ in the composition of their sub processes. The source process is similar for all of three flow types, except for the fact that the execution of open & check (O&C) process differs between the flow types. For the PA-XD the O&C is executed more easily compared to BB-XD and CW. Furthermore the three flow types mainly differ based on the delivery process. When using CW a product makes use of eight or seven logistic process, while BB-XD and PA-XD only use six or five processes, respectively. This difference is the result of the fact that the PA-XD only requires a consolidation step while BB-XD requires an extra sorting step and CW requires the two extra steps storing and picking. Besides the logistic processes related to the distribution of products, V&D’s DC’s also executes value added services (VAS) as labelling, pricing and placing anti-theft labels. These VAS activities can only be executed for products that make use of CW and BB-XD, since it would be very inefficient to execute this process for PA-XD. Whether VAS activities should be executed by V&D or not is not part of this research.

Besides the identification of the logistic processes, the process descriptions in appendix B also identifies four participants who are involved in the execution, namely the supplier, a 3PL service provider, V&D’s logistic operation (the DC, the vehicle fleet and stores) and the head office. The head office represents the logistic and the B&M department. The logistics department schedules the logistics operations, and the B&M department controls the inventory and “sources” the product in the central warehouse and stores.

2.1.2 Conclusion

This section has used the SCOR-model to answer sub question one. Based on this model the differences between the flow types with respect to their logistic processes are identified. Furthermore it has given insight into the relevant participants in the flow type selection process. The most significant conclusion of this sub section is that CW requires the highest logistic resources followed by BB-XD and PA-XD flow type. The following section answers the second sub question by describing the distribution control techniques used at V&D.

2.2 DISTRIBUTION CONTROL

This section presents an analysis of the distribution control mechanisms and logistic parameters used at V&D to control the product flow. In order to describe how each flow type is controlled a distribution control classification framework is used. As a result sub question two will be answered.

2.2.1 Distribution control framework

In order to analyse how the control of the product flow within each flow type affects the flow type decision, the process of controlling the product flow need to be described into further detail. Techniques for distribution control are diverse and the different techniques are only applicable in particular situations. To ensure that a distribution control technique fits to a particular situation de Leeuw et al.
classified the distribution control decisions according to four control decisions, presented in Table 2. Based on this classification table the control of the three flow types can be described into more detail.

<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 DGs) coordinated allocation</td>
</tr>
</tbody>
</table>

Table 2: Distribution control decisions (de Leeuw et al., 1999)

First, the three control decisions are discussed briefly. The control decision “central stock function” is already incorporated in the difference between the three flow types and therefore does not need further elaboration. The type of information used to replenish the DC and stores is based on integral information which means inventory levels throughout the supply chain are known except those of the supplier. Also, since V&D is the most downstream stage of the supply chain, the final customer demand is known and therefore independent demand information can be used for replenishment calculations. Finally, the 'type reorder planning' concerns the decision of how to forecast demand. Following from the status of information, independent demand information can be used to forecast sales. However, forecasting is the process that precedes the flow type selection and therefore should serve as an input parameter. The last control decision ‘allocation coordination’ influences the flow type selection problem significantly and therefore is discussed separately below.

### 2.2.2 Allocation coordination

Stock allocation is defined as the decision of where to put inventory in the supply chain (de Leeuw et al., 1999). There are two ways to coordinate this stock allocation, namely centrally and locally. Local coordinated allocation is defined as the ordering of goods by the local stores on their own initiative. Contrary to this, with central coordinated allocation the initiative to send a shipment of goods to a store is not made by the stores but by a central department (see Figure 7).

V&D’s wholesale products are allocated by central allocation since the allocation decisions are made by a central department. As a result stores can not order on their own initiative. However, products are allocated differently. The difference refers to how far a customer’s order penetrates the supply chain, which can be related to the logistic concepts ‘pull’ and ‘push’. A pull flow is triggered by a customer order while a push flow is triggered by expected customer demand. Similar to the local and central allocation definition, the order's initiative is either determined centrally or locally. Therefore, the push flow corresponds to the central allocation coordination and the pull flow with the local allocation coordination.

The combination between the flow types and the distribution control techniques form six different combinations, presented in table 3. As a result the flow type selection problem extents to a problem in which not only a flow type has to be selected but also an allocation coordination technique. Each combination will be referred to as a separate flow type. Table 3 shows that the CW flow type can be a mix of the push and pull allocation coordination technique. This combination is referred to as the alpha policy*. (de Leeuw et al., 1999) The α-policy is a mixture of a push and pull flow since a fraction “α” is pushed to the stores and the remaining 1 - α is retained at the central DC to be allocated (pulled) according to the amount of sales in the stores. At V&D this flow type is often chosen for fashion merchandise since it is hard to forecast how demand among the 63 stores will occur and this policy enables a more accurate allocation of products.
### 2.2.3 Classification of the product flows

The two identified types of allocation coordination techniques in section 2.2.2 are used for two different product flows. The first product flow is classified as the single flow. The single flow represents the products for which the demand forecast for a specific period is equal to the purchased amount. A product’s replenishment is often impossible since the supplier’s response time is insufficient (e.g., transportation times, production time and minimum order quantities) for replenishment during a product’s selling window. In case of V&D, approximately 70% of the wholesale products can be classified by the single flow. Appendix K gives an overview of V&D’s products and the chosen flow type. The fashionable merchandise is a typical product flow that can be classified by the single flow, goods are purchased in the Far East and as a result replenishment is impossible within the season. Promotional products experience the same constraints since the selling window is too short to let replenishment take place. Based on the characteristic of the single flow it is logical for the B&M department to choose for ‘push’ allocation coordination.

The second product flow is classified as the recurring flow. This flow represents the products for which the demand forecast does not equal the amount purchased. For this flow it is not required to purchase the forecasted demand at once since replenishment from the supplier is possible. Products that can be typified by the recurring flow are characterized by a shorter response time from the supplier or their product life is longer and thereby enables a recurring flow.

Based on the differences between the single and recurring, the flow type selection has to be divided into two different problems, namely the selection of the flow type for a single flow product and the selection for a recurring flow product (figure 8). Appendix A presents V&D’s terminology equivalent to the six classifications.

![Flow type selection problem](image)

### 2.2.4 Flow type configuration

Section 2.2.1 introduced a framework by which V&D’s flow types can be described into more detail. In section 2.2.3 it is illustrated that based on this framework six flow type combinations arise. The remaining question is how these combinations are designed with respect to the allocation techniques. This section
will describe these techniques and the logistics parameters that influence these techniques (table 4). The allocation technique and its logistics parameters will be defined as a flow type configuration. A configuration can consist of thirteen logistic parameters which are all decision variables. In this section it will become clear that these logistics parameters affect the identified tangible and intangible factors of the flow type selection problem.

<table>
<thead>
<tr>
<th>List of logistics parameters</th>
</tr>
</thead>
<tbody>
<tr>
<td>review period DC</td>
</tr>
<tr>
<td>re-order level (min level)</td>
</tr>
<tr>
<td>lead time from a DC to a store</td>
</tr>
<tr>
<td>store’s order quantity</td>
</tr>
<tr>
<td>Average demand of a store</td>
</tr>
<tr>
<td>Fraction that is retained at the DC</td>
</tr>
<tr>
<td>review period stores</td>
</tr>
<tr>
<td>order up to level (max level)</td>
</tr>
<tr>
<td>lead time from a supplier to a DC</td>
</tr>
<tr>
<td>DC’s order quantity</td>
</tr>
<tr>
<td>standard deviation of a store’s demand</td>
</tr>
<tr>
<td>product’s maximum shelf capacity</td>
</tr>
</tbody>
</table>

Table 4: List of logistics parameters

Firstly, the flow types with a local allocation technique will be described followed by the flow types with a pull allocation technique.

**Pull Allocation**

Following from table 3 three flow type are controlled according to a pull allocation technique. Figure 9, 10 and 11 illustrate the flow type configuration of each flow type within V&D’s distribution network.

Figure 9 illustrates the configuration of the CW flow type with pull allocation coordination. The store inventory is controlled by an \((R_s,S)\) inventory policy (de Kok, 2005). The \((R_s,S)\) policy implies that products in the stores are reviewed periodically with interval \(R\) and when a products inventory level drops below the value \(s\) an order is placed at the DC that will replenish the store to the \(S\)-level. For the review period three options can be selected (daily, twice a week or weekly). The same applies for the inventory kept at the DC, however in this stage the inventory policy depends on a suppliers characteristics. Basically, inventory policy is comes down to a \(R_s,S\) policy. Based on minimum order quantities or a minimum order value the review period per supplier is determined for this policy. This policy is controlled based on a fixed ordered quantity at the supplier instead of an order-up-to-level \((S)\). In practice this can be explained by a minimum order quantity set by the supplier or by the advantage of transport consolidation.

**Figure 9: Central warehousing with pull allocation**

Figure 10 illustrates the configuration of a BB-XD flow type with local allocation coordination. Each store is controlled according to the \((R_s,S)\) policy. Based on the sum of all the local orders an order is placed at the supplier. In practice suppliers only want to execute an order if it reaches a certain size. Therefore, a products order can be constraint by a minimum order quantity or a minimum order amount. Finally, figure 8 also illustrates the moment the allocation of \(Q_{1,3}\) has to be determined.
Figure 11 illustrates the configuration of a PA-XD flow type with pull allocation coordination. The only difference with the BB-XD configuration is that the sorting process is already executed at the supplier.

**Push Allocation**

Following from table 5 three flow types are controlled according to a push allocation technique. Figure 12, 13 and 14 illustrate the flow type configuration of each flow type.

Figure 12 illustrates the configuration of a CW flow type with a combination of push and pull allocation coordination. The difference with the local allocation is that inventory in the DC is not replenished. Therefore, the single flow of goods has to be allocated according to the alpha policy. An operational constraint at the DC requires that alpha's fraction needs to be determined the moment an order is placed at the supplier. In this way, the moment an order arrives at the DC the logistics department knows which fraction to push towards the stores and which fraction to keep on stock. The fraction that is kept on stock at the DC will be allocated to the stores based on pull coordination, which is controlled by either a \((R,S)\) or a \((R,s,S)\) inventory policy. The \((R,S)\) policy is different from the \((R,s,S)\) since each review period an order is placed such that the inventory position becomes \(S\). The inventory policy used is different from the one used for a pull flow and can be described as a periodic review policy with a dynamical order up to level. The order up to level \(S\) is dynamical which means it is adjusted at the time of ordering based on the demand forecast per store. For the review period the same optional values apply as for the pull allocation coordination.
Figure 12: CW with push and pull allocation

Figure 13 illustrates the configuration of a BB-XD flow type with push allocation coordination. Firstly, this flow type differs from the push coordinated BB-XD since it copes with product flows that only occur once. Secondly, the timing of the allocation decision shifts from the moment an order is placed to the moment an order arrives at the DC.

Figure 13: BB-XD with push allocation

Figure 14 illustrates the configuration of a PA-XD flow type with push allocation coordination. The only difference with the BB-XD configuration is that allocation of the Q_{ij} is determined the moment an order is placed at the supplier. As a result this decision has to be taken L_i periods earlier.

Figure 14: PA-XD with push allocation

2.2.5 Conclusion

This section has provided insight into how the flow of goods within a flow type is controlled. Moreover, the analysis shows that the three flow types are classified into six different combinations between the distribution control techniques and the flow types. Also, it is shown that a flow type is configured by many logistic parameters. All together this section has answered sub question two, which wonders how the product flow is controlled. The logistic parameters affect the tangible and intangible factors. This section
has not gone into detail about the relationship between the logistic parameters and the tangible and intangible factors because first the tangible and intangible factors need to be further identified and analysed, which will be done in the next section.

Finally, it can be concluded from this section that based on the distribution control framework of De Leeuw et al. (1999) the flow type selection problem is split into two different problems, namely the flow type selection of a single flow and the flow type selection of a recurring flow. Therefore the flow type selection model should select a flow type from one of the six classifications presented in table 5. Furthermore, the analysis showed that each flow type is configured by a number of logistic parameters. These logistic parameters need to be taken into account when building the flow type selection model.

<table>
<thead>
<tr>
<th>Single flow of goods (S)</th>
<th>Recurring flow of goods (R)</th>
</tr>
</thead>
<tbody>
<tr>
<td>CWS</td>
<td>CWR</td>
</tr>
<tr>
<td>BB-XDS</td>
<td>BB-XDR</td>
</tr>
<tr>
<td>PA-XDS</td>
<td>PA-XDR</td>
</tr>
</tbody>
</table>

Table 5: Flow type classification

2.3 TANGIBLE AND INTANGIBLE FACTORS

This section identifies and describes the tangible and intangible factors into more detail and links them with the six flow types introduced in section 2.2. This section will indentify and discuss the factors that relate to the flow type selection problem and thereby answer sub question three. A closer look at these factors is required in order to incorporate them into the conceptual model. First, the tangible factors and then the intangible are analysed. This section ends with a conclusion with respect to the relationship between the flow type selection and the tangible and intangible factors and thereby answering sub question three.

2.3.1 Tangible factors

The tangible factors refer to the factors that relate to the logistic costs, namely the transportation, inventory and handling costs. This section describes the tangible factors in relation to the flow types.

Section 2.1 has identified that execution and enabling processes relate to the flow type selection. In order to identify the relevant tangible factors the performance attributes that relate to the execution and enabling processes are analysed. Appendix C gives an elaboration of these performance attributes of the ‘source’ and ‘deliver’ process. The tangible factors correspond to the performance attribute ‘cost’ since it consists of logistic costs. Table 6 summarizes the identified costs and thereby the relevant tangible factors.

<table>
<thead>
<tr>
<th>Tangible factor</th>
<th>Explanation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Transportation</td>
<td></td>
</tr>
<tr>
<td>Inbound transport</td>
<td>The cost of transportation from the supplier to the DC</td>
</tr>
<tr>
<td>Outbound transport</td>
<td>The cost of transportation from the DC to the store</td>
</tr>
<tr>
<td>Inventory</td>
<td></td>
</tr>
<tr>
<td>Storage costs</td>
<td>The cost of m² storage space at the DC or the store</td>
</tr>
<tr>
<td>Carrying costs</td>
<td>The cost of capital</td>
</tr>
<tr>
<td>Handling</td>
<td></td>
</tr>
<tr>
<td>Handling</td>
<td>All handling activities executed in the DC and the stores.</td>
</tr>
<tr>
<td>Acquisition</td>
<td></td>
</tr>
<tr>
<td>Acquisition</td>
<td>The price for which the goods are purchased</td>
</tr>
</tbody>
</table>

Table 6: Explanation of the tangible factors

The acquisition cost differs per flow type since delivering according to the PA-XD standards a supplier has to execute more handling activities and thereby can increase the purchase price. Based on the difference in acquisition costs an easy trade-off can be made whether to choose for BB-XD or PA-XD. This trade-off can be incorporated easily in the conceptual model. The relevance of the remaining tangible factors
presented in table 6 differs between the single and the recurring flow. First the tangible factors are discussed in relation with the single flow and then with the recurring flow.

Single Flow

The single flow is typified as a flow of goods that only occurs once between the supplier and V&D. As a result the inbound logistic and the inventory carrying costs do not differ between the flow types and therefore are not relevant. The outbound transportation is executed by V&D’s own private fleet which operates according to a more or less fixed routing schedule. This fixed routing schedule is enabled by a highly consolidated flow from the DC to the different stores. For a single flow product the purchased quantity can be distributed at once, or one can keep a fraction at the DC and then sent smaller shipments to the stores based on local demand. Sending smaller shipments of one product more frequently will not result in extra tours between the DC and the stores. Also, the overall volume does not change since the total number of products transported from the DC to the stores stays equal. By sending smaller shipments more frequently volume might increase as a result of using the capacity less efficient. This research assumes that this will not result in extra tours since the average truck occupation rate is around 75% and therefore can absorb the volume increase as a result of sending smaller shipments. Furthermore, it would be complex to find a relation between the size of the shipment and the used transportation volume since V&D does not keep record of product volume. In conclusion this research assumes that outbound transportation is not relevant.

Basically, the only two tangible factors that influence the flow type selection at V&D are the handling operations and the storage costs. The handling operations differ significantly per flow type since the recurring flow from the DC to the store is more expensive than the flow of goods that is pushed to the stores at once. The cost difference between the logistic costs of the push and pull flow can be explained by the relation between the size of a shipment and the required handling. Push flows sent large shipments at once while the pull flow is characterized by small shipments. Based on the economies of scale for handling costs differ between these two flows. Appendix E introduces V&D’s logistics costs and shows the cost differences between the handling costs of the push and pull flow. It is also shown that the cost of transhipment, which means the flow of products between the stores, comes with high costs. Products are only transhipped when products are allocated inaccurate and the resulted imbalance needs to be corrected.

The second tangible factor is the cost of storing inventory. Inventory is stored at two stages in V&D’s network, namely the DCs and the stores. The costs of keeping inventory differ between the two stages since the stores are located in expensive shopping areas while the DCs are located in less expensive real estate areas. The amount of store space allocated to a product is determined by the B&M department and therefore assumed to be fixed in this research. Basically, the store space can be regarded as sunk costs. The DC storage on the other hand is relevant in case store space is sufficient to fit the purchased quantity, but one decides that a fraction of the purchased quantity has to be kept at the DC in order to enhance allocation accuracy. Furthermore appendix E shows that the total relevant tangible factors are only small fraction of the total operating costs. This strengthens the research’s aim of taken the intangible factors also into account.

Recurring flow

For the recurring flow the same factors are relevant as for the single flow. However, since the recurring flow is typified as a flow which occurs more than once the inbound transportation costs are relevant. Contrary to the outbound transportation the inbound transportation is not executed by a private fleet which benefits from highly consolidated flows. Therefore these costs depend on the frequency of delivery
and the drop size (Van der Vlist & Broekmeulen, 2006). In practice however, a supplier constraints the frequency of delivery by a minimum order quantity and or minimum order amount. Instead of making an estimation of the inbound transportation cost, which will be difficult, these order constraints are taken into account in the flow type selection problem.

Furthermore, the inventory carrying costs are also relevant since the required inventory levels will differ between the flow types. A brief explanation of this relationship: the CW flow type has a shorter response time to the store compared to the BB-XD or PA-XD flow type. In case demand variability at the store level is high the CW flow type gives the opportunity to pool this risk to the DC. As a result the total amount of safety stock at the store level can decrease and the overall inventory level can decrease.

Finally, similar to the single flow appendix E illustrates that the total relevant costs of the recurring flow are also a small fraction of the total operating cost, and therefore the intangible factors seem highly relevant.

### 2.3.2 Intangible factors

The intangible factors of the flow type selection are those factors that can not be expressed by the logistic costs. Similar to the identification of the tangible factors the performance attributes of the enabling and execution process are analysed (see appendix C). Furthermore, from interviews conducted at V&D a different intangible factor was notified, namely that of the required capability of a supplier. In practice PA-XD requires electronic data interchange (EDI) in order to exchange order information. If a supplier does not work with this technology PA-XD is not an option. In practice this constraint is easily incorporated in making decisions and therefore also easily incorporated into the conceptual model. Table 7 summarizes the identified intangible factors.

<table>
<thead>
<tr>
<th>Performance Attributes</th>
<th>Intangible Factors</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flexibility &amp; Responsiveness</td>
<td>- Total source lead time</td>
</tr>
<tr>
<td></td>
<td>- Total deliver lead time</td>
</tr>
<tr>
<td>Reliability</td>
<td>- Product availability (fill rate)</td>
</tr>
<tr>
<td></td>
<td>- On-time delivery performance</td>
</tr>
<tr>
<td></td>
<td>- Incomplete or wrong delivery</td>
</tr>
<tr>
<td>Capability</td>
<td>- Technology (EDI)</td>
</tr>
</tbody>
</table>

Table 7: Performance attributes and relevant factors

It can be concluded that the intangible factor ‘product availability’ is most significant since the other four intangible factors (except for EDI) affect the product availability. A product’s availability relates differently to the single and recurring flow and therefore will be discussed separately below. The intangible factor ‘incomplete or wrong delivery’ also affects a product’s availability but its relation is complex and therefore not taken into account. However, it is obvious that this factor is relevant for both the single and recurring flow since the PA-XD requires a high delivery standard; instead of delivering one shipment a supplier has to deliver 63 shipments. Not all suppliers are capable to execute this process with a low failure rate.

**Single flow**

A single flow can be characterized by products that are often only offered once (i.e. fashionable products) or is offered for a short period under specific circumstances (i.e. promotional products). As a result making a forecast is difficult and often inaccurate. A product’s demand is forecasted on two levels: the overall demand forecast and the forecast per store. The overall forecast determines how much is purchased and therefore does not relate to the flow type selection. The demand forecast per store on the other hand does relate to the flow type selection problem since this forecast determines the allocation of...
inventory. As described in section 2.2 allocation of inventory differs between the identified flow types. Therefore, it can be concluded that a product's availability depends on the selected flow type.

The on-time delivery has to be separated into a supplier's performance and V&D's own performance with respect deliveries from the DC to the stores. A supplier's on-time delivery performance is not relevant for the flow type selection since the three flow types do not cope differently with the supplier's performance. The CW flow type is partly controlled by local allocation and the delivery performance from the DC to store is therefore relevant.

Recurring flow

A product that uses a recurring flow has different characteristics with respect to its supplier's response time and its product life. As illustrated in section 2.2 the allocation of demand is determined based on the inventory policies at the DC and the stores. The periodic review policy \((R,s,S)\) determines when to order and how much. The variables \(s\) and \(S\) need to be determined in order to guarantee a certain product availability. This product availability can be expressed by the two types of service levels (i.e. product availability measure): the fill rate and the cycle service level. The fill rate is defined as the long-run fraction of total demand, which is being delivered from stock on hand (de Kok, 2005). The cycle service level is the fraction of cycles in which a stock out does not occur (Silver et al., 1998). The required service level serves as a constraint for the flow type selection model and thus as an input value. To achieve the service level the values of \(R, s\) and \(S\) need to be determined and these depend on the values of the logistics parameters identified in section 2.2. Two of the logistic parameters relate to the total lead time which should be taken into account while determining \(R, s\) and \(S\). The on-time delivery performance can be incorporated into the calculation of the product availability.

2.3.3 Conclusion

The analysis of the tangible and intangible factors has provided further insight into sub question three: “Which factors affect the decision between the three flow types?” Table 8 gives an overview of the relevant tangible and intangible factors. In combination with the description of the product flow control and its logistic parameters, the next section will describe the process of how distribution decisions are made in time. As a result the whole process of the flow type selection is described.

<table>
<thead>
<tr>
<th>Tangible factor</th>
<th>Single</th>
<th>Recurring</th>
</tr>
</thead>
<tbody>
<tr>
<td>Inbound transportation</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>Outbound transportation</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>Storage costs</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Carrying costs</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>Handling</td>
<td>Yes</td>
<td>Yes</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Intangible factor</th>
<th>Single</th>
<th>Recurring</th>
</tr>
</thead>
<tbody>
<tr>
<td>Product availability</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Incomplete or wrong delivery</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>On-time delivery performance</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Capability</td>
<td>Yes</td>
<td>Yes</td>
</tr>
</tbody>
</table>

Table 8: Relevant factors per flow

2.4 ANALYSIS OF THE DISTRIBUTION DECISION PROCESS

Section 2.1 to 2.3 has described the relevant processes, control mechanisms, and the tangible and intangible factors. This section answers sub question four by analysing the entire planning process. Firstly, section 2.4.1 analyses the role of the identified participants with respect to logistics parameters that need to be determined. Then, section 2.4.2 describes the decision horizon. Section 2.4.3 and 2.4.4 discuss the influence of the seasonal pattern and the marketing considerations, respectively.
2.4.1 Role of participants

Section 2.1 has identified five participants that are involved in the flow type selection. However, section 2.1 also indicates that the flow type selection problem consists of different enabling processes. These enabling processes are described in section 2.2 by the distribution control techniques. Since distribution control is the responsibility of the B&M department, this department is the most relevant participant with respect to the flow type selection. The logistics department is highly involved in this process. However, their role is limited to advising, informing and providing transparency with regard to the logistic costs. It can be concluded that the only two relevant participants are the B&M and the logistics department. This conclusion is in line with the assignment’s aim to develop a decision support tool for the logistic department which enables them to advise the B&M department with respect to the flow type selection.

2.4.2 Planning horizon of the distribution control decisions

The distribution control process consists of a number of decisions that occur in a certain sequence during the planning horizon. Again, these decisions differ between the single and recurring flow. First the single flow is described and then the recurring flow.

Single flow

Figure 15 illustrates the time line of the distribution decisions that have to be taken. Nine different moments are identified on the line. This paragraph discusses the consequences of this decision process for the flow type selection. The planning horizon for the single flow products starts when the B&M teams make a budget proposal. A budget allows a B&M team to purchase products. Based on these proposals management decides how much of the total budget is allocated to each team. Next, the budget has to be allocated to specific products, quantities, timing etc. This way a sales plan is developed for particular selling season/period. The designs of the stores need to match the sales plans and vice versa. Finally the suppliers need to be selected. After all these decision are taken the most appropriate flow type has to be selected. Figure 15 illustrates that the flow type decision is taken just before the order is placed at the supplier. As can be deduced from section 2.2 the flow types regarding the single flow differ according to the allocation coordination and the moment of making the allocation decision.

![Figure 15: Time line of the distribution decisions](image)

Three decision moments are identified in figure 15. The moment the flow type decision has to be taken the purchased quantity, the available store space, the shelf ready moment, the length of the selling season and the purchase quantity are known. Next, the flow type decision has to be taken and is mainly concerned with allocating purchased quantity to the stores in the most accurate way. The PA-XD requires that the allocation fractions of the purchased quantity are known the moment the purchased order is placed. For the BB-XD and CW flow type a store’s allocation fraction have to be known
the moment an order arrives at the DC. The final decision that might occur during the selling season is that of transhipment. Transhipment might only be required if some stores experience shortages while other stores have surpluses.

From the above reasoning two significant factors can be deduced that affect the flow type selection, namely the allocation accuracy and the available store space. Based on these two factors three situations can be distinguished for the single flow.

S.1 The purchased quantity is larger than the sum of the stores shelf capacity and as a result stock need to be kept at the DC.

S.2 The shelf capacity is sufficient but the allocation fraction accuracy is low, and as a result sales are lost or transhipment has to be considered.

S.3 If the purchased quantity is significantly larger or smaller than the actual demand, in this case allocation accuracy does not affect the profitability since either all stores cope with shortages or surpluses.

Situation one is pretty straightforward: in case the maximum shelf capacity does not allow the whole order to be pushed to the stores one keeps stock at the DC. This might occur for products that are voluminous and in combination with the limited store capacity need to be stored at the DC (e.g. suitcases and quilts).

Situation two is mainly concerned with finding a fit between a product’s allocation requirement and the flow type that fits this allocation requirement. The allocation of the purchased quantity differs between the three flow types. The differences can be described by the two logistic concepts risk pooling and postponement.

Postponement refers to a delayed decision of the allocation to the stores, which makes sense if during the postponed time something is gained. In the case of the B&M department enhanced demand information might be gathered in order to allocate the stock more accurately.

Risk pooling addresses the issue of reducing demand variability by aggregating demand across different locations (Bowersox et al., 2007). By keeping a certain amount of stock at the DC and allocate this stock based on the local allocation, variability is pooled to the DC. These two concepts are important since they relate to the allocation accuracy. Allocation accuracy is important in order to maximize sales and profit. For example, when stock is allocated to a store which experiences a lower actual demand than expected and other stores experience higher demand than expected either margin is lost or products have to be transhipped. The described situation of inaccurate allocation is defined as imbalance. The consequences of imbalance should be avoided since it negatively affects the profitability. In order to prevent inaccurate allocation a closer look has to be taken of how allocation decisions are made.

For a single flow a store’s allocation fraction is based on a store’s fraction of sales in the past for a group of similar products. This is logically because for a product classified as a single flow, no past sales data for that particular product is available since the products are sold only once. The group of products that is used corresponds with the lowest level of aggregation in V&D’s product tree defined by “group” (see appendix H). This group consists of several products and as a result the allocation fraction is the average fraction of these products. As a result some product’s allocation fraction will be too large and for others to small. How large the inaccuracy is depends on the variation between the products within a ‘group’.

Furthermore, the sales data used for determining the allocation fraction can either be from the recent past or the previous year. For seasonal products for example the initial allocation fraction at the beginning of the season is based on the previous year while during the season the allocation fraction is based on the actual sales per store of the current season. As a result the single flows that arrive during the season can not use a PA-XDS flow type since the data for making an appropriate allocation fraction is not available at the moment the product is purchased. In this case only a CWS or a BB-XDS remain possible options.
Situation three is a retro perspective situation since the success or failure of a product can only be determined at the end of a selling season. Basically, the purchased quantity is expected to be sold. However, in practice products might be a large success or demand might fall short. In case of a success or failure the flow type selection does not make a difference and as a result one should have chosen for the least expensive flow type.

Finally, when a CWS flow type is selected the pull flow from the DC to the store is controlled by an inventory policy. As can be derived from the flow type configuration presented in section 2.2, the parameters of the inventory policy (R,S) need to be determined. In situation one and two described above the order up to level (S) is known. In situation one the order up to level is determined by the initial allocation fraction and in the second situation by the maximum shelf capacity. Therefore the single flow in situation one is controlled by a (R,S) inventory policy with a fixed order up to level, while in situation two a dynamical order up to level is used. As a result the best performing stores receives the most of the fraction kept at the DC.

It can be concluded from the single flow planning horizon that the flow type selection is the final decision before a product is distributed. For the single flow the following general conclusions can be drawn:

C.1 The PA-XD flow type is the flow type with the least flexibility since the allocation decision has to be made the moment an order is placed at the supplier.
C.2 The BB-XD has the capability to postpone the allocation decision to the moment an order arrives at the DC.
C.3 The CW has the capability to postpone the allocation decision and pool risk.
C.4 The assigned available store space / shelf capacity can constraint the flow type selection.
C.5 Allocation accuracy is only relevant if the aggregated forecast is fairly similar to the actual sales. When a product is a success or failure one should have chosen for the least expensive flow type.

Recurring flow
The decision process of a recurring flow is different from that of the single flow as a result of the characteristics of this flow. Firstly, the two tangible factors, the inventory carrying costs and the inbound transportation costs are relevant. Secondly, since this product flow is recurring the part from the supplier to the DC is relevant.

The intangible factor product availability has a different meaning for the recurring flow. For a single flow product availability refers to the allocation accuracy of the purchased quantity while for the recurring flow the distribution control aims at a minimizing the stock-out probability in the store. Section 2.3.2 defined the stock-out probability by the fill rate, which is defined as the long-run fraction that is delivered from stock on hand. The long-run fraction assumes that demand occurs over a longer period while for a single flow product this can not be assumed.

The logistics parameters introduced in section 2.2 influence the stock-out probability of a product. Next, figure 16 presents the planning horizon of a recurring flow product. The planning horizon consists of the decisions with respect to the relevant logistic parameters.

<table>
<thead>
<tr>
<th>Demand forecast</th>
<th>Shelf capacity / Allocated store capacity</th>
<th>Supplier selection</th>
<th>Determine shelf availability</th>
<th>Flow type selection</th>
</tr>
</thead>
<tbody>
<tr>
<td>- average demand during the forecasted period</td>
<td>- maximum store capacity</td>
<td>- replenishment quantity</td>
<td>- shelf availability measure for product</td>
<td>- re-order level</td>
</tr>
<tr>
<td>- standard deviation during the forecasted period</td>
<td>- minimum store capacity</td>
<td>- supplier’s lead time</td>
<td></td>
<td>- order up to level</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- procurement price</td>
<td></td>
<td>- review period in the store</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- supplier’s review period</td>
<td></td>
<td>- lead time from DC - store</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- minimum order quantity of the product</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>- minimum order amount of the supplier</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Figure 16: Decisions taken before the flow type selection
As concluded in section 2.3.1 the inbound transportation costs are taken into account by the minimum order quantity, the minimum order amount and the review period per supplier.

From figure 16 it can be concluded that based on the variables on the left of the flow type selection the model should determine which flow type is able to achieve the pre-determined shelf availability. It can be concluded that the following logistic parameters are the most relevant factors for the flow type selection:
1. A product’s average demand and variation in demand
2. A product’s available shelf capacity / store space
3. A supplier's response time

2.4.3 Influence of the seasonal pattern and product life on the decision control processes?

The previous two sections have illustrated that the demand forecast is determined before the flow type selection takes place. A forecast is always made for a specific period. V&D’s product assortment consists of a wide variety of products. Products are influenced by seasonal influences and sales occur during specific periods (i.e. during Christmas, summer and winter fashion, etc). For each product group a period can be observed in which demand significantly increases, this is either caused by promotion or by seasonal influences. As a result demand highly fluctuates over time.

Figure 17 and 18 illustrate V&D’s sales pattern during the two seasons. Figure 17 illustrates the sales of the fashion related product groups for season A, the summer collection (week 44 to 17). Figure 18 presents the sales pattern of the same product groups only then for season B, the winter collection (week 17 to 44). The seasonal products often can be classified by the single flow.

Figure 19 and 20 present the sales of the fashion and non-fashion product groups with respect to the products that are sold during the whole year, which consists of products that are classified by the recurring flow. It can be observed that these products have a specific base level that peaks during specific periods. The peaks in demand during week 15 and 40 can be explained by the “prijsen circus” a big promotional period that occurs twice a year. The peak around week 49 can be explained by Sinterklaas and Christmas. Other peaks in sales differ per product group and can be explained by the type of products sold. For example figure 20 shows a large increase in sales for the office supplies. This peak in sales is caused by the start of the educational year.

It can be concluded that sales highly fluctuate over time for many products within V&D’s product assortment, and that this is caused by seasonal influences or promotions. The following two paragraphs describe the influence of the sales pattern on the flow type selection.

![Figure 17: sales season A for fashionable products](image1)

![Figure 18: sales season B for fashionable products](image2)
Single flow
Seasonal products are often controlled by a single flow since replenishment is impossible. Products are sold only during a couple of months or even weeks. The B&M department forecasts demand for this specific period. Demand forecasts are based on sales data of previous years and for the determination of the amount purchased the B&M department does not use newsboy related techniques. From this observation it can be deduced that purchasers tend to purchase a quantity that equals the average demand (Bolten et al., 2008). The length of the forecasted period differ between products and therefore the selling window of a product should be taken into consideration when selecting the appropriate flow type selection. A flow type is assigned based on a product’s characteristics for a specific selling window. During this period demand follows a certain pattern as can be seen in figure 17 and 18. The pattern can be typified as a pattern that quickly picks up and then gradually fades out till the mark-downs are enabled to increase sales or to keep sales going. The initial peak in demand is hard to estimate and depends on the success of a product. The initial store shipment should therefore cover this initial peak in sales and as a result a large fraction of the purchased goods is pushed to the stores. Then, based on sales, a product might be replenished if one has chosen for a CW flow type. In practice, if chosen for a CWS flow type, V&D uses a general rule that approximately 70% is sent to the stores at once and 30% is kept at the DC. As a result, store replenishment should be highly responsive if demand per week approaches this 70%. Appendix G illustrates the analysis of +/-1300 A-season products, it can be seen that only 1 product sold around 69% of its sales in one week. In practice a store’s replenishment from the DC will be controlled by an (R,S) inventory policy. This initial allocation of stock will be equal to order up to level S. Based on sales, this level will be dynamically adjusted. The review period plus the lead time between the DC and the store is approximately 1.5 week and as a result a store’s replenishment responsiveness is sufficient in 99% of the cases when the initial allocation fraction equals 70%. Therefore the situation where a product’s purchased quantity is smaller than the shelf capacity and one selects a CWS flow type, the R,S inventory policy with the dynamical order up to level does not influence the shelf availability. Therefore, it can be concluded that a store’s initial stock allocation for fashionable products can cope with the initial peak in demand for a large fraction of the products.

Recurring flow
The consequence of the fluctuating demand pattern during the year for the products that are controlled by one of the flow types regarding the recurring flows is that the parameters (s and S) might have to be updated during the season in order to minimize the stock-out probability and inventory carrying costs. This updating is not done for all products since it is a time consuming task. Therefore, in practice a Pareto analysis will determine the products that are most important with respect to turnover and margin. For these products the parameters are adjusted more frequently since those products are more important.
2.4.4 Marketing factors that influence the decision control processes?

During the interviews with B&M teams it appeared that logistics parameters are not only determined with the aim to minimize logistics costs and more specific the inventory levels in the stores. In order to generate sales a product requires a certain exposure. During interviews with purchasers and merchandisers it was often stated that “Empty stores do no sell” (Larson and DeMarais, 1990). In practice this means that the re-order levels and the order up to levels are not only determined based on the optimization of logistics parameters but also are set according to commercial considerations. Full shelves sell more than empty ones. Following from this the developed model should therefore incorporate this intangible factor.

2.4.5 Conclusion

This section has put all participants, relevant tangible and intangible factors, and logistic parameters into perspective of the distribution decision process. As a result this section answered sub question four. The main conclusions can be summarized as follows:

1. The flow type selection is the final decision in the distribution decision process. This means that many logistic parameters are already determined and therefore serve as an input for the flow type selection.
2. As a result of the seasonal pattern the flow type selection should not be based on an infinite horizon but on a single period. For single flow products this is logical since products are purchased for a single period. Recurring products however are often offered for a longer time period in and during this time seasonal trends can occur. As a result the chosen flow type should be able to cope with fluctuations in demand through time or input parameters for a specific period should be used to make the flow type selection.
3. For single flow products demand forecast accuracy highly affects the necessity of the flow type selection. Successful or unsuccessful products do not require an optimal allocation in order to maximize profit. This latter is only applicable when the actual demand more or less equals the purchased quantity.

2.5 LITERATURE

This section summarizes the most important and relevant elements found in literature with respect to the flow type selection problem.

2.5.1 Current status of flow type selection related research

The term flow type selection is only recently introduced by Van den Heijkant (2006). This does not mean that the aspects of flow selection have not been analysed in the past. For example, freight distribution problems analyse many aspects of flow type selection. During the eighties research on freight distribution problems assumed stationary, deterministic and constant demand (Langevin et al., 1996). Part of the freight distribution problem was the optimal allocation of products to the direct and/or indirect flow. This type of research provides insights that might be applicable to situations with corresponding characteristics. However, in practice demand is often not stationary, deterministic and constant. The retail industry which deals with many different types of products is an example of an environment in which demand can be typified as the opposite namely, volatile and variable. Fisher addressed this issue in 1997 by introducing a simple framework which distinguished innovative and functional products. These two types of products correspond to staple and fashion merchandise described in section 1.2. Functional products are characterised by longer product life cycles, predictable demand and smaller margins.
Innovative products on the other hand are characterized by highly unpredictable demand, short product life cycles and high margins. Both products require a different type of supply chain. Functional products require an efficient chain, and innovative a responsive chain. The issue addressed by Fisher (1997) resulted in a different focus in supply chain design. The trade-offs within flow type selection, as a part of supply chain design, also had to be reconsidered again. Supply chain design shifted to a field which addressed the following question: “Which type of supply chain is appropriate for which type of product?” This field can be classified as supply chain segmentation. The field did not only take the tangible factors into account but also the intangible factors. Flow type selection also needs to make this shift towards this type of research, and addresses the following issue: “Which flow type is appropriate for which type of product?”

2.5.2 Useful insights from related research

As can be concluded from the sections 2.1 to 2.4, the main question of the flow type selection can be translated to the question where to position inventory in the supply chain. Therefore some articles are discussed that examined this research question.

In the past academic research on positioning inventory in distribution systems has not provided consensus. Whybark & Yang (1996) reviewed different articles regarding this question, and some show that keeping inventory at a central warehouse is beneficial, whilst others find that very little inventory should be positioned at a warehouse. Possible explanations are the use of different inventory control systems or that shipment frequencies are not measured. As a result of this unresolved question Whybark & Yang (1996) conducted a simulation study in which they controlled all relevant aspects. The results indicate that inventory should be positioned next to the customer. An important assumption in this study is that retail stores are assumed to have identical customer properties and demand attributes. In his dissertation, Yang (1999) extended the research method of Whybark & Yang. The general conclusion was the same. However, Yang’s investigation into factors other than demand variability on inventory positioning is also of significance. Long lead times for example lead to situations in which total inventory levels are reduced when keeping stock in a central warehouse. Contrary to these results Zinn & Bowersox (1988) show in their analyses that in case of products with a high value, a distribution network with many local DCs and highly fluctuating demand, keeping central stock is beneficial. Similarly, Arnold (1989) argues that central stock is not necessary in cases of low variation in demand and a small number of DCs. Van Donselaar (1990) studies the positioning of inventory in a divergent system with integral stock norms with lot sizes. The paper shows that imbalance, which can occur in divergent systems, only influences the system performance in specific situations. For divergent systems with identical final products, the extent to which each of the final product’s inventories (on hand plus on order) deviates from the average inventory at the final stage, is known as the imbalance. Imbalance is the result of demand variability at final stage in the system and the lot-size. There are two situations in which imbalance has significant influence on the system’s performance: 1) in case of no depot (warehouse) and large imbalance, that is if the lot-sizes and coefficient of variance are both large, 2) in case the coefficient of variance of demand is relatively small and the imbalance variance is large. Van Donselaar’s article concludes that in stationary situations with unlimited capacity and identical products it is hardly ever advantageous to be very cautious with pushing inventory out of the depot. Moreover, he suggests that further research is necessary to investigate the influence of non-stationary demand process and limited capacity. Waller et al. (2006) also analysed the positioning of inventory. The authors compared delivery through a central warehouse with cross docking. The inventory at the terminals disappears when the flow type changes from central warehouse to cross-dock. In the decentralized cross docking situation, moving to
cross-docking without increasing inventory levels at the store would result in an increase in the number of stock outs at the store level. Therefore, additional inventory is required at the store to accommodate the increase in lead time. The article also shows that the relative benefit of cross-docking decreases when the number of stores increases.

2.5.3 Conclusion

Summarising the articles on positioning inventory in the supply chain: position inventory as close to the customer as possible (retail store); except for suppliers with long lead-times and systems that are characterized by both many local DCs and highly fluctuating demand.

Although the assumptions do not match with the real life problem researched in this thesis, the articles still provide insight into the relevant factors. Especially, Van Donselaars article which discuss the imbalance in a divergent system can be linked with the motives for postponing the demand allocation or keeping central stock at the DC. Van der Heijden et al. (1997) developed a method to incorporate a system’s imbalance into the calculation of the order up to levels in a divergent system. Again, this model only applies in situations with stationary demand.

The insights from the literature show that inventory must be kept as close to the customer as possible. Two factors that might change the position of the inventory are:

1. high response time to the final customer
2. high demand uncertainty

Furthermore, it can be deduced from the research of Waller et al. (2006) that the shelf capacity is a relevant factor for selecting a flow type since cross docking requires a higher shelf capacity than central warehousing.

2.6 CONCLUSION AND CONCEPTUAL MODEL

Chapter two presented an extensive analysis with respect to the first four sub questions presented in section 1.3.3. At this point the logistic processes, the control mechanisms, the participants, the logistic parameters, and relevant intangible and tangible factors related to the flow type selection are described and analysed. It can be concluded that based on the answers on sub question one and two the definition of the three flow types need to be extended to a classification of six different flow types. This extension is the result of the identification of the single and recurring flow, which each has its own characteristics. The conceptual phase has also indentified three options for selecting the most appropriate replenishment frequency, which is only relevant when a pull flow has to be controlled.

Furthermore, this chapter has shown the scope of this research. Section 2.4 has shown that a number of decisions are already made before the flow type has to be selected. As a result a number of parameters can be used as input parameters for the flow type selection model. Based on these input parameters the flow type selection can be executed. Different conclusions are drawn in this chapter; the most significant for this research is the observation that the demand forecast accuracy affects the necessity of the flow type selection.

This section will present the conceptual model that identifies the steps that have to be taken in order to select one of the flow types classified in table 8. As stated in section 1.6 this research’s aim is to develop a tool that supports the flow type decision process. Based on the logistic parameters and the identified key factors the tool should select the most beneficial flow type. Figure 21 presents the conceptual model. The next chapter presents the analytical model which will be used to answer the final sub question: “How do the identified factors affect the flow type selection?”

The conceptual model, presented on the next page, summarizes the findings of this chapter in a decision tree. Three constraints and four different decisions are presented in the conceptual model that will lead a
product to its flow type. Chapter three will elaborate on decision one to three. The three constraints and decision four are discussed below.

![Conceptual Model](image)

*Figure 21: Conceptual Model*

The orange boxes represent a temporary flow type decision while the green boxes illustrate the final flow type decision. The white boxes illustrate the relevant factors.

**Constraints**

Constraint one separates the single flow products from the recurring flow types which is an obvious step but needs to be defined clearly. Products for which the purchased quantity is equal to the forecasted demand (for a specific period) can be defined as a single flow product, and if this does not hold it is defined as a recurring flow product. The second constraint determines whether the purchased quantity is smaller or larger than the available shelf capacity. If this is the case the CWS flow type is automatically chosen. The third constraint presents the issue of available data for making an appropriate allocation decision. SD is the moment the required sales data is available and PO presents the moment the order is placed at the supplier. When the PO takes place before the SD PA-XDS is not possible, if the PO takes place after the SD then PA-XDS is chosen.

**Decision four**

Throughout this chapter three factors were identified that are not incorporated into the decision process. All three refer to the trade-off between PA-XD and BB-XD. If one chooses between the two XD flow types one should consider three factors, namely the acquisition costs, the supplier’s performance and the enabling technologies. In real life these factors can change the flow type selection. If for example the supplier’s costs for delivering PA-XD are higher than V&D’s own cost for the sorting process it is obvious there is nothing to gain for choosing a PA-XD flow type. Furthermore, if a supplier does not work with a technology that support electronic data interchange (EDI) PA-XD is not possible since this is a requirement. A PA-XD flow type requires high delivery accuracy since each wrong delivery results in a wrong allocation of products, as illustrated wrong allocation is expensive to resolve.
CHAPTER 3: THE ANALYTICAL MODEL

In this chapter, the developed mathematical models are presented which support the flow type selection. The conceptual model has shown that the flow type selection can be split into two types of products, the single flow and the recurring flow. Based on this distinction four decisions have to be made in order to select the most appropriate flow type. Three of these decisions are within the scope of this research and require the support of a quantitative model.

Firstly, the decision model for the single flow is described in section 3.1. In section 3.2 the decisions model for the recurring flow is presented. Section 3.3 discusses the limitations of the analytical model and suggests areas for future research.

3.1 MODELLING THE FLOW TYPE SELECTION FOR THE SINGLE FLOW

The conceptual phase has illustrated that the flow type selection decision of a single flow has to be taken the moment a purchase order is placed at the supplier. The three flow types differ in the decision that needs to be made at this moment and the B&M department has two questions that need to be answered, namely Q1 and Q2 present in figure 22.

![Figure 22: Overview of the push flow decisions](image)

The two questions are addressed in the conceptual model. The conceptual model divides the single flow products into two types: 1) products that do not fit into the store at once, and 2) products that do. Both type of single flow products remain with a different trade-off with respect to the flow type configuration. These different trade-offs are presented in the conceptual model by decision one and decision three. This section will only discuss decision one. Decision three refers two the configuration of the pull flow from the DC to the store. This decision has similarities with the recurring flow and therefore will be described in the next section.

3.1.1 Decision one

The conceptual model indicated that a trade-off between the logistic pull and push costs, and the costs of inaccurate allocation have to be made in order to decide whether a fraction should be kept at the DC. Moreover, the conceptual phase also showed that a single flow is allocated according to an allocation fraction. This allocation fraction is based on historical data of a group of products. Each store is assigned by an allocation fraction ($f_i$). The allocation fraction inaccuracy can be measured by calculating the...
average and standard deviation of the allocation fraction. The developed quantitative model should estimate whether it is beneficial for a product to be kept at the DC or not.

As indicated in the introduction decision model one is concerned with products which the shelf capacity is sufficient to fit the whole purchased quantity. The question that remains is which allocation flexibility is required in order to maximize profit. Profit is maximized when the identified cost factors are minimized and maximizing profit corresponds with optimizing the trade-off between the logistic push and pull costs, and the cost of inaccurate allocation.

Figure 23 presents the steps which are taken by decision one in order to determine the selection between CWS or XDS (BB-XDS or PA-XDS). Step one determines whether a fraction has to be retained at the DC, which is expressed by \( \alpha \). Input parameters for determining this \( \alpha \)-fraction are the costs of the logistic push and pull flow, the costs of inaccurate allocation and a measure of the inaccuracy of the allocation fraction. Step two compares the \( \alpha \)-fraction with the minimum required inventory level at the DC. The final outcome of this model determines whether stock has to be retained at the DC or not. Next, this outcome serves as an input for constraint three.

**Figure 23: decision process of D1**

The model is built based on three assumptions:

**A1** The purchased quantity (Q) is assumed to be equal to the expected mean demand. This assumption is supported by literature. Bolten et al. (2008) conducted a research which showed that experienced purchase managers tend to procure biased towards the mean expected demand. In practice, the B&G Department does not make use of a newsvendor-type of method to optimize the order quantity and maximize profit. Therefore, this is a reasonable assumption.

**A2** A product's availability is assumed not to be influenced by the flow type decision. Thus, the required response time from the DC to stores does not result in lost sales. The same applies when is chosen for a transhipment strategy. This assumption is also reasonable since for the single flow the initial store shipment is proved to be sufficient. Based on the analysis presented in appendix F this assumption holds for 99% of the cases. Moreover, if transhipment is required the timing of the shipment is not part of the flow type selection problem.

**A3** The allocation fraction \( f \), which is based on historical data of a number of different products, is assumed to be normally distributed. Appendix G shows that this assumption is supported by a goodness of fit analysis.

**A4** Furthermore, since the overall purchased quantity is assumed to be more or less equal to the mean expected demand, the store's demand is assumed to be negatively correlated. A negatively correlated store demand results in a situation in which one store's overshoot results in a shortage at another store.
Since it is assumed that the actual demand of a product is equal to the purchased quantity inaccurate allocation will result in overshots and shortages at the store level. Each store that has an overshoot will be followed by another store that has a shortage. A result of this reasoning is that demand among the stores is negatively correlated (A4). The costs associated with wrong allocation therefore will be maximized when the whole purchased quantity is sent to the stores at once. This situation will be taken as a starting point for the model and the formula for the maximum costs of inaccurate allocation is presented by equation 1.

$$C_{\text{max}} = C_{\text{ia}} \cdot \sum_{i=1}^{n} \int_{f_i \cdot Q_i}^{\infty} (x-f_i \cdot Q_i) \cdot P_s(x) \, dx$$  \hspace{1cm} (1)

$P_s(x)$ = the probability that a stores demand is equal to $x$

$C_{\text{ia}}$ = cost of wrong allocation

$f_i$ = fraction of $Q_2$ that is initially allocated to store $i$

$n$ = number of stores

The allocation fraction $f_i$ is an average value and therefore in practice the actual store demand can differ from the allocated fraction. The actual demand can be described by a normal distribution with the parameters $\mu_i$ and $\sigma_i$, where $\mu_i$ is equal to $f_i \cdot Q_2$. In case of sending all products to the store at once equation one can be described as follows (Silver et al., 1998):

$$C_{\text{max}} = C_{\text{ia}} \cdot \sum_{i=1}^{n} \sigma_i \cdot G\left(\frac{X_i - \mu_i}{\sigma_i}\right)$$

$$= C_{\text{ia}} \cdot \sum_{i=1}^{n} \sigma_i \cdot G\left(f_i \cdot Q_2 - f_i \cdot Q_2 \cdot \sigma_i \right)$$

$$= C_{\text{ia}} \cdot \sum_{i=1}^{n} 0.3989 \cdot \sigma_i$$

$X_i$ = allocated number of products to store $i$

The next step is to introduce the possibility of keeping stock at the DC. This is done by incorporating the $\alpha$-policy into the model. Alpha presents that fraction of $Q_2$ that is sent to the stores at once. The fraction $1-\alpha$ is kept at the DC and will be pulled to the stores with a higher demand than the initial allocated amount. In case of $\alpha=1$ the expected shortage was calculated in order to determine the maximum cost of inaccurate allocation. Since the normal distribution is symmetrical the expected shortage is equal to the expected overshoot and therefore the expected shortage is used to calculate the $C_{\text{max}}$. However, when incorporating the $\alpha$–policy the expected shortage per store will increase; however this will be less relevant since this expected shortage will be fulfilled with the retained stock at the DC. As stated before a shortage and an overshoot both result in costs with respect inaccurate allocation. Sending less stock to the stores also decreases the chance of sending to much. The advantage of the $\alpha$–policy can be expressed by the decreasing expected overshoot (OS) per store:
For every unit kept at the DC extra logistic costs will incur, defined as $C_{\text{log}}$. Based on the allocation $\alpha$-fraction these extra costs can be easily incorporated into the total cost function. The total relevant cost can be therefore be expressed as follows:

$$C_{\text{total}} = C_{\text{log}} \cdot (1-\alpha) \cdot \bar{f}_2 \cdot Q_2 + C_{\text{dc}} \cdot \sum_{i=1}^{n} \sigma_i \cdot G_u \left( 1 - \alpha \right) \frac{\bar{f}_2 \cdot Q_2}{\sigma_i}$$

(4)

After the optimal value of $\alpha$ is determined one needs to evaluate this number of products with a simple constraint that reflects the commercial consideration “empty stores do not sell”. This constraint is defined as follows:

$$\left( \alpha \cdot Q_2 \cdot \sum_{i=1}^{n} \sigma_i \right)^+$$

(5)

Basically, this constraint means that the initial amount pushed to the stores has to be larger than the required sum of minimum store inventories. Thus, the maximum value of both is chosen as initial allocation quantity.

### 3.1.2 Conclusion

Based on the formulas presented in this section the model of decision one is defined. It can be concluded that the model has the ability to provide insight into the allocation accuracy of the different product groups and a trade-off can be made between the logistics push and pull costs, and the costs of inaccurate allocation. Furthermore, from equation four the following general guidelines, which all are rather intuitive, can be deduced for the flow type selection:

1. The larger the difference between the logistic push and pull flow the smaller the incentive to keep stock at the DC
2. The larger the costs of inaccurate allocation the more beneficial it becomes to retain stock at the DC.
3. The larger the coefficient of variation of the store’s demand the more beneficial it becomes to retain stock at the DC.

### 3.2 MODELLING THE FLOW TYPE SELECTION FOR THE RECURRING FLOW

The conceptual phase indicated that the flow type selection decision for a recurring flow has to be taken when all the identified logistic parameters are known. Based on these logistic parameters a flow type has to be selected with respect to the intangible and tangible factors. This trade-off is corresponds with decision two and three in the conceptual model. Decision two relates the trade-off between the shelf availability and the handling costs. Decision three relates to the trade-off between the tangible factors, inventory carrying costs, inventory storage cost and handling cost, and the intangible factor shelf availability.
The first subsection introduces the model which can be used to estimate whether the shelf availability can be obtained.

### 3.2.1 Model for estimating the shelf availability

As the described in the conceptual phase the recurring flow is controlled by a (R,S,S) and (R,S) inventory policy. For decision two and three a model is required that estimates based on the available shelf capacity if a certain flow type can obtain a specified shelf availability. First, the assumptions of the quantitative model are presented.

The model is based on the following assumptions:

**A4** Since demand for continuous products highly fluctuates and often experience seasonal or promotional influences demand is not stationary. In order to cope with this, the model assumes a limited horizon defined by period T. In this period sales follows a stationary pattern. The B&M department which has the best insight into these seasonal and promotional influences determine the length of horizon T and the according forecast for the this period.

**A5** Shelf capacity or allocated store space for a product is assumed to be fixed for a product and therefore will be an input parameter for the model. The store space / shelf capacity is determined by the B&M department and is based on a product’s sales potential.

**A6** A product’s demand is Gamma distributed. Appendix I shows that for many products the overall demand per week can be fitted onto the Gamma distribution.

The shelf availability measure used in this model is the P_2-level, known as the fill rate. The fill rate is defined as the long-run fraction of total demand, which is being delivered from stock on hand (de Kok, 2005). In order to evaluate if the P_2-level can be obtained a store’s stock out probability (1-P_2-level) need to be determined. This stock out probability will differ between the flow types. The method that will be used for this evaluation is based on a tool developed by Professor De Kok (de Kok, 2005), which evaluates the R,s,S and R,s,Q inventory policy with respect to the P_2-level.

Following on from this tool the following variables need to be calculated in order to estimate if the shelf availability can be obtained.

- **E[U_s]** = expected undershoot of the re-order level upon ordering
- **σ[U_s]** = standard deviation undershoot of the re-order level upon ordering
- **E[D(0,L+R)]** = expected demand during the lead time plus review period
- **σ[D(0,L+R)]** = standard deviation of the demand during the lead time and review period
- **E[D(0,L+R) + U]** = expected demand during the lead time and review period plus the expected undershoot
- **σ[D(0,L+R) + U]** = standard deviation of the demand during the lead time and review period plus the expected undershoot
- **E[Q_s]** = stores expected ordered quantity
- **Q_s (S-s)** = minimal order quantity store
- **S** = order up to level
- **s** = re-order up to level

These variables can be estimated based on the input parameters that are defined in section 3.2.2.

Since the inventory policies consists of a review period, a store’s stock out probability can be estimated based on the expected shortage per replenishment cycle (ESPRC). Microsoft Excel is used to determine the

---

1 undershoot U equals the amount of stock that the stock position is below re-order s at the moment of ordering
ESPRC. Based on the above variables and the assumed gamma distributed demand, the ESPRC can be calculated given the re-order point \( s \) and the minimum order quantity \( Q_0 \) (Silver et al., 1998):

\[
\text{ESPRC} = \alpha \cdot \beta \left( 1 - \int_{s}^{\infty} \frac{\beta}{\Gamma(\alpha + 1)} x^{\alpha - 1} e^{-\frac{x}{\beta}} dx \right) - s \left( 1 - \int_{s}^{\infty} \frac{\beta}{\Gamma(\alpha)} x^{\alpha - 1} e^{-\frac{x}{\beta}} dx \right)
\]

*\( \alpha \) and \( \beta \) are the parameters of the gamma distribution

Following on from the expression of the ESPRC, the fill rate can be calculated according to the following formula (Silver et al., 1998):

\[
\text{Fill rate} = P_2 = 1 - \frac{\text{ESPRC}}{Q}
\]

Equation 7 can be applied to a situation in which the undershoot is taken into account and subsequently the equation can be written out as follows (de Kok, 2005):

\[
\text{Fill rate} = P_2 = \frac{E[D(0,L) + U](1 - s \int_{0}^{\infty} \frac{\beta}{\Gamma(\alpha)} x^{\alpha - 1} e^{-\frac{x}{\beta}} dx) - (s + Q_0) \left( 1 - \int_{0}^{\infty} \frac{\beta}{\Gamma(\alpha)} x^{\alpha - 1} e^{-\frac{x}{\beta}} dx \right)}{(Q_s + E[U])}
\]

The demand parameters of the gamma distribution \( \alpha \) and \( \beta \), can be estimated based on the average demand of a product. For \( \alpha_1 \) and \( \beta_1 \) \( E[D(0,L+R) + U] \) and \( \sigma \) \( (D(0,L+R) + U) \) are used while for \( \alpha_2 \) and \( \beta_2 \) \( E[D(0,L+R)] \) and \( \sigma \) \( (D(0,L+R) + U) \) are used.

\[
\alpha = \frac{1}{\left( \frac{\sigma[D_1]}{E[D_1]} \right)^2}
\]

\[
\beta = E[D_1] \cdot \left( \frac{\sigma[D_1]}{E[D_1]} \right)^2
\]

Based on the above formulas, an estimation of a product’s shelf availability can be calculated. This is done by varying the re-order level at the store. Next, the theory is applied for decision two and three.

3.2.2 Decision two

For the recurring flow, it has to be determined whether the required shelf availability can be obtained by a chosen flow type and furthermore minimize the tangible costs. Figure 24 illustrates the steps of the flow type selection model. Step one determines a product’s expected demand in store i and its expected variation in demand. Next, step two determines a product’s review period which differs per supplier and can be constrained by a MOQ or MOA. Step three determines whether the shelf capacity is sufficient for attaining the specified shelf availability. Step four evaluates if the required minimum inventory level is obtained. The final step evaluates which flow type is cheapest. At each step a flow type might not suffice and drop out.
Figure 24: decision process of D2

**Step 1:**
The first step determines a store’s expected demand for a product during the forecasted period. This is based on the overall demand forecast multiplied by the expected sales fraction of a store in the past. The standard deviation is based on the historical data of the product or group of products.

**Step 2:**
The conceptual phase indicated that for the recurring flow the tangible factor inbound transportation is relevant. Furthermore, it was concluded that this factor is taken into account by incorporating the MOQ and the MOA in the flow type selection model. The MOQ and MOA both constraint a possible order, as a result an order might be postponed to the next review moment. By postponing the order the lead time increases and thereby the required safety stock must be larger as well. The MOA and MOQ affect the lead time by increasing the review period.

The difference between the MOA and the MOQ is that both are determined on different levels. The MOA is determined per supplier while the MOQ is determined per product. However, both constraints can be incorporated similarly, since if the constraints are not met by an order the order is cancelled. Then, the product is reviewed one period later and evaluated again with respect to the constraints. Step one evaluates the chance that a product will not be ordered as a result of the MOQ and MOA. This chance will decrease as the review period is increased. The chance of not meeting the constraint is set to 0.01 and as a consequence the affect on the target service level can be neglected. By increasing the review period of a product this chance diminishes. By evaluating equation 11 and 12 the review period can be determined based on the constraints. Next, the maximum required review period is selected and used as an input for step two.

\[
P\left(D(o,R_i) < MOQ_x\right) < 0.01 \tag{11}
\]

\[
P\left(\sum_{i=1}^{k} D(o,R_i) \cdot P_i < MOA_x\right) < 0.01 \tag{12}
\]

**Step 3:**
The third step evaluates the distribution control of the three flow types, presented in figure 9, 10 and 11 in section 2.2.4. Based on the quantitative model presented in section 3.2.1 the following constraint need to be tested for each flow type, the flow types that meet this constraint follow on to step three.

\[
\sum_{i=1}^{k} S_{i,x} < \sum_{i=1}^{k} C_{i,x} \tag{13}
\]
Step 4:

The fifth step in the model evaluates the tangible factors per flow type. This step relates only to the flow types that meet the P₂-level. The conceptual model identified three tangible factors, namely:

1. inventory carrying costs
2. inventory storage costs
3. handling activities

The following formulas estimate the cost factors, starting by the carrying costs (Silver et al., 1998):

\[
\text{Sum of average inventory at the store} : \quad \sum_{i=1}^{n} I_i = \sum_{i=1}^{n} (S_i - E[D(0,L+R)]), + \frac{S}{2} - \frac{S_i}{2}, h
\]  \hspace{1cm} \text{(14)} \hspace{1cm} ^2

\[
\text{Average inventory kept at the DC} : \quad \bar{I}_{dc} = S_{dc} - E[D(0,L+R)]_{dc} + \frac{S_{dc} - S_{dc}}{2}, h
\]  \hspace{1cm} \text{(15)} \hspace{1cm} ^3

The storage costs are estimated as follows:

- Storage cost DC: \( IS_{\text{cost}} = V_e \cdot \bar{I}_{dc} \cdot (T / S2) \cdot C_{\text{storage per m}^2} \)
- Storage cost stores: equal among all flow types since \( C_i \) is a fixed input parameter for this model

The handling costs are estimated according to following formula:

\[
\text{Handling costs per flow type} : \quad C_{\text{handling}} = \frac{Q_2 \cdot C_{\text{handling}}}{E[Q_1]} \]  \hspace{1cm} \text{(16)}

The above cost estimations result in total cost expressed by:

\[
\text{TC} = \sum_{i=1}^{n} I_i + \bar{I}_{dc} + IS_{\text{cost}} + C_{\text{handling}}h
\]

Based on this cost estimation the most beneficial flow type can be selected with respect to the identified tangible factors.

Step 5:

The fourth step consists of the evaluation of the minimum inventory level of a product in a store. This step is the consequence of the commercial consideration, identified in section 2.4.4, empty shelves do not sell. As a result the re-order level \( s \) should therefore be at least equal to the product’s minimum inventory level. The flow type with stores’ re-order levels that are closest to this minimum shelf occupation constraint is the most appropriate flow type. Note that this step might be not relevant for all products.

\[
\left| \sum_{i=1}^{n} EP_{i} - \sum_{i=1}^{n} B_{i,i} \right| = 0
\]  \hspace{1cm} \text{(17)}

\( \bar{EP} \) = average stock at the beginning of review period

3.2.3 Decision three

Decision three of the single flow can easily be derived from the model presented in section 3.2.1. Since the products that need to be evaluated by decision model three are constrained by the maximum available shelf capacity, it seems logical that their order up to level is equal to this maximum shelf capacity. Next, the only remaining step is to check which review period is required in order obtain the target shelf availability. This corresponds with step three of decision model two.

\(^2\) Formula is an accurate estimation of the average inventory (see simulation prof. De Kok)

\(^3\) In case of a \( Q_2 \), \( S_{dc}-S_{dc} = Q_2 \)
Figure 25 presents the conceptual model which determines the parameters of the (R,S) policy. Step 1 determines the store expected demand for a product during the forecasted period. Step 2 determines if the required order up to level given the shelf availability level is sufficient.

3.2.4 Conclusion

The introduced model for the recurring flow incorporates all the identified tangible and intangible factors in the conceptual model. From the quantitative model presented in this section it can be observed that many input parameters affect the decision whether to choose one of a PA-XDR, BB-XDR or CW flow type. Each input parameter can take on a large number of values. The flow type options are only applicable in certain cases (combinations of values). In general the following general guidelines can be deduced from the formulas:

- A large shelf capacity increases the possibility of both cross-dock flow types.
- A short response time from the supplier increases the possibility of both cross-dock flow types.
- A small value for the MOQ increases the possibility of both cross-dock flow types.
- A small value for the MOA increases the possibility of both cross-dock flow types.
- A large variation in demand decreases the change of both cross-dock flow types.
- A large minimum required inventory increases the possibility of the cross-dock flow types.
CHAPTER 4: APPLYING THE MODEL

Chapter two and three have provided the conceptual model for the flow type selection and its quantitative models. This chapter will analyse the influence of the identified input parameters on the flow type selection. Furthermore the flow type selection model is applied to V&D’s situation.

The first section discussed the input parameters of the developed model. Section 4.2.1 compares the output of model with the general guidelines from the literature. Next, section 4.3 discusses the accompanied derivation of data. In section 4.4 the application of the model is illustrated for ten products. The implications of the models for V&D's situation are discussed in section 4.5 and finally section 4.6 ends with a conclusion.

4.1 THE FLOW TYPE SELECTION MODEL

The aim of this project is to identify the tangible and intangible factors of the three identified flow types. Based on these factors a tool should be developed to support the flow type selection of a product. This section will discuss the input parameters of the developed model. First the input parameters for the single flow model are discussed and secondly the input parameters for the recurring flow.

Single flow

The model for the single flow has four key input parameters: 1) the shelf capacity, 2) the logistic costs of the push and pull flow, 3) the costs of inaccurate allocation, and 4) the coefficient of variation of a store’s demand.

The shelf capacity is the first input parameter that affects the flow type selection. Its effect is logical and simple and can be expressed by a simple constraint. However, the available shelf capacity is not always as clear since for many single flow products the shelf capacity is shared with other products. Furthermore, the shelf is used by preceding products. The exact selling window and the success of products is complex to predict which results in overlapping shelf usage. As a result the shelf capacity is not an exact and fixed value. For many products store capacity is not recorded or defined very clear since the shelves have to cope with many different type of products. The aim of this constraint is not to overload stores since stores have limited capacity and overloading stores result in increasing costs of the store logistics.

The second important input parameter is the difference between the costs of keeping inventory at the DC and pushing all products to the store. As shown in the conceptual phase the pull flow consists of more handling operations compared to the push flow. Furthermore, in general, the handling costs (per item) are lower when the units that are being handled are larger (Van der Vlist, 2007). A proper cost break down of the handling activities and costs are therefore off crucial importance to estimate this input parameter. Methods as ‘ABC’ and ‘direct product profitability (DPP)’ are often implemented by companies and can be used for estimating these costs.

The costs of inaccurate allocation need to be determined by taking the costs of transhipment, the costs of lost sales and the cost of lost margin. These three aspects determine the third input parameter for the model. For a single flow it is obvious that the number of available products is limited and as a result each shortage results in a lost sale. In the assumed situation that the purchased quantity is equal to the actual demand each shortage also corresponds with an overshoot in another store. This overshoot has to be sold by initiating mark downs; which corresponds with loosing margin. Transhipment can prevent costs of lost sales and lost margin, but transhipment is an expensive process since a number of time consuming
handling activities have to be executed. Thus, when these costs are higher than the costs of lost sales and lost margin one uses the costs of the lost sales and the lost margin. Furthermore, transhipment requires time and should be timed well in order to prevent actual lost sales. For some products customers want to wait and the time of transhipment does not affect lost sales (i.e. jewellery, watches etc).

The final key input parameter is the coefficient of variation of a store’s demand. This non-negative input parameter presents the possible imbalance in the distribution system and affects the cost factor ‘inaccurate allocation’ in the model. A higher value for the coefficient of variation results in higher chance on costs of inaccurate allocation. So, if the coefficient of variation is low the chance on inaccurate allocation costs are low and when the coefficient of variation is high the chance on inaccurate allocation costs are high.

Decision model one consists of the above input parameters and is used to build an Excel-based tool. The tool optimizes the cost parameters and thereby the expected profit. The tool will be used in the next sections to provide apply the model and provide general and V&D specific results.

Recurring flow

Basically, the model for the recurring flow has five main input parameters: 1) the shelf capacity, 2) the shelf availability measure, 3) the product’s demand, 4) a product’s response time to the store, and 5) the logistic costs per flow type. The combination of the above input parameters determines which flow type is most appropriate.

The shelf capacity for products of this flow is often more clear since products are offered for a longer period. As a result the shelf capacity of product is captured in a more fixed shelf plan and therefore the shelf capacity can be better estimated.

The shelf availability target reflects the strategic aims of the company and this research has selected the fill rate to express this target. The fill rate serves as input parameter that is determined by the higher management.

Basically, a product’s demand and in specific a product’s demand pattern is the most unreliable input parameter. A product’s forecast is assumed to known. The demand pattern of a product needs to be determined based on past sales data. For a recurring flow product is often offered for a longer period as products typified by the single flow. Therefore, more sales data of the particular product is available to predict the expected demand and its variation. The variation in demand represents a measure for a product’s demand pattern. Estimating a product’s demand parameters can be done per product over a specific period. If this is too time-consuming one can use a fixed period for all products or even a group of similar products can be used to estimate the demand pattern.

A product’s response time depends on the lead time from the supplier to the DC, the lead time from the DC to the stores and a product’s review period. The total response time is the sum of both lead times and the review period. Furthermore both lead times vary in practice as a result of uncertainty in the logistic processes. The variation of the lead times affects a product’s availability and therefore should be estimated. The review period on its turn is affected by the MOQ and MOA, which are both fixed inputs and defined by a negotiation process between the supplier and the B&M department.
Finally, the logistic costs can be determined on the identified relevant tangible factors and processes. Similar to the single flow the costs can be based on the cost rates that follow from the ABC and DPP method.

The flow type selection model for the recurring flow consists of the above input parameters. Decision model two which is part of the model is built in Excel as a tool. The tool checks if the target product availability can be attained. The tool will be used in the next sections to apply the model and provide general and V&D specific results.

4.2 COMPARING THE ANALYTICAL MODELS WITH THE GENERAL GUIDELINES

This section discusses the results of the comparison of the output of the flow type selection model and the general guidelines deduced from the literature. This comparison serves as the validation of the model. Firstly, the single flow model is discussed and secondly the recurring model.

4.2.1 Comparison of the single flow model with the general guidelines

For the single flow the following general guidelines are compared with the results of the developed model:

G.1 Products with a high obsolescence risk are preferred to be controlled through a central stock point.

Contrary, products with low value do not require a central stock function (Leeuw et al., 1999).

G.2 Products with high demand uncertainty are preferred to be controlled through a central stock point.

(Leeuw et al., 1999).

G.3 A product’s stock need to be positioned as close as possible to the final customer. (Van Donselaar, 1990)

Decision model one has three key input parameters, namely $C_{\log}$, $C_{ia}$ and the coefficient of variation of a store’s demand. By varying these input parameters systematically the output of the model can be compared with the general guidelines. Three levels per input parameter are considered, namely low, medium, high. The values of each level are based on V&D’s data and are presented below. Appendix L presents the ranges of V&D’s data and based on the quartiles values of each input parameter the three levels are determined.

\[
\begin{align*}
\text{Difference between logistic costs (}C_{\log}\text{)} & = \{0.2; 0.6; 1\} \\
\text{Costs of wrong allocation (}C_{wa}\text{)} & = \{1; 3; 15\} \\
\text{Coefficient of variation} & = \{0.2; 0.5; 0.8\}
\end{align*}
\]

Based on these input values 27 combinations are put into the model. The results of each case are presented in appendix J. For each of the 27 combinations an optimal value of $\alpha$ is calculated. Since the input parameters are systemically varied the influence of each parameter can be analysed by executing a multivariate analysis of variance (MANOVA). In doing so the effect of each input parameter with respect to the calculated value of $\alpha$ can be measured. Table 9 presents the results of this MANOVA. It can be concluded that the main effect of the costs of inaccurate allocation ($C_{wa}$) has the largest F-ratio and therefore has the largest effect on alpha. Also, as marked by the white values all factors are significant. This latter can be explained by the $C_{wa}$’s range of the values, which is large compared to the other two input parameters. The suggested interaction between the $C_{ia}$ and the cv can be neglected since the input parameters are independent.
Guideline one:
A product with a high obsolescence risk corresponds with products that have a high cost of wrong allocation. As can be observed from the MANOVA analysis provided in appendix J it is shown that the $C_{ia}$ has the largest effect on $\alpha$. Therefore it can be concluded that this general guideline is supported by the model.

Guideline two:
A product with a high value for the coefficient of variation corresponds with products that experience high demand uncertainty. The influence of this parameter is also obvious since by increasing the coefficient of variation the $\alpha$-fraction increases. From the ANOVA analysis the effect of this factor is also significant. The effect of this parameter however is smaller compared to the $C_{ia}$ which can be partly explained by the smaller range of the input values.

Guideline three:
The third guideline states that stock needs to be positioned as close to customer as possible. Decision model one prefers that products with low demand uncertainty and a small difference between the logistic costs are positioned close to the customer and this corresponds with this guideline. For products that can be characterized by guideline one and two guideline three does not hold. However before the final value of $\alpha$ is determined the product is evaluated by the constraint with respect to the minimum required stock level at the stores. The required minimum stock level is significantly larger than the calculated $\alpha$ in case of high demand uncertainty and high cost of wrong allocation (equation 5). This means that from a commercial perspective stock needs to be positioned as close to the customer as possible. Therefore, also this guideline is supported by the model.

It can be concluded that the single flow model is validated by the provided comparison of the general guidelines with the output of the model. Furthermore, the presented analysis in appendix J shows that the results of the model are similar for the situation in which stores are assumed to be equal and the situation in which stores are assumed unequal.

### 4.2.3 Comparison of the recurring flow model with the general guidelines

The recurring flow is validated in a similar way as that of the single flow model. From the literature three guidelines can be deduced which are compared with the quantitative output of the model. First the general guidelines from the literature are presented:

General guidelines:
G.1 Cross docking requires a higher store inventory compared to central warehousing (Waller et al, 2006)
G.2 As a result of long lead times it is beneficial to use a central warehouse strategy (Yang, 1999)
G.3 High demand variability might be useful to pool inventory risk and therefore use a central warehouse strategy (Zinn & Bowersox, 1988).

Decision model two has a wide variety of input parameter. Similar to the comparison of the single flow, one can vary the input parameters systematically in order to compare the output of the model with the general guidelines. Two analysis are executed, one that evaluates the effect of the key input parameters on the shelf capacity and one that evaluates the effect on the logistic costs.

For the first analysis the following input parameters and their values are used to investigate the effect of the parameters:

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Values</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lead time supplier-DC ($L_2$)</td>
<td>{6, 14, 40}</td>
</tr>
<tr>
<td>Review period of product's supplier ($R_2$)</td>
<td>{1, 14, 28}</td>
</tr>
<tr>
<td>Coefficient of variation ($c_v[D]$)</td>
<td>{1; 1.8; 2.7}</td>
</tr>
<tr>
<td>Overall demand forecast ($E[D]$)</td>
<td>{2000; 4500}</td>
</tr>
</tbody>
</table>

The remaining input parameters are assumed to be fixed and the values are based on V&D’s data.

Based on the input parameters fifty four combinations arise and for each combination the required shelf capacity of the five flow type configurations is estimated (see appendix J for the results). Similar to the analysis of the single flow model a MANOVA is executed. Table 10 presents the results of this MANOVA and as presented by the white marked values it can be observed that each parameter has a significant affect on the shelf capacity. Furthermore, it can be concluded that the demand level is the most influencing factor, followed by the coefficient of variation, the review period and finally the lead time. The demand level has a strong influence since this parameter has a wide range of possible values. Note that $L_2$ and $R_2$ are not significant factors in case of a CWR flow type, which is logical since the inventory buffer separates the supply chain into two independent parts.

<table>
<thead>
<tr>
<th>Source</th>
<th>PA-XDR F-Ratio</th>
<th>PA-XDR P-Value</th>
<th>BB-XDR F-Ratio</th>
<th>BB-XDR P-Value</th>
<th>CWR(W) F-Ratio</th>
<th>CWR(W) P-Value</th>
<th>CWR(TW) F-Ratio</th>
<th>CWR(TW) P-Value</th>
<th>CWR(D) F-Ratio</th>
<th>CWR(D) P-Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>MAIN EFFECTS</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>A:R2</td>
<td>9.90</td>
<td>0.000003</td>
<td>9.34</td>
<td>0.0004</td>
<td>0.08</td>
<td>0.9198</td>
<td>0.08</td>
<td>0.9228</td>
<td>0.09</td>
<td>0.9184</td>
</tr>
<tr>
<td>B:L2</td>
<td>3.97</td>
<td>0.0256</td>
<td>3.61</td>
<td>0.0350</td>
<td>0.08</td>
<td>0.9198</td>
<td>0.08</td>
<td>0.9228</td>
<td>0.09</td>
<td>0.9184</td>
</tr>
<tr>
<td>C:s_v[D]</td>
<td>126.16</td>
<td>0.00000</td>
<td>125.24</td>
<td>0.0000</td>
<td>132.55</td>
<td>0.0000</td>
<td>133.47</td>
<td>0.0000</td>
<td>137.54</td>
<td>0.0000</td>
</tr>
<tr>
<td>D:E[D]_L2</td>
<td>167.70</td>
<td>0.00000</td>
<td>166.58</td>
<td>0.0000</td>
<td>130.16</td>
<td>0.0000</td>
<td>117.58</td>
<td>0.0000</td>
<td>110.95</td>
<td>0.0000</td>
</tr>
</tbody>
</table>

Table 10: Analysis of Variance – effect on the shelf capacity of the recurring flow

The second analysis investigates the effect of the input parameters on the logistic costs. For this analysis different input parameters are chosen which will be varied. Notice that difference between the overall coefficient of variation and the coefficient of variation at the store level is taken into account. This might explain why CWR is more beneficial than XDR since the advantage of risk pooling increases.
Lead time supplier-DC (L_2) = \{6, 14, 40\}
Review period of product’s supplier (R_2) = \{1, 14, 28\}
Coefficient of variation overall (cv[D]) = \{0.5; 0.75; 1\}
Coefficient of variation per store (cv[D]) = \{1; 1.5; 3\}
Procurement value (P_x) = \{1; 5; 15\}

The remaining input parameters are assumed to be fixed and the values are based on V&D’s data.

Fill rate = 0.95
Review Period Store-DC (R_x) = \{CWR (DAILY), CWR (TWICE A WEEK), CWR (WEEKLY)\}
Lead time DC-Store (L_x) = \{BB-XDR, PA-XDR, CWR\}
Overall demand forecast (E[D]) = \{3,000\}

Table 11 presents the MANOVA analysis of input parameters on costs of the five flow type configurations. It can be concluded that the procurement value and coefficient of variation (store) have the largest effect. The effect of the response time is not significant which can be explained by its relatively small effect compared to the two significant input parameters.

<table>
<thead>
<tr>
<th>Source</th>
<th>PA-XDR</th>
<th>BB-XDR</th>
<th>CWR(W)</th>
<th>CWR(TW)</th>
<th>CWR(D)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>F-Ratio</td>
<td>P-Value</td>
<td>F-Ratio</td>
<td>P-Value</td>
<td>F-Ratio</td>
</tr>
<tr>
<td>MAIN EFFECTS</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>A:R2</td>
<td>0.80</td>
<td>0.0525</td>
<td>0.04</td>
<td>0.9642</td>
<td>0.97</td>
</tr>
<tr>
<td>B:xC</td>
<td>63.87</td>
<td>0.0000</td>
<td>63.89</td>
<td>0.0000</td>
<td>77.88</td>
</tr>
<tr>
<td>C:cv[D]</td>
<td>0.63</td>
<td>0.5359</td>
<td>0.39</td>
<td>0.6811</td>
<td>0.10</td>
</tr>
<tr>
<td>D:cv[D]</td>
<td>41.47</td>
<td>0.0000</td>
<td>25.55</td>
<td>0.0000</td>
<td>8.62</td>
</tr>
</tbody>
</table>

Table 11: Analysis of Variance – effect on the logistic costs of the recurring flow

Next, the three general guidelines are compared with the output values of the recurring model.

Guideline one:
From the results in table 11 it is obvious that the model supports this general guideline. Only when the review period of the central warehouse is longer than that of the cross dock configuration and the lead time from supplier is short the required shelf capacity is more or less similar. This latter is logical since the total response time is equal or even smaller.

Guideline two:
Guideline two is also supported by the outcomes of the analysis and can easily be observed from table 10; when the values of the review period (R_2) and the lead time from the supplier to the DC (L_2) increase the required shelf capacity increases significantly. Moreover, it can be concluded from the data that R_2, as part of the response time, has a more significant influence as the lead time. This can be explained by the fact that during a review period no orders can be placed. As a result the safety stock increases more significant opposed to when the lead time from the supplier increases.

From the logistic cost analysis it can be concluded that the review period affect the logistic costs insignificantly. This can be explained by the fact that the costs of inbound transportation are not taken into account. The insignificance of the lead time can be explained by the relative small influence the lead time has compared to the coefficient of variation and procurement value. From the results in appendix J it can be observed that the lead time affects the logistic costs despite its insignificance.
Guideline three:
The third guideline is rather intuitive and also supported by the results presented in table 10. As can be observed from the results the increase in the coefficient of variation results a significant increase of the required shelf capacity.
The analysis of the logistic costs showed similar results. In case the coefficient of variation highly differs between the overall demand and the demand at the store level, it becomes beneficial to choose CWR over the XDR options. This can be explained by the fact that the savings in capital costs exceed the extra handling activities.

It can be concluded that the recurring flow model is validated by the provided comparison of the general guidelines with the output of the model. Both the comparison of results with respect to the shelf capacity and the logistic costs indicated that model corresponds with the general findings in literature.

4.3 DERIVATION OF DATA FROM THE FIELD

The constructed flow type selection model requires information and data in order to estimate the most appropriate flow type. The information and data required for determining the most appropriate flow type is diverse and only partly accessible. V&D’s B&M department is organised in many different teams. Each team is responsible for a certain group of products and their flow type selection. The required information with respect to each product is not all recorded in a central database and as a result this information is only known by the team member of the B&M teams. This makes it difficult to evaluate the past flow type selection decisions of products. This section discusses the retrieval of the key input parameters that are required to compare the models output with that of the decisions made in the past. The section starts by discussing the key input parameters for single flow followed by the key input parameters for the recurring flow.

Data for the single flow model

The four input parameters discussed in section 4.1 have to be gathered to select the most appropriate flow type. The first input parameter is the shelf capacity. The shelf capacity can be deduced from the design of the store layout. V&D categorizes its stores into three format types: one, two and three. Format three stores are the largest stores with often the highest sales and format one the smallest stores. The store layout of each format should be similar and therefore shelf capacity is also similar. The information with respect to the available shelf capacity per format / store is not recorded in a central database. As a result the knowledge about a product’s shelf capacity is highly decentralized. For products that made use of the BB-XDS and the PA-XDS flow type it is assumed that shelf capacity was sufficient and therefore similar to the purchased quantity. Similarly, single flow products that have re-order levels are assumed to be constraint by limited shelf capacity compared to the purchased quantity.

Next, the three input parameters for decision model one have to be determined, namely $C_{\text{imp}}$, $C_{\text{ia}}$ and the coefficient of variation of a store’s demand. The logistic costs are determined based on V&D’s activity based costing method. Each group of products involves a different rate for the identified handling activities. The rate differs between groups of product since the handling of products differs (i.e. a product’s volume and replenishment quantity influence this rate).

The costs of inaccurate allocation are determined based on the product’s selling price and its associated gross margin. It is assumed that when a product is allocated to the wrong store the costs can be expressed by a lost margin and a penalty costs. The lost margin presents the consequence of a product that is allocated to a store where demand is less than expected. As a result the product needs to be marked down
in order to be sold. This mark down is determined as the difference between the selling price and the procurement price multiplied with the expected mark down. In this research it is assumed that one looses 30\% of the contribution margin. According to the model each product that is marked down will result in a lost sales at a different store, therefore a penalty cost can be added for not satisfying this demand. This penalty cost is assumed to be zero during this analysis but can easily be incorporated by V&D’s management. In practice wrongly allocated products can be transhipped to reduce the number of wrongly allocated products, however this process is significantly more expensive as the pull flow and therefore not taken into account.

Furthermore, the coefficient of variation of a product needs to be determined. This is done by gathering the total sales of the generic article items of season A and season B during a specific sales period. For season A data is retrieved from week 40 of 2008 to week 39 of 2009, and for season B from week 16 of 2008 to week 15 of 2009. Next, the articles are categorised per store and at the group level of the family tree (appendix H). The total number of suitable products for the single flow analysis is approximately 18.000 (e.g. 9.000 of season A and 9.000 of season B). Based on the product’s sales fraction per store and the ‘group’ level the average \( f \) is determined and moreover its standard deviation.

Finally, the output of decision one needs to be compared with the minimum required inventory per store. However, about this input parameter no information is recorded centrally. The trade-off between the minimum required inventory levels and determined value of \( \alpha \) should be made by the B&M department based on the output of this model. Interviews with several B&M departments showed that unlike decision model one the minimum required inventory level per store depends on the purchased quantity. The smaller the purchased quantity the larger the incentive to allocate the whole order initially. This is in line with the commercial considerations of the B&M department: “Empty stores do not sell”. Appendix L presents an overview of the input parameters and the found ranges.

**Data for the recurring flow model**

The five input parameters discussed in section 4.1 have to be gathered to select the most appropriate flow type. The sales data used for the recurring flow products is that of the week 40 of 2008 to week 39 of 2009. Next, only products that have a recurring character are selected. This results in a database of approximately 28.640 products. For each product we retrieve the five identified input parameters. First the review period needs to be determined based on the supplier’s review period and the possible constraints expressed by the MOA per supplier and the MOQ of a product. The MOQ can be retrieved from the information system. The MOA has to be calculated per supplier, which is done by multiplying the average demand per week times the purchase value of a product. The sum of all products purchased at a supplier is used to evaluate the constraint of the MOA. The average order value per supplier is not constant and varies across year. This variation is estimated by the taking the standard deviation of the total sales of the 22.671 products. A product’s overall (all stores) average demand per week and its standard deviation is used to evaluate the MOQ of a product.

In order to determine whether a store’s shelf capacity is sufficient a stores average demand and standard deviation need to be determined. The average demand per week is estimated by multiplying a products forecast by a store’s share. The share is determined by taking the fraction of sales of a store at the group level.

Finally the following input parameters need to retrieved in order to complete the flow type selection: supplier lead time, lead time from the DC to the store, replenishment quantity to the stores, the fill rate and logistic rates of a product. These input parameters do not need to be estimated and can be based on
central recorded information and logistic information. For the fill rate this research assumes a long-run fraction of 95%.

Furthermore, it is significant to note that for the CWR three options are evaluated with respect to the response time from the DC to the stores. The set review period affects this response time and therefore in order to compare this flow type with the PA-XDR and BB-XDR specific values need to taken for the CWR flow type. The options evaluated are weekly, twice a week and daily replenishment, which corresponds with the options presented in the conceptual model. The logistic costs are again based on the ABC-method. Based on all these input parameters the flow type selection of a recurring flow product can be executed. Appendix L also presents the ranges of values found in V&D’s data with respect to the recurring flow.

4.4 NUMERICAL ANALYSIS OF ELEVEN PRODUCTS

This section’s aim is to illustrate how the flow type selection model is applied to specific products. Firstly, five products with respect to the single flow model are presented and secondly six products for the recurring flow. The eleven examples are chosen to illustrate the wide range of products for which the flow type needs to be selected. The eleven examples are selected based on the input parameters with the strongest effect on the flow type selection.

Single flow

Table 12 shows the required input parameters for the single flow model for four different products. The four products are first evaluated by constraint one, which means that the forecasted quantity equals the purchased quantity. Next, constraint two checks if the available shelf capacity is sufficient to allocate the entire purchased quantity at once. In case of product one the constraints show that this product needs to be evaluated by decision model three, which means that the CWS flow type is selected. Decision model three selects the most beneficial replenishment strategy of the CWS flow type. Based on a value of 0.95 for the fill rate the weekly replenishment strategy is chosen.

<table>
<thead>
<tr>
<th>Product characteristics</th>
<th>Product 1</th>
<th>Product 2</th>
<th>Product 3</th>
<th>Product 4</th>
<th>Product 5</th>
</tr>
</thead>
<tbody>
<tr>
<td>Product name</td>
<td>Suitcase</td>
<td>Underwear</td>
<td>Pants</td>
<td>Coat</td>
<td>Tiara</td>
</tr>
<tr>
<td>Purchased quantity</td>
<td>8.607</td>
<td>1.751</td>
<td>5.602</td>
<td>1.579</td>
<td>2.200</td>
</tr>
<tr>
<td>Sales period in weeks</td>
<td>52</td>
<td>17</td>
<td>18</td>
<td>20</td>
<td>16</td>
</tr>
<tr>
<td>Maximum Shelf capacity</td>
<td>+/-1.803</td>
<td>+/-1.751</td>
<td>+/-5.602</td>
<td>+/-1.579</td>
<td>+/-2.200</td>
</tr>
<tr>
<td>Minimum required inventory level</td>
<td>1.803</td>
<td>1.200</td>
<td>3.500</td>
<td>1150</td>
<td>600</td>
</tr>
<tr>
<td>Procurement value</td>
<td>€ 40,-</td>
<td>€ 155</td>
<td>€ 14.10</td>
<td>€ 25,-</td>
<td>€ 1,60</td>
</tr>
<tr>
<td>Selling price</td>
<td>€ 84.70</td>
<td>€ 4.33</td>
<td>€ 33.52</td>
<td>€ 52.20</td>
<td>€ 2.50</td>
</tr>
<tr>
<td>C_a</td>
<td>€ 1341</td>
<td>€ 0.85</td>
<td>€ 5.83</td>
<td>€ 8.16</td>
<td>€ 0.50</td>
</tr>
<tr>
<td>C_m</td>
<td>€ 1.82</td>
<td>€ 0.25</td>
<td>€ 0.35</td>
<td>€ 0.45</td>
<td>0.33</td>
</tr>
<tr>
<td>Shelf availability</td>
<td>0.95</td>
<td>n.a.</td>
<td>n.a.</td>
<td>n.a.</td>
<td>n.a.</td>
</tr>
<tr>
<td>Coefficient of variation of the allocation fraction</td>
<td>0.37</td>
<td>0.1</td>
<td>0.34</td>
<td>0.80</td>
<td>0.39</td>
</tr>
</tbody>
</table>

FLOW TYPE SELECTION SINGLE FLOW

C1: \( Q_2 = \text{Demand forecast} \)

C2: \( Q_2 = \sum C_i \)

Decision model one

\( n.a. \) \( \alpha = 0.95 \) \( \alpha = 0.47 \) \( \alpha = 0 \) \( \alpha = 1 \)

Decision model three

V \( n.a. \) \( n.a. \) \( n.a. \) \( n.a. \)

C3: \( Q_2 = \sum B_i \)

\( X \) \( \alpha > 0.68 \) \( \alpha > 0.53 \) \( \alpha > 0.728 \) \( \alpha > 0.27 \)

Selected flow type

CWS (weekly) XDS CWS (weekly) CWS (weekly) XDS

Table 12: Single flow products

Based on constraint two the products two, three, four and five need to be evaluated by decision model one. Constraint two showed that the available shelf capacity is sufficient to allocate the entire purchased quantity at once and subsequently decision model one evaluates whether it is required to keep stock at the DC. Table 12 presents the three key input parameters required for decision model one. The costs of
inaccurate allocation are determined by subtracting the selling price by the procurement price and multiply this by 0.3. For each product its group’s coefficient of variation is presented. Figure 26 and 27 present the graphs of the total costs for the different values of alpha. In figure 26 it is observed that the optimal value of α is approximately an half. This indicates that stock has to be kept at the DC in order to minimize the relevant costs and thereby optimize profit. The calculated value of α serves as input to evaluate the constraint five. Constraint five presents the balance between a product’s presentation and the keeping stock at the DC. The input depends on a B&M team’s vision on the products presentation. Finally, if the XDS is selected the question that remains is whether to select PA-XDS or BB-XDS. The required data for the allocation fraction and the real life issues (D4) finally select the type of cross docking that is most appropriate.

![ OPTIMAL ALPHA ]

**Figure 26: Pants and coat**

**Figure 27: Underwear**

*Recurring flow*

The six selected products presented in table 13 are randomly chosen from a pareto analysis. The pareto analysis distinguishes three categories A, B and C. The A category presents 5 to 10 % of the total number of products that account for approximately 50 percent of the sales (Silver et al., 1998). The B and C category are a larger fraction of the total number of products sold however they account for smaller fraction of the total sales. Two products are picked from the A-category and two from the B and C-category.

<table>
<thead>
<tr>
<th>Product characteristics</th>
<th>Product 1</th>
<th>Product 2</th>
<th>Product 3</th>
<th>Product 4</th>
<th>Product 5</th>
<th>Product 6</th>
</tr>
</thead>
<tbody>
<tr>
<td>Forecast</td>
<td>31,521</td>
<td>22,213</td>
<td>6,447</td>
<td>1,247</td>
<td>437</td>
<td>2,239</td>
</tr>
<tr>
<td>Sales period</td>
<td>52</td>
<td>52</td>
<td>52</td>
<td>52</td>
<td>52</td>
<td>52</td>
</tr>
<tr>
<td>Maximum Shelf Capacity</td>
<td>2,700</td>
<td>4,040</td>
<td>1,506</td>
<td>239</td>
<td>400</td>
<td>991</td>
</tr>
<tr>
<td>Minimum Required Inventory Level</td>
<td>-</td>
<td>3,854</td>
<td>-</td>
<td>239</td>
<td>-</td>
<td>865</td>
</tr>
<tr>
<td>Procurement value</td>
<td>€ 0,69</td>
<td>€ 3,10</td>
<td>€ 0,43</td>
<td>€3,46</td>
<td>€17,32</td>
<td>€3,67</td>
</tr>
<tr>
<td>Number of stores</td>
<td>62</td>
<td>62</td>
<td>62</td>
<td>62</td>
<td>58</td>
<td>62</td>
</tr>
<tr>
<td>Shelf availability</td>
<td>0,95</td>
<td>0,95</td>
<td>0,95</td>
<td>0,95</td>
<td>0,95</td>
<td>0,95</td>
</tr>
<tr>
<td>Minimum order quantity (MOQ)</td>
<td>48</td>
<td>4100</td>
<td>14</td>
<td>10</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>Minimum order value (MOA)</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>400</td>
<td>0</td>
<td>450</td>
</tr>
<tr>
<td>Store’s replenishment quantity</td>
<td>12</td>
<td>4</td>
<td>10</td>
<td>1</td>
<td>1</td>
<td>3</td>
</tr>
<tr>
<td>Supplier’s review period</td>
<td>14</td>
<td>6</td>
<td>6</td>
<td>28</td>
<td>6</td>
<td>6</td>
</tr>
<tr>
<td>Lead time (Lj)</td>
<td>73</td>
<td>3</td>
<td>2</td>
<td>6</td>
<td>6</td>
<td>6</td>
</tr>
<tr>
<td>Standard deviation of overall demand</td>
<td>1,53</td>
<td>0,53</td>
<td>0,83</td>
<td>0,41</td>
<td>1,50</td>
<td>0,67</td>
</tr>
</tbody>
</table>

**FLOW TYPE SELECTION RECURRING FLOW**

| C1: Q2= Demand forecast                  | X         | X         | X         | X         | X         | X         |
| Decision model two                       | V         | V         | V         | V         | V         | V         |
| Selected flow type                       | CWS (D)   | XDR       | CWS (W)   | CWS(D)    | CWS(D)    | XDR       |

Table 13: Recurring flow products and their flow type selection

First the four steps of the flow type selection model for the recurring flow are discussed, starting with the influence of the MOQ and MOA on the review period. The supplier does not work with a MOA so this influence can be neglected. The affect of the MOQ is analyses by equation 11. The review period of
Product's supplier is 14 days; the chance that the MOQ blocks an order has to be smaller than 0.01, which is the case when the review period is 28 days. The model will use this value for further calculations.

Step two evaluates if the available shelf capacity is sufficient to satisfy the fill rate of 0.95. Only the CWS with daily replenishment can satisfy the fill rate of 0.95 with the available shelf capacity. Step three and four are therefore not relevant anymore.

Product two is not affected by the MOQ and MOA. Furthermore its available shelf capacity is sufficient to satisfy the fill rate when is chosen for XDS. Step three evaluates which flow types come closest to the minimum required inventory level. The XDS has highest average minimum inventory level during a replenishment cycle and therefore the XDS is chosen. Step four does not need to be considered.

Product three is affected by the MOQ and therefore the review period is set to 28 days instead of 6 days. Next, step two determines that the shelf capacity selects a CWR flow type. Step three is not relevant and therefore step four determines that weekly replenishment is chosen from a cost perspective.

Product four is not affected by the MOA since during the supplier's review period of 28 days the chance of MOA is smaller than 0.01. The same applies for the MOQ. Next, step two determines that the available shelf capacity to satisfy the fill rate for any of the flow types. The flow type that comes closest is the CWR daily and therefore this one is selected. The remaining steps are not relevant.

Product five is affected by the MOQ and the review period is set to 18 days. Next, step two shows that all flow types are possible with respect to the available shelf capacity. Step three is not relevant since no minimum inventory level is required and thus step four should select the most appropriate flow type. It is shown that CWR with daily replenishment has to lowest costs.

Product six is affected by the MOA and therefore the review period is set to 6 days but 12 days. Next, step two determines that the shelf capacity is sufficient for all flow types. Step three is not relevant since there is no minimum inventory requirement. Step four determines which flow type is most beneficial from a cost perspective. Since the XDS has the lowest cost this flow type is selected.

From the examples it is observed that the input parameters can take on a wide range of values and combinations of values. For each combination it has to be determined whether which flow type is the most appropriate.

4.5 GENERAL RESULTS SPECIFIC FOR V&D

This section presents the general results with respect to V&D's specific data. The aim of the tool is to support the flow type selection process. Therefore this section evaluates V&D's flow type selection by comparing the decision made in the past by the outcome of the developed model.

First the results of the single flow products are presented and secondly the results of the recurring flow products. The single flow model is evaluated by comparing past decisions of twenty departments with that of the outcome of decision model one. The department's single flow products a ranked based on their value for the cost of inaccurate allocation; since this factor has the strongest effect according to the MANOVA analysis. A similar comparison for the recurring model is not possible since the decision model two is affected by more input parameters, thus for the recurring flow the general insights of the model are evaluated.
**Single Flow**

The largest fraction of V&D’s products can be typified by a single flow (appendix K). Each department controls product flows that can be typified by a single flow. Therefore, the pilot group consists of a wide variety of departments, presented in table 12. Furthermore the pilot group only consists of products labelled by 2009A; the spring and summer collection. Products labelled by 2008B or 2009C can be analysed similarly.

To illustrate how the model can support V&D’s flow type selection an overview is given of the average key input parameters of specific product group, which are presented in table 14 below. Since the cost of inaccurate allocation has the largest effect on the flow type selection the presented departments are selected based on the highest and lowest values found for the cost of inaccurate allocation. By showing these ‘extreme’ examples it becomes clear how the model can be applied.

<table>
<thead>
<tr>
<th>Product groups</th>
<th>cv</th>
<th>Cdv</th>
<th>Clog</th>
<th>Average Q</th>
<th>α</th>
<th>Past flow type</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0,58</td>
<td>43,50</td>
<td>0,76</td>
<td>22</td>
<td>0</td>
<td>XDS</td>
</tr>
<tr>
<td>2</td>
<td>0,26</td>
<td>12,51</td>
<td>0,21</td>
<td>57</td>
<td>0</td>
<td>XDS</td>
</tr>
<tr>
<td>3</td>
<td>0,29</td>
<td>9,95</td>
<td>0,21</td>
<td>1540</td>
<td>0</td>
<td>XDS</td>
</tr>
<tr>
<td>4</td>
<td>0,30</td>
<td>6,40</td>
<td>0,33</td>
<td>128</td>
<td>0</td>
<td>XDS &amp; CWS</td>
</tr>
<tr>
<td>5</td>
<td>0,32</td>
<td>6,00</td>
<td>0,21</td>
<td>1018</td>
<td>0</td>
<td>XDS &amp; CWS</td>
</tr>
<tr>
<td>6</td>
<td>0,27</td>
<td>6,48</td>
<td>0,21</td>
<td>30</td>
<td>0</td>
<td>XDS</td>
</tr>
<tr>
<td>7</td>
<td>0,33</td>
<td>7,37</td>
<td>1,82</td>
<td>545</td>
<td>0</td>
<td>XDS &amp; CWS</td>
</tr>
<tr>
<td>8</td>
<td>0,26</td>
<td>8,37</td>
<td>0,21</td>
<td>1130</td>
<td>0</td>
<td>XDS</td>
</tr>
<tr>
<td>9</td>
<td>0,25</td>
<td>6,82</td>
<td>0,21</td>
<td>1497</td>
<td>0</td>
<td>XDS &amp; CWS</td>
</tr>
<tr>
<td>10</td>
<td>0,30</td>
<td>1,60</td>
<td>0,37</td>
<td>240</td>
<td>0,73</td>
<td>XDS</td>
</tr>
<tr>
<td>11</td>
<td>0,37</td>
<td>1,29</td>
<td>0,37</td>
<td>788</td>
<td>0,79</td>
<td>XDS &amp; CWS</td>
</tr>
<tr>
<td>12</td>
<td>0,33</td>
<td>0,94</td>
<td>0,73</td>
<td>925</td>
<td>1</td>
<td>XDS &amp; CWS</td>
</tr>
<tr>
<td>13</td>
<td>0,37</td>
<td>0,40</td>
<td>0,26</td>
<td>896</td>
<td>1</td>
<td>XDS</td>
</tr>
<tr>
<td>14</td>
<td>0,38</td>
<td>1,11</td>
<td>0,76</td>
<td>508</td>
<td>1</td>
<td>XDS</td>
</tr>
<tr>
<td>15</td>
<td>0,38</td>
<td>0,83</td>
<td>0,76</td>
<td>3860</td>
<td>1</td>
<td>XDS &amp; CWS</td>
</tr>
<tr>
<td>16</td>
<td>0,32</td>
<td>0,87</td>
<td>0,37</td>
<td>1567</td>
<td>0,94</td>
<td>XDS &amp; CWS</td>
</tr>
<tr>
<td>17</td>
<td>0,61</td>
<td>0,58</td>
<td>0,76</td>
<td>1095</td>
<td>1</td>
<td>XDS &amp; CWS</td>
</tr>
<tr>
<td>18</td>
<td>0,37</td>
<td>0,51</td>
<td>0,37</td>
<td>828</td>
<td>1</td>
<td>XDS &amp; CWS</td>
</tr>
<tr>
<td>19</td>
<td>0,34</td>
<td>0,48</td>
<td>0,21</td>
<td>2586</td>
<td>0,95</td>
<td>XDS &amp; CWS</td>
</tr>
<tr>
<td>20</td>
<td>0,48</td>
<td>0,44</td>
<td>0,37</td>
<td>1563</td>
<td>1</td>
<td>XDS &amp; CWS</td>
</tr>
</tbody>
</table>

Table 14: Pilot groups for the single flow

* bold means most products within this department use this flow type

Decision model one calculates the α-fraction independent of the purchased quantity. However, the final step of decision model one evaluates the minimum required inventory level with the suggested fraction that should be retained at the DC. If the purchased quantity is small one has to allocate the whole order in order to provide the necessary commercial exposure. Therefore, table 14 also presents the average purchased quantity in order to take this factor into consideration when comparing it with the actual chosen flow type in the past.

From table 14 can be concluded that in practice often is chosen for the cross docking flow types. Since the input parameters present average values of the product groups’ products it is obvious that all products are assumed similar. However the results indicate that the product groups 3 and 8 do not use central warehousing while all the parameters indicate this would be the most beneficial flow type.
The product group 19 uses CWS which might be questioned based on the average input parameters. Furthermore the presented extreme case product group 1 (i.e. furniture) shows that despite one would suspect a CWS flow type, reality shows that is chosen for a XDR flow type. This can be explained by the small purchased quantities that are only used as show models. Thereupon, the actual purchased products will be sent to customers directly from the supplier. This case illustrates that the model supports the decision process but one still needs to interpret the quantitative output with respect to its context.

From the results it can be concluded that the general guidelines of the single flow model apply to V&D’s situation. An addition to these general guidelines is the effect of the minimum required inventory level which as can be observed in table 14 also has a significant effect on the flow type decision. (i.e. product group 6)
Since the developed model supports the decision on a product level a more detailed analysis is required to find the products that are assigned incorrectly. The above analysis shows in which departments one is most likely to find improvement.

Recurring Flow
The recurring flow model depends on a number of input parameters introduced in the conceptual model. The approach of the single flow model can not be applied since the number and wide ranges of the input parameter can not be categorised to give a general overview of how the model applies to V&D’s situation. Appendix J has provided an analysis that compares the estimated required shelf capacity with the available shelf capacity for each flow type. Whether the shelf capacity is sufficient is easily observed. This analysis shows that the application to V&D’s data is simple and only depends on certain input parameters. These input parameters will be discussed.

As can be deduced from the MANOVA analysis the following ranking of the input parameters can be made:
1. Average demand per week of product
2. A product’s coefficient of variation
3. A product’s review period
4. A product’s lead time

These input parameters can all have a wide range of values. Furthermore, these four main parameters are affected by other input parameters. The average demand and the coefficient of variation are both affected by the period of forecast. Since it has been illustrated in the conceptual phase that recurring products are also influenced by the seasonal pattern, the forecasted demand differs when the length of the forecast differs. A longer period of sales results in a different average demand as is chosen for a shorter period. The same applies for the product’s coefficient of variation. V&D’s data also shows that the coefficient of variation is higher for products with a lower average demand. These relationships are taken into account in the model by estimating the coefficient of variation by the following expression:

$$\sigma [D_i] = 1.97 \times E[D_i]^{0.699}$$  \hspace{1cm} (18)

Thus, based on expression 18 the coefficient of variation decreases when the average demand per store increases. Appendix I shows that the coefficient of determination, $R^2$, is 85% which means that of V&D’s data 85% is explained by this relationship.
The review period is affected by the MOQ and MOA as described in the conceptual phase. In order to calculate the review period based on the MOQ and MOA, the model requires the demand pattern of a particular product and that of the order amount per supplier. The first is approximated by calculating the overall product demand and the second by the overall demand pattern of all recurring products.

Based on these specific values for the coefficient of variation the flow type selection model can execute the steps described in the conceptual model.

Appendix J has analysed a number of situations based on a range of values for the input parameters. The following additional guidelines can be deduced from the results:

- The CWR flow type is most appropriate when savings in inventory carrying costs are larger than the costs of the extra handling.
- Step five of the flow type selection is only relevant in case the logistic costs of the XDR flow types are larger than those of the CWR flow types, since the required store inventory level is always higher for a XDR.

4.6 CONCLUSION

This chapter has applied the analytical models of chapter three. The only remaining unanswered sub question is “How do the identified factors affect the flow type selection?” By gathering data related to the key input parameters for both the single and recurring model an analysis is provided that gives the insights with respect to this sub question. For the single flow the costs of inaccurate allocation are most significant followed by the coefficient of variation and the difference in logistic costs, respectively. Furthermore, the analysis shows that based on only the analytical model most products qualify for CWS. Only products with a low selling price, low allocation inaccuracy and relative high logistic cost need to be pushed to the stores initially. Note that the analytical model is only one step in the flow type selection process, and therefore the results should be interpreted and put in to context with the other identified factors.

For the recurring flow the analysis shows that six different input parameters affect the flow type selection. The six input parameters affect the shelf capacity and logistic costs, which are both part of the analytical model. The expected demand and the coefficient of variation of the demand are most significant with respect to the required shelf capacity, followed by the review period and lead time, respectively. The procurement value and the coefficient of variation are most significant with respect to the logistic costs. It can be concluded that as a result of the wide range of the input parameters values, the number of possible combinations and the fact that the analytical model involves five steps makes drawing general conclusions difficult.

To conclude, this chapter has shown how the three decisions models should be applied within the conceptual model. The final sub question is answered and furthermore it is shown how the model works for ten specific cases.
CHAPTER 5: IMPLEMENTATION

This chapter presents the final phase of this project, the implementation of the flow type selection model. Section 1.4 discussed the research design and methodology, and stated that the implementation phase of the model is not within the scope of this research. However this chapter considers the possible implementation of the developed model and its findings. Section 5.1 discusses the flow type selection model in relation to the decision process and whilst section 5.2 reflects on the complexity of the model. Finally section 5.3 draws a conclusion based on this discussion.

5.1 DECISION SUPPORT

The aim of this project was to develop a decision support tool for the logistic department of the V&D which would advise and support the B&M department with regards to the flow type selection. The analysis in chapter two concludes that only two participants are involved in the flow type selection process, namely the B&M and logistic department. The roles of the two participants are clear: the B&M department selects the flow type and the logistic department advises the B&M department with respect to planning, supply requirements and logistic costs. The tool developed and decision framework incorporates all relevant tangible and intangible factors enabling the tool to select the most beneficial flow type from a company perspective. It optimizes both the logistic effectiveness and revenue as well as potentially reducing logistic costs. These results are desirable to the two departments and therefore the tool needs to be embedded on the interface of these departments.

The logistic co-ordinator and merchandisers are responsible for operating on this interface. It is advisable that one of these two functionaries should be the key user and this produces two potential implementation strategies.

Firstly, if the logistic coordinator becomes the key user, the tool is used when the B&M department has questions with respect to the flow type selection. The risk of this approach is that the B&M department does not take the initiative or does not observe the products with the highest potential for enhancement. On the other hand, the advantage of this approach is that it is highly centralized, since there are only two logistic coordinators and thus the required knowledge and data can be managed more easily.

Alternatively, if the merchandiser becomes the key user the model can be used in the daily decision process. This approach has two advantages. Firstly, most data required for the model is only known by the B&M teams. Secondly, since the flow type selection model should be implemented on a product level, incorporating the model within the daily decision process will apply gained insights to every product. The disadvantage is that the knowledge and required data need to be managed by many different people since the B&M department consists of approximately forty different teams. Furthermore the interaction between the two departments is not required, despite the exchange of logistic cost parameters. It can be concluded that both approach have their advantages and disadvantages with respect of how to implement it in the decision process. The next section evaluates another aspect of the implementation: the complexity.

5.2 COMPLEXITY OF THE MODEL

The developed flow type selection model is based on a number of assumptions and usage requires a thorough understanding of how the model works and should be interpreted. Especially the analytical models presented in chapter three require understanding of the assumptions and the effects of the input parameters on the output. Understanding the model is of most important for the recurring flow since the analytical model involves five steps in which a wide variety of input parameters are required, of which
some depend on the experience of the merchandiser. For example the recurring model requires a demand forecast for a specific period which has to be estimated by the merchandiser. The specific time period can be affected by a seasonal pattern and thus the quality of this input parameter depends on the experience of the merchandiser.

The analytical model for the single flow is more straightforward compared to the recurring flow and consists of only one decision step and three input parameters. The insights from this model can easily be interpreted and used in the flow type selection process.

Each of the approaches requires that the key user understand the model’s assumptions and the relationship between the input parameters and output parameters. This requires training and applying the model to real life.

5.3 CONCLUSION

From section 5.1 and 5.2 it is evident that the developed model can be implemented in two different ways. Each approach has its advantages and disadvantages. Following on from the assignment, the aim was to build a tool that enables the logistic department to advise the B&M department. For a successful implementation it is crucial that the project is owned by one department which takes responsibility for the implementation. This means that approach one is probably most likely to succeed since the project is executed at the logistic department. A potential risk however, is the fact that the model optimizes the flow type selection from a company perspective, and as a result of this perspective the inclusion of the intangible factors makes it difficult to express the potential enhancement into an actual cost saving. This makes the required efforts hard to justify for the logistic department.

It can be concluded that the flow type selection model is not completely ready for implementation, aspects that need further attention are training, data implementation and user interaction.
CHAPTER 6: CONCLUSION & RECOMMENDATIONS

This chapter presents the results of this research and gives recommendations for the employees of V&D. First the general guidelines are summarized in section 6.1. Section 6.2 presents the guidelines specifically for V&D. Next, the academic relevance of this thesis is discussed in section 6.3. Thereupon, section 6.4 discusses the limitations and the areas of future research. Finally, section 6.5 introduces some additional points of interest.

6.1 GENERAL GUIDELINES

The flow type selection model provides general guidelines with respect to the indirect flow types. The first insight provided by this research is that the flow type selection problem of indirect flow types can be distinguished into a single flow and a recurring flow problem. Both models have gained different insights and are therefore summarized separately.

The flow type selection model for the single flow has shown that CWS (i.e. an alpha policy) becomes more beneficial or necessary, when:

- A product has a high cost of inaccurate allocation.
- Demand uncertainty of a store is high which results in shortages and overshoots of products.
- The difference in the logistic costs of a pushed flow and that of a pulled flow is small.
- A product's ordered quantity is large, in which case the minimal required inventory level can be obtained and at the same time a fraction can be retained at the DC.
- A product's required minimal store exposure is low.
- A product's maximum shelf capacity is smaller than the ordered quantity.

Both cross dock flow types become more beneficial in the opposite situations. The PA-XDS and BB-XDS differ with respect to the availability of sales data, the required technology (i.e. EDI) and the complementary price for the supplier's extra handling activities. These factors are described in the conceptual model but are not incorporated into the analytical models since the applicability of these factors in practice is straightforward.

This research has also described the environment in which the single flow type selection takes place. From this description two crucial logistic parameters are used as fixed input parameters, namely a product's shelf capacity and a product's demand forecast. By using these as fixed input parameters the flow type selection model is demarcated. Optimizing the store's surface revenue is determined by the B&M department and therefore assumed to be an independent problem. A product's demand forecast accuracy also serves as a fixed input and the model assumes that the purchased quantity corresponds with the actual demand. The assumption of high demand accuracy is the basis of the analytical model since only in this particular situation shortages and overshoots will result in costs of inaccurate allocation. A product of which the forecast accuracy is low (i.e. success or failure) the necessity of the flow type selection decreases and one should to choose the least expensive flow type with respect to the tangible factors.

In general the model shows that increased logistics costs have to be outweighed by the risk of inaccurately allocating products within the divergent distribution network.
Secondly, the flow type selection model for the recurring flow has shown that CWR becomes more beneficial or necessary, when:

- A supplier's response time is low
- A product's shelf capacity is low
- A product's demand highly fluctuates over time
- A product's value is high

Both the cross docking flow types become more beneficial in opposite situations. Similar to the single flow the PA-XDR and BB-XDR differ with respect to the availability of the sales data, the required technology (i.e. EDI) and the complementary price for the supplier’s extra handling activities. Note that in case of V&D, the availability of sales data is not relevant for the recurring flow since the BB-XDR and PA-XDR are controlled exactly similar.

Besides the general guidelines presented above, this research has shown that the evaluation of the flow type selection can only be executed for a specific product. This is the result of large number of possible combinations that arise from the model’s five steps and the ten input parameters. Furthermore, it can be concluded that since the model assumes that demand is stationary, a merchandiser needs to use a representative forecast period for a product in order to get qualitative output.

In general the model evaluates whether the flow type is sufficiently responsive to attain the required shelf availability and moreover selects a flow type with the lowest logistic costs.

This section can be concluded by reflecting on the main research question and stating that the relevant tangible and intangible factors are identified and translated to a flow type decision tree that can be used to select the economical optimal flow type.

6.2 RECOMMENDATION FOR V&D

The previous section discussed the general guidelines that followed from this research. The presented guidelines apply to V&D’s situation since their data was used. However, the guidelines are not specific enough to advise the B&M department on selecting the economical optimal flow type. From chapter four it can be concluded that the model needs to be implemented in order actually support and enhance the flow type decision. Furthermore the chapter illustrated that the recurring flow model can only provide insights on the product level, while the single flow model also enables to draw more general conclusion about V&D’s single flow products. As a result of this latter, the research’s results supports V&D’s strategy of increasingly using the CWS flow type. This support is based on two reasons, firstly, the costs of wrong allocation are proved to have a stronger effect on the flow type selection than the logistic costs, and secondly, V&D’s product assortment consist mainly of products that have relatively high costs of wrong allocation compared to the logistic costs.

6.3 ACADEMIC RELEVANCE

Section 2.5 explains the difficulties in the field of supply chain management by introducing Fisher’s (1997) article “Which type of supply chain is appropriate for which type of product?” Fisher argues that despite new technology companies still struggle with this question and therefore he has introduced a framework that provides general guidelines for the match between a type of product and its required supply chain.
However, these highly aggregated guidelines do not provide an insight into the actual design of a product’s supply chain decision process.

In essence the flow type selection problem, which involves only the final part of the total supply chain, corresponds with Fisher’s issue. This problem’s aim is to design a method that optimizes the final stage in the supply chain. As a result the flow type selection problem tries to bridge the gap between Fisher’s highly aggregated and the actual decision process. Van den Heijkant (2006) has developed a model that supports the flow type selection by taking logistic costs as a basis for selecting either the DSD or CW flow type. From Fisher’s insights it can be concluded that besides the logistic costs a supply chain’s responsiveness is also a significant factor. This thesis extends the flow type selection problem by not only taking the logistic costs into account but also a flow type’s responsiveness. As a result this thesis tries to extend the knowledge on flow type selection model design.

The functionality of the developed model is innovative since this research has introduced a framework that uses a wide variety of product characteristics to select the most beneficial flow type. Furthermore, it positions the flow type selection decision with respect to other logistic parameters, of which the most important is the shelf capacity.

In conclusion, the provided framework in this thesis and its quantitative models have provided a more detailed understanding of how to apply the general guidelines provided by literature.

6.4 LIMITATIONS AND AREAS FOR FUTURE RESEARCH

This section presents some limitations of the model, which are suggested as areas for future research:

- The single flow model does apply to products in which the purchased quantity corresponds to the actual demand. For some products, especially totally new product this does not hold. The chance that a product will be a success or failure compared to chance that demand will be equal to the purchased quantity is larger. As a result in both situations (success or failure) one can better have chosen for cross-docking flow type since either an overall shortage or overshoot will occur.
- Single flow promotional products are not analysed and assumed to be similar to the seasonal products, however the assumption that promotional products can be replenished within their short selling season if chosen for a CWS might be unrealistic.
- This research has used the costs of transhipments in order to determine costs of inaccurate allocation. The timing of transhipments is not analysed instead it is assumed that if imbalance occurs and transhipment is used the imbalance will dissolve.
- The recurring model assumes that demand is stationary, while in practice many products are affected by the seasonal sales pattern.

6.5 ADDITIONAL POINTS OF INTEREST

Besides the insights provided by the flow type selection model, some other interesting points are noticed during this project:

- The B&M department does not incorporate an under- and overage costs when determining the purchase quantity. By incorporating these costs the expected profit can be further optimized.
- The B&M department has no tools which helps them to optimize the inventory levels at the stores. The developed model shows that the total logistic cost can be reduced by reducing the inventory levels at the stores by keeping stock at the DC.
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