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The PLE model
selecting the optimal distribution flowtype for Metro Cash & Carry Deutschland

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Düsseldorf, July 2010

The PLE Model

Selecting the Optimal Distribution Flowtype for Metro Cash & Carry Deutschland

By J.W.G. Bovend’eerdt

in partial fulfilment of the requirements for the degree of

Master of Science
in Operations Management and Logistics

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Preface

This report presents the results of my master thesis project at Metro Cash & Carry Deutschland. It forms the master thesis report of my study at the Technological University in Eindhoven. This report gives logistical guidance to Metro Cash & Carry Deutschland and informs other people who are interested in the subject.

Readers who want a quick view on the highlights of this report should read the management summary.

In addition I would like to thank all people who helped me during this project. First, I want to thank Niels Maas for giving me the opportunity to execute this master thesis project at Metro Cash & Carry Deutschland. Second, I want to thank my supervisors of the TU/e for their support and guidance: Karel van Donselaar and Rob Broekmeulen. Third, I want to thank Tuncay Yilmaz and Frank Röder for their insights and helping hand. And last but not least, I want to thank all remaining colleagues at the supply chain management department of Metro Cash & Carry Deutschland. My special thanks go to André Hainke and Dietmar Labov, with whom I shared the same office.

Finally, I would like to notify to all readers that all absolute figures in this report are multiplied with a certain factor due to confidentiality of the data.

Jeroen Bovend'eerdt

DISCLAMER

All figures and conclusions in this report are modified and do not represent the real situation for Metro Cash & Carry Deutschland.

Abstract

This report describes the design of the Physical Logistic Efficiency (PLE) Model, which can be used to select the economic optimal logistic structure for all given non-food supplier of Metro Cash & Carry Deutschland. The available logistic structures are direct store delivery, central warehousing, and cross-docking. Finally, the report gives some general guidelines which give a better understanding of the drivers of the logistic costs per logistic structure.

Management Summary

This section presents a summary of the master thesis of Jeroen Bovend'eerdt at Metro Cash & Carry Deutschland (MCCD). First, the problem is defined and the research design is presented. Second, the analysis of the relevant logistic cost drivers is shortly described. Third, the design of the PLE Model is explained. As a latter, the results of the PLE Model are discussed and a conclusion is presented.

The Problem Definition

The result of the problem definition is formulated in the following research question:

> Determine the optimal distribution flowtype for all functional non-food product categories of Metro Cash & Carry Deutschland with regard to its main cost drivers and customer service measures.

The following terms need further explanation:

- A distribution flowtype is the way the goods flow from the supplier to the several stores [Van Den Heijkant, 2006]. The distribution flowtypes available at MCCD are direct store delivery, central warehousing, and cross-docking. The optimal distribution flowtype is defined as the one with the overall lowest physical logistic costs.
- Fisher [1997] defines functional and innovative products as the two main product types relevant for selecting an appropriate distribution strategy. This master thesis focuses on functional products in the non-food assortment of MCCD.
- The main cost drivers for the relevant logistic costs are considered. A relevant logistic cost is defined as a physical handling, transport, or stock cost that significantly differs between the distribution flowtypes.
- The main customer service measures for the selection of a distribution flowtype are considered. These are the Stock Service Level (SSL), Stock Coverage (SC), Fill Rate (FR), Order-to-Delivery-Lead-Time (ODLT), and Late Deliveries (LD).

This master thesis focuses on MCCD's logistic costs of each distribution flowtype available for the functional products in the non-food assortment supplied by all national suppliers. The available distribution flowtypes are defined below:

- *Direct Store Delivery (DSD): w*ith DSD, a store orders directly from the supplier. The supplier picks the store orders and delivers the goods directly to the store.
- *Cross-Docking (XD):* although one can distinguish between pre-allocated cross-docking and break bulk cross-docking, MCCD only uses break bulk cross-docking for the non-food assortment. With break bulk cross-docking multiple suppliers deliver bulk quantities to the DC. Here, the orders are 'broken' down into smaller and/or more convenient flows for redistribution to the stores.
- *Central Warehousing (CW):* with CW, MCCD holds inventory at a central Distribution Center (DC) where it is ordered by a store whenever it is needed. Holding inventory at a DC helps managing the variation and uncertainty between supply and demand.

The research design of this thesis is given in figure 1 and includes a company & problem description, the analysis and diagnosis of the problem, a solution design for the problem, and a conclusion & recommendation. In the analysis and diagnosis of the problem the drivers of

the relevant handling, transport, and stock costs are analysed. In the solution design, these drivers are integrated into the Physical Logistical Efficiency (PLE) Model which calculates the logistic costs per supplier per distribution flowtype. The PLE Model is then used to select the optimal distribution flowtype for sixteen non-food pilot suppliers of MCCD. The results lead to four general guidelines concerning distribution flowtype selection and several recommendations for MCCD.

I COMPANY & PROBLEM DESCRIPTION

II ANALYSIS & DIAGNOSIS

Distribution Flowtypes Description

Distribution Costs & KPIs Description

Handling Costs Analysis	Transport Costs Analysis	Stock Costs Analysis

SOLUTION DESIGN

III PLE Model Development

Model Adoption & Implementation

IV CONCLUSION & RECOMMENDATIONS

Figure 1 Research Design & Structure of the Report

Analysis & Diagnosis

Figure 2 shows the logistic cost breakdown for MCCD's non-food assortment over the year 2009. The drivers of MCCD's relevant logistic costs are analyzed. The relevant logistic costs are the store and DC handling costs, direct and indirect transport costs, and DC stock and store backroom stock costs. It is assumed that each supplier's MOQ assures the minimization of its own relevant logistic costs: the supplier's costs are out of scope of this research.

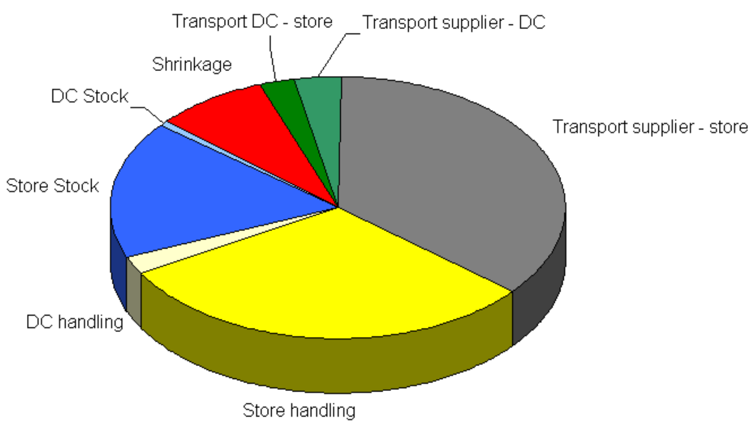


Figure 2 Logistic Cost Breakdown for MCCD's Non-food assortment for the year 2009

Handling Costs

The handling costs analyzed for MCCD consist of store handling and DC handling costs. The store handling costs are further divided into goods receiving costs and shelf replenishment costs. The driver analysis for goods receiving, shelf replenishment, and DC handling is shortly described below:

- *Goods Receiving:* first, the goods receiving activities and their drivers are identified. Second, the efficiency gain of switching from direct to indirect delivery is estimated for each goods receiving activity. Third, the costs per driver of each goods receiving activity for both direct and indirect delivery are computed. From this analysis it follows that the input required to estimate the yearly goods receiving costs associated with a particular supplier is: *a supplier's number of pallets, cartons, mixed pallets, packages and Goods Receiving lines over a year*.
- *Shelf Replenishment:* the shelf replenishment costs are driven by the balance between the Excess Shelf Coverage (ESC) and order-size. Here, the ESC is defined as the number of cartons of a supplier which fit between the can-order and must-order levels on a store's shelf. When not all cartons of an order fit on the shelf, the remaining cartons must be stored in the store's backroom and replenished later. This incurs both secondary replenishment costs and backroom stock costs. To estimate the ESC for a particular supplier, the following input is required: *a supplier's mean order to delivery lead-time, review period, associated shelf coverage, MOQ, and mean and standard deviation of daily store demand*.
- *DC Handling:* first, the DC handling activities for CW and XD together with their drivers are identified. Second, the costs per driver of each DC handling activity are computed. The main difference in DC handling costs between CW and XD are found to be the stocking costs, the order picking costs, and the goods exit costs. From this analysis it follows that the input required to estimate the yearly DC handling costs associated with a particular supplier is: *a supplier's number of pallets, cartons, and trucks over a year*.

Transport Costs

For the analysis of MCCD's transport cost drivers its retail network is split in two parts:

- *Part (A) Transport from supplier to DC or stores:* this part of the retail network is a consolidation network in which loads destined to several retailers are bundled by third party logistic service providers in a single shipment. For the computation of the associated transport costs, the transport efficiency model of Van Der Vlist and Broekmeulen [2006] is extended with the distance-estimation model suggested by Broekmeulen [2007]. From this analysis it follows that the input required to estimate the yearly transport costs of part (A) associated with a particular supplier is: *a supplier's address, its number of pallets, and its mean pallet utilization over a year*.
- *Part (B) Transport from DC to stores:* this part of the retail network is concerned with the transport of both XD and CW pallets from the DC to the stores. For the computation of the transport costs associated with a supplier, the fraction of a pallet occupied with cartons of this supplier is compared to the mean pallet utilization. Here, the average XD pallet utilization for the years 2008 and 2009 was considerably lower than the average CW pallet utilization. Therefore, the transport cost per carton on a XD pallet is significantly higher than the transport cost per carton on a CW pallet. The XD pallet utilization may be increased when the number of XD suppliers increases or when MCCD switches from a time-oriented to a quantity-oriented consolidation policy. The input required to estimate the yearly transport costs of part (B) associated with a particular supplier is: *a supplier's number of pallets and mean pallet fraction occupied over a year*.

All figures and conclusions in this report are modified and do not represent the real situation for Metro Cash & Carry Deutschland.

Stock Costs

The safety stock and cycle stock in the retail network of MCCD are analyzed. First, the total system safety stock costs are proven to not differ between the available distribution flowtypes. Therefore, the safety stock analysis is excluded from the flowtype selection mode. Second, the drivers of DC cycle stock and store cycle stock are analyzed. This analysis is shortly described below.

- *DC Cycle Stock:* the mean cycle stock at the DC is approximated by half of the total DC order-size. Because it is assumed that each supplier supplies the DC exactly once per replenishment cycle, the total DC order-size is the sum of all store orders. The DC cycle stock costs are computed by multiplying the mean DC cycle stock level with a 6,7% interest rate and a factor representing the space utilization costs.
- *Store Cycle Stock:* a store has cycle stock stacked on two locations: on the shelves and in the backroom. The shelf space available to stock products is determined by Category Management and is not influenced by the distribution flowtype. All stock stacked on the shelves does not incur stock holding costs: the shelf space is reserved for a product, whether it is filled or not.

The store backroom cycle stock is driven by the shelf space. All cartons which do not fit on the shelves are stored in the backroom where they incur stock holding costs. An equation is derived with which the mean expected backroom cycle stock level for a particular supplier can be calculated. Again, the cycle stock costs are computed by multiplying the mean cycle stock level with a 6,7% interest rate and a factor representing the space utilization costs.
Conclusively, the extra input required to estimate the yearly DC and store backroom cycle costs associated with a particular supplier is: *the mean selling price and volume of a carton from the supplier.*

Solution Design

The drivers of the relevant logistic costs which are identified in the analysis and diagnosis part are integrated into the Physical Logistic Efficiency (PLE) Model. This model estimates the total relevant logistic costs per supplier per store order-size for the three available distribution flowtypes DSD, XD and CW. The output of the PLE Model is three-fold:

1. A graph showing the behaviour of the relevant logistic cost per distribution flowtype when changing the store order-size. This graph can be used to determine the optimal store order-size of a distribution flowtype.
2. The overall optimal distribution flowtype for the supplier in question together with the accompanied handling, transport, and stock costs per carton.
3. The minimum supplier contribution required when switching from DSD to XD or CW. This can be used in the negotiation with a supplier and is equal to the difference in physical logistic cost per distribution flowtype in percentage of the supplier's total turnover.

The PLE Model is applied to sixteen different pilot suppliers ranging from A to P. The results are summarized in table 1 below and figure 3 on the next page.

Tabel 1 Distribution Flowtype Ranking per Pilot Supplier

		Pilot Supplier															
		A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P
Flowtype Ranking	DSD	1	1	2	2	2	3	3	1	3	1	2	1	1	3	1	2
	XD	2	2	1	1	1	2	2	2	2	2	1	2	2	1	2	1
	CW	3	3	3	3	3	1	1	3	1	3	3	3	3	2	3	3

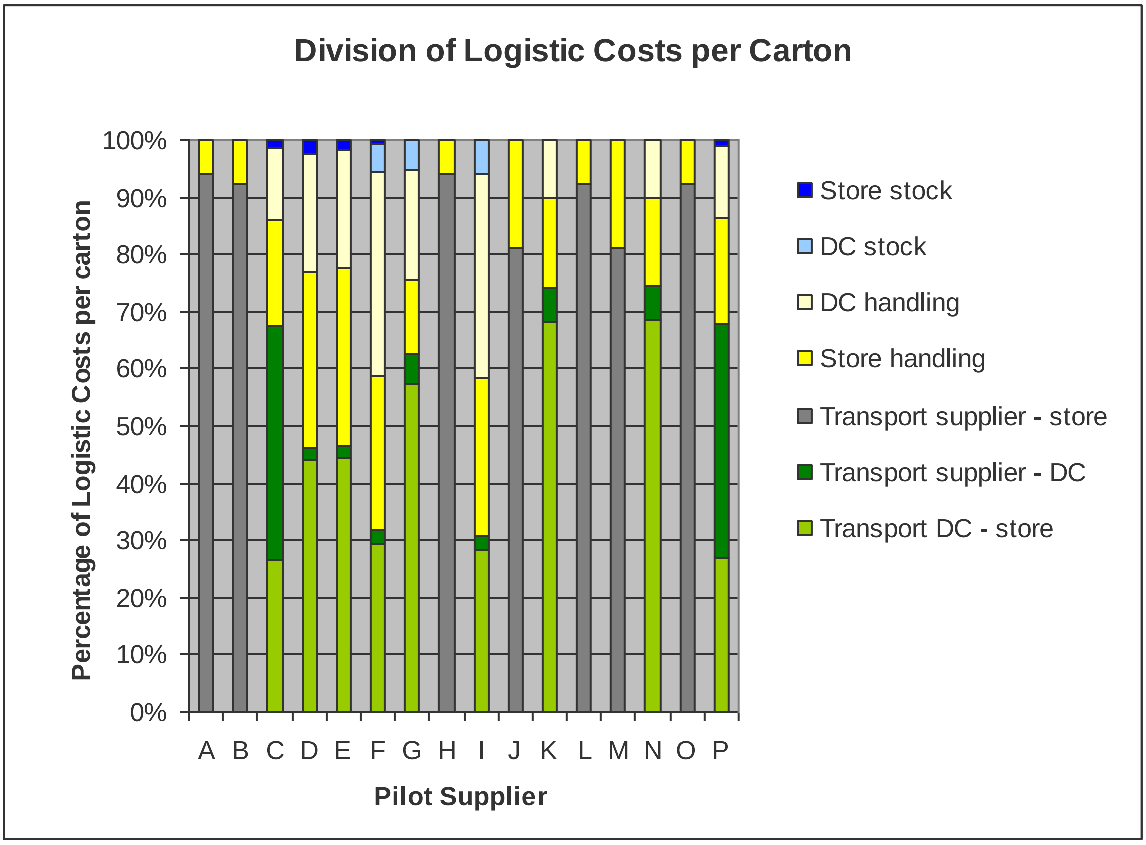


Figure 3 Division of cost per carton for the optimal distribution flowtype per pilot supplier

Table 1 shows that for 7 out of the 16 pilot suppliers DSD is the optimal distribution flowtype, for 6 of the 16 pilot suppliers XD is the optimal distribution flowtype, and for 3 out the 16 pilot suppliers CW is the optimal distribution flowtype. For all pilot supplier with XD as optimal distribution flowtype, the second-best flowtype must be chosen whenever their reliability is low. For 5 out of the 6 XD pilot suppliers, the second-best flowtype is DSD.
Figure 3 graphically represents the division of the logistic costs per carton for each pilot supplier. First, this figure shows that the handling and transport costs are responsible for more than 90% of the relevant logistic costs for all 16 pilot suppliers. Second, this figure shows that the division of transport, handling, and stock costs differs between the pilot suppliers. The PLE Model gives insight into this division and compares the relevant logistic costs for the available distribution flowtypes.

Conclusion

The analysis and diagnosis phase has resulted in four general guidelines for distribution flowtype selection in the scope of the thesis. These guidelines are summarized below:

- The store order-size has a big influence on the relevant logistic costs in a retail chain.
- Direct store delivery becomes more beneficial with an increase in store order-size, total sales volume, and distance from supplier to DC.
- Indirect delivery is only beneficial when the extra DC handling and DC stock costs are earned back by the benefits of transport consolidation.
- Central warehousing can increase the excess shelf coverage at the store to reduce secondary replenishment and backroom stock costs if they exist.

As a latter, the application of the PLE Model for the sixteen pilot suppliers of MCCD has resulted in several recommendations for MCCD.

Table of Contents

Introduction

Metro Cash & Carry Deutschland (MCCD) has three distribution flowtypes available to distribute its non-food products to all stores in Germany:

- *Direct Store Delivery (DSD)*

The wholesale stores order directly from the supplier. The supplier picks the store orders and delivers the goods directly to the store.

- *Cross-Docking (XD)*

Multiple suppliers deliver bulk quantities to the DC, where, the orders are 'broken' down into smaller and/or more convenient flows for redistribution amongst the stores.

- *Central Warehousing (CW)*

The suppliers deliver the goods to the distribution center, where they are held on stock and distributed to the stores whenever they are ordered.

This report describes the design of the Physical Logistic Efficiency (PLE) Model, which can be used to select the optimal distribution flowtype for all given non-food supplier of MCCD. The research design and structure of this report are given in figure 1. This figure gives the four research parts and eleven chapters of this report. The research parts are based on the regulative cycle of Van Strien [1997] and include: a company & problem description, the analysis and diagnosis of the problem, a solution design for the problem, and a conclusion & evaluation.

- *Company & Problem Description*

The company & problem description is given in the first part of this report: Chapter 1 gives a company description explaining the Metro Group, Metro Cash & Carry, and important retail trends. Chapter 2 describes the problem including the problem context, the research assignment, the project scope, and the level of analysis.

- *Analysis & Diagnosis*

The second part of this research contains the analysis & diagnosis. The first step of the analysis and diagnosis is the description of MCCD's relevant logistic costs and available distribution flowtypes. Chapter 3 explains the main logistic cost breakdown of MCCD and the main KPIs. Chapter 4 describes the three available distribution flowtypes at MCCD with their main advantages and disadvantages. The second step is the analysis of the drivers of the relevant logistic costs: handling costs in Chapter 5, transport costs in Chapter 6, and stock costs in Chapter 7.
Chapter 5 first analyses the drivers of store handling costs considering goods receiving and shelf replenishment. Second, it analyses the drivers of DC handling costs for both central warehousing and cross-docking. Chapter 6 first analyses the drivers of transport costs from supplier to the DC or directly to a store. Second, it analyses the drivers of transport costs from the DC to a store. Chapter 7 first analyses the safety stock, second the DC and store cycle stock, and third the costs of holding stock.

- *Solution Design*

In the third part of this report the drivers of handling, transport, and stock costs are integrated into one model: the Physical Logistic Efficiency (PLE) Model. The PLE Model calculates all

relevant logistical cost associated with a particular supplier. Chapter 8 describes the PLE Model, its input, and its assumptions.
After the development of the PLE Model it is used to determine the optimal distribution flowtype for sixteen pilot suppliers. Chapter 9 explains how these pilot suppliers are selected, gives the result of using this model for the pilot suppliers, verifies the model results, and gives important remarks about the model implementation.

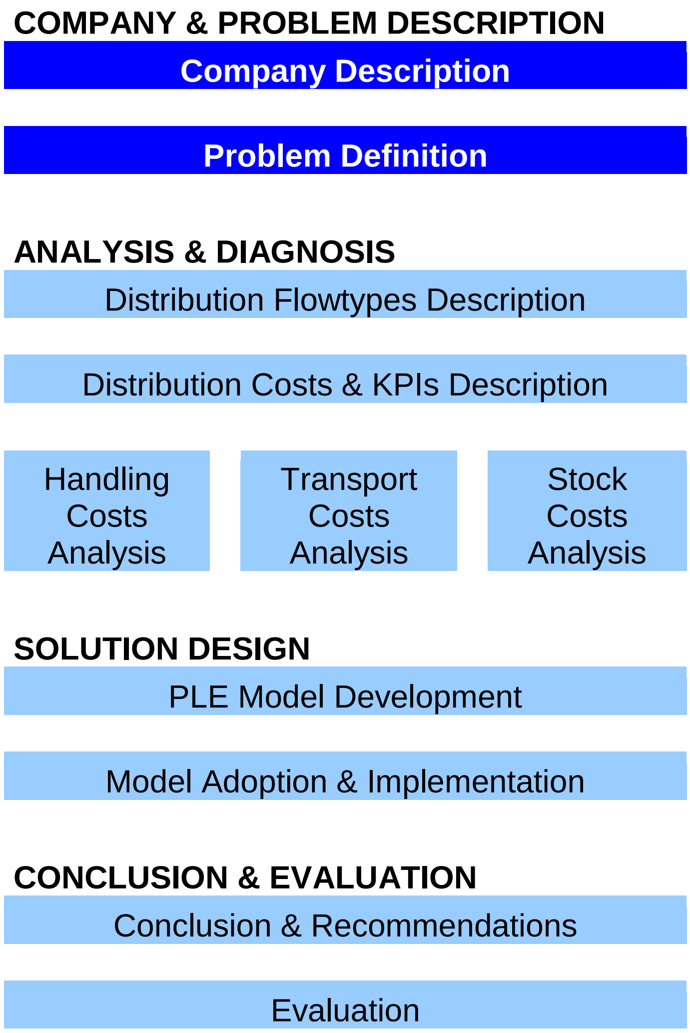
- *Conclusion & Evaluation*

The fourth part of this report contains two chapters. Chapter 10 presents the general guidelines and recommendations for MCCD which are derived from the adoption of the PLE Model for the sixteen pilot suppliers. As a latter, Chapter 11 gives an evaluation of the project in terms of strengths and weaknesses, contribution to scientific research, and personal evaluation.

Part	Chapter	
		COMPANY & PROBLEM DESCRIPTION
I	**1**	Company Description
	2	Problem Definition
		ANALYSIS & DIAGNOSIS
II	**3**	Distribution Flowtypes Description
	4	Distribution Costs & KPIs Description
	5	Handling Costs Analysis
	6	Transport Costs Analysis
	7	Stock Costs Analysis
		SOLUTION DESIGN
III	**8**	PLE Model Development
	9	Model Adoption & Implementation
		CONCLUSION & EVALUATION
IV	**10**	Conclusion & Recommendations
	11	Evaluation

Figure 1 Research Design & Structure of the Report

PART I COMPANY & PROBLEM DESCRIPTION



1. Company Description

This chapter provides a description of the company at which the master thesis is carried out. Section 1.1 introduces the Metro Group, section 1.2 describes Metro Cash & Carry Deutschland, and section 1.3 describes the main trends in the retail environment.

1.1 The Metro Group

The Metro Group is the world's third-largest retail and wholesale company, after Wal-Mart in the US and Carrefour in France. Appendix A provides an overview of the main global and European retail market players. The Metro Group was founded in 1996 with the strategy of profitable growth through customer-centricity and internationalization. Nowadays, it has more than 290.000 employees working at 2.2000 locations in 32 countries. The main business entity Metro AG manages the strategic planning and budgeting for the four sales divisions of the Metro Group. The four sales divisions of the Metro Group operate in both the business-to-consumer environment and the business-to-business environment:

- *Metro (and Makro) Cash & Carry*: self-service wholesaler providing articles in both the food (e.g. fish, meat, fruits, vegetables) and non-food (e.g. household goods, stationary and multimedia) area to professional customers such as hotel, restaurant and kiosk operators, caterers and small-food retailers, hospitals, and authorities.
- *Real*: hypermarket focusing on the provision of food articles (e.g. groceries) complemented with a limited set of non-food articles (e.g. household goods, electronics, books). The main customer groups are young families and individual consumers.
- *Media Markt and Saturn*: two providers of consumer-electronics (e.g. multi-media) to individual consumers in the business to consumer market.
- *Galeria Kaufhof*: department store focusing on the provision of household goods, fashion and lifestyle products to individual consumers in the business to consumer market.

Figure 1.1 shows the global sales share per division of the Metro Group for the year 2008 [METRO Annual Report, 2008]. This figure shows that the Metro Cash & Cary (C&C) division is responsible for about half of the total sales of the Metro Group.

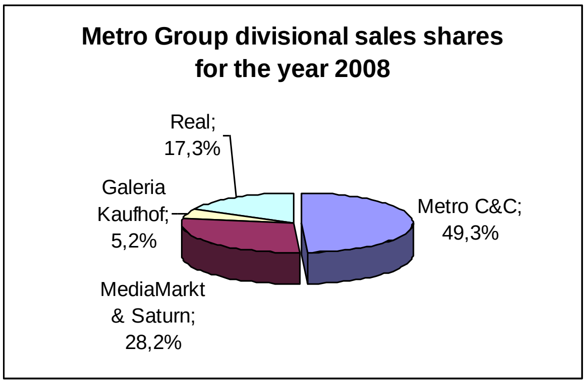


Figure 1.1 Metro Group's divisional sales shares

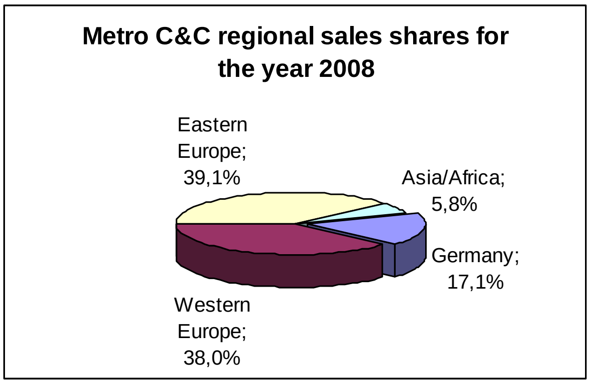


Figure 1.2 Metro C&C's regional sales shares

1.2 Metro Cash & Carry Germany

Figure 1.2 shows the regional sales share of the division Metro Cash & Carry (C&C) for the year 2008 [METRO Annual Report, 2008]. From this figure it can be seen that 17% of the global sales of Metro Cash & Carry is generated in Germany. The Metro Cash & Carry Deutschland is in the remainder of this report referred to as MCCD. In total 61 MCCD wholesale stores, 11 distribution centers, and 6 fresh-platforms are located in Germany (see appendix B). Both the national and international headquarters are located in Düsseldorf.

The assortment of MCCD consists of c.a. 20.000 food articles and 30.000 non-food articles. The food assortment consists of the following departments:

- Dry food (i.e. non-perishables, beverages and cosmetics)
- Fresh and deep frozen foods (i.e. diary, meet, fish, bread, fruit and vegetables)

The non-food assortment consists of the following departments:

- Textiles (e.g. job clothing, shoes, accessories)
- Leisure (e.g. seasonal, sport, gardening, camping)
- Multimedia (e.g. office media, entertainment, electro)
- Household (e.g. office furniture, budgetary, china)

Roughly 51% of the total assortment (food & non-food) is delivered directly, 24% is cross-docked (mainly fast-moving food products), and 25% is centrally stocked (mainly non-food import products).

1.3 Retail Trends

MCCD is a big player in the German retail environment. The retail environment is concerned with product availability to satisfy customer demand. The customer demand in a retail environment has a multiproduct nature with high fluctuations where stock outs result in lost sales [Fernie & Sparks, 2004, page2]. These demand characteristics greatly stress the flexibility of the inventory management and replenishment in the retail supply chain. This has caused retail supply chain management to follow the following four stages [Van Der Vlist, 2007]:

- *Supplier control (pre-1980)*

Suppliers made direct store deliveries on a weekly or longer basis. The stock which did not fit on the shelves of a store was stored in a backroom.

- *Centralization (1981-1989)*

Retailers in areas with a high concentration of stores constructed distribution centers to take over and centralize the role of the backroom. Furthermore, the use of distribution centers made it possible to consolidate orders for transport efficiencies and more frequent delivery to stores.

- *Just-in-time (1990-1995)*

The focus of the retailers more and more became logistic efficiency. Frequent deliveries squeezed inventory out of the downstream supply chain. The more frequent deliveries forced the suppliers to deliver from stock, as they were unable to produce the required product portfolio this frequently.

- *Relationship (1996- to date)*

The retail supply chain nowadays becomes a process with frequent deliveries in small quantities with stringent timing requirements. This process assures high product availability

and customer service while at the same time lowering inventory costs. However, a huge price is paid in terms of increasing transport and handling costs.
As can be seen from the four stages in retail supply chain management, the retail supply chain is shifted from forecast-driven (i.e. 'push' network) to demand-driven (i.e. 'pull' network). In a forecast-driven supply chain planning and scheduling decisions are driven by forecasts of sales which 'push' products out of the supply chain. This has the disadvantages of always having a forecast-error, human behaviour influencing forecasts, and sales departments often providing forecasts in currency terms which do not align with the needed operating decisions. These disadvantages eventually lead to bullwhip effects along the supply chain (i.e. increased variation upstream of the supply network) which in turn lead to inventory accumulation [Ayers & Odegaard, 2008, page238].
In a demand-driven supply chain, planning and scheduling decisions are driven by the need to replenish stocks as customer demand "pulls" products out of the supply network. Here, the customer is king, not the producer. Instead of being the passive recipients of products in anticipation of demand (forecast-driven), retailers are more and more becoming the designers and controllers of product flows through the supply chain in reaction to customer demand (demand-driven) [Fernie & Sparks, 2004, page2]. In a demand-driven supply chain with low inventory downstream, responsiveness is a driver of success. Several tools are developed to manage the transition from a forecast-driven to a demand-driven supply chain and support responsiveness. Examples are lean supply chain approaches (e.g. kanban systems, just-in-time management), constraint management (e.g. TOC) and quality improvement approaches (e.g. Six Sigma) [Ayers & Odegaard, 2008, page238].

Due to the global economic down-turn, retail prices in Germany declined resulting in higher consumer purchasing power. This has lead to an even more demand-driven supply chain strategy for MCCD the upcoming year, incorporating time-stringent replenishment [METRO Annual Report, 2008]. In this environment, the challenge is to design the retail distribution network which is logistically as efficient as possible but still maintains the high standards of a demand-driven supply chain. The logistic efficiency of a distribution network depends on the choice of the distribution flowtype. Therefore, it is important for a retailer to be able to compare the distribution flowtypes and find the one with the lowest logistic costs.

All figures and conclusions in this report are modified and do not represent the real situation for Metro Cash & Carry Deutschland.

2. Problem Definition

In this chapter the problem is defined. Section 2.1 presents the problem context, section 2.2 gives the research assignment and section 2.3 explains the project scope.

2.1 Problem Context

The initial strategy of MCCD was to only deliver products directly to its wholesale stores. This distribution flowtype is called Direct Store Delivery (DSD) and is often used when lead-times are critical and stores have high decision-making power [Simchi-Levi et al., 2008]. With the use of DSD, MCCD's wholesale stores function as warehouses in which the customers pick their own orders. This makes an average MCCD store relatively big compared to a 'normal' supermarket: an MCCD store has big shelves in the selling area all filled with high stocks. MCCD's retail stores are build to support DSD. For a long period, this strategy has proven to be very competitive.
However, the retail customers more and more demanded high assortment breadth and depth. This increased the challenge of shelf space allocation. Together with the long lead-time of several global suppliers these issues more and more urged MCCD to use a central Distribution Center (DC) for central warehousing or cross-docking.
In the last few years, MCCD has narrowed down its assortment to really focus on its specialized customers. In this situation the surplus of shelf space again makes DSD beneficial for many products. However, MCCD nowadays wants to use a considerable part of its stores' space for marketing and extended customer services. This means that indirect delivery again becomes an interesting distribution flowtype.
Clearly, MCCD is constantly evaluating the decision to distribute a product directly or via a DC. Currently, MCCD's choice to distribute a product directly or via a DC is mainly determined by the store format and negotiation with the supplier. Here, the supplier pays a compensation fee when delivering to the DC in stead of to the local wholesale stores. This compensation should be at least MCCD's costs for using the DC. However, MCCD has no clear insight into the cost and service effects of the different distribution flowtypes for the non-food assortment.

Several academic researches show that handling and transport costs dominate the logistical cost in a retail chain (see. e.g. Van Der Vlist [2007], and Broekmeulen et al. [2004]). Minimizing these costs often means increasing the order-size to increase economies of scale in transport and handling. However, in a retail chain a big order-size often incurs extra replenishment costs and storing costs at the store: there is only limited space on the store's shelves and storing products in the backroom incurs high shelf replenishment and stocking costs. Conclusively, the optimal order size is a result of balancing transport, handling, and stock costs in such a way that the overall costs are minimized. MCCD's available flowtypes all have a different optimal store order-size which minimizes the overall costs.

2.2 Research Assignment

The research preparation has resulted in the following research assignment:

> Determine the optimal distribution flowtype for all functional non-food product categories of Metro Cash & Carry Deutschland with regard to its main cost drivers and customer service measures.

The following terms need further explanation:

- A distribution flowtype is the way the goods flow from the supplier to the several stores [Van Den Heijkant, 2006]. The distribution flowtypes available at Metro Cash & Carry Deutschland (MCCD) are direct store delivery, central warehousing, and cross-docking. The optimal distribution flowtype is defined as the one with the overall lowest physical logistic costs.
- Fisher [1997] defines functional and innovative products as the two main product types relevant for selecting an appropriate distribution strategy. This master thesis focuses on functional products in the non-food assortment of MCCD.
- The main cost drivers for the selection of a distribution flowtype are considered.
- The main customer service measures for the selection of a distribution flowtype are considered.

2.3 Project Scope

This master thesis focuses on MCCD's logistic costs for the functional products in the non-food assortment supplied by all national suppliers. This scope is described in more detail in the next subsections.

2.3.1 Supplier Costs

The scope of this research encompasses the retail distribution costs of MCCD excluding its suppliers' costs. However, the different flowtypes have different optimal order-sizes which also influence the supplier's costs: often production set-up costs require significant order-sizes to gain economies of scale for the supplier. This is why many suppliers adopt a Minimum Order Quantity (MOQ) to force MCCD to order in bigger batches. It is assumed that the MOQ settings of each supplier are exogenous and assure the minimization of the supplier's relevant logistic costs.

2.3.2 Functional vs Innovative Products

A product's nature of demand affects the suitability of a distribution strategy and in turn the selection of an optimal distribution flowtype [Fisher, 1997]:

- Functional products satisfy basic needs which don't change much over time. This results in stable predictable demand and long life cycles. However, their stable demand pattern invites competition which often leads to low contribution margins. Examples of functional products are staplers, washing machines, and ceramic. The distribution strategy for functional products must focus on cost efficiency.
- Innovative products are novel which makes their demand very unpredictable. Furthermore, their life cycle is short because imitators quickly erode the competitive advantage that innovative products have which lowers contribution margins. Therefore, companies are forced to introduce a steady stream of more novel innovations. The short life cycles and the great variety of innovative products further increase their unpredictability. Examples of innovative products are fashion apparel and personal computers. The distribution strategy for innovative products must focus on market responsiveness.

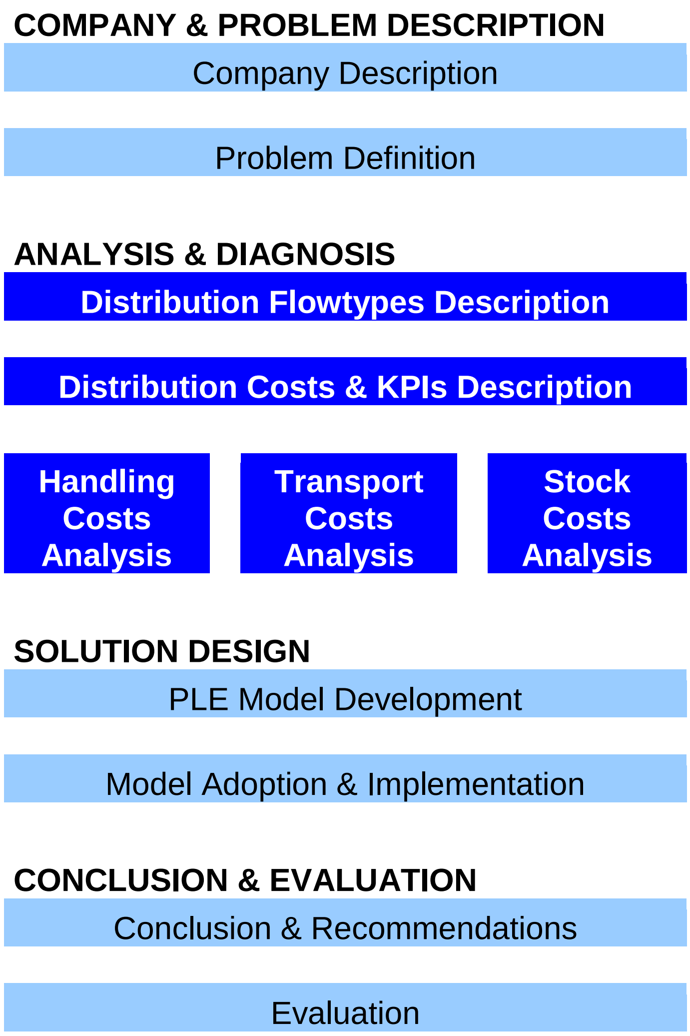
This master thesis follows a cost minimization perspective, which is in line with the distribution strategy for functional products. However, for innovative products the results of this master thesis must be considered with caution: the physical logistic costs may be minimized but market responsiveness is not assured. Low market responsiveness for innovative products may result in huge lost sales due to wrong allocation of products [Fisher, 1997]. Appendix C gives a categorization table with which the products of a particular supplier can be classified as either functional or innovative. This table can be used to decide whether a supplier supplies mainly functional or mainly innovative products. Furthermore, appendix C shows that it is important for the following non-food suppliers to test whether their products are innovative:

- Suppliers of textiles
- Suppliers of seasonal products
- Suppliers of garden/camping products
- Suppliers of bureau- and gastronomy multimedia
- Suppliers of household products (the product group, not the department)

2.3.3 National vs Import Suppliers

All international suppliers deliver to the central warehouse. The most important reasons for this are the big transport distance from supplier to DC/store stressing the importance of flow consolidation and the boarder costs. Delivery to each store separately would incur big lead-times, big transport costs, and big boarder costs. Therefore, all import products flow trough the central warehouse and import suppliers are out of scope of this research.

PART II ANALYSIS & DIAGNOSIS



3. Distribution Flowtypes

This chapter describes the available distribution flowtypes for the non-food assortment of Metro Cash & Carry Deutschland (MCCD). The main advantages and disadvantages of each distribution flowtype give a first insight into their differences. Section 3.1 first gives a graphical representation of the available distribution flowtypes. Next, section 3.2 describes direct store delivery, section 3.3 describes central warehousing, and section 3.4 describes cross-docking.

3.1 Available Distribution Flowtypes

A distribution flowtype is defined as the way in which goods move from the supplier to the stores [Van Den Heijkant, 2006]. Figure 3.1 shows the three available distribution types for the non-food assortment of MCCD: direct store delivery, central warehousing, and cross-docking. In this figure, a square represents a wholesale store, a triangle represents a warehouse (i.e. either from a supplier or from MCCD) and a circle represents a cross-docking terminal. The dotted arrows in the figure represent information flows and the straight arrows represent the physical flow of goods. A formal description of each distribution flowtype including its main advantages and disadvantages is given next.

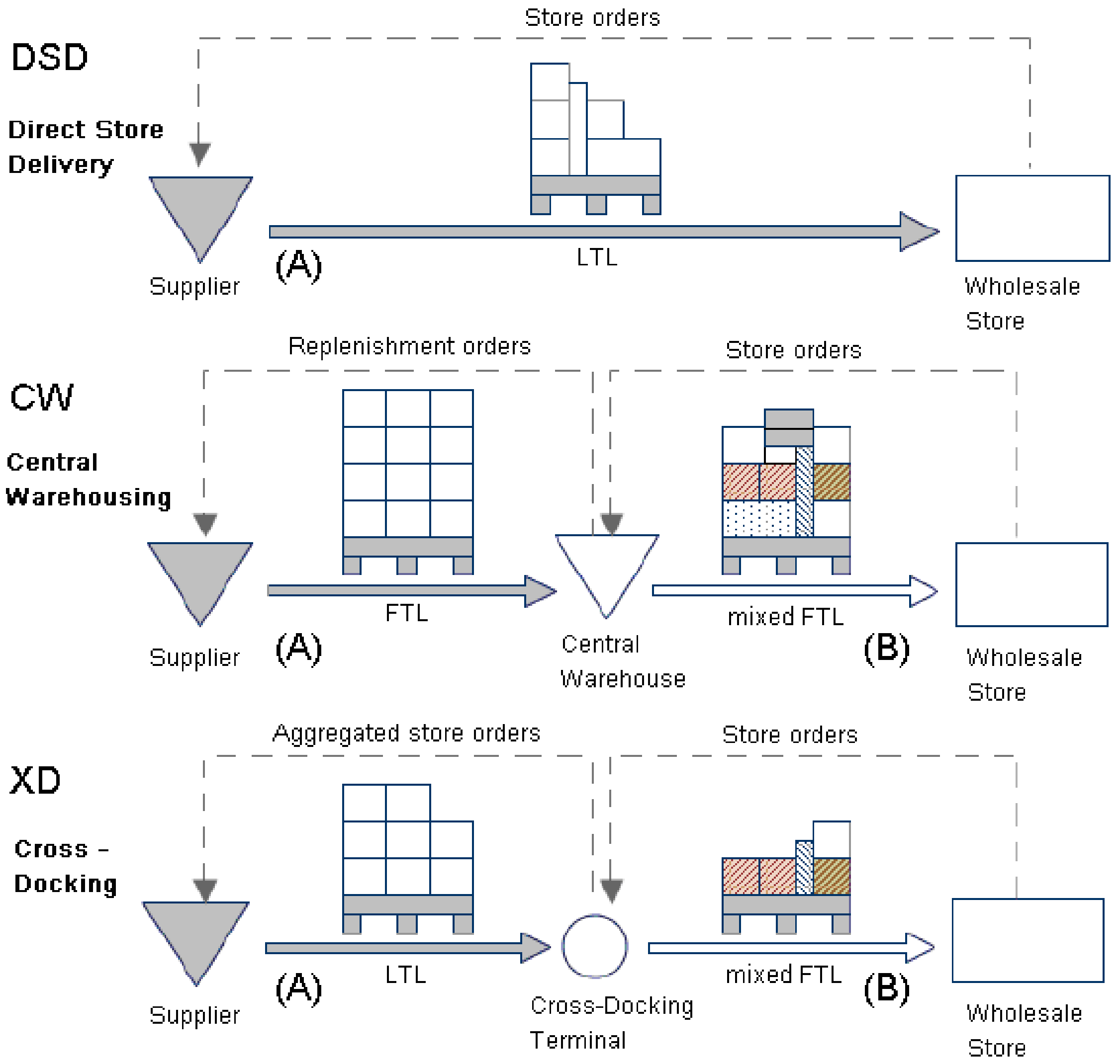


Figure 3.1 Available distribution flows for the non-food assortment of MCCD [Van Der Vlist, 2007]

3.2 Direct Store Delivery

Distribution flowtype A in figure 3.1 is called Direct Store Delivery (DSD). Here, MCCD's stores order directly from the supplier. The supplier picks the store orders and delivers the goods directly to the store. The clear advantage of DSD is the avoidance of distribution center costs (e.g. inventory holding, order picking, and administration). The main disadvantages of DSD are the long lead-times for remotely located suppliers and small drop sizes at the stores. Long lead-times lead to lower supply chain responsiveness and small drop sizes result in many truck visits to each store. When a supplier would replenish stores less frequently the drop sizes would increase and there would be a higher utilization of truck capacities, fewer visits to the stores, and less picking costs for the supplier [Van Der Vlist, 2007]. However, when there is a limited shelf space, an increase in drop size would require more shelf replenishment and backroom stock at the store which is very costly.

3.3 Central Warehousing

Distribution type B in figure 3.1 is called Central Warehousing (CW). With CW, MCCD holds inventory at a Distribution Center (DC) located in Unna (see appendix B). Holding inventory at a DC helps managing the variation and uncertainty between supply and demand. The main advantages of this distribution flowtype are for the stores: they experience short lead-times, get the goods assembled by category and delivered with reasonable drop sizes due to consolidation at the DC. Consolidation refers to the logistic process of combining several order flows for the same wholesale store to increase transport and handling efficiency. Moreover, the stores have fast access to more stock and still avoid costly shelf replenishment and backroom usage. CW thus enhances customer service [Simchi-Levi et al., 2008] while avoiding problems concerning shelf space. However, this comes with the price of expensive stock holding and order picking at the DC.

3.4 Cross-Docking

Distribution type C in figure 3.1 is called Cross-Docking (XD). Although one can generally distinguish between pre-allocated cross-docking and break bulk cross-docking, MCCD only uses break bulk cross-docking for the non-food assortment. Pre-allocated cross-docking is often applied for the food-assortment since it is effective for groups of very fast moving products with high daily demand volumes.

With break bulk cross-docking multiple suppliers deliver bulk quantities to the DC. Here, the order is 'broken' down into smaller and/or more convenient flows for redistribution amongst the stores [Van Der Vlist, 2007]. With break bulk cross-docking, the DC functions as inventory coordination point rather than inventory storage point. In the remainder of this report break bulk cross-docking is referred to as XD.

The main advantages of XD are the avoidance of inventory holding costs at the DC and the improved transport efficiency due to consolidation of store orders. Moreover, XD combines the main advantage of DSD (avoidance of DC stock) and the main advantage of CW (transport consolidation). However, there are also two major disadvantages of XD compared to DSD and CW. Compared to DSD, XD requires a longer transport distance and requires coordination and order-picking time at the DC. Furthermore, the high coordination requirements between supplier and retailer make the scheduling at the DC difficult and increase store stock-outs compared to CW. Therefore, XD is most effective in the following environment [Simchi-Levi et al., 2008]:

- Large distribution network where consolidation matters
- Reliable suppliers because of high coordination requirements

4. Distribution Costs & KPIs

For a comparison of the available distribution flowtypes, the relevant logistical costs and KPIs must be known. A relevant logistical cost is defined as a cost that significantly differs between the distribution flowtypes. A relevant KPI is defined as a measure which influences the costs per distribution flowtype or influences a supplier's suitability for a particular distribution flowtype. This chapter describes the logistic cost breakdown of Metro Cash & Carry Deutschland (MCCD) in section 4.1 and the main KPIs of MCCD in section 4.2. Given the available distribution flowtypes with their (dis)advantages and the relevant logistic costs and KPIs, section 4.3 explains on which level the distribution flowtypes are going to be compared.

4.1 Logistic Cost Breakdown

Figure 4.1 shows the logistic costs for MCCD's non-food assortment for the year 2009. On this point it is not yet known which of these costs is relevant for distribution flowtype selection. The question of which costs are relevant logistic costs will be answered throughout this report. For now, figure 4.1 contains the following logistic costs:

- *Transport DC – store:* represents all costs of transporting goods from the DC to all stores
- *Transport supplier – DC:* represents all costs of transporting goods from the suppliers to the DC
- *Transport supplier – store:* represents all costs of transporting goods directly from suppliers to the stores
- *Store handling:* represents all costs associated with store goods-handling activities (i.e. goods receiving, shelf replenishment, and others)
- *DC handling:* represents all costs associated with DC goods-handling activities (i.e. goods receiving, stocking, order picking, goods exit, and others)
- *Store stock:* represents all costs of holding stock in the stores
- *DC stock:* represents all costs of holding stock in the DC
- *Shrinkage:* represents all costs associated with the loss of products due to causes like stock overage, damage in transit, and theft. Also included here are the depreciations of materials and losses due to price discounts.

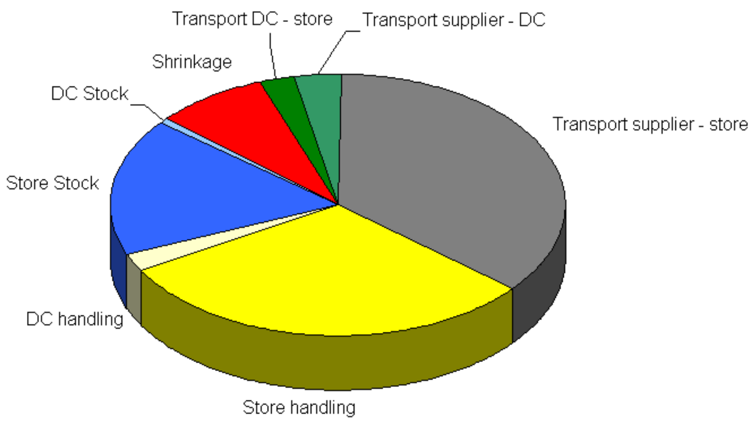


Figure 4.1 Logistic Cost Breakdown for MCCD's Non-food assortment for the year 2009

Figure 4.1 shows that the total handling cost and total transport cost together dictate MCCD's logistical costs. The remainder is caused by stock and shrinkage. Note that a big part of the total turnover of MCCD's non-food assortment is delivered directly while a small part flows through the DC. This causes the total DC handling cost, DC stock cost, and transport cost of indirect delivery to be fairly low. Nevertheless, it is clear that both handling and transport costs dominate MCCD's logistical cost breakdown.

The fact that handling and transport costs dominate the retail cost breakdown is in line with the results of several academic empirical studies (see. e.g. Van Der Vlist [2007], and Broekmeulen et al. [2004]). These studies indicate that the handling and transport costs are mainly driven by the ordering behaviour of the retail stores in terms of order-size and order-frequency [Van Der Vlist, 2007]. Therefore, this project examines the effect of a store's order size on the relevant logistic costs per distribution flowtype: transport, handling, and stock costs.

Note that although shrinkage is a considerable share of the cost breakdown for MCCD's non-food assortment, it will not change significantly due to a change in distribution flowtype for non-food products: product damage, theft, and price discounts are assumed to remain the same regardless of the way the goods are distributed. Therefore, shrinkage is out of scope and not included in this report.

4.2 Main Key Performance Indicators

MCCD's most important Key Performance Indicators (KPIs) together with their focus, equation, and definition are depicted in table 4.1. The first three KPIs in this table measure the customer service and are related to product availability at the stores. The latter three KPIs measure the supplier performance and are related to lead-time and reliability.

MCCD's Stock Service Level (SSL) is the fraction of time that there is stock on the shelf. This is equal to the ready rate or P_3 service measure defined by Silver et al. [1998]. The ready rate finds common application in the case of equipment used for emergency purposes like military hardware. However, in a retail environment, the most frequently used service measures is the non-stock-out probability or P_1 service measure (see Van Der Vlist [2007], Van Donselaar [1990], Silver et al. [1998], and De Kok [2005]). The P_1 service measure is defined as the probability of not being out-of-stock just before an order-arrival [De Kok, 2005]. Here, a stock-out is defined as the occasion when the on-hand stock drops to the zero level. In scientific literature, the P_1 measure is used to calculated the required safety stock for a certain service level. To be able to do the same for MCCD, the SSL is re-defined as the P_1 service measure: SSL = P_1 for the remainder of the report.

MCCD's Stock Coverage (SC) indicates how many days of forecasted demand are covered by the stock in the stores. For many non-food products of MCCD the SC is very high. This indicates that the stores have sufficient shelf space to hold much stock.

The On-Shelf Availability (OSA) is measured by the store personnel by performing gap-checks. This is done to show a supplier the availability of its products in a MCCD store. The OSA will not be used in the remainder of this report.

Both MCCD's Fill Rate and Late Deliveries KPI measure a supplier's reliability. Because cross-docking is often a cheap flowtype but requires very high supplier reliability, these measures will be used to test a supplier's suitability for cross-docking.

MCCD's Order-to-Delivery-Lead-Time (ODLT) gives the number of days between order generation and delivery. This measure will be used to calculate the maximum demand during lead-time.

Table 4.1 Main KPIs of Metro Cash & Carry Germany

Focus	Name	Equation	Definition
Stock	Stock Service Level	$\left(1-\frac{\sum days\_no\_stock\_no\_sales}{\sum sales\_days}\right)\cdot 100\%$	Percentage of total sales days that an item is on stock
	Stock Coverage	$\left(\frac{Average\_daily\_stock}{Average\_daily\_sales}\right)$	Number of days the available stock covers the average daily sales
	On-shelf Availability	$\left(1-\frac{\sum days\_without\_sales}{\sum sales\_days}\right)\cdot 100\%$	Percentage of days an item is available on the shelf
Order	Fill Rate	$\left(\frac{\sum delivered\_quantity}{\sum ordered\_quantity}\right)\cdot 100\%$	Percentage of actually delivered quantity versus ordered quantity
	Order to Delivery Lead-Time	$\left(date\_of\_delivery - date\_of\_ordering\right)$	Number of days between order generation and order delivery
	Late Deliveries	$\left(\frac{\sum late\_delivered\_items}{\sum total\_delivered\_items}\right)\cdot 100\%$	Percentage of the total delivered items that is delivered too late

4.3 Level of Analysis

Figure 4.1 shows that handling, transport, and stock costs are the main logistical costs for MCCD. Van Der Vlist [2007] explains that these costs are greatly effected by a store's order-size. Next to a store's order-size every main logistical cost of MCCD has other drivers, like the transport distance (a driver of transport costs), delivery lead-time (a driver of stock costs) and excess shelf space (a driver of handling costs). These drivers are all supplier dependent: the order size may be constrained by the supplier's MOQ, the transport distance depends on a supplier's location, the delivery lead-time is supplier-dependent, and the excess shelf space depends on the supplier's lead-time [Van Der Vlist, 2007]. Therefore, the appropriate level of analysis is the supplier level.

Conclusively, for each supplier the handling, transport, and stock costs per distribution flowtype are analysed. Thereafter, these costs are integrated into one single model which calculates the logistic costs per supplier per distribution flowtype.

5 Handling Costs

Chapter 3 and 4 explained that handling, transport, and stock are the main logistic costs for Metro Cash & Carry Deutschland (MCCD). Now the drivers of these logistical costs are analysed, starting with the handling costs in this chapter. Chapter 5 determines the drivers of the handling costs at the stores and the DC of MCCD. Section 5.1 analyzes the drivers of store goods receiving costs. Section 5.2 analyzes the drivers of shelf replenishment costs and section 5.3 analyzes the drivers of the DC handling costs.

5.1 Store Handling Drivers

The description of the handling activities in a MCCD store is based on two major inputs. The first input is a description of the instore logistics of Makro Nederland by Van Stipdonk [2007]. This description is based on existing scientific literature by Van Zelst et al. [2006] and by Kotzab and Teller [2005]. Based on this description of instore logistics, the handling activities in a MCCD store are defined. These activities are verified with the second input: the results of observing and interviewing the retail staff in three MCCD stores (Düsseldorf, Neuss, and Muhlheim).

After the identification of the handling activities, the required Full Time Employees (FTEs) per handling activity are identified with the help of the retail staff. The division of the FTEs over the handling activities is used to allocated the total store handling costs over the activities. As a latter, the retail staff is asked if it makes any difference when products arrive directly from a supplier or via the DC. This results in efficiency gains of switching from direct delivery to indirect delivery. A detailed explanation of how each handling activity, its costs, and its driver are determined is given in appendix D.

Table 5.1 shows the results of the handling driver analysis. Note that the handling activities in *italic* format consume store handling costs but are not relevant to the distribution flowtype selection for non-food suppliers. Therefore, these handling activities are out of the scope of this research. The drivers of the relevant handling activities are pallets, cartons, mixed pallets, packages, and GR Lines. Here, a carton may contain only one article (e.g. refrigerator) or multiple articles (e.g. pencils). For MCCD, one carton equals one selling/packaging unit, or one VerPakkungsEinheit (VPE).

Table 5.1 Costs, drivers, and efficiency gains per store handling activity

Handling Activity	Costs (x1000)	Driver	Efficiency Gain	€ per Driver DSD	€ per Driver XD / CW
Non-food Receiving	510 €	Pallets	0%	0,884 €	0,884 €
Rough Order Check	255 €	Pallets	35%	0,475 €	0,309 €
Detailed Order Check	127 €	Cartons	96%	0,002 €	0,000 €
Pallet Allocation	204 €	Mixed Pallets	LoM	LoM	0,834 €
Packages Handling	612 €	Packages	93%	0,349 €	0,024 €
WE-Buro Non-food	255 €	GR Lines	90%	0,024 €	0,002 €
WE-Buro Food	*382 €*	-	-		
Others	*382 €*	-	-		
GOODS RECEIVING	2.727 €				
Shelf Replenishment	7.468 €	*	*	0,070 €	0,070 €
Others (customer contact, cleaning etc.)	*3.747 €*	-	-		
STORE OPERATIONS	11.215 €				
TOTAL STORE HANDLING	13.942 €				

***To be determined in section 5.2**

From table 5.1 it can be seen that the shelf replenishment costs are far bigger than the total goods receiving costs (€7,5million versus €2,7million). However, the shelf replenishment driver cannot be modelled by a single factor and is therefore separately explained in section 5.2. The remainder of this section focuses on goods receiving costs.

The interviews with the retail staff show that indirect deliveries have several advantages over direct deliveries concerning the goods receiving activities. Below, for each goods receiving activity the efficiency gain of indirect delivery versus direct delivery is explained. The efficiency gain for a handling activity is defined as the percentage cost reduction of going from direct to indirect delivery. For example, an efficiency gain of 35% in Rough Order Check means that it costs 35% less to execute this activity for indirect delivery than for direct delivery.

- *Rough Order Check*

Goods arriving from the distribution center all contain RFID tags whereas goods arriving from a supplier mostly don't. Goods already containing RFID-tags are automatically checked by driving the pallet through the RFID portal in the goods receiving area from a MCCD store. Goods without RFID-tags must be checked manually which takes more time (i.e. going through a list and walking to the WA-Buro). The retail staff estimates this efficiency gain to be a 35% reduction in time.

- *Detailed Order Check*

Goods arriving from the distribution center are already checked in detail, whereas all goods from directly delivering suppliers still need to be checked in detail. Note that damaged goods always need to be checked in detail, regardless of their origin. Therefore, the efficiency gain is estimated to be a 96% reduction in time.

- *Pallet Allocation*

All pallets arriving from the distribution center contain mixed loads of goods destined for several departments. This means that it takes a significant time to distribute the goods from such a mixed pallet to their designated backroom area. Pallets arriving from a supplier who delivers directly contain goods destined for less separate departments. This means that the time needed to distribute goods to their designated department backrooms is less. It is assumed that the pallet allocation costs are linear to the 'Level of Mixture' (LoM) of a pallet. Here, the LoM of a pallet is defined as the percentage of goods destined to different departments. Now the pallet allocation costs are driven by the number of pallets and LoM for a particular supplier. For example, when a supplier has a LoM of 50%, it costs €0,42 per DSD pallet allocation and €0,83 per XD / CW pallet allocation. Note that for this activity direct delivery is more beneficial than indirect delivery, because the LoM of an indirectly delivered pallet is always 100%. The calculation of the LoM per supplier is given in appendix E.

- *Packages Handling*

The handling activities associated with packages are very costly. Packages always need to be checked in detail and need to be put in the system manually at the WE-Buro of non-food. The efficiency gain of handling goods from a pallet in stead of handling them as packages is based on avoidance of these activities. The average of the efficiency gain for detailed order check (96%) and WE-Buro non-food (90%) is 93%. Therefore, the estimated efficiency gain of delivering goods on pallets in stead of on packages is 93%.

- *WE-Buro Non-food*

Goods arriving from the distribution center are already booked into the system, whereas goods from directly delivering suppliers need to be booked manually. This suggests a 100%

efficiency gain for this activity. However, several orders from the distribution center still need WE-Buro activities because of failures in the system. Therefore, the retail staff estimates this efficiency gain to be a 90% reduction in time.

The efficiency gains and resulting costs per handling activity driver are given in the three most right columns of table 5.1. Table 5.1 shows that package handling is the most expensive goods receiving activity: package handling is responsible for €0,6million of the total of €2,7million of goods receiving. However, package handling has a huge efficiency gain of 93% which can be reached when switching from direct to indirect delivery. With indirect delivery the goods will arrive on mixed pallets in stead of packages. Thus, package handling is expensive and can be avoided by indirect delivery. Therefore, an important driver of goods receiving costs at a MCCD store is the number of packages delivered by a particular supplier.
Non-food receiving is the second-largest relevant cost factor of goods receiving, responsible for €0,5million. However, because there is no efficiency gain the costs of this handling activity will only vary between distribution flowtypes if the required number of pallets varies between the distribution flowtypes. The difference in required number of pallets between distribution flowtypes is explained later in this report.
WE-Buro Non-food is the third-largest relevant cost factors of goods receiving, responsible for €0,3million. The huge efficiency gain for WE-Buro Non-food (90%) makes that an important driver of goods receiving costs at a MCCD store are the number of GR Lines for a particular supplier.
Rough Order Check is also responsible for €0,3million of the total goods receiving costs. However, this activity has an efficiency gain of 35% and will therefore only result in a minor difference between distribution flowtype costs.
Pallet allocation is the fourth-largest relevant cost factor responsible for €0,2million with an efficiency gain of -51%. This means that this handling activity costs more for CW and XD than for DSD.
Although Detailed Order Check is the smallest cost factor responsible for only €0,1 million, the efficiency gain is 96%. This means that difference in costs between distribution flowtypes of this handling activity may still be important.

Conclusively, in order to estimate the goods receiving costs per distribution flowtype associated with a particular supplier, her following input is required:

1. # pallets supplied over the year*
2. # cartons supplied over the year
3. Level of Mixture (LoM) per pallet of the supplier†
4. # goods receiving lines (GR Lines) over the year
5. # packages supplied over the year

* The number of pallets supplied over the year depends on the volume per order-size. Appendix F explains how the number of pallets is derived from a supplier's carton volume and a store's order size.

† The Level of Mixture (LoM) indicates how costly the pallet allocation will be. Appendix E explains how the LoM for a particular supplier is calculated.

A supplier's costs per handling activity can now be calculated by multiplying the number of associated drivers with the costs per driver. Important in this respect is that the difference in costs per handling activity not only depends on the difference in costs per driver: it also depends on the difference in number of drivers per distribution flowtype. This means that for one supplier (with many package deliveries) the total package handling costs might be most important while for another supplier (with a broad assortment) the pallet allocation might be most important.

5.2 Shelf Replenishment Drivers

Table 5.1 shows that the largest part of the store handling costs is caused by shelf replenishment. The critical driver of shelf replenishment costs is the balance between Excess Shelf Coverage (ESC) and order-size (Q) [Van Der Vlist, 2007]. In order to understand how the balance between ESC and Q drives shelf replenishment, the ESC is explained first.

5.2.1 Excess Shelf Coverage

Figure 5.1 shows the shelf space in a store that has been assigned to a certain product. The total number of cartons fitting on that shelf space is defined as the Shelf Coverage (ShC). Remember that a carton is defined as one selling unit and may contain only one article (e.g. television) or multiple articles (e.g. pencils). The Category Management decides on the ShC per product group. According to a general Category Manager the shelf space assigned to a product group is equal to the ShC of the product group. Appendix G gives the ShC per product group.

Figure 5.1 also shows the latest possible reorder level, marked with an *s*. This latest reorder level equals the maximum demand covered during the replenishment lead-time and review period to assure a service level of SSL. Assuming non overlapping replenishment orders, the latest reorder level is [Van Der Vlist, 2007]:

$$s = \mu(L + R) + k\sigma\sqrt{L + R} \qquad (5.1)$$

Where

s := the latest possible reorder level
μ := mean daily demand in number of cartons
σ := standard deviation of the daily demand in number of cartons
L := replenishment lead-time in days*
R := review period in days†
k := service factor chosen such that:
$\phi(k) = SSL$; where $\phi(\cdot)$ is assumed to be Normally distributed

* The lead-time of each MCCD supplier delivering directly to a store is measured with the ODLT KPI from Table 4.1. Thus, in case of direct store delivery, L is equal to a supplier's ODLT. The lead-time of each Non-food delivery from the DC to a MCCD store is equal to 2days.

† The review period R is 5days for each non-food delivery with DSD and XD and 2days for each non-food delivery with CW.

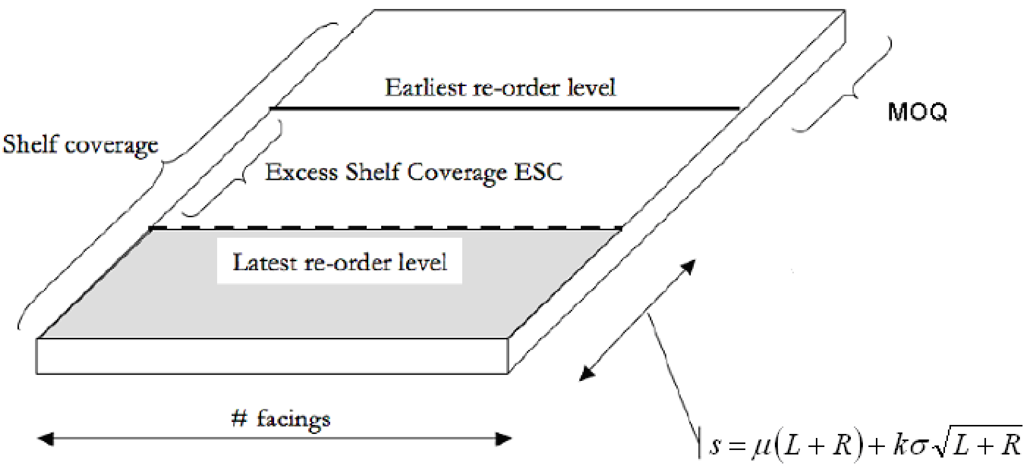


Figure 5.1 Shelf Coverage [Van Der Vlist, 2007]

The service factor k in equation 5.1 is derived from the target SSL. In section 4.2 MCCD's SSL is re-defined as the non-stock-out probability or P_1 measure. A target non-stock-out probability of 98% results in a service factor of $k = 2{,}00$.

Next to the latest reorder moment, there is an earliest reorder moment. The earliest reorder moment is the moment when so many cartons have been sold, that the contents of the smallest new order just fit on the shelf, behind the cartons still on the shelf. One could draw a line, parallel to the back of the shelf, to mark this earliest possible reorder level. Since several non-food suppliers adopt an MOQ to define the minimum order size, the earliest reorder level is equal to the MOQ (see figure 5.1).

The two reorder levels on the shelf resemble the can-order and must-order levels known from joint replenishment systems. The number of cartons fitting between these two levels is defined as the Excess Shelf Coverage (ESC) [Van Der Vlist, 2007]:

$$ESC_i = ShC_i - s_i - MOQ_i \tag{5.3}$$

Where

ESC_i := Excess Shelf Coverage in number of cartons associated with supplier i

ShC_i := Shelf Coverage in number of cartons associated with supplier i

MOQ_i := Minimum Order Quantity in number of cartons of supplier i

s_i := Maximum demand during the replenishment lead-time in number of cartons of supplier i

5.2.2 Secondary Replenishment Drivers

Equation 5.3 in the previous section calculates the ESC associated with a particular supplier. Equation 5.4 shows how the balance between the ESC and the store order-size drives the secondary replenishment costs. This equation shows that, when the store order-size is bigger than this ESC plus the supplier's MOQ ($Q^{store} > ESC + MOQ$), not all cartons of that order fit on the shelf at once. All cartons which do not fit on the shelf need to be brought back to the store backroom incurring extra shelf replenishment costs. These extra shelf replenishment costs are assumed to be equal to primary replenishment costs derived from Table 5.1 (€0,070) per carton), since the same store handling activities must be executed once more. It is assumed that with secondary replenishment, only those cartons that fit on the shelf are taken from the backroom and stacked on the shelf. Therefore, all cartons which do not fit on the shelf only incur one additional shelf replenishment cost equal to €0,070. This means that there will never be tertiary replenishment and the extra shelf replenishment costs for the cartons which initially don't fit on the shelf are:

$$2RC_i = 0{,}070 \cdot \underbrace{\left(Q_i^{store} - ESC_i - MOQ_i\right)^+}_{X_i} \tag{5.4}$$

Where

$2RC_i$:= 2nd Replenishment Costs in € associated with supplier i

Q_i^{store} := Order size in number of cartons from a store to supplier i

ESC_i := Excess Shelf Coverage in number of cartons of supplier i

MOQ_i := Minimum Order Quantity of supplier i

X_i := Number of cartons of supplier i which do not fit on the shelf

$(Y)^+$:= the maximum of Y and 0

The ESC can be negative and positive. When the ESC is negative not enough shelf space is assigned to the product. This will result in costly secondary replenishment.

However, when the ESC is positive, the secondary replenishment costs depend on the order-size and the supplier's MOQ. When the order-size is bigger than the ESC plus the supplier's MOQ (Q^{store} > ESC + MOQ), X_i will be positive and secondary replenishment will occur. When the order size is smaller than the ESC plus the supplier's MOQ (Q^{store} < ESC + MOQ), X_i will be zero. In this case no secondary replenishment is necessary because there is an overage of ESC to fit all cartons from an order on the shelves. This makes room to change the order-size and shift the replenishment moments without incurring secondary replenishment. Shifting replenishment moments opens the way to break through the time pressure, to group replenishments, and level replenishment volumes over the week. This balances the shelf replenishment workload at the stores but also the order picking workload at the DC [Broekmeulen et al., 2004].
For MCCD, category managers from the buying department determine the shelf space assigned to a particular product assortment which drives the ESC. This means that the decisions of the category management not only set the commercial presentation to customers, but also have a huge influence on the logistic replenishment possibilities and costs [Van Der Vlist, 2007].

Appendix G shows that all products of the non-food department have a huge ShC: for most product groups, the ShC covers a period of forecasted demand of about 100days. (Note that the ShCs in appendix G are defined as the number of days with forecasted demand covered by the cartons on the shelf. Multiplying this ShC with the mean daily demand of a supplier's cartons gives the ShC from equation 5.3). This means that for many suppliers, the ESC is big enough to avoid secondary replenishment even with big order-sizes and long lead-times. However, the non-food products with a very high demand per day, high variation, and long lead-time may have a small ESC. With a small ESC, the chance of secondary replenishment increases. For a proper estimation of shelf replenishment costs per distribution flowtype it is thus important to evaluate the balance between ESC and order-size.
Conclusively, in order to estimate the shelf replenishment costs per distribution flowtype applied for a particular supplier, her following input is required:

6. Mean daily store demand in # cartons
7. Standard deviation of daily store demand in # cartons
8. Mean supplier lead-time in days (ODLT)
9. Review period in days
10. Associated Shelf Coverage in # cartons
11. MOQ in # cartons

5.3 DC Handling Drivers

Next to the handling activities in a MCCD store, the handling activities in the DC also differ between distribution flowtypes. With DSD, all DC handling activities are avoided and with CW more handling is needed than with XD. The costs per driver of a DC handling activity are analysed in this section.
The description of the handling activities in the DC is based on two major inputs. The first input is a typical time division of an order picker as proposed by Broekmeulen [2007] and Van Moorsel [2009]. The second input consists of the yearly financial account of MGL (the logistics service provider responsible for the DC) and an interview with a division manager of MGL. The costs of DC handling are allocated over the goods receiving, stocking, order picking, and goods exit activities. A detailed explanation of how each activity, its costs, and its driver are determined is given in appendix H. The resulting handling activities in the DC are given in table 5.2.

Table 5.2 Division, costs, & drivers per DC handling activity

	Handling Activity	Division	Driver	XD Costs (x1000)	XD € per Driver	CW Costs (x1000)	CW € per Driver
	Basic Time	15%	Trucks	87 €	4,827 €	52 €	4,827 €
	Truck Stopping Time	20%	Trucks	116 €	6,553 €	70 €	6,552 €
	Unloading Time	15%	Pallets	87 €	0,276 €	52 €	0,276 €
	Stocking	50%	Pallets	0 €	0,000 €	173 €	1,492 €
I	GOODS RECEIVING			290 €		346 €	
	Order Picking	50%	cartons	1.536 €	0,081 €	456 €	0,119 €
II	ORDER PICKING						
	Loading Time	15%	Pallets	85 €	0,271 €	58 €	0,495 €
	Truck Stopping Time	20%	Trucks	114 €	6,435 €	77 €	7,987 €
	Basic Time	15%	Trucks	85 €	4,827 €	58 €	5,991 €
III	GOODS EXIT			285 €		191 €	

Table 5.2 shows that there are three main differences between the DC handling activities for cross-docking and central warehousing. These differences are explained below and their causes can be derived from figure 5.2.

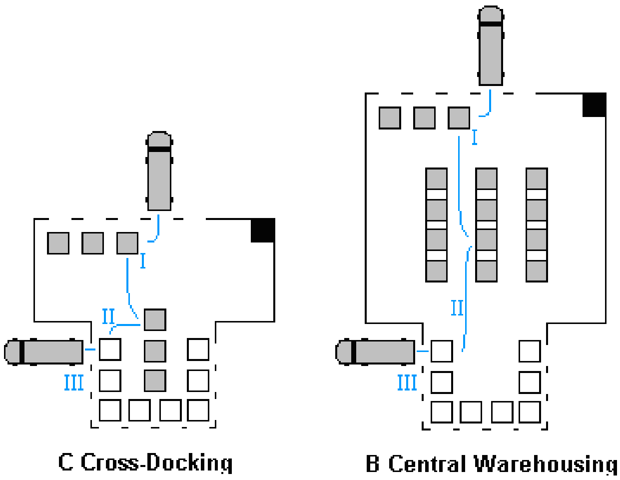


Figure 5.2 DC Handling Activities for central warehousing & cross-docking

- *Stocking (see figure 5.2 – I)*

With XD, the pallets received from a supplier are directly transported to the docking area. With CW, the received pallets are transported to the warehouse, where they are allocated to their designated storage area. This extra process step is defined as 'stocking' and costs about €1,50 per pallet stocked (see table 5.2).

- *Order Picking (see figure 5.2 – II)*

With XD, the pallets with the ordered cartons are located in the loading area from which the orders can directly be picked and allocated to store-dedicated pallets. This order picking process costs about €0,08 per carton. With CW, the ordered cartons need to be transported from the warehouse to the loading area. Therefore, the order picking process for CW requires more transportation time. The order picking process for CW costs about €0,12 per carton (see table 5.2).

- *Goods Exit (see figure 5.2 – III)*

With CW, the goods exit always handles a combination of different products coming from different suppliers. Therefore, the goods exit activities for CW are difficult to standardize. With XD, the same goods exit activities are executed every time when the goods from the same supplier are cross-docked. Therefore, the goods exit processes for XD are easily standardized. This leads to the fact that every goods exit activity is cheaper for XD than for CW.

Conclusively, in order to estimate the DC handling costs per distribution flowtype applied for a particular supplier, her following input is required:

12. # cartons over the year
13. # pallets over the year*
14. # trucks over the year†

* The number of pallets supplied over the year depends on the volume per order-size. Appendix F explains how the number of pallets is derived from a supplier's carton volume and order-size.

† The number of trucks over the year is derived from the number of pallets over the year, assuming every truck is fully loaded with 33 pallets. This assumption is verified by a General Manager of the 3PL.

A supplier's costs per handling activity can now be calculated by multiplying the number of associated drivers with the costs per driver. Just like with the store handling activities, the difference in costs per DC handling activity depends on the costs per driver and the number of drivers per distribution flowtype. This means that for one supplier (with voluminous products) the total stocking time might be most important while for another supplier (with a broad assortment) the order picking might be most important.

6 Transport Costs

So far, part II analysed the drivers of the handling costs per distribution flowtype. This chapter analyses the drivers of the transport cost per distribution flowtype. Section 6.1 explains the transport network of Metro Cash & Carry Deutschland (MCCD). Section 6.2 explains the driver of transport costs from the supplier to MCCD's DC or to the stores. Section 6.3 analyzes the drivers of transport costs from the DC to the store. As a latter, section 6.4 discusses the relatively low cross-dock pallet utilization.

6.1 Network Structure

Figure 6.1 shows the current available distribution flowtypes existing in MCCD's non-food network. MCCD's network structure is divided into the transportation part from supplier to DC and/or stores (A) and the transportation part from the DC to the stores (B). This is necessary because in part (A) the orders are shipped with procurement logistics, while in part (B) the orders are shipped with MCCD's own fleet.

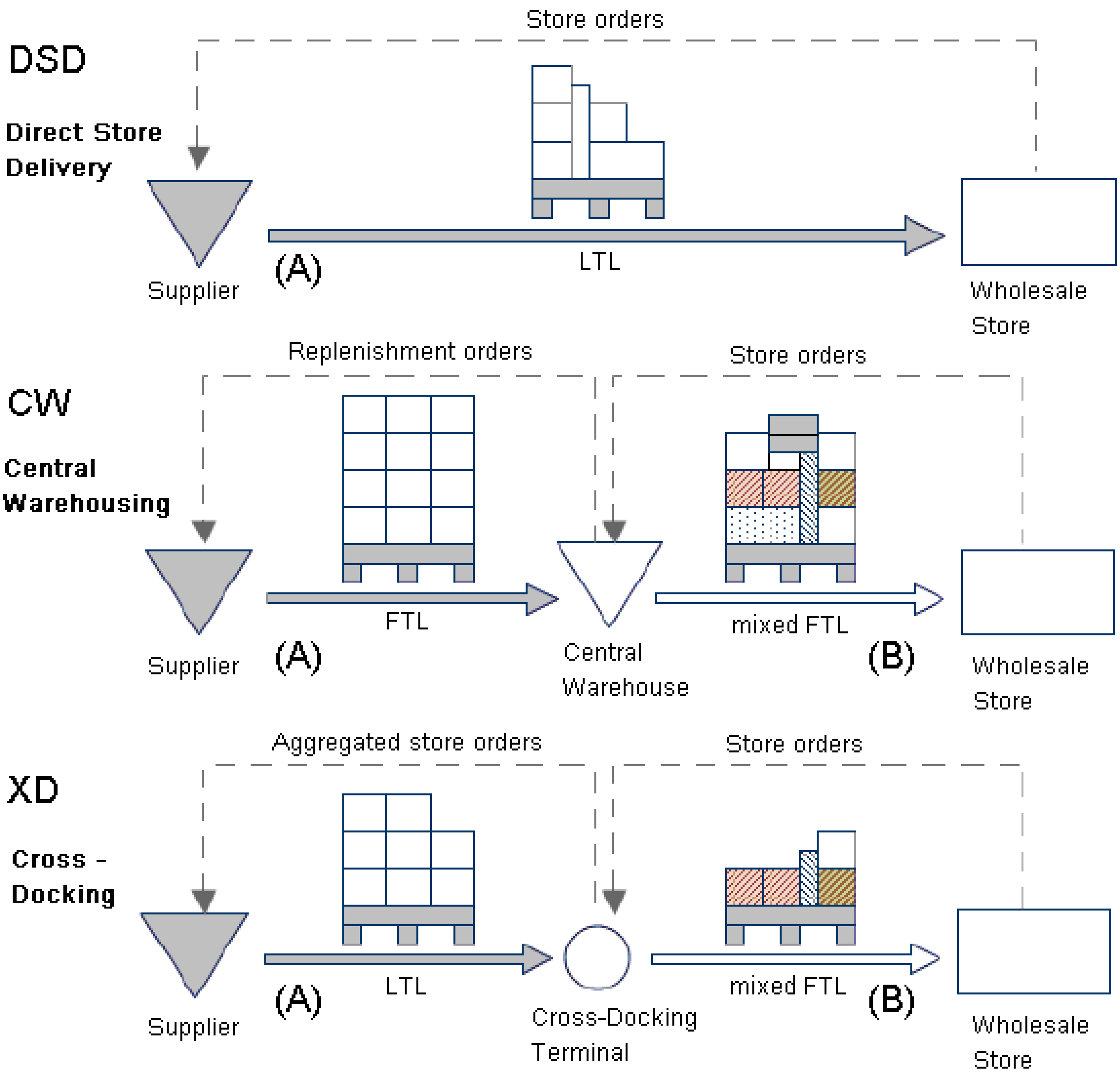


Figure 6.1 Copy of Figure 3.1: Available distribution flowtypes for the non-food assortment of MCCD

6.2 Part (A) – Retail Consolidation Network

Part (A) in Figure 6.1 is a retail consolidation network in which loads destined to several retailers are bundled by third party logistic service providers in a single shipment. A third party logistic service provider (e.g. DHL, Kuhn & Nagel, Hasenkamp) picks up the orders at a supplier for several retailers to fill up a truck and gain economies of scale through consolidation. The consolidated flow is broken down and the goods ordered by MCCD are shipped to the MCCD stores with a multi-stop route in the region. The transport costs per pallet in this situation can be approximated with equation 6.1 [Van Der Vlist & Broekmeulen, 2006].

$$TC^{A}_{i,j} = d_{i,j} \cdot C \cdot \left(u_{i,j}\right)^{1-r} \qquad (6.1)$$

Where

$TC^{A}_{i,j}$:= Transport costs in € per pallet for part (A) of the retail distribution network from origin i to destination j
$d_{i,j}$:= Distance from origin i to destination j in kilometer
C := Costs of shipping a full pallet over a distance of one kilometer
$u_{i,j}$:= Mean utilization of a pallet shipped from origin i to destination j
r := transport inefficiency factor.

The mean utilization of a pallet shipped from a supplier to the DC or a store, $u_{i,j}$, depends on the volume of an order at that supplier. Appendix F shows that using a DC allows consolidation of orders which results in higher pallet utilization and cheaper transport. Shipping directly to stores results in a lower pallet utilization, making the transport relatively expensive.

The inefficiency factor r is added because the transportation costs are non-linear to the fraction of the pallet that is filled. Setting the inefficiency parameter to 0 assumes the transportation costs are linear with the volume: as efficient as possible. A better approximation of the transport cost structure is setting the inefficiency parameter r to 0,435, which is a generalized finding of the functions used by logistic service providers based on regression modeling [Van Der Vlist, 2007]. The resulting relationship between pallet utilization and transport costs per kilometer is depicted in Figure 6.2. The transport cost factor in figure 6.2 is the fraction of the full pallet transport costs assigned to the pallet.

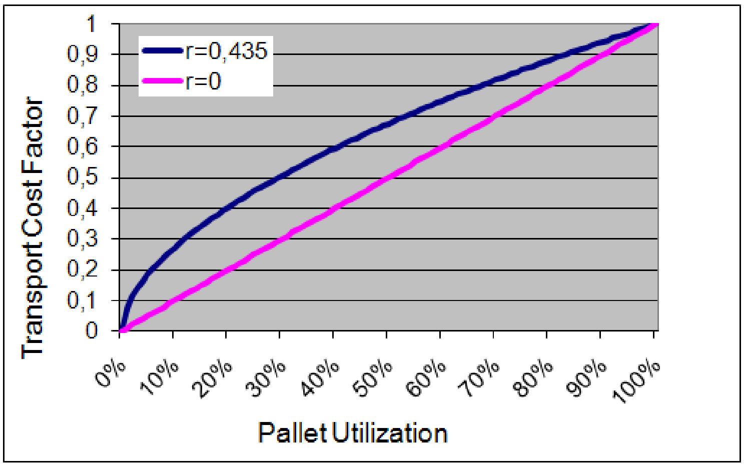


Figure 6.2 Pallet Transport Cost Behavior for Network Part (A)

The estimated mean distance from a German supplier to a MCCD store $d_{i,j}$ is 576km, derived in appendix I. Independent of a supplier's location several stores will always be close to the supplier while others will be far away. Then, assuming that a supplier always supplies all 61 stores of MCCD, each supplier will have the same mean distance of 576km to a random MCCD store.
Logically, the distance from a random German supplier to the DC does depend on the location of the supplier and the DC. From the addresses of a supplier and the DC the radians (longitude and latitude) can be derived with e.g. batchgeocode.com. Given the radians of the supplier and the DC, Haversine's equation can be used to calculate the straight-line distance from the supplier to the DC. Haversine's equation calculates the shortest distance between two points on a sphere indicated by their longitudinal and latitudinal radians [Broekmeulen, 2007]:

$$d_{i,j} = 2 * R * \arcsin * \sqrt{\left(\sin\left(\frac{lat_i - lat_j}{2}\right)\right)^2 + \cos(lat_i) * \cos(lat_j) * \left(\sin\left(\frac{lon_i - lon_j}{2}\right)\right)^2} \qquad (6.2)$$

Where

$d_{i,j}$	:= Distance from point A to point B in km
R	:= Radius of the earth (i.e. 6367km)
lat_i	:= Latitude of point i in radians
$long_i$	:= Longitude of point i in radians

Now the mean distance from a supplier to a MCCD store is known to be 576km and the distance from a supplier to the DC can be estimated with equation 6.2. When the costs of transporting a full pallet over one kilometer are known, the transport costs per pallet can now be calculated.
A division manager of MGL states that the average costs of shipping a full pallet from its origin to its destination in part (A) are €24,57. It is assumed that the transport costs for a full pallet are balanced over Germany and thus do not differ significantly among different regions. Furthermore, the transport costs for a full pallet are assumed to be linear to transport distance. Given that the mean distance between a random origin (supplier) and a random destination (store or DC) is 576km, the costs of shipping a full pallet over a distance of one kilometer equals $C = €0{,}043$.

Conclusively, the supplier-dependent information required to estimate the transport costs for part (A) of MCCD's retail network is:

1. # pallets supplied over the year*
2. Mean pallet utilization
3. Supplier's address

* The number of pallets supplied over the year depends on the volume per order-size. Appendix F explains how the number of pallets is derived from a supplier's carton volume and a store's order size.

A supplier's costs for transport part (A) can now be calculated by multiplying the number of pallets with their costs which are driven by the pallet utilization and transport distance.

6.3 Part (B) –Transport from DC to Store

Part (B) of Figure 6.1 is the transport from the DC to the stores. With XD and CW all pallets shipped from the DC to a store are stacked with varying products ordered by the store. A truck coming from the DC carries pallets with cross-docked (XD) goods and pallets with stocked (CW) goods. However, a single pallet in this truck will only carry solely XD goods or solely CW goods. Appendix J shows that the average utilization of a pallet containing XD goods transported from DC to store is [redacted]. The average utilization of a pallet containing CW goods transported from DC to store is [redacted].

The transport costs of both types of pallets are shared by all cartons stacked on that pallet. The cartons stacked on a pallet shipped from the DC to a store come from different suppliers (remember that the LoM of a DC pallet is 100% - see appendix E). This means that the transport costs of the pallet are shared with cartons of other suppliers. The costs associated with the transport of the cartons from a single supplier are assumed to be linear to the fraction of a full pallet occupied. Therefore, for part (B) of the transportation network equation 6.1 is used with an inefficiency factor *r* of 0.

Appendix J shows that the costs per transported pallet from the DC to a store equal $d_{i,j} * C =$ €9,66. For part (B) of the transportation network a XD pallet with a utilization of only [redacted] costs as much as a CW pallet with a utilization of [redacted]. This means that XD goods must share pallet transport costs of €9,66 with fewer goods as CW does. This must be taken into account for a proper comparison of the distribution flowtypes.

Figure 6.3 illustrates the fraction occupied by cartons of a supplier and equation 6.2 shows how to calculate it. The fraction occupied by cartons of a particular supplier depends on the volume per store order for that supplier. Appendix F explains how a supplier's fraction on a pallet is derived from the volume and order-size of a supplier's cartons.

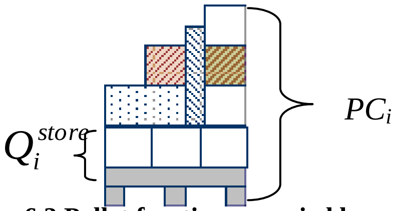


Figure 6.3 Pallet fraction occupied by supplier *i*

$$u^{i}_{DC-store} = MAX\left[1;\left(\frac{Q_i^{store}}{PC_i}\right)\right] \qquad (6.2)$$

Where

$u^{i}_{DC-store}$:= Mean fraction of a pallet shipped from DC to store occupied by supplier *i*

Q_i^{store} := Mean store order-size in number of cartons of supplier *i* per store

PC_i := Pallet capacity in number of cartons of supplier *i* per pallet

In equation 6.2, the pallet capacity PC_i is set to [redacted] of a full XD pallet and [redacted] of a full CW pallet. The resulting behavior of transport costs for XD and CW is given in figure 6.4.

The transport costs per carton on a XD pallet are almost always bigger than the transport costs per carton on a CW pallet: the transport cost factor increases faster for a XD pallet than for a CW pallet. Moreover, when a store order from a particular supplier is cross-docked and occupies [redacted] of a pallet it already costs €9,66. When a store order from a particular supplier comes from the central warehouse it only costs €9,66 when it occupies [redacted] of the pallet.

Equation 6.2 is used to estimate the transport costs for part (B) associated with the order of a particular supplier. From this equation it can be seen that the driver of transport costs for part (B) is the occupied pallet fraction. Conclusively, in order to estimate a supplier's transport costs for part (B) of MCCD's network, its following input is required:

4. # pallets supplied over the year*
5. Mean pallet fraction occupied

* The number of pallets supplied over the year depends on the volume per order-size. Appendix F explains how the number of pallets is derived from a supplier's carton volume and a store's order size.

A supplier's costs for transport part (B) can now be calculated by multiplying the number of pallets with their costs which are driven by the pallet fraction occupied.

6.4 Cross-Dock Pallet Utilization

The previous section shows that there is a big difference between the mean pallet utilization for XD and CW for part (B) of the transport network. These pallet utilizations have a big effect on the total transport cost, illustrated in figure 6.4: the transport of a CW pallet is very efficient while the transport of a XD pallet is very inefficient.
The high pallet utilization with CW can be realized because supply from the DC to the stores is uncoupled from the supply to the DC. However, with cross-docking the supply from the DC to the stores is coupled to the supply to the DC. This results in a time-stringent situation in which management decisions must be taken with care. Subsection 6.4.1 explains how MCCD's managerial policy influence the mean XD pallet utilization. Subsection 6.4.2 presents a sensitivity analysis about the influence of the mean XD pallet utilization on transport costs of part (B) of the network.

6.4.1 Cross-Dock Consolidation Policy

The mean XD pallet utilization depends on the applied consolidation policy. Higginson & Bookbinder [1994] define three consolidation policies for cross-docking:

- *Time Policy*

A time-policy dispatches each store order according to a pre-determined time schedule, independent of the volume. This policy is often referred to as "scheduled shipping" and is applied when management follows a service-optimization-perspective. From a logistic cost perspective, the time policy can be dangerous: a short holding time and small order arrival rate at the DC will result in frequent small loads. Frequent small loads result in low pallet utilization and high transport costs per carton [Higginson & Bookbinder, 1994]. When the holding time increases, there is a better chance of transport consolidation. The higher the holding time, the more XD resembles CW.

- *Quantity Policy*

Under a quantity policy, all orders are shipped when a minimum consolidated volume is reached. This policy is applied when management follows a cost-minimization-perspective: when the minimum consolidation volume is equal to the volume just fitting on a pallet, a quantity policy yields the lowest logistic costs per carton [Higginson & Bookbinder, 1994]. Here, the transport costs are minimized because only XD pallets with a high pallet utilization are shipped.

When the minimum consolidation volume is lower than the volume just fitting on a pallet, the performance of this policy relative to that of the time policy will depend on the holding time and order arrival rate at the DC [Higginson & Bookbinder, 1994]. For example, a time policy will perform as good as the quantity policy if the holding time is long enough to accumulate large loads and assure high pallet utilization. The higher the holding time, the more XD resembles CW.

- *Time-and-quantity Policy*

A time-and-quantity policy holds all orders for a particular destination until a predetermined time or consolidation volume is reached. This policy will never be cheaper than the quantity policy and may be more expensive than the time policy. However, a time-and-quantity policy will have less delays than the time policy and quantity policy [Higginson & Bookbinder, 1994].

MCCD applies a time-policy for the consolidation of store orders, with a holding time of maximally 1 day. As described above this situation often results in a low pallet utilization. Furthermore, MCCD is trying to reduce the Level of Mixture (LoM) of XD pallets to decrease the store handling costs. An unwanted side-effect of lowering the LoM is an even lower pallet utilization. This explains why the mean XD pallet utilization of MCCD is so low.

6.4.2 Sensitivity Analysis of Cross-Dock Pallet Utilization

For part (B) of the transpor network, the mean XD pallet utilization is [redacted] while the mean CW pallet utilization is [redacted]. The reasons for this big difference are explained in the previous subsection. This subsection presents a sensitivity analysis to show the effect on transport costs of an increase in the mean XD pallet utilization.

Figure 6.5 shows the behavior of the transport costs of a pallet shipped from DC to store for five different mean pallet utilizations. Here, the transport costs are calculated like described in section 6.3. The purple line shows the behaviour for the lowest mean utilization and the blue line shows the behaviour for the highest mean utilization. The lines inbetween show the effect of a 10% change in mean pallet utilization on transport cost per pallet.

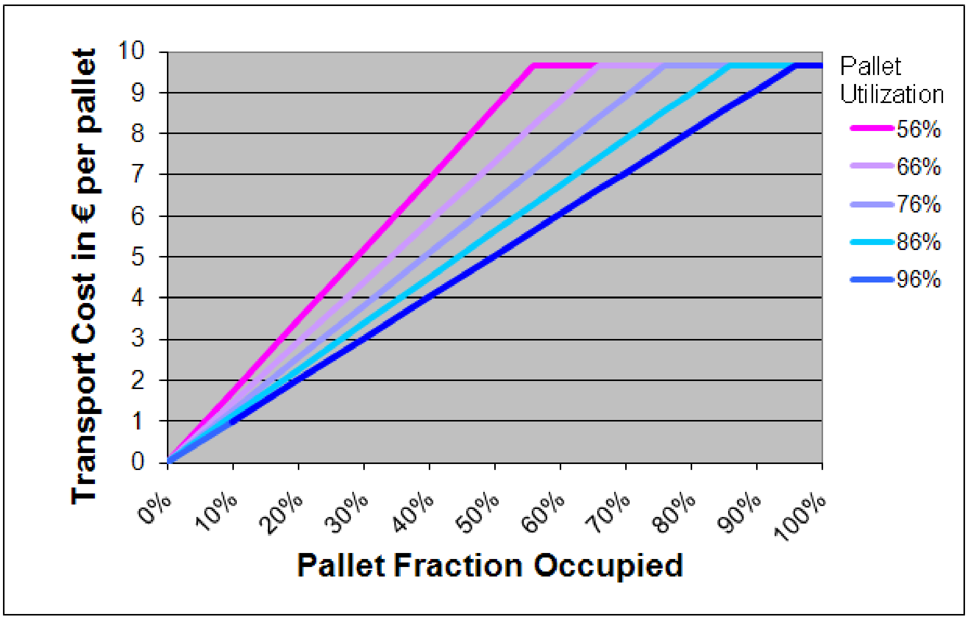


Figure 6.5 Pallet Transport Cost Behaviour for different Pallet utilizations

Figure 6.5 shows that the mean pallet utilization has a big influence on the pallet transport costs for part (B) of the network. With a mean pallet utilization of 56%, a supplier occupying 56% of the pallet pays €9,66 transport costs. When the mean pallet utilization would be 66%, that same supplier occupying 56% of the pallet would only pay €8,20. This is a difference of €1,46 (15%) per pallet shipped! This is illustrated by the dotted line in figure 6.5. Clearly, an increase in the mean pallet utilization greatly reduces the transport costs per carton.

Subsection 6.4.1 has explained that the consolidation policy applied by MCCD results in a low pallet utilization. MCCD can increase its mean pallet utilization by switching from a time policy to a quantity policy. The effect of switching to a quantity policy is out of scope of this research. However, this is an interesting topic for future research directions.

When MCCD wants to maintain the time policy with the same holding time, the only way to increase the mean pallet utilization is an increase of the order arrival rate [Higginson & Bookbinder, 1994]. The order arrival rate will increase when the number of cross-dock suppliers increases. Conclusively, when the number of cross-dock suppliers increases, the mean pallet utilization will increase and the XD transport costs per carton will decrease.

7 Stock Costs

Part II analyses the drivers of the logistical costs per distribution flowtype. Chapter 5 has analysed the handling cost drivers and Chapter 6 has analysed the transport cost drivers. This Chapter analyses the stock cost drivers. First, section 7.1 explains why the total safety stock is not a relevant logistical cost. Second, section 7.2 analyzes the DC cycle stock. Third, section 7.3 analyses the cycle stock in a store of MCCD. As a latter, section 7.4 explains what costs are associated with holding stock.

In a retail distribution network there are two types of inventory: safety stock and cycle stock. Safety stock is used to cope with uncertainty which comes from variability in demand during the lead-time and review period. Safety stock is the price one pays for the lack of information. Cycle stock results from ordering goods in batches and from ordering at different moments in time. Overall, cycle stock is the price one pays for the inflexibility of the processes in the distribution network [Van Der Vlist, 2007].

7.1 Safety Stock

The required safety stock is driven by the uncertainty in demand over the lead-time plus review period and the target non-stock-out probability (P_1) [Van Der Vlist, 2007]. Note that the Stock Service Level (SSL) at MCCD is re-defined as the non-stock-out probability (P_1) in section 4.2. Below, the safety stock for each distribution flowtype is analyzed from which it follows that the safety stock does not differ between the distribution flowtypes.

7.1.1 Safety Stock with DSD

For DSD, the P_1 directly translates into the required safety stock level at the stores by taking the inverse of the demand distribution function [Van Der Vlist, 2007].

$$\text{Safety stock} = k \cdot \sigma_{L+R} \tag{7.1}$$

Where σ_{L+R} the standard deviation of the demand in cartons over the lead-time L plus the review period R. Here, k is a safety factor selected such that:

$$\phi(k) = P_1$$

With $\phi(\cdot)$ assumed to be the normal probability distribution function.

7.1.2 Safety Stock with CW

In CW, the DC reorders from the suppliers commissioned by headquarters which takes into account the stock level of the retailers. In this situation, assuming the stores face independent normally distributed demand, the total system safety stock is calculated by equation 7.2 [Van Donselaar, 1990].

$$\text{System safety stock} = k\sqrt{L \cdot \sum_{i=1}^{N} \sigma_i^2 + \left\{ \sum_{i=1}^{N} \sqrt{l_i + R} \cdot \sigma_i \right\}^2} \tag{7.2}$$

With L the lead-time from supplier to DC and l the lead-time from DC to each of the stores, with σ_i the standard deviation of the demand at the i-th store and N the number of stores. Van Donselaar [1990] suggests using the following approximation to calculate the safety factor k for the CW system as a whole:

$$\phi(k) = \frac{1}{3} + \frac{2}{3} \cdot P_1 \qquad (7.3)$$

7.1.3 Safety Stock with XD

With XD, the DC of MCCD orders from the suppliers and allocates the incoming goods to the retailers on equal stock-out probability. The total system safety stock with XD is calculated with the same equation as for CW (equation 7.2), but using the regular safety factor *k* from equation 7.1 instead of the one from equation 7.3 [Van Der Vlist, 2007].

7.1.4 Safety Stock Differences

Van der Vlist [2007] has derived that in a retail network, the total system safety stock with XD is equal to the total system safety stock of DSD when retail demand is uncorrelated and the following condition holds:

$$L << N(l + R)$$

Where the variables are defined as in equation 7.2
Given that the lead-time from DC to store is 2days and the review period of the Non-food assortment is 2days, the lead-time from supplier to DC must be much smaller than (2+2) four times the number of stores supplied. Because there are 61 MCCD stores in Germany, the safety stock for DSD and XD will be the same when a supplier’s lead-time to the DC is much smaller than 244 days. This is true for all national suppliers of Non-food products. Therefore, the total system safety stock does not differ between XD and DSD.
Equation 7.2 and equation 7.3 show that CW requires a higher total safety factor than cross-docking in the same situation. This is due to the fact that with CW, the DC must assure a higher P_1 to the stores so that the stores are able to reach the desired P_1 to the customer. However, from a cost-perspective all extra safety stock will be placed on the store’s shelves because there it does not incur extra holding costs (Chapter 5 explains that stocking more products on the shelves does not incur extra holding costs). Therefore, it is assumed that the costs of the total system safety stock for CW is equal to that of XD. Note that this assumptions is violated for innovative products, because for these products it is beneficial to place the extra safety stock at the DC for risk-pooling advantages!

Based on the arguments above, it is assumed that the total system safety stock does not differ between DSD, XD, and CW. Assuming that the stock costs are system-wide and risk-pooling effects are neglected, the safety stock is placed at the shelves in the stores. Then, the total safety stock costs are the same for each distribution flowtype and are therefore not relevant logistic costs. This means that, from a cost-perspective, the safety stock analysis can be excluded from the distribution flowtype comparison.

7.2 DC Cycle Stock

When it is assumed that supply and demand is not synchronized, the cycle stock at the DC on average will be half the total order-size [Van Der Vlist, 2007]. This is graphically represented in figure 7.1. In this figure, τ_0 depicts the moment that the first DC order arrives while τ_1 depicts the next DC order arrival moment. During the time interval [τ_0; τ_1] the whole DC order is consumed so that the average cycle stock will be $\frac{1}{2}Q_{DC}$ (see equation 7.4).

It is assumed that each supplier supplies exactly once per replenishment cycle. Here, the replenishment cycle is the period in which all stores have replenished their inventory with an

order at the DC. In this situation, the order-size at the DC Q_{DC} equals the mean store order-size Q_{store} multiplied with the number of stores supplied N ; $Q_{DC} = N*Q_{store}$. Assuming that all 61 stores are always supplied, only the store order-size Q_{store} must be known to estimate the DC cycle stock level in this situation. This means that in the model, no extra input of a particular supplier is required.
Note that a supplier may supply the DC more often than once per replenishment cycle. This would lead to a different situation as described: a higher delivery frequency, a lower order-size and therefore a lower stock level. On the contrary, a supplier may supply the DC fewer times than once per replenishment cycle. This would lead to yet another situation: a lower delivery frequency, a higher order-size and therefore a higher stock level. The assumption that each supplier supplies exactly once per replenishment cycle is thus of big influence on the relevant logistic costs!

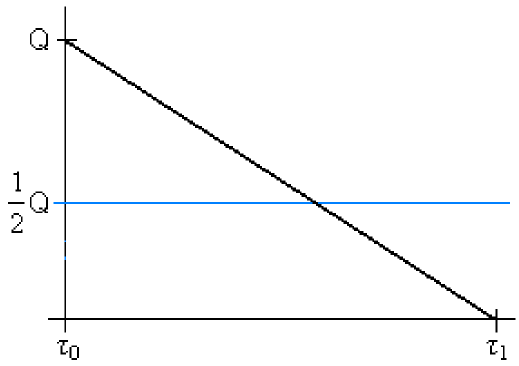


Figure 7.1 The DC Cycle Stock Level

$$E[I_{DC}] = 1/2\, Q_{DC} \qquad (7.4)$$

Where
$E[I_{DC}]$:= Expected DC stock level in number of cartons
Q_{DC} := Mean DC order-size in number of cartons

7.3 Store Cycle Stock

A store has stock stacked on two locations: on the shelves and in the backroom. Because the previous section shows that the safety stock is excluded from the research, this section only considers the cycle stock on the shelves and in the backroom. Subsection 7.3.1 discusses the cycle stock on a store's shelf and subsection 7.3.2 discusses the cycle stock in a store's backroom.

7.3.1 Cycle Stock on Shelf

In section 5.2 it is stated that almost all inventory of a MCCD store is on the shelves. The available shelf space to carry store stock is determined by Category Management (CM). Whether the available shelf space contains stock has almost no influence on the relevant logistical costs: MCCD pays for the shelf space reserved by CM, not for the space occupied by the stock stacked on the shelf. Furthermore, MCCD is slowly narrowing its assortment to focus on professional customers running their own restaurant or kiosk. This indicates that the store space coming available by a possible reduction of store stock is of little value to MCCD.

Conclusively, the only difference in store stock costs between distribution flowtypes appears when the contents of an order do not fit on the shelves and backroom stock is required. Given that the shelf coverage for many non-food products is very high (see Appendix G), almost all non-food products will always fit on a store's shelf. Therefore, the difference in store cycle stock costs between distribution flowtypes will be minor: only for a few products, backroom space is required to stock the products of a store order which do not fit on the store's shelves.

7.3.2 Backroom Cycle Stock

Subsection 7.3.1 explains that a store's cycle stock costs are only driven by the cartons which do not fit on the shelf and need to be stored in the backroom. Therefore, the backroom cycle stock level drives the store cycle stock costs. The backroom cycle stock level depends on the store's order-size, the Excess Shelf Coverage (ESC) and a supplier's MOQ.
In a MCCD store, only the part of an order which does not fit on the shelf will incur backroom stock costs. This part is already computed in equation 5.4 and indicated with $X_i = \left(Q_i^{store} - ESC_i - MOQ_i\right)^+$. This X_i will be consumed before a new order arrives which is why the expected backroom cycle stock is less than the ½Q_{store} shown in figure 7.1. The behaviour of a store's backroom stock is illustrated in figure 7.2. Here, it is assumed that the store backroom stock is consumed at the moment that there is shelf space available to store the product. At that moment, secondary replenishment takes place (see section 5.2). In figure 7.2, X/μ is the expected number of days after order arrival τ_0 that the backroom stock becomes zero. Given that MCCD has 300 selling days per year, the number of selling days between two order arrivals [τ_0 ; τ_1] equals: $\frac{300}{D/Q_{store}}$

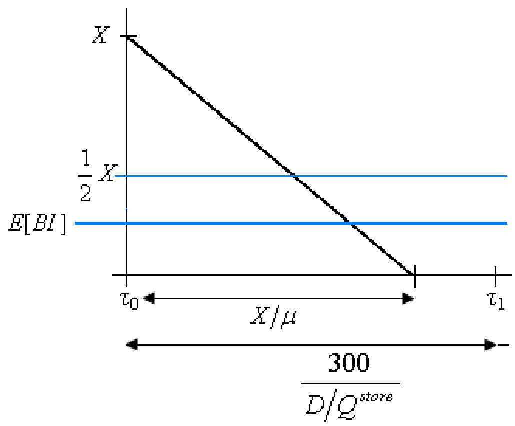


Figure 7.2 The Backroom Cycle Stock Level

From figure 7.2 it can be seen that the expected backroom cycle stock is equal to:

$$E[BI] = 1/2 \cdot X \cdot \frac{\left(\frac{X}{\mu}\right)}{\left(\frac{300}{D/Q_{store}}\right)} \tag{7.5}$$

Where
$E[BI]$:= Expected backroom stock level per store in number of cartons
X := Number of cartons per store which do not fit on the shelf (see equation 5.4)
μ := Mean daily demand per store in number of cartons
D := Total demand per store over the year in number of cartons
Q_{store} := Order-size per store in number of cartons

Inserting equation 5.4 in equation 7.5 and simplifying results in the following:

$$E[BI] = \frac{D\left(Q_{store} - ESC - MOQ_i\right)^2}{600\mu \cdot Q_{store}} \qquad (7.6)$$

From equation 7.6 it can be seen that the expected backroom cycle stock level heavily depends on the balance between the order-size and the excess shelf space: a decrease in the order size *Q* makes the nominator of equation 7.6 decrease faster than the denominator, resulting in a lower expected backroom cycle stock level. Furthermore, with ESC $\leq$ 0 the whole order-size will be stored in the backroom.
Given that the shelf coverage for many non-food products is very high (see appendix G), the ESC will mostly be higher than a store's order-size. This means that the *E*[*BI*] is often very low and the difference in a store's cycle stock between distribution flowtypes will therefore be minor. However, those suppliers with limited associated shelf space, a long lead-time, and a high demand variation may have a high maximum demand during the lead-time and review period. The products of those suppliers may have a low ESC when delivering directly. Delivering via the DC will then greatly decrease the lead-time and thus increase the ESC. This means that there may be a significant difference in store stock costs between distribution flowtypes for these suppliers. In order to properly model this difference per order-size, the following input per supplier is required:

1. # cartons supplied over the year
2. Mean daily demand per store in number of cartons
3. The shelf coverage per store for the supplier's products

7.4 Stock Costs

The costs of holding a carton on stock can generally be described by the interest paid on the value of the carton and the costs associated with the space the carton is taking (building rental, heating, maintenance etc.). The total yearly stock costs for the cartons of a particular supplier therefore include both the interest and space costs as follows:

$$SC_i = I_i\left(0{,}067 \cdot P_i + V_i \cdot SUC\right) \qquad (7.7)$$

Where
SC_i := Stock cost in € per year of a carton from supplier *i*
I_i := Mean yearly stock level in number of cartons at location *i*
P_i := Mean selling price of a carton from supplier *i*
V_i := The volume of an average carton from supplier *i* (derived from appendix G)
SUC := Space utilization cost of using 1,00m^3 of stocking space over a year

In equation 7.7, only a carton's mean yearly stock level I_i differs per distribution flowtype. For the store stock costs, I_i is replaced by $E[BI]$ from equation 7.6. For the DC stock costs, I_i is replaced by $E[I_{DC}]$ from equation 7.4.

When a carton's mean yearly stock level is known, the interest paid is fairly easy to calculate: MCCD applies an interest rate of 6,7% of the value stored per year for each non-food carton. However, to estimate the yearly cost of the carton's utilized space, a more detailed analysis is required.

All figures and conclusions in this report are modified and do not represent the real situation for Metro Cash & Carry Deutschland.

The Space Utilization Costs (*SUC*) is estimated by using data of MGL. The mean yearly stock level at the DC, the mean volume per carton held at the DC, and the total warehouse space utilization costs at the DC are used to estimate the yearly costs of storing 1,00m^3. Note that it is assumed that the *SUC* for store backroom stock is equal or more than the *SUC* for DC stock. Because the total backroom stock level associated with a supplier will mostly be negligible, assuming that both *SUC's* are equal will not have a big impact on the overall model results.
Over the year 2009, the DC had an average stock level of [redacted] cartons with a mean volume of 0,033m^3 per carton. Given that the total space utilization costs were €[redacted], the *SUC* is €1.424 per m^3 per year (€3,90 per m^3 per day). Table F.1 in appendix F is used to choose the mean volume of the cartons delivered by a particular supplier.

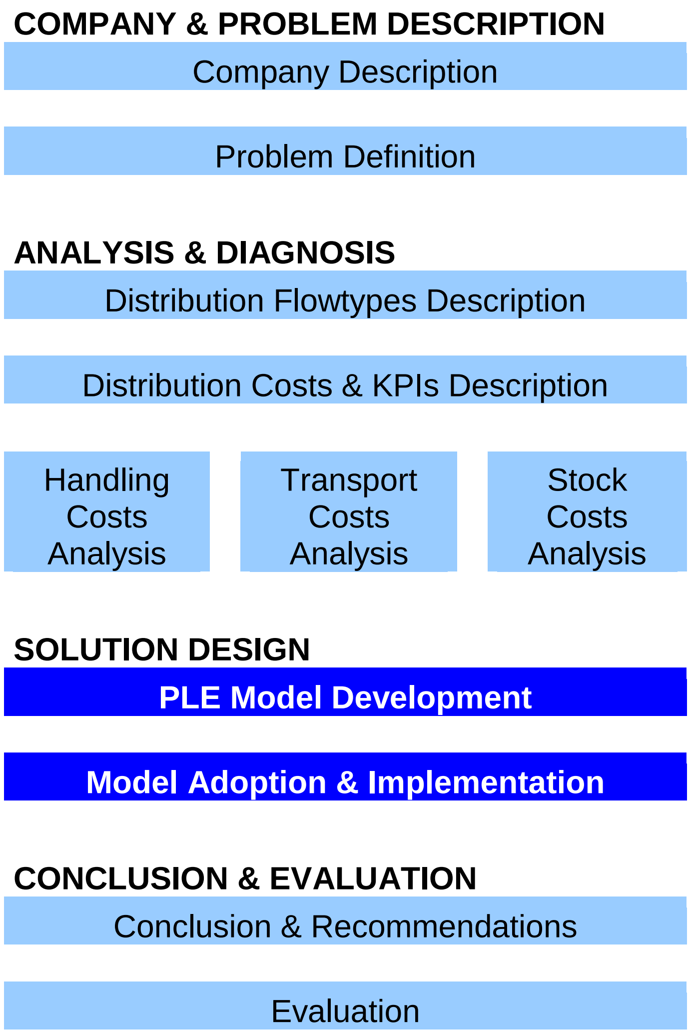
Equation 7.8 is derived from equation 7.7 and shows that the value of an average-sized carton (0,033m^3) must be more than €703 for the interest costs to be higher than the space utilization costs per carton:

$$0{,}067 * P_i > 0{,}033 * €1426 \rightarrow P_i > €703 \quad (7.8)$$

Moreover, the value of a carton per square meter, defined as the Product-Value-Density (PVD) [De Leeuw et al., 1999], must be higher than €21.283 (€703 / 0,033 m^3) for the interest costs to be higher than the *SUC* costs. This seems high but e.g. a new mobile phone of €300 packed in a carton of 10cm*10cm*20cm already has a PVD of €150.000. Therefore, both the interest costs and *SUC* costs are important stock holding costs. Therefore, the estimation of the stock costs associated with a particular supplier requires her following input:

4. Mean selling price of a carton in €
5. Mean volume level of a carton in m^3

PART III SOLUTION DESIGN



8 The PLE Model

Part II has analyzed the drivers of the relevant logistic costs for the distribution flowtype comparison per supplier. Chapter 8 combines these drivers into a model and starts with a short description of the model in section 8.1. Next, section 8.2 explains the additional requirements concerned with cross-docking and section 8.3 summarizes the main assumptions underlying the model.

8.1 Model Description

The transport costs, handling costs, and stock costs are the relevant Physical Logistic Costs (PLC) for Metro Cash & Carry Deutschland (MCCD). A store's order-size has a big impact on the behaviour of these costs given a particular distribution flowtype. For each change in the store order-size the difference in PLC between the distribution flowtypes changes. Furthermore, every distribution flowtype has its own optimal store order-size resulting in the minimum PLC for the supplier in question. Therefore, comparing the distribution flowtypes for one single order-size will not result in the optimal distribution flowtype. Moreover, the PLC of all three distribution flowtypes needs to be calculated for a range of store order-sizes.
The Physical Logistic Efficiency (PLE) Model estimates the total PLC for a supplier per store order-size for the three available distribution flowtypes (DSD; XD; CW). The building blocks of the PLE Model are the drivers and equations of each relevant logistic cost developed in part II of this report. At the end of each cost driver analysis, the required input parameters for an estimation of that particular logistical cost is given. When all these required input parameters are combined the result is a general overview of total required input per supplier for the PLE Model. This total required input per supplier is given in table 8.1 below.

Table 8.1 Required Input per Supplier for the PLE Model

1. # cartons & € supplied over the year
2. Mean Volume Level of a carton in m^3
3. Mean and Stand Dev of daily store demand in # cartons
4. Mean supplier lead-time in days (ODLT)
5. Shelf Coverage per store in # cartons
6. Level of Mixture (LoM) over the year in %
7. # goods receiving lines (GR Lines) over the year
8. # packages supplied over the year
9. MOQ in # cartons
10. Supplier's address

A. Fill Rate*
B. Lateness*

* To be explained in section 8.2

Note that two additional inputs are added to the list in table 8.1: a supplier's fill rate and lateness. These inputs are explained in section 8.2. When for a particular supplier all input from table 8.1 is known, the PLE Model calculates the PLC for each store order-size ranging from 5 cartons to 200 cartons. The PLE Model generates three outputs:

4. A graph showing the behaviour of the PLC per distribution flowtype when changing the store order-size. The order-size is translated to the number of days with forecasted demand covered by the order. This is done by dividing the order-size in number of cartons with the daily demand in number of cartons. The graph can be used to determine the optimal store order-size of a distribution flowtype. Furthermore, this graph shows whether the supplier's MOQ restricts the optimal store order-size with DSD.
5. The overall optimal distribution flowtype for the supplier in question together with the accompanied handling, transport, and stock costs per carton.
6. The minimum supplier contribution (Logistik Kost Anteil – LKA) required when switching from DSD to XD or CW. This can be used in the negotiation with a supplier and is equal to the difference in PLC per distribution flowtype in percentage of the supplier's total turnover.

Appendix K shows an example of the three outputs from the PLE Model for a supplier of Haushold goods.

For all non-food suppliers the required input is gathered into one full list of input parameter values per supplier for the year 2009 (see Appendix L). When the optimal distribution flowtype of a particular supplier must be derived, the supplier's input can directly be copied from this list into the PLE Model. After copying the input into the PLE Model, the model is ready to run its calculations for the range of store order-sizes: by clicking "Control+Q" the model calculates the relevant logistic costs per distribution flowtype for the range of store order-sizes and gives the output as described above. With this procedure it is a matter of a few seconds to determine the optimal distribution flowtype for a single supplier.

8.2 Extra Cross-Docking Requirement

The PLE Model described in the previous section calculates the PLC per distribution flowtype per store order-size for a particular supplier. The model implicitly assumes that all required resources are available when needed and there are no time restrictions. However, for cross-docking there are two important conditions which must be met to assure that the PLE Model gives a realistic estimation of the PLC.
The first condition is the availability of a large distribution network. Section 3.4 already explained that it is important to have a large distribution network where consolidation matters. This is obviously the case for MCCD, where 61 stores are supplied by hundreds of national suppliers located in a circular area with a 500km radian.
The second condition for successful implementation of cross-docking is the reliability of the supplier in question. Cross-docking is a very time-stringent process in which the relationship between the supplier and the retailer is pushed to the limit [Simchi-Levi et al., 2008]. This means that coordination is very complex and important at the same time. In this environment, the goods must arrive exactly on time at the DC so that the orders can immediately be allocated to the store-destined pallets. Late deliveries will result in queues of cross-docking products waiting to be processed which will unbalance the total workload in the DC. Thus, late deliveries with cross-docking has consequences for many DC processes. Therefore, a supplier is only a good candidate for cross-docking when its reliability is high. This is why a supplier's fill rate KPI and lateness KPI from table 4.1 are added to the required input parameters in table 8.1.

8.3 Model Assumptions

The PLE Model has seven underlying assumptions, which are summarized below. These assumptions must be taken into account when using the PLE Model to select the optimal distribution flowtype for a supplier.

1. *The overall distribution strategy focuses on physical logistical efficiency (see Section 2.3)*

The Physical Logistic Efficiency (PLE) Model estimates which distribution flowtype has the minimal relevant logistical costs. Therefore, the PLE Model is only suitable when the user's distribution strategy focuses on physical logistical efficiency. According to Fisher [1997], this type of distribution strategy is appropriate for functional products with stable predictable demand satisfying basic consumer needs. However, many products in the Non-Food assortment of MCCD are innovative having high demand seasonality and unpredictability. These innovative products require another distribution strategy focusing on market responsiveness. The PLE Model is not appropriate for suppliers of innovative products.
Appendix C gives a categorization table with which the products of a particular supplier can be classified as either functional or innovative. This table can be used to decide whether a supplier supplies mainly functional or mainly innovative products.

2. *A supplier's MOQ assures the minimization of her relevant logistical costs (see Section 2.3)*

The handling and stock costs of the supplier are out of the scope of this project. It is assumed that a supplier's MOQ settings assure the minimization of her relevant logistical costs. However, in practice the order-size does influence the supplier's costs of order picking and stock holding. A supplier is likely to adopt her supplier contribution to MCCD to changes in these costs. This must be taken into account when negotiating the supplier contribution based on the third output of the PLE Model. In general, DSD will require more handling for the supplier because of small store-specific orders while with CW it is easier to synchronize orders to the production process and gain economies of scale [Van Den Heijkant, 2006].

3. *The daily demand is normally distributed (see Section 5.2)*

For the estimation of the excess shelf coverage, the latest reorder level is calculated. The latest reorder level equals the maximum demand covered during the replenishment lead-time and review period. For the calculation of the latest reorder level it is assumed that the demand is normally distributed.

4. *Full pallet transport costs are linear to distance and balanced over the area including all suppliers (see Section 6.2)*

The transport costs per full pallet are assumed to be linear to distance and nation-wide. The mean distance with the associated transport costs from a supplier and the DC to a store is already known and independent of the supplier's location. However, the distance and thus transport costs from a supplier to the DC differs per supplier location.
Transporting a pallet over the border incurs extra border costs which differ among countries. Therefore, the PLE Model can only be used for national suppliers. For all import suppliers, the optimal distribution flowtype is CW.

5. *Store backroom stock holding costs equal DC stock holding costs (see Section 7.1)*

The stock holding costs are assumed to be the same for the cycle stock at the store backroom and the cycle stock at the DC. In practice, the Space Utilization Costs (SUC) at the store backroom stock are higher than the SUC at the DC. This is due to the fact that the store is located closer to a city for which the land price is higher and thus space is more costly. However, for practically all non-food suppliers of MCCD their products all fit on a store's shelves. Only a few suppliers require store backroom stock. Thus, for practically all suppliers a violation of this assumption does not have a big effect on its relevant logistic costs.

6. *The supplier only delivers one order to the DC per replenishment cycle. (see Section 7.2)*

It is assumed that each supplier supplies exactly once per replenishment cycle. Here, a replenishment cycle is the period in which all stores have replenished their inventory with one order at the DC.
Note that a supplier may supply the DC more often than once per replenishment cycle. This would lead to a different situation as described: a higher delivery frequency, a lower order-size and therefore a lower stock level. Furthermore, a higher delivery frequency from supplier to DC can reduce the consolidation effect of indirect delivery. This results in higher transport costs per carton. It is thus clear that this assumption has a big influence on the results of the PLE Model.

7. *Shelf stock is driven by Category Management (see Section 7.3)*

The available shelf coverage to carry store stock is determined by Category Management. Because most product groups have a huge shelf coverage set by the CM (see appendix G), there is practically no difference in store stock costs between the distribution flowtypes. When the shelf coverage would be limited, the optimal order-size would decrease and the differences between distribution flowtypes would change. Thus, the decisions of CM greatly influence the distribution flowtype selection.

9 Model Application & Implementation

Chapter 8 described the model derived from the cost driver analysis in part II. This Chapter shows the result of applying the model to sixteen pilot suppliers and verifies the results. Chapter 9 starts with the definition of four selection criteria used to choose the sixteen pilot suppliers in section 9.1. Thereafter, section 9.2 shows the results of using the PLE for these pilot suppliers. Section 9.3 verifies the transport cost model and section 9.4 compares the results for the pilot supplier with the findings in academic literature. As a latter, section 9.5 discusses the implementation issues and limitations of the PLE Model.

9.1 Selection of Pilot Suppliers

This section describes the selection procedure for the pilot suppliers. Because the total list of non-food suppliers contains more than 800 suppliers, a limited number of suppliers is selected and analyzed with the PLE Model. The suppliers are divided into groups based on four criteria. The criteria used to define the groups are derived from the main drivers found in Part II of this report.

Chapter 4 has shown that MCCD's main logistic costs include handling, transport, and stock costs. The drivers of handling, transport, and stock costs are evaluated to define the criteria.
For the handling costs, Chapter 5 has shown that the total goods receiving costs are much lower than the total shelf replenishment costs. Furthermore, for almost all suppliers, shelf replenishment costs do not differ between distribution flowtypes due to the high shelf space in a store. This means that the major differences in handling costs per distribution flowtype relate to DC handling. The DC handling costs are driven by the number of cartons, trucks, and pallets over the year, where the number of pallets (and thus trucks) depends on the cartons' volume and the mean store order-size.
For the transport costs, Chapter 6 has shown that the main drivers are distance from supplier to DC and the volume of a store order-size. Note that the mean distance from the supplier to a store and the mean distance from the DC to a store are independent of the supplier's location (see Section 6.2).
For the stock costs, Chapter 7 has shown that store cycle stock rarely makes a difference between distribution flowtypes. Furthermore, the DC cycle stock costs depends on the total of all store order-sizes. The costs of holding a carton on stock are driven by its value and volume.
The most important drivers identified above function as selection criteria for the pilot suppliers. The resulting selection criteria are given in table 9.1. The definition of the two extreme classes for each criterion is based on a quick scan of the input list per supplier in appendix L. Based on the selection criteria in table 9.1 and the defined extreme classes, 16 (2^4) different Haushold pilot suppliers are chosen. The suppliers all differ on their score for the selection criteria, which is either above the upper extreme (*u*) or below the lower extreme (*l*). The resulting settings of the selection criteria for the 16 pilot suppliers are given in appendix M.

Table 9.1 Definition and Extremes of the Selection Criteria for the Pilot Suppliers

	Selection Criteria	Upper Extreme	Lower Extreme
1.	# cartons supplied over the year	> 500.000 cartons	< 5.000 cartons
2.	Mean volume level of a carton from the supplier	> l	< s
3.	Distance from supplier to DC	> 400 km	< 50 km
4.	Value per carton in €	> 100 €	< 5 €

9.2. Results for Pilot Suppliers

The results of applying the PLE Model for the 16 pilot suppliers identified in section 9.1 are given in appendix N. Table 9.2 and figure 9.1 summarize these results. An important remark here is that a sample of sixteen pilot suppliers is too small to derive valid statements about all non-food suppliers of MCCD. More pilot suppliers must be tested to increase the validity of the results. Nevertheless, the results for the sixteen suppliers already give good guidance for distribution flowtype selection.

Table 9.2 gives the ranking of the three available distribution flowtypes for each of the 16 pilot suppliers. This table shows that for 7 out of the 16 pilot suppliers DSD is the optimal distribution flowtype, for 6 of the 16 pilot suppliers XD is the optimal distribution flowtype, and for 3 out the 16 pilot suppliers CW is the optimal distribution flowtype. For all pilot supplier with XD as optimal distribution flowtype, the second-best flowtype must be chosen whenever their reliability is low. For 5 out of the 6 XD pilot suppliers, the second-best flowtype is DSD. Only for pilot supplier ‘N’ (a supplier of large expensive fast-moving products which is located near the DC) CW is the second-best flowtype. The three pilot suppliers of small and/or cheap fast-moving products which are located near the DC have CW as the optimal flowtype.

		Pilot Supplier															
		A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P
Flowtype Ranking	DSD	1	1	2	2	2	3	3	1	3	1	2	1	1	3	1	2
	XD	2	2	1	1	1	2	2	2	2	2	1	2	2	1	2	1
	CW	3	3	3	3	3	1	1	3	1	3	3	3	3	2	3	3

Table 9.2 Distribution Flowtype Ranking per Pilot Supplier

Figure 9.1 graphically represents the division of the logistic costs per carton for each pilot supplier defined in section 9.1 when its optimal distribution flowtype is applied.

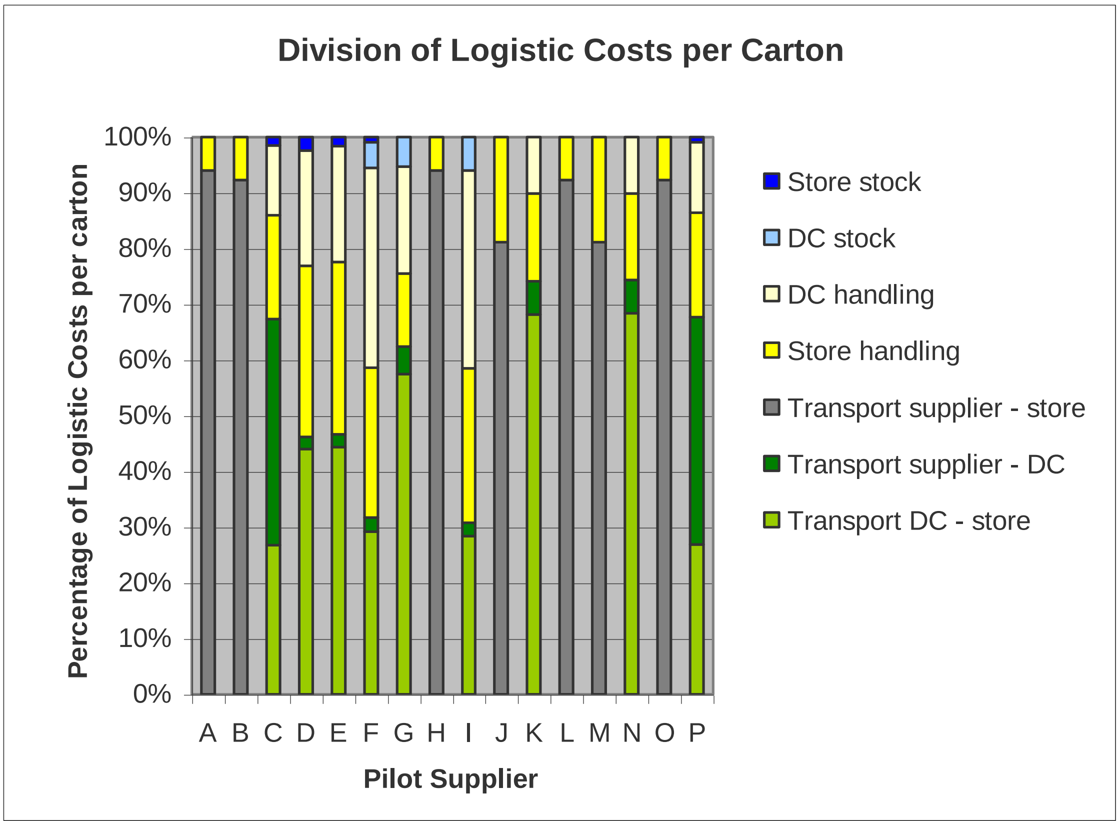


Figure 9.1 Division of cost per carton for the optimal distribution flowtype per pilot supplier

- First, figure 9.1 shows that the handling and transport costs are responsible for more than 90% of the relevant logistic costs for all 16 pilot suppliers.

- Second, for all 7 DSD pilot suppliers, the transport costs are responsible for more than 80% of the relevant logistic costs. For XD and CW, this varies between 30% and 75%. Chapter 6 has shown that the transport costs are driven by order-size, carton volume, and transport distance.

Considering the order volume, both XD and CW have the advantage of bundling orders over part (A) of the retail network (i.e. transport from supplier to DC) and increase the order volume. Therefore, the average pallet utilization with XD and CW is higher and the transport costs considerably lower than with DSD. However, when the cartons to be shipped are more voluminous, the advantage of bundling orders decreases and the required number of pallets will be higher. This is why suppliers of voluminous cartons have high transport costs and often supply directly to avoid DC handling and DC stock costs (see appendix N).

Next to order volume, the distance between a supplier and the DC is a driver of transport costs. When a supplier is located far from the DC it is unattractive to first transport the goods to the DC and second transport them to the stores. When a supplier is located near to the DC the savings in transport costs must outweigh the extra DC handling and/or DC stock costs for indirect delivery to become beneficial. Remember that the mean distance between a supplier or DC and the stores is independent of the supplier's location.

- Third, the total handling costs for all XD and CW pilot suppliers are higher than the total handling costs for all DSD pilot suppliers. This is mainly due to the extra DC handling costs associated with indirect delivery. Especially the CW pilot suppliers have considerable extra DC handling costs (see supplier F and I in figure 9.1). The DSD pilot suppliers do not have any DC handling costs. This means that the drivers of DC handling are of big importance to distribution flowtype selection. These drivers are the store order-size, and the number of cartons supplied over the year.

- Fourth, figure 9.1 shows that the store cycle stock costs are only responsible for maximally 3% of the total relevant logistic costs. This indicates that the store shelves are so big that for practically each supplier the cartons of an optimal store order all fit on the shelves. Therefore, little backroom stock is required. This is explained in Chapter 5 of this report. Thus the drivers of backroom stock are of minor importance to flowtype selection for MCCD.

- Fifth, only for the pilot suppliers with CW as the optimal distribution flowtype (supplier F, G, and I in figure 9.1), there exists DC cycle stock. For these suppliers, the DC cycle stock is responsible for maximally 7% of the relevant logistic costs. The three pilot suppliers for which CW is optimal all supply fast-moving products with a low volume and/or value and are located near the DC. This can be seen from the selection criteria settings in appendix M.

- Sixth, figure 9.1 only shows the division of relevant logistic costs per carton for the optimal distribution flowtype of each pilot supplier. However, the relative importance of transport, handling, and stock costs differs between the available distribution flowtypes for an individual supplier. Furthermore, each supplier may have a totally different division of relevant logistic costs per carton compared to any other supplier. This division of relevant logistic costs per carton depends (among others) on supplier-specific factors like address, lead-time, and MOQ.

The division of relevant logistic costs per carton is not known beforehand. Insight into this division and a comparison of the relevant logistic costs for the available distribution flowtypes for a particular supplier are given by the PLE Model.

9.3 Verification of the Transport Cost Model

Section 9.2 has shown that the differences in relevant logistical costs per distribution flowtype are primary driven by transport costs. It is therefore important to verify the computation of the transport costs. This verification is split up in a verification of the full pallet transport costs in subsection 9.3.1 and a verification of the average pallet utilization for part (B) of the transport network in subsection 9.3.2.

9.3.1 Verification of Full Pallet Transport Costs

In part II, the estimation of the transport costs are based on MGL's financial account and the shipment data of the year 2009. This section verifies the estimated transport costs with MGL's financial account and shipment data for the year 2008.
As can be seen in figure 6.1, the transportation network of MCCD consists of a retail consolidation network (part (A)) and the transport from DC to stores (part (B)). Part (A) of MCCD's transport network is a retail consolidation network for which the transport costs are calculated with equation 6.1. A division manager of MGL states that the costs of shipping a full pallet with a service provider from its origin to its destination in Germany is €24,57. In appendix I the estimated distance from an origin to a destination in Germany is 567km. This means that shipping a full pallet with a service provider over one kilometer costs MCCD *€0,043.*

Table J.2 in appendix J shows that over the year 2009 MCCD pays €9,66 for the transport of a full pallet in part (B) of MCCD's transport network. To verify these costs, the shipment data of the year 2008 are used. The resulting costs in the year 2008 of transporting a full pallet in part (B) of MCCD's network are given in Table 9.3.

Table 9.3 Costs of Transporting a Full Pallet from the DC to a store for 2008

CW			XD		
Total (*1000)	# Pallets	€ per Pallet	Total (*1000)	# Pallets	€ per Pallet
[redacted]		€ 9,70	[redacted]		€ 9,70

Table 9.3 shows that the transport costs per full pallet in 2008 where slightly higher than in 2009. This is a small difference which may be caused by the increase in total number of pallets transported in 2009 compared to 2008. This increase might have led to economies of scale for the 3rd party logistics providers which. However, this difference is small enough to verify the plausibility of the full pallet transport costs for part (B) of the transport network. Given that the mean distance from the DC to a store is 245km, the costs of shipping a full pallet over one kilometer equals *€0,040*.

The transport costs per kilometer of part (A) are a minor *€0,003* more expensive than the transport costs per kilometer of part (B). Because the transport in part (B) is arranged by a 3rd party service provider, this *€0,003* is expected to be the profit per kilometer which goes to the service provider. Thus, the resulting transport costs per kilometer for part (A) are plausible when they are compared with the transport costs per kilometer for part (B).

9.3.2 Verification of Average Pallet Utilization

For part (B) of MCCD's transportation network, appendix J has calculated the average pallet utilization of a CW pallet and a XD pallet with shipment data of the year 2009 (see table J.2). The resulting average pallet utilization for CW is [redacted] and for XD it is [redacted]. These average pallet utilizations are very important input for the calculation of transport costs for part (B). Therefore, the shipment data of the year 2008 is used to verify the utilizations.

In the year 2008, there are [redacted] pallets used to ship [redacted] m^3 of Non-food products from the DC to the stores through central warehousing. Appendix J shows that each pallet has a capacity of 1,78m^3. Dividing the total transported volume ([redacted] m^3) through the total available volume gives an average pallet utilization for CW of [redacted].

In the year 2008 there are [redacted] pallets used to ship [redacted] m^3 of DryFood products from the DC to the stores through cross-docking. Following the same calculation as above this results in an average pallet utilization for XD of [redacted].

Conclusively, the average pallet utilization for CW and XD pallets in part (B) of the transportation network do not differ significantly between the years 2009 and 2008. Therefore, the average pallet utilization for XD and CW are plausible.

9.4 Verification of the Model Results

This section verifies the PLE Model results with the findings in academic literature. First, subsection 9.4.1 verifies the behavior of the relevant logistic costs over a range of store order-sizes. Second, subsection 9.4.2 verifies the effect of each main driver on the distribution flowtype selection.

9.4.1 Verification of the Logistic Cost Behavior

Van Der Vlist [2007] has analyzed the behavior of retail costs over a range of order-sizes (Q). The result is given in figure 9.2. In this figure the overall cycle stock costs are defined as the inventory carrying cost. Furthermore, the overall transport and handling costs are defined as the transaction cost. The total cost is defined as the sum of inventory carrying cost and transaction cost.

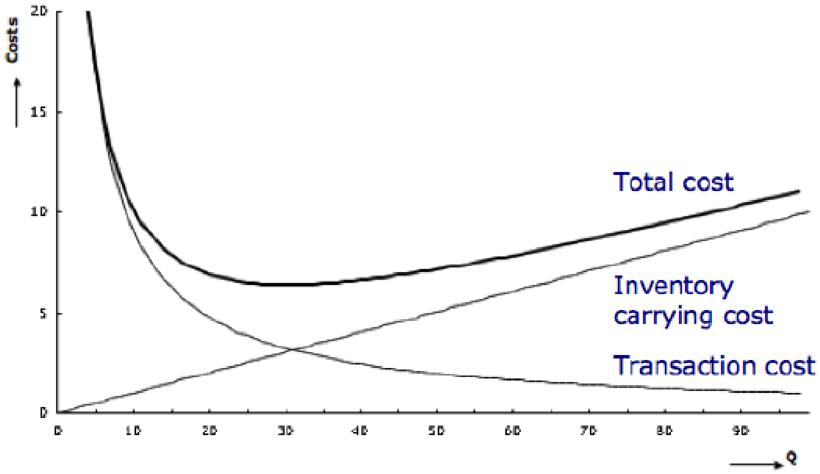


Figure 9.2 Logistic cost behaviour for different order sizes [Van Der Vlist, 2007]

Figure 9.2 shows that increasing the order-size increases the inventory carrying costs per carton and decreases the transaction costs per carton. Figure K.1 of appendix K shows that the PLE Model illustrates the same behavior. Remember that DSD and XD have practically no stock costs. Therefore, their relevant logistic costs lines in Figure K.1 follow the transaction cost line of Figure 9.2. Next to that, CW experiences both economies of scale in transaction costs and increased DC stock costs when the order-size increases. Therefore, the relevant logistic costs line in Figure K.1 for CW follows the total cost line of figure 9.2. Conclusively, figure 9.2 and figure K.1 show that the optimal store order-size with CW will be lower than the optimal store order-size for XD or DSD. Herewith, the behavior of the relevant logistical cost per distribution flowtype is verified with the findings of Van Der Vlist [2007].

9.4.2 Verification of the Main Driver Effects

From the results of the pilot suppliers given in section 9.2 it follows that transport costs and handling costs explain more than 80% of the total logistic costs of the optimal distribution flowtypes for the pilot suppliers. This section verifies how in the PLE Model the drivers of these costs effect the decision for a particular distribution flowtype. This is done by comparing the PLE Model findings with the general guidelines in academic literature.

Store order-size & Transport costs

Figure 9.3 gives the first output of the PLE Model for two pilot suppliers of fast-movers. Here, a supplier of fast-movers is defined as a supplier of more than 500.000 cartons per year (see table 9.1).

The left graph gives the output for a supplier located near the DC. The right graph gives the output for a similar supplier located twice as far from the DC. Both graphs show the effect of the store's order behavior: a decrease of the store order-size makes indirect delivery (XD / CW) more beneficial than direct delivery (DSD). This is in line with the findings of the distribution flowtype research for Metro Cash & Carry Nederland from Van Den Heijkant [2006]. The main reason for this is the fact that indirect delivery offers the possibility to consolidate shipments to reduce transport costs. This effect increases when the store order-size decreases [Van Der Vlist, 2007].

The effect of consolidating orders on the optimal distribution flowtype decreases when the distance from the supplier to the DC increases: the right graph of figure 9.3 shows that for a supplier located far from the DC, DSD is almost always the optimal distribution flowtype. Here, the consolidation effects are countered by the extra distance to cover from the supplier to the DC.

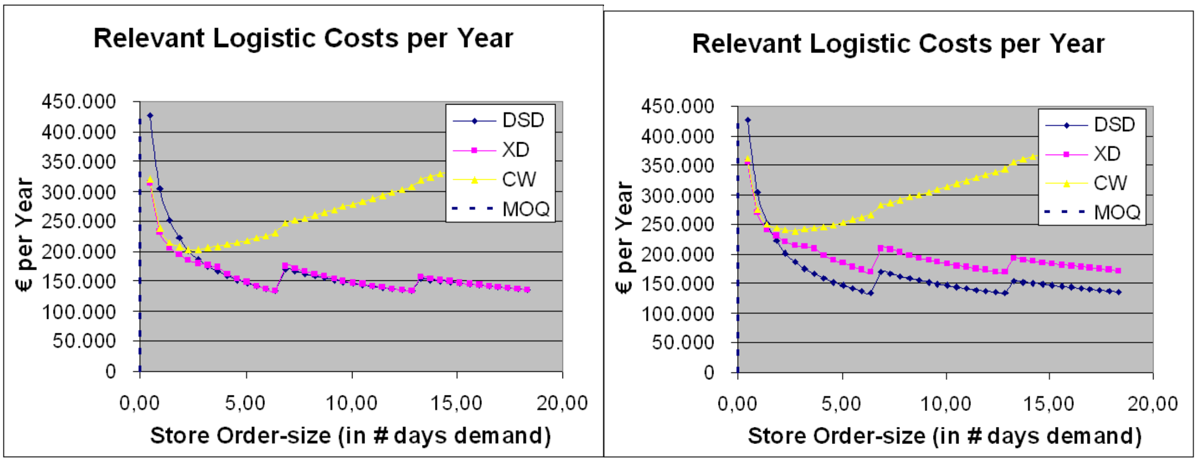


Figure 9.3 PLE Model output for a supplier of fast-movers near the DC (left) and far from the DC (right)

Store order-size & Excess Shelf Coverage

Figure 9.4 gives the first output of the PLE Model for two pilot suppliers of slow-movers. Here, a supplier of slow-movers is defined as a supplier of less than 5.000 cartons per year (see table 9.1).

The left graph gives the output for a supplier with limited associated excess shelf coverage. The right graph gives the output for a similar supplier with twice as much excess shelf coverage. Both graphs show that CW is not beneficial for a supplier of slow-movers. The reason for this is that CW brings costly DC handling and the DC stock for slow-movers incurs high interest and space utilization costs.

Figure 9.4 also shows that the optimal store order-size increases when the excess shelf coverage increases: the right graph of figure 9.4 shows a bigger optimal store order-size than the left graph of figure 9.4. This is in line with the findings of the retail supply chain dissertation of Van Der Vlist [2007]. He states that many slow-moving non-food products have a big excess shelf coverage and for the suppliers of these products, the store order-size can be high enough to reach a high pallet utilization without the need for consolidation.

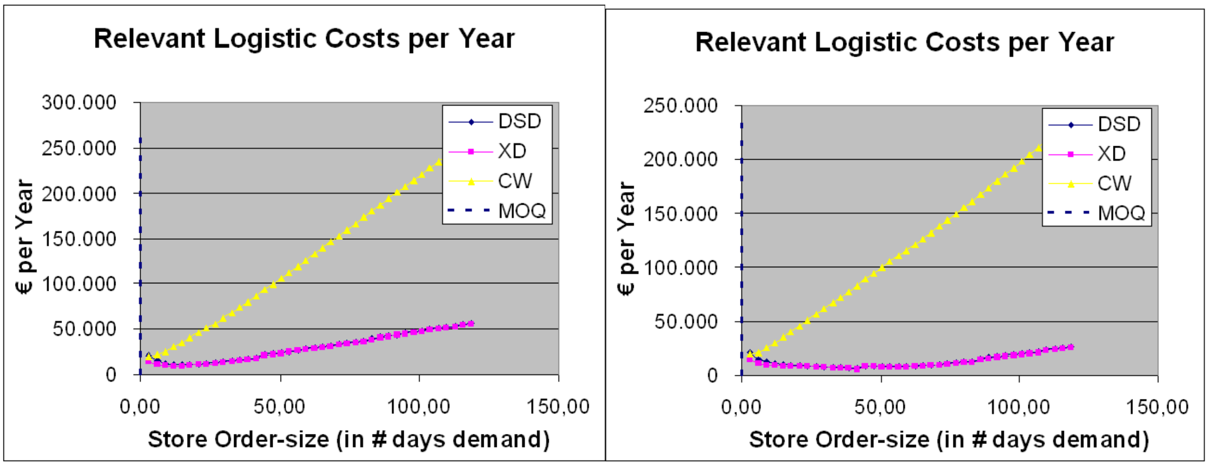


Figure 9.4 PLE Model output for a supplier of slow-movers with limited ESC (left) and big ESC (right)

The excess shelf coverage can be used to shift store replenishment moments which, with indirect delivery, can lead to a better balance in order picking workload at the DC and transport consolidation advantages. Whenever reordering a product, as much cartons as fit on the store's shelves must be ordered [Van Der Vlist, 2007]. This maximizes the transport and handling efficiency while avoiding extra store handling and backroom stock.

Store order-size & DC costs

Figure 9.3 shows that with a small store-order size for a supplier near the DC, indirect delivery decreases transport costs. However, indirect delivery incurs extra DC handling and transport costs. For indirect delivery to be beneficial, these additional DC handling and DC stock costs should be earned back by the benefits of transport consolidation [Van Den Heijkant, 2006]. Chapter 5 has shown that DC handling costs with XD are lower than with CW. Furthermore, XD does not incur any DC stock costs while CW does. Therefore, XD is most beneficial in this situation given that the supplier is reliable. Many of the non-food suppliers of MCCD are not reliable and therefore not suitable for XD. For these suppliers the extra DC handling and DC stock costs for CW must be weighed against the transport consolidation benefits. For suppliers of fast-movers, figure 9.3 shows that with small order-sizes CW performs nearly as goods as XD. For suppliers of slow-movers, Figure 9.4 shows that the extra DC costs of CW make this flowtype very expensive. This is in line with the results of the distribution flowtype research of Van Den Heijkant [2006].

General Insights

From the results of the sixteen pilot suppliers the following general insights are derived:

- The main logistical costs for the sixteen pilot suppliers of MCCD are the transport and handling costs. These costs are primary driven by the store order-size.
- The process of breaking down larger orders and reassemble them into other orders and the fact that it is an order-driven process that is constrained in time, is the dominant cost element in the MCCD's distribution network.
- Moving goods from the supplier to the store should be done in as few shipments as possible with full pallets.
- Ideally all inventory fitting on the shelves is being shifted to the stores, holding back at the DC only so much as cannot be stored on the shelves. From a supply chain perspective positioning more stock in the stores does not mean higher inventory costs, because once a batch of products has been produced, the stock exits and its associated costs are born [Van Der Vlist, 2007]. For MCCD this effect is stimulated by the fact that the shelf cycle stock does not incur extra stock costs.
- Indirect delivery becomes beneficial when the additional DC handling and DC stock costs are earned back by the benefits of transport consolidation.
- Commercial and logistic interests differ and at the same time have a huge influence on each other's main concerns. Category Management desires a high delivery frequency and small store order-size to have a constantly filled shelf. However, in most cases the logistical costs of MCCD are minimized when the delivery frequency is low and the store order-size is large.

9.4 Implementation Issues & Limitations

This section presents the implementation of the PLE Model. The PLE Model described in this report should be embedded in the supply chain department of MCCD. This department can use the PLE Model to determine the optimal distribution flowtype for a national supplier of non-food products. A description of the model, its input, output, and assumptions is given in chapter 8 of this report. Furthermore, a complete list of input parameter values for all Non-food suppliers of MCCD is developed (see Appendix L) and the manual of the PLE Model is given in appendix O.

The PLE Model makes use of the calculated costs per driver of each relevant logistical cost. In order to have a valid output of the model the costs per driver should be updated regularly. This can be done by making use of the yearly shipment data and financial account of MGL and the yearly MartinelliList developed by the supply chain department of MCCD.

Finally, the PLE Model has the following limitations:

- *Seasonality*: the model follows a physical cost minimization strategy suitable for products with a stable demand pattern. Products with high seasonality require a different distribution strategy for which the PLE Model is not suitable.
- *Promotions*: the model does not consider the promotions of MCCD. Promotions cause shifts in demand patterns and therefore changes in store order-sizes over the year. The PLE Model is not suitable for promotional products.
- *Assortment width*: the model only partly takes into account the assortment width of a particular supplier (see the LoM in Appendix E). The model gives a rough cost estimation based on an 'average' product per supplier. However, when a supplier supplies several products with different demand patterns and volumes, the total relevant costs may behave differently. This is an important limitation of the PLE Model and should be taken into account every time the model is used.

PART IV CONCLUSION & EVALUATION

Company Description

Problem Definition

ANALYSIS & DIAGNOSIS

Distribution Flowtypes Description

Distribution Costs & KPIs Description

Handling Costs Analysis

Transport Costs Analysis

Stock Costs Analysis

SOLUTION DESIGN

PLE Model Development

Model Adoption & Implementation

CONCLUSION & EVALUATION

Conclusion & Recommendations

Evaluation

10 Conclusion & Recommendations

This chapter presents the most important results of this research and gives recommendations for the supply chain management department of Metro Cash & Carry Deutschland (MCCD). Section 10.1 provides general guidelines and section 10.2 presents recommendations for MCCD. As a latter, section 10.3 presents a few points of interest.

10.1 General Guidelines

This report provides four main insights considering the three distribution flowtypes direct store delivery, cross-docking, and central warehousing.
The first insight is that the store order-size has a big influence on the relevant logistical costs in the retail distribution network:

- The smaller the store order-sizes the more beneficial transport consolidation becomes.
- The bigger the store order-size the more economies of scale in handling.
- The balance between the store order-size and the excess shelf coverage drives the costs of secondary replenishment and backroom stock.

The second insight is that direct store delivery becomes more beneficial when:

- The store order-size increases
- The total sales volume increases
- The distance from the supplier to the DC increases

The third insight is that indirect delivery is only beneficial when the extra DC handling and DC stock costs are earned back by the benefits of transport consolidation:

- With cross-docking the DC handling and DC stock costs are lower than with central warehousing. However, an extra condition with cross-docking is that the supplier must be reliable enough to not cause any coordination problems at the DC.
- With central warehousing, the DC handling and stock costs are higher than with cross-docking. Here, the extra DC handling and stock costs are likely to be higher than the benefits of transport consolidation.

The fourth insight is that central warehousing can increase the excess shelf coverage at the store. For suppliers with a large lead-time switching to central warehousing can significantly reduce the store replenishment lead-time. A reduction of replenishment lead-time leads to an increase in excess shelf coverage. An increase in excess shelf coverage leads to a decrease in secondary replenishment and a decrease in backroom stock.

10.2 Recommendations for Metro Cash & Carry Germany

The research assignment is:

> Determine the optimal distribution flowtype for all functional non-food product categories of Metro C&C Germany with regard to its main cost drivers and customer service measures.

The PLE Model can be used to determine the optimal distribution flowtype for a particular non-food supplier of MCCD. The model calculates the relevant logistical costs per distribution flowtype for a range of store order-sizes.

The use of the PLE Model for sixteen pilot suppliers of MCCD has led to the following recommendations:

- The non-food assortment of MCCD contains many products with considerably large excess shelf coverage. For these products the store order-size can be high enough to make direct store delivery beneficial.
- There are two reasons why the store order-size may be small: for products with a small excess shelf coverage a small store order-size avoids extra store backroom stock and secondary replenishment. Second, for several products category management obligates a high delivery frequency and thus small store order-size to assure high product visibility.
- For small store order-sizes indirect delivery brings the opportunity to consolidate orders and reduce transport costs. Unfortunately, with indirect delivery extra DC handling and DC stock costs are born. Therefore, indirect delivery is only beneficial when the extra DC costs are earned back by the benefits of transport consolidation.
- Cross-docking is a cheaper way of indirect delivery than central warehousing. However, cross-docking is only suitable when the supplier is reliable. Many suppliers of MCCD have a low fill rate and high lateness indicating that they are unreliable. For these suppliers, central warehousing is the only way to consolidate orders and reduce transport costs.
- With central warehousing, the benefit of reduced transport costs comes at a price of DC stock costs. These DC stock costs are extra high when the product's value and/or volume are high.
- When a supplier's contribution for a particular distribution flowtype is higher than the associated extra costs, shifting to this distribution flowtype is cost-beneficial.

10.3 Points of Interest

In addition several points of interest are presented which are discovered during the research but where out of the project scope. These points are listed below:

- A carton's volume and the store order-size determine how many pallets are required to ship the ordered cartons. The number of required pallets drives both transport costs and handling costs. At MCCD, the volume of all directly delivered Non-Food cartons is not available in the system. The accuracy of the relevant logistic costs estimation would be greatly improved when the Non-Food carton dimensions are known.
- Packaging is a very costly goods receiving activity at a store. However, few suppliers only distribute their goods through packaging. Therefore, it would be interesting to analyse the packaging process.
- For many Non-Food products the excess shelf may be reduced without consequences for the relevant logistic costs. This excess shelf space could be reduced by narrowing the shelf space. The result is more space availability at a store which can be used for marketing.
- The distance from a supplier to the DC greatly influences the transport costs. The current location of the DC (see appendix B) might not be the most beneficial location to minimize the overall transport costs. Therefore, it would be interesting to determine the optimal location of the DC.
- A supplier must be reliable for cross-docking to be possible. A reliable supplier for which cross-docking is the optimal distribution flowtype is a good candidate to adopt RFID tagging. With RFID tagging, electronically recognizable chips on the cartons assure a quick and flawless flow of the goods. This will reduce coordination problems at the DC and in the store.

11 Evaluation

This chapter gives an evaluation of the project. Section 11.1 presents the most important strengths and weaknesses of the research. Section 11.2 describes the main contribution to scientific research and section 11.3 gives a personal evaluation.

11.1 Strengths and Weaknesses

The two most important strengths of this master thesis are given below.
The developed model is easy to use and quickly shows several relevant insights concerning distribution flowtype comparison. This makes the model very pragmatic and applicable for the employees at the supply chain management department of MCCD.
This research not only shows how the relevant logistic costs differ between distribution flowtypes, it also shows the main effects of changing the store order-size. Because each distribution flowtype has its own optimal store order-size, this is a relevant addition to the model.
The two most important weaknesses of this master thesis are given below.
The general guidelines given in the conclusion are derived from applying the PLE Model for the 16 pilot suppliers. In order to derive valid statistically significant results, it would have been better to have a larger sample size of suppliers to be representative for the whole non-food assortment of MCCD.
The developed model is only suitable for functional products and not for innovative products. Although appendix C shows some classification factors it still has to be determined which suppliers of MCCD supply functional products and which suppliers of MCCD supply innovative products.

11.2 Contribution to Scientific Research

First, this master thesis has developed a model for MCCD’s store handling costs by extending the work of Van Stipdonk [2007] to fit MCCD’s situation This master thesis has also developed a model for MCCD’s DC handling costs based on the work of Broekmeulen [2007] and Van Moorsel [2009].
Second, three models from the scientific literature are applied or extended to model the relevant logistic costs in a retail chain. These are the excess-shelf-coverage model of Van Der Vlist [2007], the transport efficiency model of Van Der Vlist and Broekmeulen [2006] extended with the distance-estimation model suggested by Broekmeulen [2007], and the system safety stock equation of Van Donselaar [1990]. The complexity and interrelatedness of these models for the relevant logistic costs in a retail chain are discussed in this thesis.
Third, this master thesis has developed its own model for the store backroom cycle stock. For a particular store order-size, this model compares the number of cartons which do not fit on the shelves with the expected demand between two order arrival moments. From this comparison the mean number of cartons in a store’s backroom can be derived.
Fourth, this master thesis shows how the handling, transport, and stock models interrelate by combining them into one flowtype selection model. Here, the flowtype selection model shows how an increase in store order-size is beneficial for the handling and transport costs in the retail chain but often not beneficial for the stock costs in the retail chain.

Both Van Den Heijkant [2006] and Maris [2010] have done a comparable master thesis about distribution flowtype selection. The main differences between this master thesis and those of Van Den Heijkant and Maris are the following:

- Van Den Heijkant's model only compares DSD and CW and Maris' model only compares CW and XD. This master thesis compares DSD, XD, and CW. A clear advantage is that this master thesis explicitly shows the difference in store handling between direct and indirect delivery and the difference in DC handling costs between XD and CW.
- This master thesis and the master thesis of Van Den Heijkant both only consider physical logistic factors while Maris' master thesis also considers intangible factors like product availability and the costs of wrong allocation.
- Both the studies of Van Den Heijkant and Maris calculate the logistic costs for one derived order-size. This master thesis shows how the logistic costs per flowtype behave for a range of different order-sizes. This illustrates the effect of changing the order-size on the cost per flowtype and the difference between the flowtypes.
- Van Den Heijkant and Maris both focus on a retailer with stores in The Netherlands. The mean transport distance in The Netherlands is relatively small and the difference in transport distance between Dutch suppliers is minor. Therefore, both studies do not take into account the effect of transport distance. This master thesis focuses on a retailer with stores in Germany. The mean transport distance in Germany is far bigger than that in The Netherlands. This significantly increases the transport costs. Furthermore, the transport distance can differ considerably between German suppliers. Therefore, this master thesis includes the effect of transport distance on the transport costs.
- Van Den Heijkant's master thesis simply excludes the safety stock analysis from the flowtype selection. This master thesis explicitly shows why the safety stock analysis may be excluded from the flowtype comparison: it explains that MCCD's total system safety stock does not differ between the flowtypes.

11.3 Personal Evaluation

During this master thesis I learned a lot about myself and about doing research for a company:
First of all I've learned many things about the importance of communication. It took a while for me to learn how to encourage people to help me get the right information. This was due to the fact that my German pronunciation was not fluently and MCCD is very hierarchical and bureaucratic. During my project, the key to success was to know the right people who give you the right information in due time.
Second, I've found out that it is very hard to adopt the theoretical findings to a company's practical situation. The world of supply chain management is so complex that several simplification steps where required for the PLE Model.
Finally, I discovered that I can be a hard worker but must be careful to focus on the things which really matter. Because of the complexity of the topic it was really important but also hard for me to first identify the most important issues before moving on to detailed analyses.

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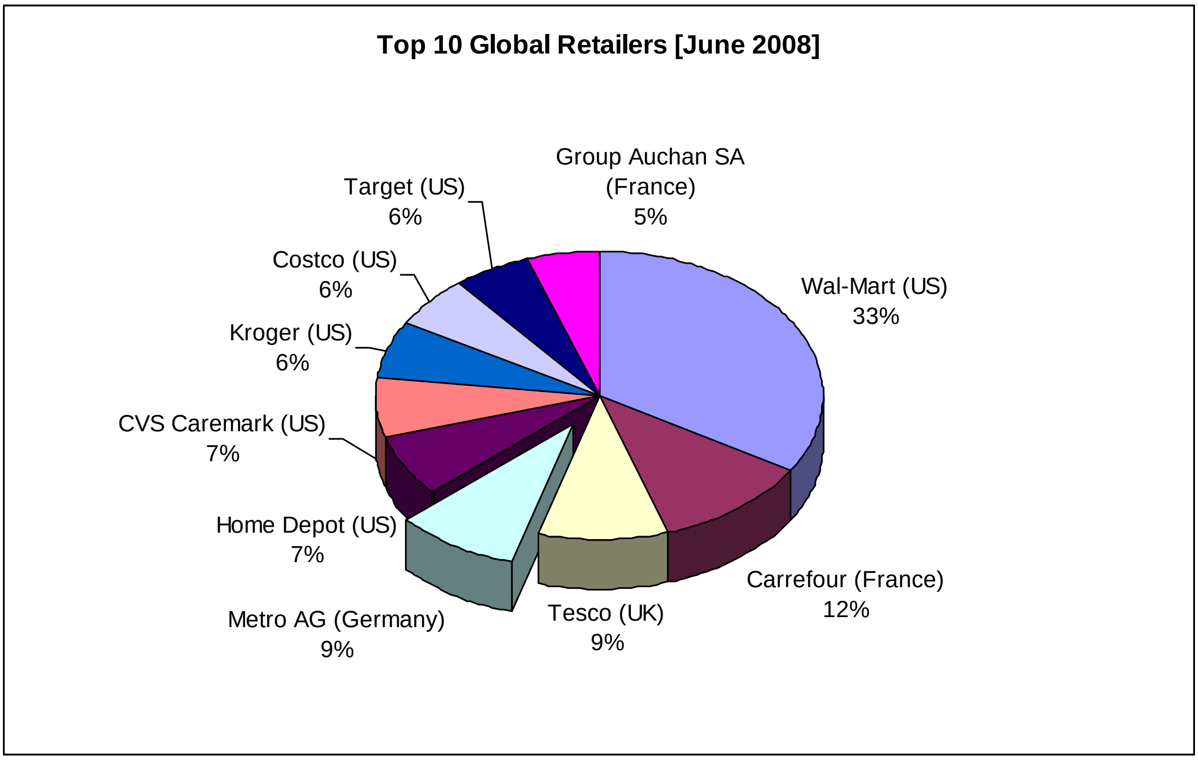
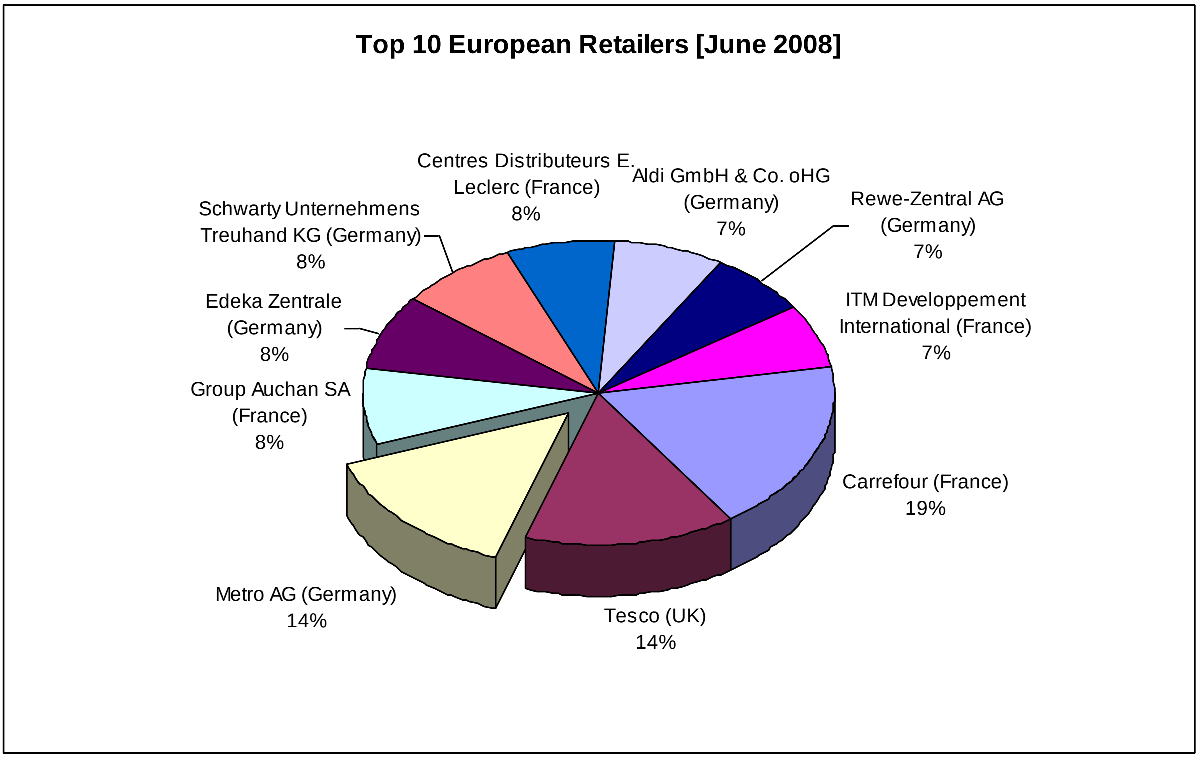
Appendices

Appendix A Top 10 Global & European Retailers





Source: *www.licensemag.com/licensemag/Retail/Top-25-Global-Retailers, Feb 2010*

Appendix B Locations of stores and platforms of Metro Cash & Carry Germany

Stores

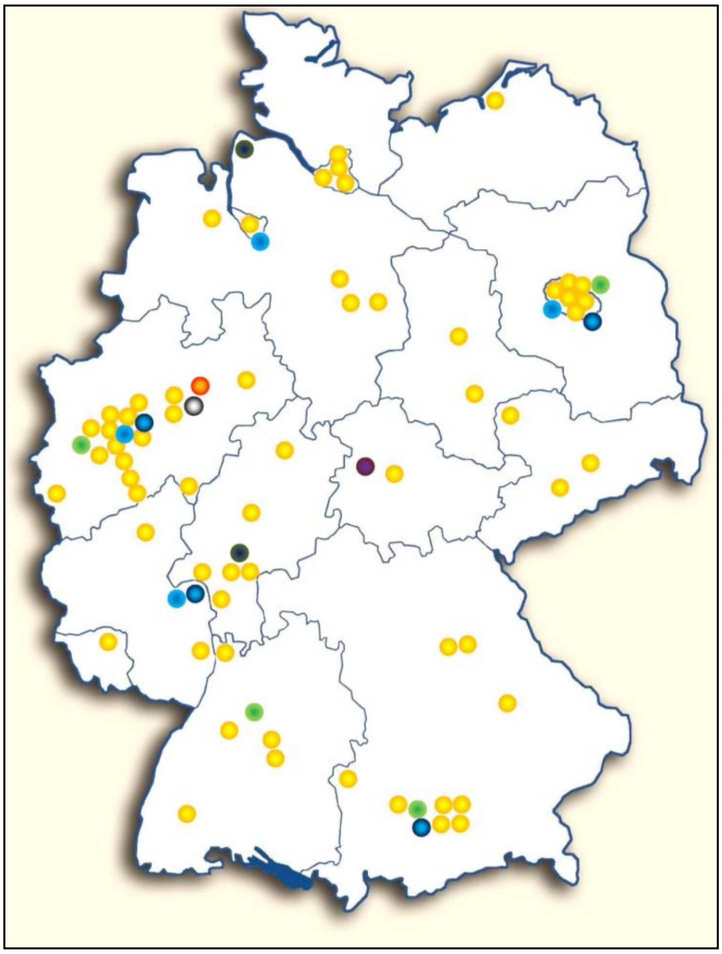
- locations: 61

Platforms

- fresh fish: 2
- fresh: 4

Distribution Centers

- frozen: 1
- Non- & dry-food import: 1
- clothes: 1
- fruit & vegetables: 4
- fresh: 4



Appendix C Categorization of Functional and Innovative Products

The results of the report are only valid for suppliers of functional products. Whether the products of a particular supplier are functional or innovative can be determined with table C.1 below. This table shows the main classification factors for the classification of functional and innovative products given in the article of Fisher [1997].

Table C.1 Classification of functional and innovative products [Fisher, 1997]

Functional Versus Innovative Products: Differences in Demand

	Functional (Predictable Demand)	**Innovative** (Unpredictable Demand)
Aspects of Demand		
Product life cycle	more than 2 years	3 months to 1 year
Contribution margin*	5% to 20%	20% to 60%
Product variety	low (10 to 20 variants per category)	high (often millions of variants per category)
Average margin of error in the forecast at the time production is committed	10%	40% to 100%
Average stockout rate	1% to 2%	10% to 40%
Average forced end-of-season markdown as percentage of full price	0%	10% to 25%
Lead time required for made-to-order products	6 months to 1 year	1 day to 2 weeks

* The contribution margin equals price minus variable cost divided by price and is expressed as a percentage.

Fisher [1997] states that functional products have low demand uncertainty and low seasonality while innovative products have high demand uncertainty and high seasonality. Therefore, a look at the demand behaviour of all product groups already gives a rough indication of the existence of innovative products in a particular product group. Figure C.1 and figure C.2 give the weekly demand for all non-food product groups of MCCD over 2007, 2008, and 2009.

Figure C.1 shows that the textile department contains many product groups with high demand variation. Furthermore, figure C.1 shows that especially the ‘770: season’ and ‘772: garden/camping’ product group of the leisure department have high demand seasonality. Thus, before applying the PLE Model to a supplier of textile, seasonal, or garden/camping products, it is important to test whether these products are innovative. If they are, the PLE Model must not be used!

Figure C.1 Weekly Demand per Textile and Leisure Product Category of MCCD

Figure C.2 shows that only the '782: bureau- and gastronomy-bedarf' product group of the multimedia department has considerable demand variation. Furthermore, figure C.2 shows that household department does not contain high demand variability and/or seasonality, except for the '794: household' product group. Thus, before applying the PLE Model to a supplier of bureau- and gastronomy-multimedia or household products, it is important to test whether these products are innovative. If they are, the PLE Model must not be used!

Figure C.2 Weekly Demand per MultiMedia and Household Product Category of MCCD

Appendix D Store Handling Activities, Costs & Drivers

Table D.1 gives the description of each store handling activity defined with the help of the retail store staff in three MCCD stores. With the help of the retail store staff and the NonFood supply chain manager, the allocation of FTE's over the store handling activities in table D.1 is determined. Based on this FTE allocation the total instore logistics costs for MCCD for the year 2009 of €[redacted] are allocated to the handling activities. This results in the first four columns of table D.2.

Table D.1 Description of store handling activities

Handling Activity	Description	Driver
NonFood Receiving	Employee opens the door for the distributor and unloads the pallets from the truck	Pallets
Rough Order Check	Employee counts the boxes on the pallet and checks them with the order list	Pallets
Detailed Order Check	Employee opens boxes, scans an article and checks the number of articles with the order list	Cartons
Pallet Allocation	Employee transports the (mixed) pallets from the receiving area to their designated department(s)	(Mixed) Pallets
Packages Handling	Employee opens door, unloads packages, executes a detailed check, and allocates the packages to their designated departments	Packages
WE-Nüro NonFood	Employee (manually or automatically) registers the received goods in the system	GoodsReceiving Lines
Shelf Replenishment	Employee transports the required articles from the receiving area (primary) or backroom (secondary) to the shelf and puts them on the shelf	Cartons

Section 5.3 of the report gives the efficiency gains in handling activities of indirect versus direct delivery estimated from the store visits. The efficiency gain for a handling activity is defined as the percentage cost reduction of going from direct to indirect delivery.

The fifth, sixth, and seventh column of table D.2 show the number of drivers over the year 2009 per handling activity, derived from MCCD's data warehouse. Taking into account the estimated efficiency gains, the costs per handling activity are calculated. The results are shown in the last three columns of table D.2. on the next page.

Table D.2 Calculation of Cost per Store Handling Activity Driver

Handling Activity	FTEs	Costs (x 1000)	Driver	# Drivers Total	# Drivers DSD	# Drivers CD / CW	Efficiency Gains	Cost per Driver Mean	Cost per Driver DSD	Cost per Driver CD / CW
NonFood receiving	[redacted]	€ 865	Pallets	[redacted]	[redacted]	[redacted]	0%	€ 1,500	€ 1,500	€ 1,500
Rough order check	[redacted]	€ 433	Pallets	[redacted]	[redacted]	[redacted]	35%	€ 0,750	€ 0,807	€ 0,525
Detailed order check	[redacted]	€ 216	Cartons	[redacted]	[redacted]	[redacted]	70%	€ 0,002	€ 0,003	€ 0,001
Pallet allocation	[redacted]	€ 346	Mixed Pallets	[redacted]	[redacted]	[redacted]	-51%	€ 1,106	€ 0,937	€ 1,415
Packages	[redacted]	€ 1.038	Packages	[redacted]	[redacted]	[redacted]	83%	€ 0,056	€ 0,056	€ 0,009
WE-Büro Non Food	[redacted]	€ 433	GR Lines	[redacted]	[redacted]	[redacted]	90%	€ 0,038	€ 0,041	€ 0,004
WE-Büro Food	[redacted]	*€ 649*	-							
others	[redacted]	*€ 649*	-							
Goods Receiving	[redacted]	**€ 4.629**								
Shelf Replenishment	[redacted]	**€ 12.672**	Cartons	[redacted]	[redacted]	[redacted]	0%	€ 0,119	€ 0,119	€ 0,119
Gapcheck, Cleaning, Pricing	[redacted]	€ 6.663	-							
Customer Contact	[redacted]	*€ 5.711*	-							
Others	[redacted]	*€ 952*	-							
Store Operations	[redacted]									
Total Instore Logistics	[redacted]	**€ 23.665**								

Appendix E Calculation of the Level of Mixture

A supplier's 'Level of Mixture' (LoM) drives the costs of pallet allocation in a store's goods receiving area. A supplier's LoM indicates the broadness of its product assortment and is calculated with equation E.1.

$$LoM_i = 1 - 1/n_i \qquad \text{(E.1)}$$

Where
LOM_i := Level of Mixture in percentage on a pallet of supplier i
n_i := The number of different departments supplied by supplier i

Table E.1 shows the number of departments s supplied and the accompanying LoM. From table E.1 it can be derived that over 700% of all NonFood suppliers only deliver goods for one department. These suppliers have a LoM of 0% for DSD compared to a LoM of 100% for XD or CW. This means that the pallet allocation costs will differ significantly among different flowtypes. On the other hand, for suppliers with a high LoM (e.g. 75%), the difference between DSD and XD or CW is less. For these suppliers the difference in pallet allocation costs will be minor.

Table E.1 LoM per Supplier

Supplier Nr.	# Departments Supplied	LoM
54614	2	50%
29184	2	50%
53557	1	0%
28350	1	0%
23654	2	50%
38210	1	0%
44707	4	75%
32601	1	0%
42316	1	0%
…	…	…
53669	1	0%
53670	1	0%

Appendix F Estimation of the Required Pallets

Several handling costs and the transport costs are driven by the number of required pallets. To estimate these handling and transport costs the total required number of pallets per order must be known. The total required number of pallets per order depends on the available volume per pallet and required volume per order. The available volume per pallet is 1,78m^3: from MCCD's the service agreement with its 3rd party logistics provider MGL it can be seen that europallets (0,8m*1,2m) are used and can be stacked up to a height of 1,85m. Note that there is no double-stacking of pallets for the NonFood assortment of MCCD.

The required volume per order depends on the volume per carton and the order-size. For the NonFood assortment of MCCD there are no carton volumes available in the system. Only for the (limited) assortment delivered from the DC the volume is known. Based on these volume figures, six volume levels are defined in which the cartons of each supplier must be categorized. The defined volume levels are given in table F.2 below. Note that the pallet capacity (right column) gives the maximum number of VPEs which can be placed on one single pallet. This pallet capacity is rounded down because single articles cannot be split to fill up all the available volume on a pallet.

Table F.2 Volume Levels Defined

Volume Level	VPE Volume	Pallet Capacity
XS	< 0,05 m^3	32 articles
S	< 0,10 m^3	16 articles
M	< 0,20 m^3	8 articles
L	< 0,40 m^3	4 articles
XL	< 1,00 m^3	2 articles
XXL	> 1,00 m^3	1 articles

When both the mean order-size per store and the volume level of the cartons are known, the number of required pallets per order can be calculated. Given the total number of cartons sold over a year and the mean store order-size, the number of orders over a year is known. Equation F.1 shows how the required number of pallets to a store is calculated.

$$\underbrace{RP_i^{store} = ROUNDUP\left[\frac{Q_i^{store}}{PC_i}\right]}_{\text{\# pallets per order}} * \underbrace{N * \frac{D_i^{total}}{Q_i^{store}}}_{\text{\# orders per year}} \quad \text{(F.1)}$$

Where

RP_i := Required number of pallets over the year for supplier *i*

Q_i^{store} := Mean order-size in number of cartons of supplier *i* per store

PC_i := Pallet capacity in number of cartons of supplier *i* per pallet

N := Number of stores supplied (assumed to be 61)

D_i^{total} := Total demand over the year in number of cartons of supplier *i*

ROUNDUP(X):= X rounded up to an integer

Equation F.1 calculates the required pallets for transport from a supplier *i* directly to the stores. For the distribution flowtypes XD and CW the required pallets to the DC also need to be calculated. For this calculation, equation F.2 is used.

$$RP_i^{DC} = \underbrace{ROUNDUP\left[\frac{Q_i^{store} * N}{PC_i}\right]}_{\text{\# pallets per order}} * \underbrace{\frac{D_i^{total}}{Q_i^{store}}}_{\text{\# orders per year}} \quad \text{(F.2)}$$

Where all variables are defined as in equation E.1.

Equation F.2 shows that the consolidation of the store orders assures a higher utilization of the pallets. A higher pallet utilization leads to economies of scale for transport and several handling activities. The utilization per pallet to a store is estimated with equation F.3 and the utilization per pallet to the DC is estimated with equation F.4 below.

$$u_{i-store} = \frac{Q_i^{store} / PC_i}{RP_i} \quad \text{(F.3)}$$

$$u_{i-DC} = \frac{Q_i^{store} * N / PC_i}{RP_i} \quad \text{(F.4)}$$

Where

u_{i-j}	:= Mean utilization of a pallet shipped from supplier *i* to destination *j*
Q_i^{store}	:= Mean order size in number of cartons of supplier *i* per store
PC_i	:= Pallet capacity in number of cartons of supplier *i* per pallet
N	:= Number of stores supplied (assumed to be 61)
RP_i	:= Required number of pallets over the year for supplier *i*

Appendix G Shelf Coverage per Product Group

An important input for the estimation of secondary replenishment costs is the Excess Shelf Coverage (ESC). For the calculation of the ESC the Shelf Coverage (ShC) assigned to the cartons of a particular supplier is required. Table G.1 shows how the ShC associated with the cartons of a supplier is derived: the supplier's turnover per product group times the ShC for that product group. The ShC in table G.1 is defined as the number of days with forecasted demand covered by the number of cartons fitting on the shelf. The ShC used in the report is defined as the number of cartons fitting on the shelf. This can be derived from the ShC in table G.1 by multiplying it with the mean daily sales of the supplier in question.

Table G.1 Shelf Coverage per Supplier Derived of Product Groups

Department	**760**	**761**	**762**	**763**	**764**	**765**	**766**	**767**	**...**	**796**	
Shelf Coverage (days)	163	128	112	99	1	111	88	1	...	107	Supplier's Shelf Coverage (days)
Lief	WE NNEK	WE NNEK	WE NNEK	WE NNEK	WE NNEK	WE NNEK	WE NNEK	WE NNEK	...	WE NNEK	
54614	0	[redacted]	0	0	0	0	0	[redacted]	...	0	[redacted]
29184	0	0	0	0	0	0	0	0	...	0	[redacted]
53557	0	0	0	0	0	0	0	0	...	0	[redacted]
28350	0	0	0	0	0	0	0	0	...	0	[redacted]
23654	0	0	0	0	0	0	0	0	...	0	[redacted]
38210	0	0	0	0	0	0	0	0	...	0	[redacted]
44707	0	0	0	0	0	0	0	0	...	0	[redacted]
32601	0	0	0	0	0	0	0	0	...	0	[redacted]
42316	0	0	0	0	0	0	0	0	...	[redacted]	[redacted]
50406	0	0	0	0	0	[redacted]	0	0	...	0	[redacted]
53669	0	0	0	0	0	0	0	0	...	0	[redacted]
53670	0	0	0	0	0	0	0	0	...	[redacted]	[redacted]

Note that table G.1 gives a very rough estimation of the ShC associated with the cartons of a supplier. However, the Level of Mixture (LoM) of more than 70% of all NonFood suppliers is 0%. This means that more than 70% of these suppliers only supplies one product group for which one ShC is defined. For these suppliers the approximation of the ShC will be closer to real-life. Furthermore, the ShC will eventually have only a very small effect on the logistical costs of a few suppliers (see Appendix N). Therefore, it is allowed to use this rough approximation of the ShC per supplier.

A first look at table G.1 already shows that many NonFood products have a huge ShC of over 80days forecasted demand.

Appendix H DC Handling Activities, Costs & Drivers

Table H.1 gives the description and required time of each DC handling activity as derived from Broekmeulen [2007]. The studies of Broekmeulen [2007] and Van Moorsel [2009] give a typical breakdown of DC handling cost which is used to divide the total DC handling costs over the handling activities. It is assumed that the goods exit process (including order picking) is exactly the opposite from the goods receiving (including stocking) process.

Table H.1 Description of DC handling activities

Handling Activity	Description	Driver
Basic Time (15%)	Truck driver receives docking- & order information at the administration desk	Trucks
Truck Stopping Time (20%)	Truck driver searches for the unloading location and connects to the dock	Trucks
Unloading Time (15%)	Employee opens the door for the distributor and unloads the pallets from the truck	Pallets
Stocking (50%)	Employee transports the pallets from the receiving area to the warehouse storage place	Pallets
Order Picking (50%	Employee picks the articles destined for a particular store order	Articles
Loading Time (15%)	Employee opens the door for the distributor and loads the pallets on the truck	Pallets
Truck Stopping Time (20%)	Truck driver searches for the unloading location and connects to the dock	Trucks
Basic Time (15%)	Truck driver receives docking- & order information at the administration desk	Trucks

The yearly financial account of MGL together with Table H.1 results in the first four columns of Table H.2 and Table H.3. Table H.2 calculates the handling activity costs per driver for Central Warehousing (CW) while Table H.3 calculates the handling activity costs per driver for Cross-Docking (XD). The costs differ between CW and XD in the following way:

- *Goods Receiving*

The basic time and stopping time per truck arrival is more expensive for CW. This can be explained by the fact that in the current situation CW is only applied to import-suppliers, which brings difficulties concerning language and process recognition. Furthermore, the unloading time for CW is more costly since unloaded import-pallets often must be reorganized to the warehouse departments.

- *Stocking (see Figure 5.2 – I)*

With XD, the received pallets are directly transported to the docking area. With CW, the received pallets are transported to the warehouse, where they are allocated to their designated storage area. This extra process step is defined as 'stocking' and costs about €[redacted] per pallet stocked.

- *Order Picking (see Figure 5.2 – II)*

With XD, the pallets with the ordered articles are located in the loading area from which the orders can directly be picked and allocated to store-dedicated pallets. This order picking process costs about €0,14 per carton. With CW, the ordered articles need to be transported from the warehouse to the loading area. Therefore, the order picking process for CW requires more transportation time. The order picking process for CW costs about €0,20 per carton.

- *Goods Exit*

With XD, the loading time, truck stopping, and basic time are cheaper than with CW. This can be explained by the fact that the process is more standardized and often executed by the personnel.

Table H.2 Calculation of Cost per DC Handling Activity Driver for CW

Handling Activity	Cost Division	Costs (x 1000)	Driver	# Drivers	Cost per Driver
Goods Receiving		**588 €**			
Basic Time	15%	88 €	Trucks	[redacted]	9,197 €
Truck Stopping Time	20%	118 €	Trucks	[redacted]	12,263 €
Unloading Time	15%	88 €	Pallets	[redacted]	0,760 €
Stocking	50%	294 €	Pallets	[redacted]	2,532 €
Order Picking	**50%**	**774 €**	**Cartons**	[redacted]	**0,202 €**
Loading Time	15%	98 €	Pallets	[redacted]	0,840 €
Truck Stopping Time	20%	130 €	Trucks	[redacted]	13,557 €
Basic Time	15%	98 €	Trucks	[redacted]	10,168 €
Goods Exit		**325 €**			

Table H.3 Calculation of Cost per DC Handling Activity Driver for XD

Handling Activity	Cost Division	Costs (x 1000)	Driver	# Drivers	Cost per Driver
Goods Receiving		**493 €**			
Basic Time	30%	148 €	Trucks	[redacted]	8,193 €
Truck Stopping Time	40%	197 €	Trucks	[redacted]	11,122 €
Unloading Time	30%	148 €	Pallets	[redacted]	0,469 €
Stocking	0%	0 €	Pallets	[redacted]	0,000 €
Order Picking	**40%**	**2.160 €**	**Cartons**	[redacted]	**0,137 €**
Loading Time	18%	145 €	Pallets	[redacted]	0,460 €
Truck Stopping Time	24%	193 €	Trucks	[redacted]	10,923 €
Basic Time	18%	145 €	Trucks	[redacted]	8,193 €
Goods Exit		**805 €**			

The difference in goods receiving between CW and XD is explained by the fact that CW is currently only import. Because this research focuses on national suppliers of MCCD and almost all XD suppliers are national, the costs per driver for XD are used to estimate the goods receiving costs at CW for national suppliers. Here, it is assumed that there are no standardization gains (like there are in goods exit). The resulting costs per driver for CW and XD are given in table 5.2 of the report.

Appendix I Transport Costs per Full Pallet per Kilometer

Transport costs are relevant logistical costs for MCCD and need to be estimated per supplier. This appendix calculates the transport costs per fully filled pallet. Here, the costs of transporting a fully utilized pallet are assumed to be linear to the distance covered. Given that the average costs of full pallet transport through Germany is €24,57, the average distance covered needs to be estimated.

This thesis does not include overseas and import suppliers. Therefore, it is assumed that the supplier locations are uniformly distributed in the circular area represented in Figure I.1 (see Appendix B). This circular area has a radian of 500km and MCCD's DC (Unna – point A in Figure I.1) is located 185km away from this circle's centre (Fulda – point B in Figure I.1).

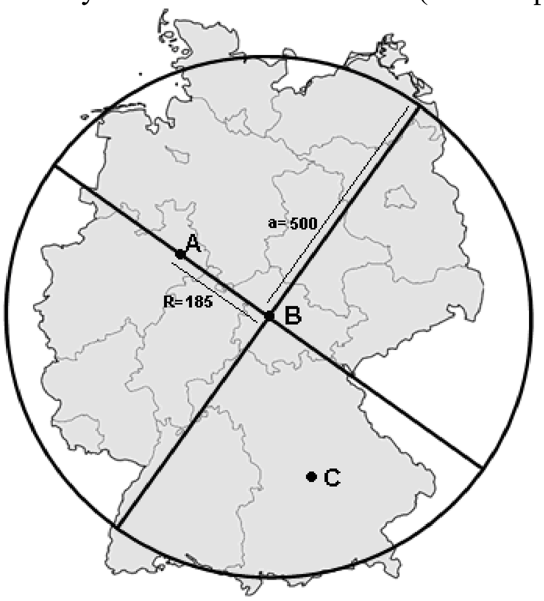


Figure I.1 Circular area for distance estimation

The distance between two random points (e.g. from a random supplier to a random store) in the circular area defined in Figure I.1 can be estimated with Manhattan's norm. The Manhattan norm can be used to calculate the distance between two random points in a circular area as follows [Broekmeulen, 2007]:

$$E(d) = \frac{512}{45\pi^2} a \qquad \text{(H.1)}$$

Where

E(d) := Expected distance from a supplier to a store in kilometer

a := Radius of the circle in kilometer

Given that *a*= 500km, the expected distance between two random points in Germany is 576km. This distance is used in section 6.2 of the report to estimate a full pallet's transport costs per kilometer.

Appendix J DC – Store Pallet Utilization

Table J.1 shows part of the shipment data of MGL which are used to calculate the average pallet utilization of a XD and CW pallet. Here, the column 'NonFood' represents all shipments coming from the DC through central warehousing. 'Cross Docking' represents all DryFood shipments coming from the DC through cross-docking.

Table J.1 MGL Shipment data over the year 2009

Table J.1 shows that over 2009, there are [redacted] pallets (Anzahl TE) used to ship [redacted] m^3 (cbm) of NonFood products from the DC to the stores through central warehousing. MGL's service agreement specifies that only EURO-pallets (0,8*1,2) are used and stacked up to a height of maximally 1,85m. This means that each pallet has a capacity of 1,78m^3. This results in a total volume available of [redacted] m^3. Dividing the total transported volume through the total available volume gives an average pallet utilization for CW of [redacted].

Table J.1 shows that over 2009, there are [redacted] pallets (Anzahl TE) used to ship [redacted] m^3 of DryFood products from the DC to the stores through cross-docking. Following the same calculation as above this results in an average pallet utilization for XD of [redacted].

Note that there are only four Non-Food suppliers delivering through cross-docking. For these suppliers no shipment data is available. Therefore the shipment data of the cross-docked DryFood is used as a representative approximation. However, an average NonFood product is expected to have a higher volume than an average DryFood product. This leads to the expectation that the average pallet utilization must be higher for the NonFood assortment. However, due to the high variation in NonFood product volumes, the average pallet utilization is assumed to be as low as for DryFood shipments.

The costs of shipping a full pallet from the DC to a store is calculated by dividing the total transport costs for part (B) of the transportation network through the total pallets shipped from DC to stores for the year 2009 (see table J.2). Table J.2 shows that for both CW and XD the resulting costs per full pallet shipped from DC to store are €9,66.

Table J.2 Costs of Transporting a Full Pallet from the DC to a store for 2009

CW			XD		
Total (*1000)	# Pallets	€ per Pallet	Total (*1000)	# Pallets	€ per Pallet
[redacted]	[redacted]	€ 9,66	[redacted]	[redacted]	€ 9,64

Appendix K Example Output of the PLE Model

This appendix shows an example of the three outputs from the PLE Model for a supplier of Haushold goods. Figure K.1 shows the graph with the behaviour of the total logistical costs per distribution flowtype when changing the store order-size. Furthermore, it shows the whether the supplier's MOQ restricts the store order-size in case of DSD. This graph can be used to determine the optimal store order-size of a distribution flowtype. Figure K.2 shows the share of handling, transport, and stock costs per distribution flowtype for the accompanying optimal order-size. The third and last output of the PLE model is shown in table K.1. The optimal distribution flowtype for this example supplier is XD with an optimal store order-size of 140 cartons. When MCCD would like to switch from DSD to XD, the supplier does not have to offer any contribution because it will get cheaper for MCCD anyway: the minimum supplier contribution margin for XD in this example is negative. However, when MCCD would like to switch from DSD to CW, the supplier contribution must be at least 4,7% for MCCD to not loose money.

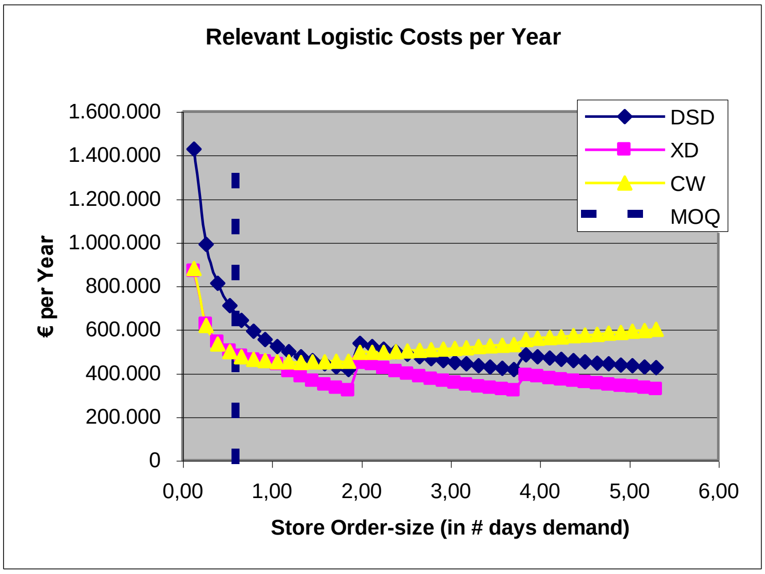


Figure K.1 Example of the 1st output of the PLE Model

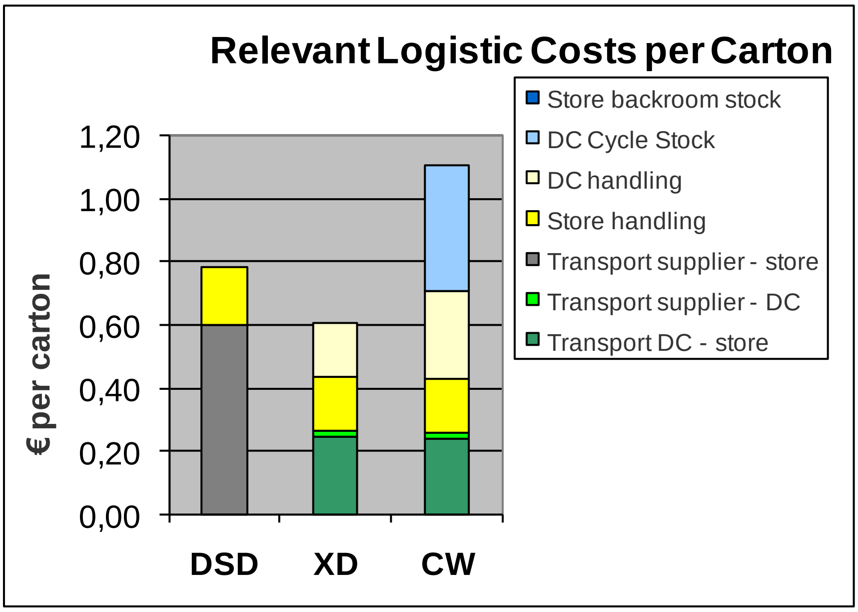


Figure K.2 Example of the 2nd output of the PLE Model

Table K.1 Example of the 3rd output of the PLE Model

TOTAL	TOTAL PER CARTON		TOTAL PER CARTON		TOTAL PER CARTON	
TRANSPORT	**DSD**	**DSD**	**XD**	**XD**	**CW**	**CW**
DC - store						
supplier - DC						
supplier - store						
TOTAL						
STORE HANDLING						
Goods Receiving						
Shelf Replenishment						
TOTAL						
DC HANDLING						
Goods Receiving						
Order Picking						
Goods Exit						
TOTAL						
DC STOCK						
Warehouse Space						
Interest						
TOTAL						
STORE STOCK						
Backroom space						
Interest						
TOTAL						
OVERALL COST						

STORE ORDER SIZE	140	cartons
Supplier Contribution (XD)	-4,01%	
Supplier Contribution (CW)	4,71%	
Supplier MOQ (in # days demand)	0,59	

Appendix L List of Required Input per Supplier

Table L.1 shows the required input parameter values for the year 2009 for (part of) the national Non-Food suppliers of MCCD. Note that the parameter values of a supplier can change over time (e.g. mean daily demand, number of packages, or lateness). Therefore, it is advised to regularly update the input parameter values from the list in order to have a valid output of the PLE Model.

Table K.1 Required Input Values per national NonFood supplier of MCCD

Appendix M Settings of the Pilot Suppliers

This appendix shows the selection criteria used to choose the pilot suppliers for a test of the PLE model. Table M.1 shows the definition of each selection criteria and it's upper and lower extreme class. Note that the volume levels '*l*' and '*s*' used in table M.1 are defined in table F.2 of appendix F.

A pilot supplier's score on one of the four criteria can either be above the upper extreme (*u*) or below the lower extreme (*l*). Given that there are two classes per criterion and four criteria, the total number of pilot suppliers is 16 (2^4). Table M.2 gives the 16 different suppliers (supplier A to P) with their scores on the defined selection criteria (1 to 4).

Table M.1 Definition and Extremes of the Selection Criteria for Pilot Suppliers

	Selection Criteria	Upper Extreme	Lower Extreme
1.	# cartons supplied over the year	> 500.000 cartons	< 5.000 cartons
2.	Mean volume level of a carton from the supplier	> *l*	< *s*
3.	Distance from supplier to DC	> 400 km	< 50 km
4.	Value per carton in €	> 100 €	< 5 €

Table M.2 Criteria Setting per Pilot Supplier

	1.	2.	3.	4.
A	u	u	u	u
B	l	u	u	u
C	l	l	u	u
D	l	l	l	u
E	l	l	l	l
F	u	l	l	l
G	u	u	l	l
H	u	u	u	l
I	u	l	l	u
J	u	l	u	l
K	l	u	l	u
L	l	u	u	l
M	u	l	u	u
N	u	u	l	u
O	l	u	l	l
P	l	l	u	l

Appendix N Results for the Pilot Suppliers

Table N.1 shows the results of applying the PLE Model for the pilot suppliers. Here, all pilot suppliers are assumed to be reliable (they have a high fill rate and low lateness). The first three rows of the table show for each pilot supplier the ranking of the distribution flowtypes. Here, the flowtype with ranking '1' is the optimal flowtype and the flowtype with ranking '3' is the worst flowtype. The other rows show for each pilot supplier the costs per carton when the optimal distribution flowtype and order-size are chosen.

Supplier	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P
DSD	1	1	2	2	2	3	3	1	3	1	2	1	1	3	1	2
XD	2	2	1	1	1	2	2	2	2	2	1	2	2	1	2	1
CW	3	3	3	3	3	1	1	3	1	3	3	3	3	2	3	3
Transport DC - store																
Transport supplier - DC																
Transport supplier - store																
Store handling																
DC handling																
DC stock																
Store stock																
Total																

Table N.1 Distribution Flowtype Ranking and Logistic Costs per Carton for Pilot Suppliers

Figure N.1, Figure N.2, and Figure N.3 illustrate the costs per carton resulting from running the PLE model for the 16 pilot suppliers. These figures are based on the output given in Table N.1. Figure N.1 shows the costs per carton of all suppliers for which DSD is the optimal distribution flowtype, figure M.2 does the same for XD pilot suppliers, and figure N.3 does the same for CW pilot suppliers. In all three figures, each character on the X-axis of a figure stands for a particular combination of the selection criteria given in appendix M. Note that these figures differs from figure 4.1 because they only show MCCD's logistical costs relevant to distribution flowtype selection. Figure 4.1 shows MCCD's total logistical cost division over the year 2009. Remember that a relevant logistical cost is defined as a cost that significantly differs between the distribution flowtypes.

All figures and conclusions in this report are modified and do not represent the real situation for Metro Cash & Carry Deutschland.

Figure N.1 Costs per carton for the Pilot Suppliers with optimal flowtype DSD

Figure N.1 shows that for 7 out of the 16 pilot suppliers DSD is the optimal distribution flowtype. Furthermore, Figure N.1 shows that for all DSD suppliers, the transport costs are the dominant logistical costs. Third, supplier J and M have significantly lower logistical costs per carton than the others. From appendix L it can be seen that both supply products with a low volume and all other DSD suppliers supply voluminous products.

Figure N.2 Costs per carton for the Pilot Suppliers with optimal flowtype XD

Figure N.2 shows that, when all pilot suppliers are assumed to be reliable, for 6 out of the 16 pilot suppliers XD is the optimal distribution flowtype. Here, supplier K and N have significantly higher logistical costs per carton than the others. A comparison of the characteristics of the XD pilot suppliers (see Appendix M) shows that K and N both supply voluminous products whereas others supply products with a low volume.

Figure N.3 Costs per carton for the Pilot Suppliers with optimal flowtype CW

As a latter, for only 3 out of the 16 pilot suppliers CW is the optimal distribution flowtype. For these suppliers, both transport and handling are responsible for a big share of the total relevant logistical costs. Compared to DSD and XD, the DC handling costs share has increased considerably and an extra cost factor is added: DC stock. Furthermore, the difference in total logistical costs for supplier G versus supplier F and I can be explained by the difference in product volume: supplier G supplies voluminous products while supplier F and I supply products with a low volume.

Appendix O Manual of the PLE Model

This is a brief manual for the PLE Model. The PLE Model is an Excel-tool which calculates the optimal distribution flowtype for a particular national supplier of NonFood products. For a good understanding of the PLE Model the user is advised to read the Master Thesis report of J.W.G. Bovend'eerdt:

J.W.G.Bovendeerdt, 2010, *The PLE Model: Selecting the Optimal Distribution Flowtype for Metro Cash & Carry Deutschland*, Master Thesis Report at Eindhoven University of Technology, The Netherlands

In order to determine the optimal distribution flowtype for a particular supplier, the row with its input parameter values should be copied from the list of input parameter values (described in appendix K). Next, this input should be pasted in the designated row of the first sheet of the PLE Model ("0 Overall Cost"). After pressing 'Control+Q' the model runs a cost calculation for a range of store order-sizes. The resulting output gives the optimal distribution flowtype with its optimal store order-size. Inserting this store order-size in the 'STORE ORDER SIZE'-cel gives the associated costs per carton. The graphical representation of these costs is given in a graph and the associated minimal supplier contribution is also given.