The ordering process of Dry Food groceries under promotion: A study of order commitment timing and ordering methods

by

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Abstract

This master thesis describes a research on the ordering process in a supplier-retailer environment for Dry Food grocery articles under promotion. The first part of the thesis investigates two variants of order commitment timing: early and late order commitment. Both have implications for the retailer on the performance in terms of costs, which consist of market mediation costs, related to supply and demand risk, and physical costs, related to labor consumption concerned with ordering. It is examined which factors affect the optimal choice between the two order commitment timing variants. A simulation model is built in which these factors are taken as input variables. The effects of the several factors on the performance are analyzed. The retailer under consideration is advised to early-order its Dry Food promotion articles as much as possible, mainly motivated by the risk of high costs under late order commitment. Additionally, the second part of the thesis presents a redesign for the early ordering method currently used by the retailer.
Executive summary

Problem environment

Metro Cash & Carry is an international market leader in the sector of self-service wholesale. In order to inform its customers on price promotions, Metro uses a biweekly brochure in which the promoted products are displayed along with their offering prices.

Metro’s central buying department forecasts the total order quantities for an upcoming brochure period, which is called budgeting. The budgets are sent to the suppliers at least 6 weeks in advance of the brochure period, in order to give them an early indication of how much to produce for all of the Metro stores. For articles in the Dry Food category, which is the focus product category in this thesis, each store places its early orders at the suppliers approximately 4 weeks before the brochure period. Delivery of the early orders takes place only a few days before the brochure period starts. Early order commitment, referred to as Order Commitment Timing type 1 (OCT1), is Metro’s formal procedure for brochure articles, which goal is to ensure that the supplier is able to cope with an increase in demand due to the brochure (i.e. minimization of supply risk). However, compared to late order commitment (Order Commitment Timing type 2 – OCT2) in which the order is placed in the last week before the brochure period, OCT1 has a number of possible disadvantages: (1) less accurate determination of order quantities due to the use of premature information, (2) higher incurred overhead costs if a late reorder is placed in addition to the early order, and (3) difficulties with compliance to Minimum Order Quantity (MOQ) restrictions for articles which are ordered at the same supplier as the early ordered article. The stores acknowledge the disadvantages of early ordering. Despite the formal procedure, they decide to order part of the brochure articles shortly before the brochure period (i.e. OCT2) through their short-term ordering system. This decision is made based on experience or rules-of-thumb. Grounded rules that support the choice of OCT type do not exist. Concluding, Metro requires a better understanding for making the right choice of Order Commitment Timing (OCT) type.

Furthermore, the used method of placing early orders functions insufficiently. The so-called brochure concept plays a central role, which is a matrix list displaying the brochure articles of a specific brochure along with information such as pricing and the budget values. The stores have to fill in their early order quantities on this paperwork. The paper format of the brochure concept easily leads to (human) errors and it makes the ordering process very time consuming. Thus, the method used for early brochure ordering needs to be redesigned in order to make it less time consuming and less error prone.

Research questions

The following two research questions are answered in this thesis:

1. Which factors affect the optimal choice of order commitment timing (OCT) types for Dry Food brochure articles and how do they affect this choice?

2. In what way should Metro improve its current early order commitment method?

Research design

In order to answer the first research question, a simulation model is built which represents the supplier-retailer relation in a single-item situation (i.e. MOQ problems related to early ordering are neglected). The factors that affect the performance of the two OCT types are taken as input variables to the model, each with a predetermined set of input levels. A unique setting of the input variable values is called an experiment. The model simulates every experiment for both OCT types, and produces values for the
output variables. Statistical inference is used to draw conclusions on the generated output with regard to the effects of the input variables on the performance. The simulation study is concluded with recommendations on how to translate the general conclusions to the practical situation.

The second research question is addressed by carrying out the design step of the Business Process Management lifecycle. A redesign of the early order commitment method is developed in discussion with process stakeholders and using several best practices in business process redesign.

**Order commitment timing**

To answer the first research question, the performance of the two OCT types is examined under different settings through use of simulation. Performance is expressed in terms of costs. Total costs (TC) consist of physical costs (PC) and market mediation costs (MMC). The physical costs consist of labor expenditure for placing as well as receiving an order. Market mediation costs consist of costs due to out-of-stocks (OOS) and excess stock.

**Investigated factors**

The eight factors which are investigated in the simulation study are denoted in bold characters below.

**Article's demand characteristics.** (1) The mean regular demand of an article expresses its average sales under the regular selling price, thereby distinguishing between slowmovers and fastmovers. (2) The lift factor indicates the typical relative increase in the article’s sales due to the promotion.

**Metro’s forecasting capabilities.** (3) Budget inaccuracy expresses the deviation of the budget value from the actual sales. (4) The store utilizes more recent information while forecasting demand at the late order moment. The forecast improvement coefficient expresses the magnitude of improvement of the demand forecasts between the early and late order moment. The probability function of demand is updated through a Bayesian approach.

**Metro’s ordering decisions.** (5) The promotional P1 service level is expressed as the probability of not being out-of-stock just before a reorder arrives. The store applies the desired service level while determining the order quantity. A higher service level leads to a higher order quantity.

**Supplier characteristics.** (6) Market share indicates the fraction of the supplier’s total sales of the product which is attributed to the retailer. The market share relates the retailer’s demand for the article with its competitors’ demand. It thereby affects the relative size of the supplier’s inventory buffer, which can be used to satisfy the retailer’s promotional demand if the promotional production quantity does not suffice.

**Cost parameters.** One physical cost parameter and one market mediation cost parameter are varied: (7) the costs of placing an early order and (8) the costs of stockouts respectively.

**Order commitment timing.** Given a unique input level setting of the factors, the decision has to be made which OCT type suits best. The OCT type is the so-called control variable of the model.

**Conclusions and recommendations**

Physical costs are generally low. Market mediation costs, mainly through stockouts, outweigh physical costs tremendously, so the factors that affect MMC are important. The factors that mostly affect the choice on the right OCT type are:

(1) The promotional service level. Costs of stockouts are relatively high compared to costs of excess stock.

As a consequence, costs are generally minimized if the retailer orders abundantly. However, if the
retailer orders more scanty, OCT2 can be much more expensive than OCT1, since several factors increase the supply risk under OCT2 in particular.

(2) The budget inaccuracy. By triggering the supplier’s production planning, budgets have a large effect on the supply risk under OCT2 in particular. Overestimated budgets (i.e. the budget value is on average higher than the occurring demand) minimize costs, since these secure a larger amount of supply than underestimated budgets.

Furthermore, other factors with a significant but smaller effect on performance are market share, the demand characteristics, and the examined cost parameters. It has been found that forecast improvement, which is strictly required for OCT2 to outperform OCT1 in terms of market mediation, does hardly make any difference.

The optimal choice of OCT type is unambiguous. OCT1 should be chosen as the optimal order commitment timing. The possible cost savings of OCT2 over OCT1 are marginal. If circumstances are not right for OCT2, choosing for this OCT type is hazardous, and choosing for OCT1 instead leads to substantial cost savings.

Metro is advised to early-order its Dry Food brochure articles as much as possible, mainly motivated by the risk of high costs under OCT2. Currently, one of the main reasons of the stores for not choosing to order through OCT1 is the fact that the early ordering process is time consuming. If the early ordering method is automated (recall research question 2), it will stimulate the stores to choose for OCT1 more often. They should also be made aware of the gained insight that OCT1 is a safer choice and is generally not much less efficient.

**Early ordering method**

The second research question addresses Metro’s current early ordering method, the brochure concept (BC) method. The most significant shortcomings of the BC method are:

(i) **Unnecessary tasks.** The written-down order quantities on the BC are transcribed to actual orders by a different department within the store.

(ii) **Many sources of information.** The store employee has to look at a variety of sources to determine the early order quantities.

(iii) **Lack of automated functions.** The paper format of the BC lacks several automated functions, such as an ordering blockade, an MOQ compliance check, a delivery date check, a trading unit check, and a notification on the deadline of submitting the early orders.

A new digital method, referred to as the brochure early ordering application, is proposed, which eliminates the transcription function, makes the right pieces of information quickly accessible for the store, and includes automated functions in order to prevent currently encountered mistakes. The application should be connected to Metro’s business system MBS and should have an intuitive interface similar to the current short-term ordering system (dispo system).

The current early ordering method consumes 10 man-hours per brochure per store for Dry Food articles only. The redesigned early ordering method is estimated to reduce man-hour consumption to 6.4 hours. Based on labor costs of €20 per man-hour, the redesign will save €33,000 annually for Dry Food articles. In addition, the redesign will improve the quality of the process by preventing (1) early orders for blocked articles, (2) delivery date mistakes, (3) early orders which do not comply with the MOQ condition, (4) early orders which do not comply with the trading unit, and (5) early orders committed after the deadline date.
Preface

This thesis is the result of my final project to complete my MSc degree in Operations Management & Logistics at the University of Technology Eindhoven. In the previous months, I conducted research on the ordering process of grocery articles under promotion at Metro Cash & Carry Nederland. It took long before the definite research assignment was determined. I started by analyzing Metro’s ordering process in a broad context and delivered a report with several possibilities for further research. I am glad we finally succeeded in establishing an assignment which both satisfies academic requirements and benefits the professional field, resulting in this thesis.

I would like to take this opportunity to show my gratitude to the people who supported me during the project.

First of all, I would like to thank my first supervisor from the TU/e, Karel van Donselaar, for his guidance throughout my Master’s and especially during the last period of graduation. I truly appreciated his helpful comments on my work. He impressed me with his ability to quickly grasp the essence of complex issues. Also, I have enjoyed his friendly personality. Furthermore, I would like to thank my second supervisor from the TU/e, Hajo Reijers. His critical reviews provided useful insights for this thesis.

I thank my daily supervisor at Metro, Mariska van Stipdonk, for supporting me throughout the project. Her down-to-earth approach suited perfectly to this project, in which I struggled to unite academic research with the company’s interests. It was an absolute pleasure to work with her.

I would also like to thank Karel Bossema and Wim Griffioen for giving me the opportunity to carry out this project within Metro’s organization. Thanks to many of the Metro staff, both from headquarters and the stores, who were more than willing to give their views on the topic. I thank the people from the IS department for the pleasant working environment and the many amusing lunch breaks. I really have enjoyed my time at Metro thanks to you all.

Special thanks are in place for my family and in particular my parents for their continuous encouragement during my period as a student. Finally, I would like to thank my friends and especially my girlfriend for supporting me by just being there. Thank you all for the support.

Jorn Bückers

Amsterdam, January 2010
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<td>administrative logistics centre (ALC)</td>
<td>function of the Goods Receiving department in a store which, amongst other things, processes the filled-out brochure concept (BC) or brochure replenishment lists (BPL) into actual orders to suppliers</td>
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<tr>
<td>advance brochure order</td>
<td>placement of an order in advance of the brochure period</td>
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<tr>
<td>brochure</td>
<td>Metro’s biweekly printed paper in which promoted products are displayed along with their offering prices</td>
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<tr>
<td>brochure concept (BC)</td>
<td>printed list of all brochure items on which the sales departments of the store can fill in their desired advance brochure order quantities</td>
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<tr>
<td>brochure item / brochure article</td>
<td>product that is advertised in the brochure</td>
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<td>brochure period</td>
<td>the period of two weeks in which the offerings of a particular brochure are exerted</td>
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<tr>
<td>brochure replenishment list (BRL)</td>
<td>printed list of all brochure items, made available to the sales departments of the store on a daily basis during the brochure period, on which they can fill in their desired reorder quantities</td>
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<tr>
<td>budgeting</td>
<td>determining the sales quantities for an upcoming brochure period</td>
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<tr>
<td>buyer</td>
<td>position within the buying department with responsibility for a number of products groups in terms of assortment, presentation, supplier arrangements, etc.</td>
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<td>direct supplier</td>
<td>supplier that directly delivers the goods at the stores, without the interference of a 3PL warehouse</td>
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<td>dispo system</td>
<td>part of the MBS system which is at the sales department’s disposal for reordering products by using their computer, automatically sending orders to the suppliers during the night-run of the MBS system</td>
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<tr>
<td>early (advance) order</td>
<td>placement of an order several weeks in advance of the brochure period</td>
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<tr>
<td>late (advance) order</td>
<td>placement of an order maximally one week in advance of the brochure period</td>
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<tr>
<td>lift factor (LF)</td>
<td>the ratio of an article’s sales during promotion to its sales during regular demand</td>
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<td>market mediation</td>
<td>letting supply meet demand</td>
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<tr>
<td>Makro Business System (MBS)</td>
<td>Makro’s information system that is used for many purposes</td>
</tr>
<tr>
<td>sales department</td>
<td>department within a store which is responsible for inventory control, ordering, refilling and presentation of a certain product category (such as dry food products) in that particular store</td>
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<td>service level</td>
<td>a measure for the extent to which supplying resources satisfy customer requirements</td>
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## List of abbreviations

<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Description</th>
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<tr>
<td>3PL</td>
<td>Third Party Logistics provider</td>
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<td>ALC</td>
<td>Administrative Logistics Centre</td>
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<td>ANOVA</td>
<td>analysis of variance</td>
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<td>BC</td>
<td>brochure concept</td>
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<tr>
<td>BI</td>
<td>budget inaccuracy</td>
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<tr>
<td>BRL</td>
<td>brochure replenishment list</td>
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<tr>
<td>cdf</td>
<td>cumulative distribution function</td>
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<tr>
<td>CV</td>
<td>coefficient of variance</td>
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<td>DF</td>
<td>dry food</td>
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<td>LF</td>
<td>lift factor</td>
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<tr>
<td>MBS</td>
<td>Makro Business System</td>
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<td>MMC</td>
<td>market mediation costs</td>
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<td>MOQ</td>
<td>minimum order quantity</td>
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<td>OCT</td>
<td>order commitment timing</td>
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<td>OOS</td>
<td>out-of-stock</td>
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<td>PC</td>
<td>physical costs</td>
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<tr>
<td>RC</td>
<td>reorder criterion</td>
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<tr>
<td>SSP</td>
<td>supply shortage probability</td>
</tr>
<tr>
<td>TC</td>
<td>total costs</td>
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1 Introduction to the research project

This chapter introduces the research project. In paragraph 1.1, the business environment of Metro Cash & Carry B.V., in which this master thesis project has been executed, is described. The problem environment and the problem definition are presented in paragraphs 1.2 and 1.3. In paragraph 1.4, the two main research questions are given. Paragraph 1.5, 1.6, and 1.7 subsequently discuss the research design, the scope of the research, and the relevance of the project. An outline of the thesis is given in paragraph 1.8.

1.1 Metro Cash & Carry

This project is carried out at Metro Cash & Carry Nederland, which is a subsidiary of the Metro Group.

1.1.1. Metro Group

The Metro Group (Metro AG) is a German holding company, operating several retail brands in four different divisions (see Figure 1.1). Metro Group is one of the largest retailers in the world, taking a global fourth place based on total dollar sales in 2007 according to Deloitte’s ranking of retailers (Deloitte, 2009). Furthermore, the group was ranked 218th in the Forbes 2000 in 2008, which is a list of the world’s largest companies based on a composite of sales, profits, assets, and market (Forbes, 2008). In 2007, net sales of Metro Group were over 64 billion (€), which implies a growth of 10% relative to 2006. However, part of this increase is due to acquisitions of the Wal-Mart Germany group and the Polish Géant business, that were made in the reporting year. Without these acquisitions, the increase in sales was 7.4%, relative to the previous year. The Metro Group has over 2200 stores worldwide, most of them in Germany and the rest of Western Europe. In total, Metro is present in 32 countries and employs around 280,000 people worldwide. (Metro Group, 2008)

1.1.2. Metro Cash & Carry

Metro Cash & Carry is an international market leader in the sector of self-service wholesale. Cash & Carry refers to the retail format in which customers pay cash at the check-out counter of the store and then carry their purchased items away themselves. Its product assortment is geared exclusively towards commercial customers, such as hotel and restaurant operators and small to medium-sized retailers.

Metro Cash & Carry operates under the Metro and Makro brands a total of 615 stores in 29 countries, employing approximately 104,000 people and generating net sales of €31.7 billion (almost 50% of Metro Group’s total turnover) in 2007. Each store offers up to 20,000 articles in the area of food and beverages as well as 30,000 non-food articles. The food business generates more than 70 percent of sales.

Metro Cash & Carry Nederland operates 17 stores in The Netherlands under the Makro store brand. The Makro stores fall into the category of warehouse membership club stores. The stores are accessible with a special membership pass, which can only be acquired with a subscription to the Chamber of Commerce. Hence, the target customers are companies, who seek to buy their supplies in large amounts and at low prices.
Metro Cash & Carry Nederland will be referred to as *Metro* in following chapters. The company’s organization charts, and details on the assortment can be found in Appendix A.

### 1.2 Problem environment

In order to inform its customers on price promotions, Metro uses a biweekly brochure in which the promoted products are displayed along with their offering prices. This project focuses on the ordering process of products that are advertised in this brochure. These products will be referred to as brochure items or brochure articles.

Metro’s central buying department is responsible for determining the contents of each brochure (i.e. product selection, pricing, advertising), and making arrangements with suppliers on buying prices, delivery schemes, and order quantities. The buying department also forecasts the total order quantities for an upcoming brochure, which is called *budgeting*. The budgets are sent to the suppliers approximately 6 weeks in advance of the brochure period, in order to give them an early indication of how much to produce.

Each of the stores places most of the orders itself at the suppliers¹. The stores place an *early order* approximately 4 weeks before the brochure period. The goal of placing an early order is to notify the supplier a sufficient time beforehand to ensure the supplier is able to cope with an increase in demand due to the brochure.

The so-called *dispo system* is used by the stores to place orders for short-term delivery. The dispo system is linked to each supplier’s ordering and delivery scheme. Each day, articles appear in this system, so that they can be ordered for delivery on the supplier’s next delivery day. The dispo system is formally only used to order regular articles, and to reorder brochure articles. In practice, the system is also occasionally used for short-term advance ordering of brochure articles. Such an order is referred to as a *late order*.

Appendix B contains flow diagrams of the brochure ordering process. A full discussion of the ordering process can be found in Bückers (2009).

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¹ This is the case for articles of the Dry Food category which are the focus of this project (see paragraph 1.6).

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**Figure 1.2. The ordering process for brochure articles**

### 1.3 Problem definition

An analysis of the ordering process for Dry Food brochure articles (Bückers, 2009) revealed a variety of flaws in the process with different significance. The most urgent problems are related to the placement of the *early order*.

First of all, the method of placing the early order is time consuming and error prone. The so-called *brochure concept* plays a central role in the early order method. The brochure concept is a matrix list...
displaying the brochure articles of a specific brochure along with information such as pricing and the budget values. The sales department\(^1\) has to fill in their desired early order quantities on this paperwork, while taking notion of several other sources of information (e.g. store layout plans, articles’ sales history in digital form, and the proof brochure). When the entire brochure concept is filled out, it is brought to the Administrative Logistics Centre (ALC) of the store, which transcribes the written-down order quantities to actual (digital) orders to the suppliers. The paper format of the brochure concept easily leads to (human) errors and it makes the ordering process very time consuming. More information on the brochure concept can be found in Appendix B2.

Second, the value of the early order is questionable. Early order commitment is aimed at securing the supply of brochure articles: earlier order commitment leads to higher chances that the supplier can fulfill the order quantity on time (i.e. low supply risk). It has the following possible disadvantages:

- **Higher demand risk**
  
  The use of early information to determine order quantities can lead to less accurate order quantities, which in turn leads to excess inventory and out-of-stocks, compared to late order commitment.

- **Higher ordering costs**
  
  After placing an early order, sales departments often place an extra (late) order as well, for delivery on the same delivery day as the early order. Each order consumes a certain amount of man-hours for tasks concerned with order placement and receiving the goods. If an extra order is placed, these tasks are executed twice, leading to extra labor costs compared to late order commitment.

- **Problems with Minimum Order Quantity compliance**
  
  Orders have to comply with Minimum Order Quantity (MOQ) restrictions: each (multi-item) order to the supplier has to be at least the MOQ. When an early order quantity of an article is on-order for delivery on the next delivery day, the sales department will most probably not order a large quantity of this particular article. This can make it hard to place an order for the other articles of the supplier which complies with the MOQ restriction.

\[ \text{FIGURE 1.3. EARLY ORDER COMMITMENT (OCT1) VERSUS LATE ORDER COMMITMENT (OCT2)} \]

According to Metro’s formal procedures, the sales departments should order brochure articles early. This is referred to as *Order Commitment Timing type 1 (OCT1)*. However, the sales departments acknowledge the disadvantages of early ordering. In practice, they order part of the brochure articles shortly before start of the brochure period through the dispo system. This is referred to as *Order Commitment Timing type 2 (OCT2)*.

\(^1\) The stores are divided into sales departments which are the actual entities that place the orders. This project focuses on the Dry Food sales department.
The sales department makes the choice of using one of these two OCT types for an article either based on an ungrounded rule-of-thumb or based on experience. The most common rule-of-thumb is to order the brochure articles that will be displayed on a promotion head or square through OCT1. Brochure articles that will be stacked in the regular shelves get ordered through OCT2. This rule-of-thumb is motivated solely by the impact of the increased sales volume on the supplier’s ability to deliver: head or square articles are generally fastmovers, and are ordered in a high quantity relative to brochure articles placed on the shelves. Grounded rules that support the choice of OCT type do not exist.

Summarizing, Metro faces the following challenges:

i. Better understanding is required for making the right choice of Order Commitment Timing (OCT) type.

ii. The method used for early brochure ordering needs to be redesigned in order to make it less time consuming and less error prone.

1.4 Research definition

Metro needs to enhance its knowledge on the factors that play a role when determining the best Order Commitment Timing type. Moreover, if early orders are required, Metro should redesign its early ordering method. These challenges are the subject of this master thesis. Two main research questions will be answered:

1. Which factors affect the optimal choice of order commitment timing (OCT) types for Dry Food brochure articles and how do they affect this choice?

2. In what way should Metro improve its current early order commitment method?

The research assignment is formulated as follows:

Determine the major factors that affect performance under various order commitment timing types and develop conjectures regarding the impact of the factors on performance which can support the choice of the right order commitment timing type. Furthermore, make recommendations to Metro how to redesign its current early order commitment method.

The first research question focuses on order commitment timing. It will be investigated which factors play a role in the choice of OCT type, and how these factors are related to performance. Performance will be expressed in terms of costs. Under different settings of the factors, the difference between applying OCT2 and OCT1 in terms of costs will be evaluated. This will lead to conjectures\(^1\) on the impact of the factors. These conjectures should create insights into the relationships between the factors, the OCT types, and the performance indicators, which can be used by Metro to support their decision on OCT type in different situations (different articles, different suppliers, etc.).

The second research question focuses on Metro’s current order commitment methods. It will lead to recommendations which Metro can apply in order to make the process of placing the early brochure order more efficient. The recommendations will touch upon the application of the gained insights on OCT types in practice, as well as on the modification of the current early ordering method (i.e. the brochure concept method) in order to make the process of placing the early brochure order less time consuming and less error-prone.

\(^1\) Conjectures are propositions which are not proven analytically, but are presumed to be true in the specific environment.
1.5 Research design and methodological foundation

In this paragraph, the approach to answer the two research questions is discussed.

The first research question is addressed by the methodology presented by Mitroff et al. (1974). They present a four-phased methodology that is applicable in operational research and combines normative empirical research with rigor:

1. Conceptualization

The research problem is conceptualized, by using operations research literature as well as interviews with experts and stakeholders in the problem environment. Decisions are made on which variables need to be included in the model, and the scope of the model is addressed.

2. Modeling

A quantitative model is built, defining causal relationships between the variables. Quantitative modeling constructs from academic literature are used. The quantitative model translates the identified input variables into estimates of the output variables (i.e., performance).

Many variables are stochastic and have numerous relations with other variables. Due to the complexity of the model, analytical models for problem solving are not feasible. Therefore, simulation is used to compare the two OCT types using a limited set of input levels for the input variables. Simulation is regularly used in supply chain literature to compare and evaluate variants (e.g., Broekmeulen & Van Donselaar, 2009; Lau et al., 2008). The set of input levels are determined based on empirical data and estimations from experts. The simulation model is validated by demonstrating it to the people who know the system. The steps depicted in Figure 1.5 are followed to perform the simulation study (Law, 2007).

The simulation model is dynamic (i.e., time dependent), discrete-event (i.e., the state variables change instantaneously at separate points in time), and stochastic (i.e., containing random variables). It is also terminating (i.e., output parameters are defined relative to specific initial and stopping conditions that are part of the model). (Law, 2007)

3. Model solving

Analysis is conducted based on experimentation with the simulation model and the determined set of input levels. Statistical inference is used to draw general conclusions (‘conjectures’) based on the generated output.

4. Implementation

The actual implementation is out-of-scope, due to time limitations. The research is concluded with recommendations on how to translate the conjectures to the practical situation.
The *second research question* is answered by following the Business Process Management lifecycle (Smith and Fingar, 2003). In earlier work (Bückers, 2009), the lifecycle was followed until the design step. Succeeding, first attempts to carry out the design step are made in this thesis. A redesign is developed by combining empirical insights gained from stakeholder interviews with several best practices in business process redesign as described by Reijers and Liman Mansar (2005).

![Simulation Study Diagram](image)

**Figure 1.5. Simulation Study (LAW, 2007)**

### 1.6 Scope

Several demarcations are made for this research project:

**Focus on the Dry Food article category**

As large differences exist between article categories, the focus will be limited to articles of the Dry Food category (see Appendix A3). The Dry Food category was chosen for a number of reasons. Dry Food articles possess characteristics that simplify its analysis. Its assortment changes less frequently than many other assortments, most articles are part of the base assortment and continued to be sold after a brochure period, and the articles rarely have a stringent expiry date resulting in shrinkage. When it comes to process improvements within Metro’s organization, Dry Food often serves as a frontrunner within the article groups.

**Focus on Direct Suppliers**

Approximately 75% of Dry Food orders are delivered through direct suppliers, whereas the other 25% through a central warehouse operated by a 3rd party logistics provider (3PL). Table 1.1 shows how the ordering process for central warehouse articles is significantly different from the process for direct supplier articles. Only the ordering process for direct suppliers is investigated with respect to OCT types due to time limitations.

**Evaluation of two Order Commitment Timing types**

Two OCT types are currently employed by Metro (Figure 1.3). Theoretically, the timing of order commitment can be freely varied between the moment of budget communication and the moment of the dispo order placement (OCT2), thereby basically creating an infinite number of possible OCT types. Simulation will be used to investigate the impact of the factors on OCT performance (paragraph 1.5), and only 2 fixed OCT types will be evaluated in order to limit the number of simulation experiments required. This is sufficient to extract valuable conclusions.

---

1 Recently, a large improvement step was made in the ordering process for (non-promotional) Dry Food articles by implementing a new Automated Store Ordering (ASO) system called ‘SAF’. 
Single-item environment

For complexity reasons, a single-item situation will be analyzed. In practice, orders sent to suppliers can contain multiple articles (items). One of the disadvantages of early ordering is Minimum Order Quantity compliance for dispo orders, which can only be analyzed in a multi-item environment. This aspect will be left out of the analysis.

**Table 1.1. Comparison of direct suppliers and the central warehouse (3PL)**

<table>
<thead>
<tr>
<th>Direct suppliers</th>
<th>Central warehouse (3PL)</th>
</tr>
</thead>
<tbody>
<tr>
<td>The supplier's inventory replenishment is controlled by the supplier itself.</td>
<td>The supplier’s inventory replenishment is controlled by Metro, specifically Metro’s central Stock Planning Team.</td>
</tr>
<tr>
<td>The supplier receives a budget approximately 6 weeks before the brochure period.</td>
<td>The supplier does not receive a budget.</td>
</tr>
<tr>
<td>The supplier receives the initial brochure order approximately 4 weeks before the brochure period.</td>
<td>The supplier receives the initial brochure order approximately 2 weeks before the brochure period.</td>
</tr>
<tr>
<td>The supplier requires the (early) order to cope with Metro’s promotional demand, but the budget also enables the supplier to plan its production, yet before the real order is received.</td>
<td>The supplier requires the (early) order to cope with Metro’s promotional demand for managing its order picking process in-time. Receiving a budget yet before this real order is received would not help.</td>
</tr>
</tbody>
</table>

### 1.7 Relevance

This paragraph discusses the relevance of the research project. In the first section, it will be discussed how the research project contributes to the scientific field. In the second section, it is described how this research addresses company challenges.

#### 1.7.1 Scientific relevance

Fisher (1997) introduced a simple framework for determining which type of supply chain is required based on the classification of the product into the functional or innovative product category. Functional products have a low profit margin, long life cycle, and stable, predictable demand. Given these characteristics, companies that make such products should focus on minimizing physical costs, i.e. production, transportation, and inventory storage. Innovative products have a high profit margin, short life cycle, and unpredictable demand. Companies that make these products should focus on market mediation costs, i.e. costs of excess or shortage of supply to demand, instead of focusing on physical costs.

Dry Food products can unmistakably be categorized as functional products. However, extensive use of price promotions for these products makes their demand much less predictable. Strategies to manage the uncertainty of demand are not only relevant to innovative products, but can also benefit functional products under heavy and frequent promotion. Fisher (1997) discusses three strategies to manage the uncertainty of demand: (1) reduce it, (2) avoid it, and (3) hedge against it. First, reducing uncertainty can be done by finding sources of new data that can serve as leading indicators. Second, avoiding uncertainty can be done by cutting lead times and increasing the supply chain’s flexibility to order the product at a time closer to when demand materializes and can be accurately forecast. Third, uncertainty can be hedged against with buffers of inventory or excess capacity.
Order timing postponement

Most research on promotional products focuses on the first strategy (Van Loo, 2006; De Schrijver, 2009; van den Heuvel, 2009). This research will focus on the second strategy, i.e. on the possibility of timing orders closer to the selling period in order to benefit from, amongst other things, more accurate forecasts. Fisher & Raman (1996) wrote a notable article on the second strategy. They analyzed the decisions required for a situation in which lead times are shortened sufficiently to allow a greater portion of production to be scheduled in response to initial demand (i.e. Quick Response). After observing some early sales, a company can make a better forecast for the remainder of the selling season, provided that early demand is correlated with later demand, which is a plausible assumption. Many succeeding research extended on the article of Fisher & Raman (1996). Examples are Iyer & Bergen (1997) and Choi (2006), who analyzed the potential of Quick Response, but focused on the value of gathered information regarding sales of related pre-seasonal products to be used to decrease forecast error. It was concluded that an appropriate pre-seasonal product and a precise information update model are required for an effective QR policy.

In this research, shortening lead times (i.e. using a late OCT type) will not make early (promotional) demand information directly available. However, it can make other recent demand information available, i.e. demand of the product for the regular (non-promotional) price and promotional demand of the product during other brochure periods (i.e. in case the product is repeatedly put on promotion). Furthermore, more recent information on inventory level and competitor prices also becomes available. A number of research articles discuss a more generic view on updating of information and forecast accuracy improvement over time (Gurnani and Tang, 1999; Graman and Sanders, 2009; LeBlanc et al., 2009).

Broad context

The objective of this research is to determine the major factors that affect performance under various order commitment timing (OCT) types, and analyze the impact of these factors in relation with the OCT type on performance. This research extends on existing literature that investigated order timing postponement (where the postponed order is placed still in advance of the selling season) and its benefits from forecast improvement (e.g. Gurnani & Tang, 1999). It takes this issue into a broader context. It does not only look at the effect of order timing postponement on performance through the benefits of forecast improvement over time. It also considers other factors that play a role in the decision whether to postpone or not, such as factors that determine the attainability of order timing postponement and serve as boundary conditions. Examples of these other factors include demand characteristics and supplier configurations. No previous research has incorporated the impact of demand characteristics, supplier characteristics, and order commitment timing together in order to investigate their joint impact on supply risk and demand risk, as well as on a potential reduction of orders.

Applying order timing postponement models to Dry Food grocery retailing is fairly uncommon in literature, due to the predictable nature of Dry Food products. However, heavy and frequent (price) promotions decrease their demand predictability. It is therefore interesting and refreshing to investigate order timing for Dry Food products under promotion.

1.7.2 Company relevance

Paragraph 1.3 introduced two challenges faced by Metro. This research project will address these two challenges.

Metro recently devoted most effort to the first strategy of reducing uncertainty of demand for promotional products (Fisher, 1997). Examples are the implementation and improvement of the automatic store...
ordering system SAF and research of De Schrijver (2009) on forecasting promotional demand. This research will address the second strategy within Metro’s environment. It will create insight for Metro into the benefits of the right order commitment timing type, and into the factors that constraint the choice of the right OCT type, such as supplier characteristics and forecast accuracy. Currently, the choice of using one of the two OCT types for an article is made either arbitrarily or based on an ungrounded rule-of-thumb. The insights can support Metro in its decision on the right OCT type, and/or support in the negotiation with suppliers on order commitment timing. Choosing the right OCT type can potentially lead to less physical costs, fewer stockouts and/or less excess stock, and fewer MOQ problems.

The research project will also lead to recommendations on how Metro can make its process of placing the early order for promotion products more efficient. The recommendations will touch upon the translation of the gained insights on OCT types in practice, as well as on the modification of the current early ordering method (i.e. the brochure concept) in order to make the process of placing the early order less time consuming and less error-prone.

1.8 Thesis outline

The outline of the remainder of this thesis is as follows.

In Chapter 2, the conceptual model is presented. The conceptual model introduces the factors that are relevant to the OCT problem, and it describes their relations qualitatively.

Chapter 3 discusses the real-world system of Metro and its fit to the model. Results on company data analyses are presented. These results are used to build the quantitative simulation model, and to set the initial levels of the variables in the model.

The quantitative model is described fully in Chapter 4. The used variables and their relations are mathematically expressed. The chapter concludes with a simulation flow model, summarizing the different simulation steps.

In Chapter 5, the results of the simulation study are given. The effects of the input variables on the performance variables are described. At the end of the chapter, the conclusions drawn from the simulation are presented.

Chapter 6 answers both main research questions. First, the developed conjectures on the OCT problem are summarized, and translated to recommendations for Metro specifically. Second, the first steps are made in redesigning Metro’s current working method for placing early orders.

Chapter 7, the final chapter of this thesis, concludes with a review of the main findings, a discussion of the limitations, and an outlook on future research possibilities.
2 Conceptual model

In order to answer the first research question, a simulation model is built which represents the supplier-retailer environment under consideration. The model is simulated for several settings of the investigated factors, for each of which the performance is evaluated. The first step in this process is to build the conceptual model. The conceptual model is a qualitative representation of the problem environment and introduces the main variables and their relations. This chapter will present the different aspects of the conceptual model. The factors that affect the performance of the two OCT types and their relations are discussed.

The chapter is structured as follows. Paragraph 2.2 discusses the evaluation of performance. Paragraph 2.3 goes into the concepts of budgets and orders. Paragraph 2.4 differentiates regular demand from promotional demand. In paragraph 2.5, it will be described how order quantity decisions will be modeled. Paragraph 2.6 discusses the aspects related to the modeling of the supplier’s behavior. Finally, paragraph 2.7 will conclude this chapter with a review of the conceptual model.

2.1 Introduction

The main structure of the model is depicted in Figure 2.1. The factors which effects will be examined are regarded as environmental variables, since these are not controllable by the retailer. They will be further referred to as the input variables of the simulation study. The OCT type is the so-called control variable of the model, as it represents the decision the retailer has to make. Finally, the output variables are measures of the performance of the model.

Figure 2.2 below displays the time frame of the model. The budget is communicated to the supplier 6 weeks in advance of the brochure period. The early and late order (OCT1 and OCT2) are sent by the store to the supplier respectively 4 weeks and 1 week before the brochure period. The OCT2 order is received by the supplier at the same time as order release. The time between the OCT2 order and delivery equals the net leadtime (without any production time). The brochure period lasts 12 days. During the brochure period, the store is able to place a reorder once, which is delivered after the net leadtime.
The model focuses on a single store. An important terminological distinction should be made. The term store refers to the retailer's store which is focused on. The other stores of the retailer are also included in the model, and will be referred to as other stores. The term retailer will be used if no distinction between the focus store and the other stores is necessary.

### 2.2 Performance

Performance will be evaluated based on physical costs (PC) and market mediation costs (MMC) (Fisher, 1997). The physical costs of interest consist of labor costs of placing orders and labor costs of receiving orders. Market mediation costs, i.e. excess or shortage of supply to demand, consist of out-of-stocks (OOS) and excess inventory. Each performance variable will be evaluated individually under the different factor settings. Also, in order to make final conclusions on the best OCT type under a given factor setting, the individual performance variables are combined into the final performance variable total costs (TC).

#### 2.2.1 Physical costs

Both types of the physical costs involve a fixed cost per order. Placing orders consumes a certain amount of time for determining the order quantity and placing the order. Recall that in Metro's current situation, the OCT1 ordering method using the brochure concept consumes more time than the OCT2 ordering method using the dispo system.

In most manufacturer-retailer relations, the manufacturer bears the fixed transportation costs and order processing/material handling costs incurred at the manufacturer's location, but the retailer bears the order processing/handling costs incurred at the retailer's location (Nagarajan and Rajagopalan, 2008). Receiving orders consumes a certain amount of time due to tasks performed by Goods Receiving and Accounts Payable.

Under OCT1, and given that there is forecast improvement over time (paragraph 2.5.3), the retailer optionally places a second (late) order. This only occurs if the updated (late) forecast is significantly higher than the early forecast. When there is no forecast improvement over time, or under OCT2, there is always only 1 order going to the supplier prior to brochure start (Table 2.1).

<table>
<thead>
<tr>
<th>Table 2.1. Moments of order placement</th>
</tr>
</thead>
<tbody>
<tr>
<td>Early order moment</td>
</tr>
<tr>
<td>OCT1, no forecast improvement</td>
</tr>
<tr>
<td>OCT2, no forecast improvement</td>
</tr>
<tr>
<td>OCT1, forecast improvement</td>
</tr>
<tr>
<td>OCT2, forecast improvement</td>
</tr>
</tbody>
</table>
2.2.2 Market mediation costs

A retailer attempts to let supply meet demand which is called market mediation. When supply meets demand, excess or shortage of supply to demand is minimized. It is related to the notion of supply and demand risk for the retailer.

An important question in supplier–buyer relations is the allocation of demand and supply risks among the parties. In the most extreme case, if buyers order after observing demand, the supplier is forced to decide on the production quantity under uncertainty and hence bears the demand risk. In this case, the buyers’ order quantities are limited by the supplier’s production quantity, and they may face lost sales when the production quantity is less than the demand. This phenomenon is referred to as the supply risk. The buyers can avoid the supply risk by committing to an order quantity before the production run since the supplier can now produce and deliver the orders in full. However, the buyers bear the ‘demand risk’ in this setting. (Bakal and Geunes, 2009)

Late order commitment increases the chance that the supplier cannot fulfill the order on time (i.e. shortage) compared to early order commitment. The retailer’s supply risk is increasing over the lateness of order commitment. Moreover, the supplier probably gives priority to early orders in case of supply shortage, which accelerates this effect.

On the other hand, demand risk is decreasing for the retailer over the lateness of order commitment, as a more accurate order quantity can be determined by using more, and more recent, information:
- Recent demand data for the product under the regular (non-promotional) price
- Recent demand of the product during other brochure periods (in case the product is repeatedly put on promotion)
- Recent inventory level
- Recent competitor prices
- Recent brochure details (e.g. pricing)

The demand risk is increasing for the supplier over the lateness of order commitment, since chances are higher that he runs out-of-stock or is left with excess stock after the retailer’s orders have arrived. The model is mainly focused on the retailer’s perspective, and incorporates both supply and demand risk by evaluating (1) the stockout quantity at the store \( Q_{OOS} \), and (2) the excess stock quantity at the store \( Q_{excess} \).

The costs related to these two quantities are referred to as market mediation costs. In addition, the excess stock quantity at the supplier \( Q_{excess, supplier} \) is evaluated, in order to make projections on the supplier’s expected willingness to cooperate with a different ordering scheme.

2.2.3 Total costs

Total costs \( (TC) \) is the performance variable on which a final decision can be based. It is the sum of the retailer’s physical costs \( (PC) \) and market mediation costs \( (MMC) \). As the model is taken from the retailer’s perspective, the excess stock quantity at the supplier is not included in the total costs variable, but rather evaluated separately.

---

1 Late changes to the brochure configuration have less effect when ordering late, leading to less excess or shortage. The objective of Metro’s central buying department is to more often adjust prices only shortly before the brochure starts in response to competitor price setting.
2.3 Budgets and orders

Metro’s central buying department makes projections of the total sales during the brochure period for all brochure articles. These projections are called budgets. The objective of the budget is manifold. It is used for performance evaluation of Metro’s buyers. It can support the stores’ sales departments in their ordering quantity decisions; but the stores rarely use the budget value in practice. The budget is also aimed to inform the suppliers on the projected sales, which is relevant to the model. Suppliers use the budget in their production planning (paragraph 2.6). The budgets are sent to the suppliers approximately 6 weeks in advance of the brochure period. It is a forecast of total brochure period sales in all 17 Metro stores combined.

Each of the stores commitments its own orders. The model focuses on one store. Early orders (i.e. OCT1) are committed approximately 4 weeks in advance of the brochure period. Late orders (i.e. OCT2) are committed approximately 1 week in advance. Both advance orders are not aimed at satisfying customer demand until the end of the brochure period, but rather until the moment that a reorder quantity arrives during the brochure period (see the dashed line in Figure 2.2). Although the budget is in practice a projection of total brochure sales, the budget quantity is modelled as a projection of the sales until the first reorder quantity delivery day.

2.3.1 Budget inaccuracy

The budget value generally deviates from the actual sales, and this is referred to as budget inaccuracy (BI). Budget inaccuracy is expressed as:

$$BI = \frac{\text{demand until first reorder delivery day}}{\text{budget value until first reorder delivery day}}$$  [1]

$BI>1$ indicates an underestimated budget (i.e. the budget value is lower than the occurring demand), while $0<BI<1$ indicates an overestimated budget (i.e. the budget value is higher than the occurring demand).

2.4 Regular and promotional demand

The retailer generally knows well which articles sell fast and which articles sell slowly. The average sales of every product under the regular selling price are well documented figures. There is no such thing as average sales under (price) promotion, since each promotion is in some way distinct from the other. When a product is put on promotion, it typically sells a certain unique factor more than under its regular price. Many researches have been devoted on predicting this factor using a variety of predictor variables (e.g. Van Loo, 2006; De Schrijver, 2009, Van de Heuvel, 2009). The so-called lift factor (LF) is defined as the ratio of an article’s sales during promotion to its sales during regular demand, and the Lift Factor value thereby indicates the relative increase in sales due to the promotion.

For these reasons, the model incorporates the following demand characteristics of the article under consideration:

1. Regular daily customer demand (distribution and parameters)
2. Lift factor (LF)

Both are easily recognized and usable characteristics of an article under promotion.
2.5 Ordering decisions

This section will discuss how out-of-stock costs and excess stock costs are related to a desired service level. It will also be discussed how a demand distribution leads to an order quantity, and how forecast improvement over time is included in the model.

2.5.1 Market mediation and service level

Being out-of-stock is highly undesirable for brochure articles. It not only leads to lost sales and thereby lost profits in the short-run, but also loss of customer goodwill in the long-run. Excess stock traditionally leads to unnecessary inventory holding costs. It can be reasoned that the retailer prefers having excess stock over being out-of-stock, because:

- The order quantity that is placed in advance of the brochure period has to satisfy demand until the first reorder delivery day during the brochure period. After the first reorder delivery day, there are still brochure period days left to sell the excess inventory.
- The majority of brochure articles can be sold for regular prices after the brochure period ends.
- Obsolescence does not play a significant role for DF articles.

For these reasons, it is smarter to order an abundant quantity than risking stockouts by ordering scantily. However, although excess inventory is less important than stockouts, excess inventory is in fact still undesirable. A too large excess stock resulting from the advance order will lead to excess (unnecessary) inventory holding costs even after the brochure period, taking into account that demand during the second half of the brochure period is decreasing (Figure 2.4). Inventory holding costs stem from handling and storing activities concerned with the excess stock, as well as opportunity costs that the retailer could receive had money been invested in something else instead of the particular article on inventory (Simchi-Levi et al., 2008).

The relation between the costs of stockouts and the costs of excess stock will be incorporated in the conceptual model through the setting of a service level according to a **Newsvendor model** (Silver et al., 1998), where underage costs consist of the stockout cost parameter \( c_{\text{OOS}} \) and overage costs consist of the excess stock cost parameter \( c_{\text{excess}} \). The relation between the promotional P1 service level\(^1\) \( SL_{\text{promo}} \), \( c_{\text{OOS}} \) and \( c_{\text{excess}} \) is as follows:

\[
P[Demand \leq \text{Order quantity}] = \frac{c_{\text{OOS}}}{c_{\text{OOS}} + c_{\text{excess}}} = SL_{\text{promo}}
\]  

[2]

Service levels should be generally high, especially for promotional goods, and this captures the high relative importance of avoiding stockouts compared to avoiding excess inventory. As a consequence, forecast improvement over time will mainly decrease the amount of excess inventory instead of decreasing the amount of stockouts.

---

\(^1\) P1 customer service level is the probability of not being out-of-stock just before a replenishment order arrives.
### 2.5.2 Order quantity determination

Based on the assumption that demand is normally distributed\(^1\) with mean \(\mu\) and standard deviation \(\sigma\), the retailer should order the following quantity:

\[
\text{order quantity} = \mu + k \cdot \sigma
\]  
\[3\]

with \(k\) such that:

\[
\Phi(k) = SL_{\text{promo}}
\]  
\[4\]

\(\Phi(.)\) denotes the standard normal cdf. \(k\) is referred to as the safety factor, and \(k\cdot\sigma\) is the safety volume (or safety stock). According to Van Donselaar (1990), safety stock should account for the effect of the retaining inventory at the supplier on the resulting customer service level at the retailer. The retailer should aim for a higher service level than originally intended as it is affected by the supplier’s service level. The model will incorporate an adapted service level value and safety factor (Van Donselaar, 1990):

\[
\Phi(k_\alpha) = \frac{1}{3} + \frac{2}{3} \cdot SL_{\text{promo}} = SL_{\text{promo}}^{\text{ad}}
\]  
\[5\]

where \(SL_{\text{promo}}^{\text{ad}}\) denotes the adapted service level value that is required to achieve a service level of \(SL_{\text{promo}}\).

### 2.5.3 Demand estimation and forecast improvement

Customer demand is assumed to be normally distributed with mean \(\mu\) and standard deviation \(\sigma\). A high coefficient of variation (i.e. \(\sigma/\mu\)) implies highly unpredictable demand, whereas a low coefficient of variation implies predictable demand. The uncertainty about the value of a random variable such as demand has two sources (Fisher, 1996): (1) inherent randomness in the process generating the value, and (2) uncertainty about the parameters/distribution of the process. Inherent randomness is almost inevitable, but it assumed that the uncertainty about the parameters/distribution of the demand can be reduced by using more and more recent information when ordering close to the start of the selling period.

This is captured through a Bayesian approach discussed in Gurnani & Tang (1999). The store utilizes information \(I\) observed between the early order moment and the late order moment to update the

---

\(^{1}\) The assumption of normally distributed demand will be tested in Chapter 3.
probability function of demand. The probability function of demand at the early order moment \( D_{\text{early}} \) is normally distributed with mean \( \mu_1 \) and standard deviation \( \sigma_1 \). The probability function of information \( I \) is normally distributed with mean \( m \) and standard deviation \( s \), where \( m = \mu_1 \) and \( s = \sigma_1 \) (i.e. the store’s estimation of the demand process at the early order moment was right). Following, the updated pdf of demand at the late order moment \( D_{\text{late}} \) is modeled by a joint distribution of information \( I \) and demand \( D_{\text{early}} \). This is a bivariate normal distribution with means \( m \) and \( \mu_1 \), standard deviations \( s \) and \( \sigma_1 \), and the correlation coefficient \( \rho \) (\( 0 \leq \rho \leq 1 \)). \( D_{\text{late}} \) is equal to \( D_{\text{early}} | I \), which is also normally distributed with mean \( \mu_2 \) and standard deviation \( \sigma_2 \) (expressions will be given in Chapter 4). If \( \rho > 0 \), \( \sigma_2 \leq \sigma_1 \) which means that uncertainty about the demand process has reduced. The correlation coefficient \( \rho \) is the variable that expresses the magnitude of forecast improvement. It will be taken as an input variable to the model and referred to as forecast improvement coefficient.

2.5.4 Reorder criterion
Under OCT1, and given that there is forecast improvement over time (i.e. correlation coefficient \( \rho > 0 \)), the retailer can place a second (late) order. He does not do this every time. It only occurs if the updated (late) forecast is significantly higher than the early forecast. The retailer checks whether the costs that incur when placing the reorder are expected to be lower than the costs that incur when no reorder is placed. If so, he will place the reorder. This criterion is called the Reorder Criterion.

2.6 Supplier behavior
This paragraph discusses how the supplier’s inventory management and production decisions will be incorporated into the model. The supplier distinguishes the retailer’s promotional orders from regular orders. Regular orders from the focus retailer and its competitors are satisfied directly from stock. The supplier keeps an inventory buffer for this purpose, which he continuously replenishes. The retailer’s promotion period is known by the supplier prior to the start of the year. The supplier reserves extra production capacity for this promotion in its long-term master production schedule.

2.6.1 The supplier’s inventory point
The supplier’s article is stocked in an inventory point, owned by the supplier. This inventory point is aimed to satisfy the regular demand from the retailer as well as from the competitor retailers which also sell the article. The inventory point is continuously replenished by the supplier based on regular demand for the article. The supplier keeps a safety stock level for its inventory point such that a desired P1 service level of \( SL_{\text{inv}} \) can be obtained under the regular demand. It is assumed that the regular demand is normally distributed, say with mean \( \mu \) and standard deviation \( \sigma \). The supplier’s inventory point keeps an amount of stock that is computed in a similar way as the retailer’s order quantity in paragraph 2.5.2:

\[
\text{start inventory level} = \mu + k_\beta \cdot \sigma
\]

with \( k_\beta \) such that:

\[
\Phi(k_\beta) = SL_{\text{inv}}
\]

At the moment of order release of the retailer’s promotional goods, also the regular orders for the retailer and other retailers are being released. If required, promotional orders can be satisfied from the inventory point, but regular orders are given priority.
Market share

In order to relate the retailer's regular demand for the article with the competitors' regular demand, the notion of *market share* (MS) is introduced to the model. The market share variable is defined as the fraction of total regular demand for the article at the supplier which can be attributed to the retailer (all stores of the retailer combined). If the retailer demands a fraction of MS, the competitors demand a fraction of 1-MS (Figure 2.6).

2.6.2 Promotional production

Production capacity is modeled as:

\[
\text{production capacity} = \text{production rate} \times \text{production time}
\]  

The OCT2 orders are received by the supplier at the moment of order release, so no production is possible after the actual store orders have arrived. In case of OCT2, the supplier bases its production decision solely on the budget received. Only base production capacity can be employed here (Figure 2.7), which is modeled as a base production rate \( c_1 \) over the time of budget receipt until the time of order release. Under OCT1, the supplier can employ a flexible production capacity as well. First, when the budget has been received, he starts producing according to a base production rate \( c_1 \) and reserves some extra capacity for after receiving the OCT1 orders by determining the flexible production rate \( c_2 \). When the supplier receives the actual store orders, he is able to adjust the production rate upwards, with an upper limit of \( c_2 \) (i.e. the red graph in Figure 2.7). Obviously, he can also adjust the production rate downwards. The horizontal graphs in Figure 2.7 indicate the assumption of capacity uniformity over time.
It is known to the supplier that retailers typically order more than their sales forecast (i.e. the budget), in order to account for variance in demand (i.e. safety stock). The supplier plans its production based on the following:

- The budget value
- The typical variance of customer demand for the supplier's products at the retailer's stores
- The safety factor which the retailer uses when ordering
- The distribution and parameters of the budget inaccuracy created by the retailer

The supplier bases the value of \( c_1 \) on the presumption that the budget value is true. Even if the retailer in general makes overestimated budgets, the supplier is inclined to produce the budget value, because he is more or less obliged to be able to deliver at least that quantity. Under OCT1, the value of \( c_2 \) is based on the budget value as well, but it also accounts for budget inaccuracy. Under OCT2, there is no flexible production capacity, so no \( c_2 \).

When the goods have to be released for transportation, the promotion production quantity can turn out to be insufficient, i.e. less than the total ordered quantity. Chances of the promotion production quantity being insufficient are higher under OCT2 than under OCT1, as there is no flexible production possible under OCT2. In case of insufficiency, the shortage will be taken from the inventory point, if possible. The inventory point gives priority to regular orders. If there is still a shortage after addressing the inventory point, an allocation rule is used to allocate the available stock to the retailer's stores, such that they have an equal stock-out probability, i.e. the Fair Share rationing rule (Eppen & Schrage, 1981):

\[
P[\text{demand at the store} < \text{allocation quantity store}] = P[\text{demand at the other stores} < \text{allocation quantity other stores}] \tag{9}
\]

under the constraint that allocation quantities can not be negative.

There is no flexible promotion production capacity under OCT2. The same service level as under OCT1 can only be attained if the supplier uses a base production rate \( c_1 \) which is higher compared to OCT1. However, the supplier does not want to increase its demand risk due to the retailer's switch from OCT1 to OCT2. He sets \( c_1 \) to the same level under OCT2 as under OCT1, such that the exact budget quantity can be produced. This will decrease the attained service level compared to OCT1: switching from OCT1 to OCT2 does not hurt the supplier, but it hurts the retailer in terms of supply risk.

Let's have a look at which aspects have an affect on the service level decrease. We have just seen that the value of \( c_2 \) under OCT1 depends on the budget value and on the budget inaccuracy. Under OCT1, higher budget inaccuracy \( BI \) increases the relative importance of \( c_2 \) compared to the inventory buffer w.r.t. attaining a certain service level. Contrarily, lower \( BI \) increases the relative importance of the inventory buffer. Therefore, when the retailer switches from OCT1 to OCT2, and thereby eliminates the supplier's flexible production \( c_2 \), it will decrease the service level more under high budget accuracy than under low budget inaccuracy. Obviously, a large decrease in service level is undesirable. As \( BI \) is basically controllable by the retailer by improving the accuracy of its budgets, the retailer can bound the service level decrease when switching to OCT2.
2.7 Review

This chapter described the conceptual model. The first paragraph detailed the time frame of the model, clarifying the sequence and the timing of the occurrences in the OCT problem under consideration. The second paragraph discussed that performance will be measured in terms of costs. Total costs consist of (1) market mediation costs, caused by stockouts and excess stock, and (2) physical costs, which are incurred due to fixed labor costs per order. The third paragraph explained budgets, early orders and late orders, which are all concepts of communication between the supplier and the retailer w.r.t. the required article quantities for the promotion. The notion of budget inaccuracy was introduced. The fourth paragraph presented how the article’s regular customer demand can be related to its promotional demand through the lift factor variable. The fifth paragraph touched upon the retailer’s ordering decisions. It was discussed that a Newsvendor model is used to express the relative importance of stockouts versus excess stock, and how this leads to a high service level which is used to determine order quantities. Moreover, the modeling approach for capturing forecast improvement over time was introduced. Finally, the sixth paragraph described the supplier’s inventory buffer, and how the supplier responds to the budgets and committed orders from the retailer. Figure 2.8 below summarizes the key aspects of the conceptual model.

The next chapter discusses an analysis of the real-world situation of Metro. This shows how the conceptual model fits to the real environment. It also leads to more details in order to build the quantitative model, and to the right input values for the input variables.
3 Analysis of the current situation

This chapter will discuss how the real-world situation of Metro fits to the conceptual model of Chapter 2. Data was collected in order to build the quantitative simulation model, and set the initial levels of the variables in the model. Statistical methods are used to determine the means and variances of data samples from the real world system. Probability functions are fitted to the data samples in order to assess the probability distributions for the stochastic variables. For some aspects of the model, the required data was neither available nor collectable. In those cases, the data was estimated by using the experience of people who are familiar with the operation. (Goossenaerts and Pels, 2009)

3.1 Regular and promotional demand

This section presents the key characteristics of the regular and promotional demand for Dry Food products within Metro.

3.1.1 Regular daily customer demand

The assumption that regular daily customer demand is normally distributed can be supported by regular daily sales data (see Appendix C1). Next to descriptive statistics and graphical methods, a nonparametric test of normality (Kolmogorov-Smirnov test) was used to determine whether an article’s daily sales volume is well-modeled by a normal distribution. After outlier removal, 67% of the articles were found normally distributed at a 0.01 significance level.

Recall paragraph 1.3 that a rule-of-thumb is often used by Metro to early-order the brochure articles that are planned to be placed on a head or square and to late-order the brochure articles that are planned to be placed on the shelves. This rule-of-thumb implicitly holds the assumption that the demand of head or square articles increases to a higher extent than shelf articles under promotion. Whether an article is a head or square article is not included in the model, since the lift factor variable is used as a more precise expression of the increase in demand under promotion. The implicit assumption of the rule-of-thumb appears to be true (Table 3.1), but one note should be made. There is a connection between the article’s regular sales volume and head or square placement during the brochure period. Metro more often puts fastmovers (i.e. articles with a high regular sales volume) on the promotion heads and squares during the brochure periods than slowmovers (i.e. articles with a low regular sales volume). See Appendix C2 for the analysis of this observation. Although slowmovers are less often placed on heads and squares, they are particularly subject to a higher LF when they are put on a head or square (Table 3.1). Fastmovers are more often placed on heads and squares, but this increases their LF less significantly. This observation shows that the rule-of-thumb is limited. A richer rule which includes more factors is potentially more effective.

| Table 3.1. Effects of regular demand and location on the lift-factor |
|---|---|
| Location | \( \text{Head or square} \) |
| Regular sales Low* | LF = 3.2 ± 0.52 (95\% conf.) | LF = 5.9 ± 1.22 (95\% conf.) |
| Regular sales High* | LF = 3.4 ± 0.52 (95\% conf.) | LF = 4.0 ± 1.06 (95\% conf.) |

* Articles with mean regular sales below the median value (33) are categorized as low; articles with mean regular sales above the median value are categorized as high.
The mean regular daily demand of Dry Food articles\(^1\) varies widely (Table 3.2). The coefficient of variation (CV) of regular daily demand is typically low. Approximately 80% of the articles have a CV ranging between 0.35 and 0.80, and the median CV value is approximately 0.5 (Appendix C3).

Given the fact that the variation of demand typically falls in a narrow range, only the mean regular daily customer demand will be taken as a multi-level input variable to the model. The standard deviation of demand can be computed using the median CV that belongs to the particular mean regular daily demand value. The mean regular daily demand is an easily recognized and usable characteristic of every article, which serves the goal of the simulation study to support Metro in its decision on OCT type for its articles.

For this reason, the mean regular daily customer demand is regarded as an important input variable and is set to three different levels (the corresponding standard deviation is put between brackets): 13 (6); 33 (15); 83 (46). These three parameters settings of the normally distributed demand lead to the generation of 1.51%, 1.39%, and 3.56% of negative demand values respectively. Since negative demand is not possible, the normal distribution has to be truncated at 0.

<table>
<thead>
<tr>
<th>Percentiles</th>
<th>5</th>
<th>10</th>
<th>25</th>
<th>50</th>
<th>75</th>
<th>90</th>
<th>95</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean daily</td>
<td>10.1</td>
<td>13.0</td>
<td>19.6</td>
<td>32.9</td>
<td>54.4</td>
<td>82.7</td>
<td>110.0</td>
</tr>
</tbody>
</table>

**3.1.2 Lift factor**

The Lift Factor \(LF\) is defined as the ratio of an article's sales during promotion to its sales during regular demand, and the Lift Factor value thereby indicates the relative increase in sales due to the promotion (Van Loo, 2006). In the analysis of the Lift Factor among Metro’s Dry Food articles (Appendix C4), the Lift Factor is computed according to the following expression (Van den Heuvel, 2009):

\[
LF_{a,i} = \frac{s_{a,i}}{\overline{s}_{a-5,a-1,i}}
\]

where \(LF_{a,i}\) denotes the Lift Factor of sales of product \(i\) in the 12-day promotion period \(a\) compared to the regular sales level, \(s_{a,i}\) denotes the sales of article \(i\) in the 12-day promotion period \(a\), and \(\overline{s}_{a-5,a-1,i}\) denotes the average 12-day sales of article \(i\) during 5 regular 12-day periods before promotion period \(a\). A histogram of the \(LF\) values is shown in Figure 3.1. The mean \(LF\) is 4 and the median is 3. Notice the long right tail of the distribution. Given the median value and the positive skew, the \(LF\) variable is set to two input levels: 3 and 6.

---

\(^1\) Dry Food articles that belong to Category A were analyzed. Category A articles make up 29% of all Dry Food articles and they jointly generate 80% of the total Dry Food sales volume in euros (ABC classification, see for instance Silver et al., 1998). Metro’s buyers tend to put their well-performing articles in the brochure for promotion in order to comply with turnover requirements, so Category B and C articles are not likely to become brochure articles.
3.2 Demand estimation

This section discusses forecast improvement and budget inaccuracy within Metro.

3.2.1 Budget inaccuracy

In the model, Budget Inaccuracy ($BI$) is the ratio of the actual occurring promotional demand until the first reorder delivery day to the budget value (recall paragraph 2.3). In practice, the budget is a forecast of the total brochure sales. Therefore, Budget Inaccuracy is measured in the real system as the ratio of the total brochure sales to the budget. It was found that normality of $BI$ can be assumed (see Appendix C5).

\[
BI = \frac{\text{sales}}{\text{budget}}
\]

Half of the $BI$ values fall within the first and third quartile values, 0.65 and 1.08. It was chosen to set the input levels of mean budget inaccuracy $\mu_{BI}$ as these first and third quartile values. The variances corresponding to these $BI$ values are determined based on the coefficient of variance of $BI$, $CV_{BI}$. The observed coefficient of variance is 0.39, and so $CV_{BI}=0.39$. This leads the corresponding standard deviations $\sigma_{BI}$ of respectively 0.25 and 0.42. In order to prevent unrealistically low or high budget values relative to the actual sales, the $BI$ distribution is truncated at 0.07 and 1.23, and at 0.10 and 2.06, for $\mu_{BI} = 0.65$ and $\mu_{BI} = 1.08$ respectively, which eliminates 1% of the generated values at both sides.

3.2.2 Forecast improvement

Based on conversations with several people within Metro, it is presumed that some forecast improvement occurs in practice. As was mentioned earlier, more recent data is available to the ordering person at the late (advance) order moment than at the early (advance) order moment. Moreover, Metro’s central buying department recently decided to more often adjust the prices of brochure articles only shortly before the brochure starts in response to competitor price setting.

The forecast improvement coefficient $\rho$ can theoretically be set to values between 0 (i.e. no forecast improvement) and 1 (i.e. perfect forecasting at the late order moment as $\sigma^2$ becomes zero). Unfortunately, the real value of $\rho$ in Metro’s situation cannot be estimated from the data that is consolidated in Metro’s information systems. The chosen coefficient levels allow for comparison of the situation without the existence of any forecast improvement to the situation where a moderately small effect of forecast improvement occurs.
improvement is assumed. The forecast improvement coefficient will be set at the following two values: \( \rho = 0 \) (i.e. no forecast improvement); \( \rho = 0.3 \) (i.e. small forecast improvement).

### 3.3 Ordering decisions and market mediation costs

This section discusses the input settings of the service level, and subsequently the parameters of the stockout costs and excess stock costs.

#### 3.3.1 Service level

Metro does not keep a record of its \( P_1 \) or \( P_2 \) customer service level\(^1\). Metro aims for not going out-of-stock under promotion in 98% of the cases (\( P_1 \) service level). However, it is questionable whether this service level is actually achieved in practice. \( SL_{\text{promo}} \) is set at two input levels: 0.98, which is the most likely case; and 0.8, which is less likely but allows for investigation of the effect of the service level.

There is no data available on the service level of the supplier’s inventory buffer. For ease of purpose, the supplier is assumed to have a fixed service level of 0.95.

#### 3.3.2 Costs of stockouts

In this simulation study, costs of stockouts will be solely based on lost profits. The long-term effects of stockouts on customer goodwill, which increases the real cost of stockouts, is hard to measure and will not be taken into account. Substitution effects (i.e. the customer buys a substitute article if he finds his first choice article to be sold out), which decreases the real cost of stockouts, are also neglected. These two effects are assumed to even each other out.

Profits per sold item during promotion of Dry Food articles were analyzed (see Appendix C6), based on the articles of four recent brochures. It was found that 50% of the profit values lie between the reasonably small range of €XXX to €XXX with €XXX as the median value. The first input level of \( c_{\text{OOS}} \) is set to 0.40. In paragraph 5.2.1, it will be found that \( c_{\text{OOS}} \) has a large effect on the outcome of the Reorder Criterion. It will therefore be set to a second input level of 2.50.

![Figure 3.3. Histogram of profit values](image)

#### 3.3.3 Costs of excess stock

The parameter of excess inventory costs \( c_{\text{excess}} \) is related to \( c_{\text{OOS}} \) through the setting of the service level [2]. \( c_{\text{excess}} \) is set to the input levels as shown in Table 3.3.

---

\(^1\) Metro uses a different method for service level measurement.
3.4 Physical costs

This section presents the physical cost parameters, i.e. the fixed costs of placing and receiving an order.

3.4.1 Costs of receiving an order

In Appendix C7, it was found that every multi-item order sent to a supplier got accounted a fixed cost of €XX (one half man-hour) due to tasks carried out after receiving the order (e.g. Goods Receiving and Accounts Payable). Early orders (i.e. brochure concept orders) currently compose of X items on average, whereas late orders (i.e. dispo orders) compose of Y items on average. This would lead to a fixed cost per item of €Z and €W for early and late orders respectively (Table 3.4). However, in order not to give a direct advantage to late ordering in this simulation study, the costs of receiving an order, $c_{\text{receive}}$, will be based on the average number of items on early orders and late orders combined, which is a more prudent assumption. Therefore, $c_{\text{receive}}$ is set to €V.

3.4.2 Costs of placing an order

Every multi-item order also consumes a certain amount of time for determining the order quantity and placing the order (see Appendix C7). Under OCT1, it is possible that a reorder is placed. This means the order person performs the ordering activities twice for the same article, consuming an extra amount of his time.

In Metro’s current situation, placing the early order consumes more time than the late order ($c_{\text{early}} > c_{\text{late}}$). This is caused by the methods used. For the early order, the brochure concept method is used, while for the late order, the dispo system is used. If Metro decides to redesign the brochure concept method, the labor costs for placing early orders, $c_{\text{early}}$, can be reduced (see Appendix C7). Two cases will therefore be evaluated: (1) early ordering is more time consuming than late ordering (i.e. the current situation; $c_{\text{early}} > c_{\text{late}}$), and (2) early and late ordering consume the same amount of time (i.e. the possible future situation; $c_{\text{early}} = c_{\text{late}}$). To differentiate these two cases, $c_{\text{late}}$ will be set to a fixed input level, and $c_{\text{early}}$ will have two input levels, one higher than and one equal to $c_{\text{late}}$. The first case unambiguously gives an advantage to OCT2 based on labor costs. The second case only gives a disadvantage to OCT1 if a reorder is placed.

The DF sales department and the ALC spend $XX$ hours on ordering activities per Brochure Concept. Given the average number of Dry Food articles per BC (328) and the assumed cost of a man-hour (€20), the high input level for $c_{\text{early}}$ is set to €V. It is projected that ordering through a redesigned early order method would save $YY$ hours per BC (see Appendix C7). This leads to the low input level for $c_{\text{early}}$ set to €W. Ordering through the dispo system is similarly time consuming, so $c_{\text{late}}$ is also set to €V.

---

### Table 3.3. Market mediation costs

<table>
<thead>
<tr>
<th></th>
<th>$SL_{\text{promo}}$</th>
<th>$c_{\text{excess}}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.4</td>
<td>0.98</td>
<td>0.008</td>
</tr>
<tr>
<td>0.4</td>
<td>0.8</td>
<td>0.10</td>
</tr>
<tr>
<td>2.5</td>
<td>0.98</td>
<td>0.051</td>
</tr>
<tr>
<td>2.5</td>
<td>0.8</td>
<td>0.625</td>
</tr>
</tbody>
</table>

### Table 3.4. Costs of receiving an order

<table>
<thead>
<tr>
<th></th>
<th>Average number of articles per order</th>
<th>Fixed costs per order</th>
<th>Fixed costs per article</th>
</tr>
</thead>
<tbody>
<tr>
<td>BC order</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dispo</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
### Table 3.5. Costs of placing an order

<table>
<thead>
<tr>
<th></th>
<th>Man-hours per BC</th>
<th>Average number of DF articles per BC</th>
<th>Man-hours per DF article on BC</th>
<th>Fixed cost of man-hour</th>
<th>Man-hour costs per article</th>
</tr>
</thead>
<tbody>
<tr>
<td>Current early order method</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Redesigned early order method</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### 3.5 Market share

For the majority of the Dry Food products, the 17 Metro stores combined sell only a few percent of the supplier's total sales volume. So Metro generally has a small market share. A discussion of Metro's market share can be found in Appendix C8. The market share factor $MS$ will be set to two input levels: $MS = 0.015$ (i.e. 1.5%); $MS = 0.1$ (i.e. 10%).

Note that the $MS$ level indicates the market share of the 17 Metro stores combined. The first input level is directly based on Metro's 1.5% market share in the Dutch supermarket business. The second input level is much higher than the findings on Metro’s market share indicate, but it is set this high to investigate the effect of high market share on supply risk.

### 3.6 Time frame

The time line shown in Figure 2.2 is based on the following:

- The budget is communicated to the supplier approximately 6 weeks before the brochure period.
- The early orders arrive approximately 4 weeks before the brochure period at the supplier.
- The late orders arrive in the last week before the brochure period starts at the supplier.
- The majority of the direct suppliers deliver each store only once a week (Figure 3.4).
- The suppliers have a fixed lead time. A leadtime of 3 to 5 days is most common (Figure 3.5).
- The brochure period generally lasts 12 days (2 weeks, closed on Sundays).

---

![Figure 3.4. Delivery days per week, Dry Food (direct) suppliers, store Amsterdam](image1.png)

![Figure 3.5. Leadtime in days, Dry Food (direct) suppliers, store Amsterdam](image2.png)
3.7 Review

This chapter showed how the real-world environment matches the model. A simple analysis of the correlation between the mean regular demand, the lift factor, and head or shelf placement proved the imprecision of the commonly used rule-of-thumb. Making the OCT type decision based on head or shelf placement only is too limited. Furthermore, it was shown that:

- Normality of demand can be assumed. It was also found that the variance of demand for Dry Food articles varies within a limited range. Additionally, the typical values for the lift factor of Dry Food articles under promotion were determined.

- Normality of budget inaccuracy can be assumed. Overestimation of budgets is more common than underestimation.

- No good sense of the magnitude of forecast improvement can be obtained. Two input values are taken for the forecast improvement coefficient, one for no improvement and one for a small improvement, in order to account for this deficiency.

- Not going out-of-stock is essential for promotion articles, so high service levels are common, justifying the use of a Newsvendor model. An additional lower input level for the service level is chosen to examine the effect of the variable.

- Metro’s market share is generally small. A second high input level for market share is chosen to examine the effect of the variable.

- Placing early orders is currently more expensive than placing late orders based on labor costs. It is decided to vary the costs of placing the early order, since the redesign of the early ordering method will potentially lead to a decrease in labor costs (recall the second research question). In addition, fixed input levels were determined for the costs of placing the late order, and for the costs of receiving an order.

- The time frame of the model matches the real-world situation.

Thus far, the conceptual model has been described and the current situation of Metro has been analyzed. The next chapter will describe the quantitative model. It will present the mathematical expressions which underlie the simulation model.
4 Mathematical model

The conceptual model of Chapter 2 is combined with the findings of Chapter 3 and translated into a quantitative model. This chapter presents the quantitative model. Paragraph 4.1 introduces the input variables. Paragraph 4.2 discusses the time frame. Paragraphs 4.3 and 4.4 respectively present the retailer’s and supplier’s steps. Paragraph 4.5 describes the performance evaluation, and paragraph 4.6 concludes the chapter with an overview.

4.1 Introduction

A large number of variables are included in the mathematical model. For a definition of all variables, a reference list is given in Appendix D1. Table 4.1 contains the multi-level input variables of the mathematical model on which analysis will be performed. Table 4.2 displays the fixed input variables and their values.

<table>
<thead>
<tr>
<th>Variable name</th>
<th>Label</th>
<th>Levels</th>
<th>Values</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean regular daily demand (and standard deviation)</td>
<td>μD (σD)</td>
<td>3</td>
<td>{13 (6), 33 (15), 83 (46)}</td>
</tr>
<tr>
<td>Lift factor of promotional demand</td>
<td>LF</td>
<td>2</td>
<td>{3, 6}</td>
</tr>
<tr>
<td>Mean budget inaccuracy</td>
<td>μBI</td>
<td>2</td>
<td>(0.65, 1.08)</td>
</tr>
<tr>
<td>Forecast improvement coefficient</td>
<td>ρ</td>
<td>2</td>
<td>{0, 0.3}</td>
</tr>
<tr>
<td>Market share of the retailer in the supplier’s article</td>
<td>MS</td>
<td>2</td>
<td>(0.015, 0.1)</td>
</tr>
<tr>
<td>Costs of placing an early order</td>
<td>cearly</td>
<td>2</td>
<td>XXX</td>
</tr>
<tr>
<td>Costs of stockouts (per item)</td>
<td>cOOS</td>
<td>2</td>
<td>{0.40, 2.50}</td>
</tr>
<tr>
<td>Service level for retailer’s promotional demand</td>
<td>SLpromo</td>
<td>2</td>
<td>{0.8, 0.98}</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Variable name</th>
<th>Label</th>
<th>Levels</th>
<th>Values</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coefficient of variance of budget inaccuracy</td>
<td>CVBI</td>
<td>1</td>
<td>{0.39}</td>
</tr>
<tr>
<td>Costs of receiving an order</td>
<td>crceive</td>
<td>1</td>
<td>XXX</td>
</tr>
<tr>
<td>Costs of placing a late order</td>
<td>clate</td>
<td>1</td>
<td>XXX</td>
</tr>
<tr>
<td>Service level of supplier’s inventory point for regular demand</td>
<td>SLpromo</td>
<td>1</td>
<td>{0.95}</td>
</tr>
</tbody>
</table>

4.2 Time frame

The time frame of the simulation experiment is fixed. It is clarified in Figure 4.1 and Figure 4.2. In Figure 4.1, the days before and during the brochure period are numbered. Number 1 indicates the first brochure period day, and negative numbers indicate the number of days before the brochure period starts. The same numbering is used on the timeline in Figure 4.2.

- On day -37 (6 weeks before the brochure period starts), the budget value $B_{t=-37}$ is communicated to the supplier.

- Under OCT1, on day -25, an actual order of $Q_{t=-25}$ is sent to the supplier. An extra order can be placed on day -6, i.e. $Q_{t=-6}$.

- Under OCT2, only on day -6, an actual order $Q_{t=-6}$ is sent to the supplier. $Q_{t=-25}=0$.

- At $t=-6$, the supplier releases the goods for transportation (i.e. no production is possible after $t=-6$).
- On day -3, the orders placed on day -25 and -6 get delivered at the retailer's stores. The time between t=-6 and t=-3 is composed of distribution time.

- The ordering and delivery schedule of the supplier for regular sales are respectively 0100000 and 0000100 (i.e. the retailer's stores can order on Tuesday for delivery on Friday). The supplier delivers from stock when following these schedules (i.e. the time between ordering and delivery is composed of distribution and transportation time only; it does not allow for any production).

- On day 1, it would be possible to place a reorder at the supplier according to the ordering schedule, but too little promotional demand has been observed to determine a reorder. On the next ordering day, day 7, enough demand has been observed, and a reorder is placed for delivery on day 10. The retailer aims to initially order enough inventory to at least satisfy demand until the first (and only) delivery day during the brochure period, day 10 (see the dashed blue line in Figure 4.2). The promotional demand from day 1 to day 10 is therefore the demand process under consideration.

![Figure 4.2. Time line](image)

### 4.3 Demand estimation and ordering decisions

#### 4.3.1 Demand processes

The store’s regular daily customer demand $D_{StoreRegDay}$ is normally distributed with on average $\mu_D$ and a standard deviation of $\sigma_D$:

$$D_{StoreRegDay} \sim N(\mu_D, \sigma_D)$$ \hspace{1cm} [11]

Under promotion, the store sells a factor $LF$ more. The store’s promotional daily demand (i.e. extra demand on top of the regular demand) is:

$$D_{StorePromoDay} \sim N((LF-1) \cdot \mu_D, \sqrt{LF-1} \cdot \sigma_D)$$ \hspace{1cm} [12]

The 16 other retailer’s stores combined have a similar demand process under regular and promotional sales:

$$D_{OtherStoresRegDay} \sim N(16 \cdot \mu_D, \sqrt{16} \cdot \sigma_D)$$ \hspace{1cm} [13]
The retailer’s market share in the article is equal to \( MS \) under regular sales. The competitor retailers sell \( 1-MS \) of the total article sales. These retailers only have regular daily demand, which in correspondence with their market share is:

\[
D_{\text{CompetitorsDay}} \sim N\left( 17 \cdot \frac{1-MS}{MS} \cdot \mu_D, \sqrt{17 \cdot \frac{1-MS}{MS} \cdot \sigma_D} \right)
\]

**4.3.2 Ordering decisions**

The store aims to initially order enough promotional inventory \( Q_{\text{promo}} \) to satisfy demand until the first (and only) reorder delivery at day 10 with a \( P_1 \) service level of \( SL_{\text{promo}} \). The total order quantity to satisfy this 10-day promotional demand is:

\[
Q_{\text{promo}} = Q_{t=-25} + Q_{t=-6}
\]

At \( t=-37 \), the central buying department estimates the 10-day promotional demand process for all 17 stores, and this leads to the budget value \( B_{t=-37} \). The budget is a sales forecast, which is sent to the supplier. At \( t=-25 \), the store’s estimation of the store’s demand process is:

\[
X_{D(t=-25)} \sim N(\mu_1, \sigma_1)
\]

Under OCT1, this estimation is used to determine the order quantity, while under OCT2, no order is placed:

\[
Q_{t=-25} = \begin{cases} \text{ } & \text{if OCT1} \uparrow \\ 0 & \text{if OCT2} \end{cases}
\]

where \( F_{t=-25}^{-1}() \) denotes the inverse of the cdf of \( X_{D(t=-25)} \).

The store utilizes information \( I \) observed between \( t=-25 \) and \( t=-6 \) to update the probability function of demand. It is assumed that:

\[
I \sim N(m, s)
\]

with \( m=\mu_1 \) and \( s=\sigma_1 \) (i.e. the store’s estimation of the demand process at \( t=-25 \) was right).

At \( t=-6 \), the store’s estimation of the demand process, \( X_{D(t=-6)} \), is equal to \( (X_{D(t=-25)}|I) \). It follows a bivariate normal distribution with means \( m \) and \( \mu_1 \), standard deviations \( s \) and \( \sigma_1 \), and the correlation coefficient \( \rho \) (\( 0 \leq \rho \leq 1 \)). It can be derived that \( X_{D(t=-25)} \) is also normally distributed:

\[
X_{D(t=-6)} \sim N(\mu_2, \sigma_2)
\]

with

\[
\mu_2 = \mu_1 + \rho \cdot \frac{(1-m)}{s} \cdot \sigma_1
\]

and

\[
\sigma_2 = \sigma_1 \cdot \sqrt{1-\rho^2}
\]

\[\uparrow\] Note that the \( Q_{t=-25} \) value under OCT1 can also be expressed as the expected 10-day demand (i.e. \( \mu_1 \)) plus a safety stock that satisfies demand under a \( P_1 \) service level of \( SL_{\text{promo}} \) (i.e. \( k_\alpha=\Phi^{-1}(SL_{\text{promo}}) \); \( \Phi^{-1}() \) denotes the inverse of the standard-normal cdf).
MATHEMATICAL MODEL

Given that \( m = \mu \) and \( s = \sigma \), we can rewrite [21] to:

\[
\mu_2 = \mu_1 + \rho \cdot (1 - \mu_1) \quad \text{[23]}
\]

This estimation of demand is used to determine the order quantity \( Q_{t=-6} \) as follows:

\[
Q_{t=-6} = \begin{cases} 
0 & \text{if OCT1 and reorder criterion not satisfied} \\
F_{t=-6}^{-1}(SL_{\text{prom}}) - Q_{t=-25} & \text{if OCT1 and reorder criterion satisfied} \\
F_{t=-6}^{-1}(SL_{\text{prom}}) & \text{if OCT2}
\end{cases} \quad \text{[24]}
\]

where \( F_{t=-6}^{-1}(\cdot) \) denotes the inverse of the cdf of \( X_{D(t=-6)} \). The reorder criterion is:

\[
(c_{\text{QOS}} + c_{\text{excess}}) \cdot \sigma_2 \cdot \left[ G(K) - G(k_e) \right] + c_{\text{excess}} \cdot \left( \mu_1 - \mu_2 + k_e \cdot (\sigma_1 - \sigma_2) \right) - c_{\text{receive}} - c_{\text{late}} > 0 \quad \text{[25]}
\]

with \( K = \frac{F_{t=-25}(SL_{\text{prom}}) - \mu_2}{\sigma_2} \), and \( G(x) = \frac{1}{\sqrt{2\pi}} \int_{-\infty}^{x} (z-x) \exp \left( -\frac{1}{2} z^2 \right) dz \).

Appendix D4 contains the derivation of the reorder criterion. Combining [16], [18], and [24] gives:

\[
Q_{\text{promo}} = \begin{cases} 
F_{t=-25}^{-1}(SL_{\text{prom}}) & \text{if OCT1 and reorder criterion not satisfied} \\
F_{t=-6}^{-1}(SL_{\text{prom}}) & \text{if OCT1 and reorder criterion satisfied} \\
F_{t=-6}^{-1}(SL_{\text{prom}}) & \text{if OCT2}
\end{cases} \quad \text{[26]}
\]

Appendix D3 explains the computation steps to obtain the other stores’ promotion order quantity \( Q_{\text{promo}^*} \), which are similar to the computation steps for the focus store.

**4.3.3 Occurring demand and budget inaccuracy**

The actual occurring promotional demand during the first 10 days of the brochure period is:

\[
D_{\text{StorePromo10Day}} \sim N(\mu_2, \sigma_2) \quad \text{[27]}
\]

The other stores encounter the same forecast improvement (i.e. same \( \rho \)) as the focus store. The demand parameters for the other stores are generated similarly (Appendix D3), leading to:

\[
D_{\text{OtherStoresPromo10Day}} \sim N(\mu_2^*, \sigma_2^*) \quad \text{[28]}
\]

\( BI \) is expressed as the ratio of the actual occurring promotional demand during the first 10 days of the brochure period \( D_{\text{StorePromo10day}} + D_{\text{OtherStoresPromo10day}} \) to the budget value \( B_{t=-37} \), and so it holds that:

\[
B_{t=-37} = \frac{D_{\text{StorePromo10day}} + D_{\text{OtherStoresPromo10day}}}{BI} \quad \text{[29]}
\]

where

\[
BI \sim N(\mu_{BI}, \sigma_{BI}) \quad \text{[30]}
\]

with:

\[
\sigma_{BI} = \mu_{BI} \cdot CV_{BI} \quad \text{[31]}
\]

†† Similar to the \( Q_{t=-25} \) value under OCT1, \( Q_{t=-6} \) under OCT2 also consists of the expected 10-day demand (i.e. \( \mu_2 \)) plus a safety stock that satisfies demand under a \( P \) service level of \( SL_{\text{prom}} \) (i.e. \( k_e \sigma_2 \)). Also note that the reorder criterion, which must be satisfied to place a reorder at \( t = -6 \) under OCT1, ensures that the costs of placing a reorder do not outweigh the costs that incur if no reorder is placed. For a derivation of this criterion, see Appendix D4.
4.3.4 Discrete simulation steps of the retailer

Here is an overview of the discrete steps of the retailer.

The parameters of the store’s demand estimation at t=-25 are set to:

\[
\begin{align*}
\mu_1 &= 10 \cdot (LF - 1) \cdot \mu_D \\
\sigma_1 &= \sqrt{10 \cdot (LF - 1) \cdot \sigma_D / \sqrt{1 - \rho^2}}
\end{align*}
\]

The mean of the store’s demand estimation at t=-6 can be generated given [19], [23], and [32], and the standard deviation can be computed given [22]:

\[
\begin{align*}
\mu_2 &= \mu_1 + \rho \cdot (l - \mu_1) \\
\sigma_2 &= \sqrt{10 \cdot (LF - 1) \cdot \sigma_D}
\end{align*}
\]

A value for the 10-day promotional demand variable \(D_{StorePromo10day}\) is generated using [27], [34], and [35].

\(Q_{promo}\) is calculated using [26].

All steps above are similarly repeated for the other retailer’s stores, leading to \(Q_{otherPromo10day}\) and \(D_{OtherStoresPromo10day}\) (Appendix D3).

Given [30], a BI value can be generated. This leads to a budget value using [29].

Note that the model incorporates the forecast improvement by increasing the standard deviation of the early demand forecast, \(\sigma_1\), instead of decreasing the standard deviation of the late demand forecast, \(\sigma_2\) (see Table 4.3), in order to generate the actual occurring demand \(D_{StorePromo10day}\) with identical parameters for both situations. Under \(\rho = 0.3\), \(\sigma_1\) is 4.8% higher than \(\sigma_2\).

<table>
<thead>
<tr>
<th>Forecast improvement</th>
<th>Standard deviation of early demand forecast</th>
<th>Standard deviation of late demand forecast</th>
<th>Results</th>
</tr>
</thead>
<tbody>
<tr>
<td>(\rho = 0)</td>
<td>(\sigma_1)</td>
<td>(\sigma_2)</td>
<td>(\sigma_1 = \sigma_2)</td>
</tr>
<tr>
<td>(\rho &gt; 0)</td>
<td>(\sigma_1 \uparrow)</td>
<td>(\sigma_2)</td>
<td>(\sigma_1 &gt; \sigma_2)</td>
</tr>
</tbody>
</table>

4.4 The supplier’s production and inventory management

According to the delivery schedule, the supplier delivers once a week (i.e. once every 6 days) to the retailer’s stores and to the competitor retailers. Regular daily demand expressions [11], [13], and [15] can be translated to regular weekly demand at the supplier as follows:

\[
\begin{align*}
D_{StoreRe\_gWeek} &\sim N\left(6 \cdot \mu_D, \sqrt{6} \cdot \sigma_D\right) \\
D_{OtherStoresRe\_gWeek} &\sim N\left(6 \cdot 16 \cdot \mu_D, \sqrt{6 \cdot 16} \cdot \sigma_D\right) \\
D_{Competitors\_Week} &\sim N\left(6 \cdot 17 \cdot \frac{1 - MS}{MS} \cdot \mu_D, \sqrt{6 \cdot 17 \cdot \frac{1 - MS}{MS}} \cdot \sigma_D\right) \\
D_{TotalRe\_gWeek} &\sim N\left(\mu_{TotalRe\_gWeek}, \sigma_{TotalRe\_gWeek}\right)
\end{align*}
\]
where \( \mu_{\text{Total RegWeek}} = 102 \frac{MS}{\mu} \) and \( \sigma_{\text{Total RegWeek}} = \sqrt{\frac{102}{MS}} \sigma_D \).

**4.4.1 Starting inventory level**

The starting inventory level of the inventory point right before order release at \( t=-6 \), \( I_{t=-6} \), consists of a safety stock plus the mean regular demand:

\[
I_{t=-6} = k_\beta \cdot \sqrt{\frac{102}{MS}} \sigma_D + \frac{102}{MS} \mu_D
\]  

where \( k_\beta \) denotes the safety factor to achieve the service level of \( SL_{\text{inv}} \). i.e. \( k_\beta = \Phi^{-1}(SL_{\text{inv}}) \), where \( \Phi^{-1}(.). \) denotes the inverse of the standard-normal cdf.

**4.4.2 Setting of production capacity**

Production rate \( c_1 \) makes up a base promotion production capacity expressed as (recall Figure 2.7):

\[
\text{base promotion production capacity} = \int_{-37}^{6} c_1 = 31 \cdot c_1
\]  

Production rate \( c_2 \) makes up a flexible promotion production capacity expressed as:

\[
\text{flexible promotion production capacity} = \int_{-37}^{6} (c_2 - c_1) = 19 \cdot (c_2 - c_1)
\]  

After receiving the budget value at \( t=-37 \), the supplier plans its production by setting the values of \( c_1 \) and \( c_2 \). The supplier knows (1) the budget value \( B_{t=-37} \), (2) the typical variance of customer demand for the supplier’s products at the retailer’s stores \( CV_D \) (3) the safety factor that the retailer uses when ordering \( k_\alpha \), and (4) the distribution and parameters of the retailer’s budget inaccuracy \( BI \sim N(\mu_{BI}, \sigma_{BI}) \) (recall paragraph 2.6.2).

The value of \( c_1 \) is based on the presumption that the budget value is true. Under that presumption, the retailer will order \( B_{t=-37} + k_\alpha \cdot (CV_D \cdot B_{t=-37}) \). The value of \( c_1 \) is therefore set as follows:

\[
c_1 = \frac{B_{t=-37} + k_\alpha \cdot CV_D \cdot B_{t=-37}}{31}
\]  

Under OCT1, a value for \( c_2 \) is set. The value of \( c_2 \) is based on the budget value as well, but it also accounts for budget inaccuracy. Given the budget inaccuracy, the supplier expects the retailer to order \( \mu_{BI} \cdot (B_{t=-37} + k_\alpha \cdot (CV_D \cdot B_{t=-37})) \) with a standard deviation of \( \sigma_{BI} \cdot (B_{t=-37} + k_\alpha \cdot (CV_D \cdot B_{t=-37})) \). The value of \( c_2 \) is therefore set as follows:

\[
c_2 = \frac{\mu_{BI} \cdot (B_{t=-37} + k_\alpha \cdot CV_D \cdot B_{t=-37}) + k_\beta \cdot \sigma_{BI} \cdot (B_{t=-37} + k_\alpha \cdot CV_D \cdot B_{t=-37}) - 12 \cdot c_1}{19}
\]

where \( k_\beta = \Phi^{-1}(SL_{\text{inv}}) \).
Recall that the $c_2$ production rate involves a reservation of capacity that will only be addressed if necessary (i.e. after receiving committed orders). The value of $c_2$ increases over $\mu_{Bl}$ (i.e. more flexible capacity in case of underestimated budgets), while $c_1$ is unaffected by $\mu_{Bl}$. Figure 4.3 shows the relation between the relative amount of flexible promotion production capacity (i.e. $(c_2 - c_1)/c_1 \cdot 100\%$) and $\mu_{Bl}$. For values of $\mu_{Bl}$ lower than 0.556, the $c_2$ value is set lower than the $c_1$ value which is impossible. However, $\mu_{Bl}$ values of lower than 0.556 will not be used as input to this simulation model. For the $\mu_{Bl}$ values used in this simulation study, 0.65 and 1.08, the relative flexible promotion production capacity is 28% and 154% respectively.

### 4.4.3 Promotion production quantity

The values for $c_1$ and $c_2$ have been determined. The promotion production quantity $p$ can be expressed as follows:

$$
\begin{align*}
    p &= \begin{cases}
        12 \cdot c_1 + 19 \cdot \min \left[ c_2; \max \left( 0; \frac{Q_{t=-25} + Q'_{t=-25} - 12 \cdot c_1}{19} \right) \right] & \text{OCT1} \\
        31 \cdot c_1 & \text{OCT2}
    \end{cases}
\end{align*}
$$

where $Q_{t=-25} + Q'_{t=-25}$ indicates the promotional order quantities from all 17 stores sent to the supplier at $t=-25$.

### 4.4.4 Discrete simulation steps of the supplier

Here is an overview of the discrete steps of the supplier.

- **$t=-37$ Budget receipt $B_{t=-37}$**
  - Determine $c_1$ (both OCT types) and determine $c_2$ (OCT2 only) using [43] and [44].
  - Start production with production rate $c_1$.

- **$t=-25$ Order receipt $Q_{t=-25}$ and $Q'_{t=-25}$ (OCT1 only)**
  - Adjust production rate for $t=-25$ until $t=-6$ based on $Q_{t=-25} + Q'_{t=-25}$.

- **$t=-6$ Order receipt $Q_{t=-6}$ and $Q'_{t=-6}$ and goods release (both OCT types)**
  - No production is possible anymore. The value of $p$ is computed using [45].
  - Release the goods for regular orders from the retailer’s stores and the competitor retailers (regular orders have priority). Then, release the goods for the retailer’s promotion.
The quantity that the store will receive for its promotion is $Q_{\text{promo, receive}}$. Figure 4.4 displays the rationale for determining $Q_{\text{promo, receive}}$. $Q_{\text{promo, receive}}$ depends on:

- The promotion production quantity $p$ compared to the total promotion order quantity of the focus store and the other stores $Q_{\text{promo}} + Q'_{\text{promo}}$. If enough was produced for the retailer’s promotion, the focus store will receive its order quantity $Q_{\text{promo}}$ fully.

- The inventory point’s inventory level $I_{t=-6}$ and the total regular demand $D_{\text{Total Reg Week}}$. If the inventory point has excess stock after satisfying the regular demand, the excess stock can be allocated to the retailer’s stores.

- If the promotion production quantity was insufficient to satisfy the promotion order quantities from all stores and if the inventory point does not have enough stock available to fully fill up this gap, an allocation method is used to allocate the inventory to the retailer’s stores. The Fair Share rationing rule (Eppen & Schrage, 1981) is used, which minimizes the difference in stock-out probability between the focus store and the 16 other stores under the constraint that allocation quantities can not be negative.

\[
\begin{align*}
Q_{\text{promo, receive}} = Q_{\text{promo}} & \text{ if } p \geq Q_{\text{promo}} + Q'_{\text{promo}} \text{ and } I_{t=-6} - D_{\text{Total Reg Week}} + p - Q_{\text{promo}} - Q'_{\text{promo}} \geq 0 \\
Q_{\text{allocation to store}} = Q_{\text{allocation to store}} & \text{ where } Q_{\text{allocation to store}} \text{ is such that} \\
p^* D_{\text{StorePromo10day}} < Q_{\text{allocation to store}} \text{ and } p + (I_{t=-6} - D_{\text{Total Reg Week}}) + Q_{\text{allocation to store}} = D_{\text{OtherStoresPromo10day}} < Q_{\text{allocation to store}}
\end{align*}
\]

**Figure 4.4. Calculation of quantity received $Q_{\text{promo, receive}}$**

### 4.5 Performance evaluation

The stockout quantity at the end of day 10 is denoted as $Q_{\text{OOS}}$, the excess stock quantity as $Q_{\text{excess}}$, the occurrence of an order at $t = -25$ as $Q_{\text{early}}$, and the occurrence of an order at $t = -6$ as $Q_{\text{late}}$. The total costs $TC$ are expressed as:

\[
TC = Q_{\text{OOS}} \cdot c_{\text{OOS}} + Q_{\text{excess}} \cdot c_{\text{excess}} + O_{\text{early}} \cdot (c_{\text{receive}} + c_{\text{early}}) + O_{\text{late}} \cdot (c_{\text{receive}} + c_{\text{late}})
\]

where:

\[
\begin{align*}
Q_{\text{OOS}} &= (D_{\text{StorePromo10day}} - Q_{\text{promo, receive}}) \times \\
Q_{\text{excess}} &= (Q_{\text{promo, receive}} - D_{\text{StorePromo10day}}) \times \\
O_{\text{early}} &= \begin{cases} 1 & \text{if OCT 1} \\ 0 & \text{if OCT 2} \end{cases} \\
O_{\text{late}} &= \begin{cases} 1 & \text{if OCT 1 and reorder criterion not satisfied} \\ 0 & \text{if OCT 1 and reorder criterion satisfied} \end{cases}
\end{align*}
\]
4.6 Review

This chapter presented the mathematical expressions which underlie the simulation model. Appendix D2 presents an overview of the expressions. Figure 4.5 displays the simulation flow diagram. The diagram shows all simulation steps in subsequent order.

**Figure 4.5. Simulation flow diagram**

### 4.6.1 Verification and validation

Validation of the mathematical model involves determining whether it is an accurate representation of reality. This can be done by comparing its output to that of the existing situation, and by demonstrating it to the people who know the system (Goossenaerts and Pels, 2009). The first was not possible, because not all of the required data for this purpose can be consolidated from Metro’s information systems. The model was validated by demonstrating it to people who know the real-world system, which included some of Metro’s buyers and four of Metro’s Dry Food suppliers.

The mathematical model described in this chapter is a platform independent model. It was translated to an executable model using Microsoft Excel and the programming language Visual Basic. While building the platform specific model, it was continuously checked whether the mathematical model was correctly being translated into an executable model (i.e. verification) by running the simulation using different settings of input and checking the output, and by looking at the trace of the simulation program.

The resulting Excel-based tool is easy to use and it has a straightforward interface. For an impression of the simulation control interface, see Appendix D5. The next chapter discusses the main results of the simulation study performed with the input levels given in paragraph 4.1.
5 Simulation analysis and conclusions

This chapter presents the main results of the simulation study. Paragraph 5.1 describes the experimental design. Paragraphs 5.2 and 5.3 subsequently discuss the absolute performance and the relative performance based on physical costs, market mediation costs, and total costs. In paragraph 5.4, two additional performance statistics are discussed. The main conclusions are summarized in paragraph 5.5.

5.1 Experimental design

An experiment is a unique combination of the input variable levels as shown in Table 4.1. 384 experiments are performed for both OCT1 and OCT2. A unique OCT–experiment combination is referred to as a scenario. The 768 scenarios are replicated 4000 times (paragraph 5.1.2). In order to compare the performance of the two OCT types, both OCT types are subject to the same generated input levels of the stochastic variables in every replication of an experiment. Table 5.1 depicts the standard experimental setup.

<table>
<thead>
<tr>
<th>Experiment</th>
<th>Replication</th>
<th>(n)</th>
</tr>
</thead>
<tbody>
<tr>
<td>OCT1</td>
<td>1</td>
<td>y(<em>{OCT1,11}) y(</em>{OCT1,12}) \ldots y(_{OCT1,n})</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>y(<em>{OCT1,21}) y(</em>{OCT1,22}) \ldots y(_{OCT1,2n})</td>
</tr>
<tr>
<td>OCT2</td>
<td>1</td>
<td>y(<em>{OCT2,11}) y(</em>{OCT2,12}) \ldots y(_{OCT2,1n})</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>y(<em>{OCT2,21}) y(</em>{OCT2,22}) \ldots y(_{OCT2,2n})</td>
</tr>
</tbody>
</table>

5.1.1 Performance variables

Absolute and relative performance can be distinguished. Absolute performance is defined as the performance variable outcome for a particular scenario. Relative performance is aimed at direct comparison of OCT1 and OCT2 through subtracting the performance variable outcome under OCT2 from the outcome under OCT1 for a particular experiment.

Performance is expressed in terms of costs. Total costs (TC) consist of Physical Costs (PC) and Market Mediation Costs (MMC). As will be found in paragraph 5.2.1, PC can take on only a limited set of values and is mainly dependent on the outcome of the Reorder Criterion. Relative performance in terms of PC, \(\Delta PC\), is very straightforward and will not be thoroughly discussed.

MMC depends on the stockout quantity \(Q_{OOS}\) and the excess stock quantity \(Q_{excess}\). MMC can virtually take on every real number, and as a consequence, the same holds for TC. For this reason, both absolute and relative performance variables w.r.t. MMC and TC are evaluated in detail. Absolute performance is evaluated based on the expected stockout quantity, the expected excess stock quantity, and the expected total costs: \(E[Q_{OOS}]\), \(E[Q_{excess}]\) and \(E[TC]\) respectively. Their relative performance is evaluated as follows. In every replication of an experiment, both scenarios (i.e. OCT1 and OCT2) are subject to the same generated...
input levels of the random variables, and directly compared by (1) $\Delta Q_{OOS} = Q_{OOS,OCT1} - Q_{OOS,OCT2}$, (2) $\Delta Q_{excess} = Q_{excess,OCT1} - Q_{excess,OCT2}$, and (3) $\Delta TC = TC_{OCT1} - TC_{OCT2}$. Then, for every experiment, the relative performance is evaluated based on the following performance variables:

<table>
<thead>
<tr>
<th>Stockout quantity</th>
<th>Excess stock quantity</th>
<th>Total costs</th>
</tr>
</thead>
<tbody>
<tr>
<td>$E[\Delta Q_{OOS}]$</td>
<td>$E[\Delta Q_{excess}]$</td>
<td>$E[\Delta TC]$</td>
</tr>
<tr>
<td>$P[\Delta Q_{OOS}&gt;0]$</td>
<td>$P[\Delta Q_{excess}&gt;0]$</td>
<td>$P[\Delta Q_{excess}&gt;0]$</td>
</tr>
<tr>
<td>$E[\Delta Q_{OOS}</td>
<td>\Delta Q_{OOS}&gt;0]$</td>
<td>$E[\Delta Q_{excess}</td>
</tr>
<tr>
<td>$P[\Delta Q_{OOS}&lt;0]$</td>
<td>$P[\Delta Q_{excess}&lt;0]$</td>
<td>$P[\Delta Q_{excess}&lt;0]$</td>
</tr>
</tbody>
</table>

where $E[X]$ denotes the expectancy of variable $X$, $P[Y]$ denotes the probability of argument $Y$ being true, and $E[X|Y]$ denotes the expectancy of variable $X$ given that argument $Y$ is true. Their mathematical expressions are given in Appendix E1. Note that positive values for $\Delta Q_{OOS}$, $\Delta Q_{excess}$, and $\Delta TC$ are in favor of OCT2, while negative values are in favor of OCT1.

In addition to performance evaluation based on costs, the supply shortage and excess stock at the supplier are evaluated. Expressions for the supply shortage probability $SSP$ and the expected excess stock quantity at the supplier $E[Q_{excess,supplier}]$ are given in Appendix E1.

### 5.1.2 Law’s criterion

The experiments are set up in way that valid conclusions can be obtained in an efficient way. As it will be a terminating simulation, there will not be a warm-up period and the run length of a replication is predetermined. However, it has to be determined how many replications per experiment are required in order to display results at a certain confidence level. Replication is defined as executing the same experiment a number of times, but with different random numbers in each run. An approach for determining the number of replications required to ascertain a relative degree of error between the estimated mean and the true mean of a performance indicator is given by Law (2007). Law presents a sequential procedure in which the number of replications are increased one-by-one until the $100(1-\alpha)\%$ confidence-interval half-length divided by the estimate of the mean is equal to or less than the relative error:

$$\frac{t_{n-1,1-\alpha/2} \sqrt{s^2(n)}}{n} \leq \gamma' \quad \text{with} \quad \gamma' = \frac{\gamma}{1+\gamma} \quad [51]$$

where $n$ is the number of replications, $\bar{X}(n)$ is the estimated mean, $s^2(n)$ is the estimated variance, $\gamma$ is the relative error, and $t_{n-1,1-\alpha/2}$ is taken from the $t$-distribution. The procedure assumes that the mean and variance are converging over an increasing number of replications.

The procedure was applied to the variables $Q_{OOS}$, $Q_{excess}$, $TC$, $\Delta Q_{OOS}$, $\Delta Q_{excess}$, and $\Delta TC$ for $\alpha=0.1$ and $\gamma=0.1$ (Appendix E2). Due to the low probability of stockout occurrence, $Q_{OOS}$ and especially $\Delta Q_{OOS}$ require an
incredibly large number\(^1\) of replications in order to let their variance converge enough to satisfy Law’s criterion. Nonetheless, the number of replications is set to 4000, since more replications would be unrealistic. Under 4000 replications, all of the experiments comply with Law’s criterion w.r.t. \(TC\), and most of the experiments comply w.r.t. \(\Delta TC\).

### Table 5.2. Input variables with significant effects on the performance variables

<table>
<thead>
<tr>
<th>Performance variable</th>
<th>Significant input variables</th>
<th>OCT1</th>
<th>OCT2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Absolute</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(E[Q_{oos}])</td>
<td>(\mu_D, LF, SL_{prom}, \rho)</td>
<td>(\mu_D, LF, SL_{prom}, \mu_D, MS)</td>
<td></td>
</tr>
<tr>
<td>(E[Q_{excess}])</td>
<td>(\mu_D, LF, SL_{prom}, \rho)</td>
<td>(\mu_D, LF, SL_{prom}, \mu_D)</td>
<td></td>
</tr>
<tr>
<td>(E[TC])</td>
<td>(\mu_D, LF, SL_{prom}, CO)</td>
<td>(\mu_D, LF, SL_{prom}, CO, \mu_D)</td>
<td></td>
</tr>
<tr>
<td>SSP</td>
<td>(\mu_D, SL_{prom}, \mu_D, \rho)</td>
<td>(\mu_D, LF, SL_{prom}, \mu_D, MS)</td>
<td></td>
</tr>
<tr>
<td>(E[Q_{excess_supp}])</td>
<td>(\mu_D, LF, SL_{prom}, \mu_D, \rho)</td>
<td>(\mu_D, LF, SL_{prom}, \mu_D)</td>
<td></td>
</tr>
</tbody>
</table>

| Relative             |                             |      |      |
| Absolute             |                             |      |      |
| \(E[\Delta Q_{oos}]\) | \(\mu_D, LF, \mu_D, MS, SL_{prom}\) |
| \(E[\Delta Q_{excess}]\) | \(\mu_D, LF, \mu_D, CO, \mu_D, \mu_D, SL_{prom}\) |
| \(E[\Delta TC]\)     | \(\mu_D, LF, \mu_D, \mu_D, MS, CO, \mu_D, SL_{prom}\) |
| \(\Delta SSP\)       | \(\mu_D, LF, SL_{prom}, \rho, \mu_D, MS\) |
| \(E[\Delta Q_{excess_supp}]\) | \(\mu_D, LF, SL_{prom}, \mu_D\) |

### 5.2 Absolute performance

This paragraph discusses the effects of the model variables on performance in absolute terms. Section 5.2.1 focuses on Physical Costs. Section 5.2.2 describes the effects on Market Mediation Costs and Total Costs. Appendix F contains the results of the performed statistical analyses for more clarification.

#### 5.2.1 Physical costs and the Reorder Criterion

The possible outcome values for Physical Costs (PC) are limited (Table 5.3). Under OCT2, only a late order is placed \(O_{\text{early}}=0; O_{\text{late}}=1\). Under OCT1, an early order is placed \(O_{\text{early}}=1\) and a reorder can be placed dependent on whether the Reorder Criterion (RC) gets satisfied \(O_{\text{late}}=1\) if RC gets satisfied, \(O_{\text{late}}=0\) if RC does not get satisfied. \(\Delta PC\), defined as the PC value under OCT1 minus the PC value under OCT2, is therefore affected by the setting of the physical cost parameters \(c_{\text{receive}}, c_{\text{early}}, \text{and } c_{\text{late}}\) as well as by the outcome of the RC. Given that \(c_{\text{early}}\) is the only 2-level physical cost parameter (i.e. the others are fixed to one level), \(\Delta PC\) can only have four different outcome values (Figure 5.1). All outcome values are either in favor of OCT2, or indifferent toward both.

### Table 5.3. Possible outcome values for PC and \(\Delta PC\)

<table>
<thead>
<tr>
<th>RC</th>
<th>(c_{\text{early}})</th>
<th>(PC_{\text{OCT1}})</th>
<th>(PC_{\text{OCT2}})</th>
<th>(\Delta PC)</th>
</tr>
</thead>
<tbody>
<tr>
<td>satisfied</td>
<td>(\bullet)</td>
<td>(\bullet)</td>
<td>(\bullet)</td>
<td>(\bullet)</td>
</tr>
<tr>
<td>not satisfied</td>
<td>(\bullet)</td>
<td>(\bullet)</td>
<td>(\bullet)</td>
<td>(\bullet)</td>
</tr>
</tbody>
</table>

---

\(^1\) After 50,000 replications, variable \(\Delta Q_{oos}\) does still not satisfy Law’s criterion under all experiments. More replications were not tried.


**Figure 5.1. Possible outcomes for Physical Costs**

**Expectancy and probability of the Reorder Criterion**

The Reorder Criterion (RC) was expressed in [25]. The left side of expression [25] should be positive to satisfy the criterion. For a given setting of \( \text{OOS, } \mu_0, \text{ LF, } \rho, \text{ SL}_{\text{proma}}, c_{\text{receive}}, \text{ and } c_{\text{late}}, \) the expectancy of the Reorder Criterion \( E[\text{RC}] \) equals:

\[
E[\text{RC}] = (c_{\text{OOS}} + c_{\text{excess}}) \cdot \sigma_2 \left[ G(K) - G(k_{\alpha}) \right] + c_{\text{excess}} \cdot \left( k_{\alpha} \cdot (\sigma_1 - \sigma_2) \right) - c_{\text{receive}} - c_{\text{late}}
\]

\[ (52) \]

with \( K = \frac{k_{\alpha} \cdot \sigma_1}{\sigma_2} \).

Perhaps even more important than the expectancy of the Reorder Criterion, is the probability that the Reorder Criterion gets satisfied under a given setting of the variables. The probability of \( \text{RC}>0 \) is denoted as \( P[\text{RC}>0] \). For a given setting of \( \text{OOS, } \mu_0, \text{ LF, } \rho, \text{ SL}_{\text{proma}}, c_{\text{receive}}, \text{ and } c_{\text{late}}, P[\text{RC}>0] \) equals:

\[
P[\text{RC}>0] = P \left[ \left( c_{\text{OOS}} + c_{\text{excess}} \right) \cdot \sigma_2 \left[ G(K) - G(k_{\alpha}) \right] + c_{\text{excess}} \cdot \left( \mu_1 - \mu_2 + k_{\alpha} \cdot (\sigma_1 - \sigma_2) \right) - c_{\text{receive}} - c_{\text{late}} > 0 \right]
\]

\[ (53) \]

with \( K = \frac{\mu_1 + k_{\alpha} \cdot \sigma_1 - \mu_2}{\sigma_2} \).

\( E[\text{RC}] \) is deterministic for a given setting of the variables. \( P[\text{RC}>0] \) is not deterministic, as it depends on the random variable \( \mu_2 \). Appendix F1 shows the results of the analysis of the variables' effects on the values of \( E[\text{RC}] \) and \( P[\text{RC}>0] \), where \( P[\text{RC}>0] \) was computed over 4000 drawings of \( \mu_2 \). The analysis revealed that (1) all variables have significant effects on \( E[\text{RC}] \) and \( P[\text{RC}>0] \), (2) \( \rho, \text{OOS, } \text{ and } \text{SL}_{\text{proma}} \) are the most influential variables on the outcome of the RC (Table 5.4), (3) the breakeven values of \( \text{OOS, } \mu_0, \text{ creceive} \)

---

1 The Reorder Criterion (RC) itself is of the form 'expression > 0'. For ease of purpose, the 'expression' will be referred to as the Reorder Criterion, and the expectancy of the expression will therefore be denoted as \( E[\text{RC}] \).

2 These are the required input variables for computation of the Reorder Criterion. \( c_{\text{excess}}, k_{\alpha}, \mu_1, \sigma_1, \text{ and } \sigma_2 \) can be computed from these variables, and \( \mu_2 \) can be generated as a random number.
and $c_{\text{late}}$ for which $E[\text{RC}]=0$ can be algebraically derived given a fixed setting of all other variables (Table 5.4 and Figure 5.2), and (4) the value of the RC is deterministic when $\rho=0$:

$$RC_{\rho=0} = -c_{\text{receive}} - c_{\text{late}} \Rightarrow E[\text{RC}]_{\rho=0} = -c_{\text{receive}} - c_{\text{late}} \land P[\text{RC}>0]_{\rho=0} = 0$$

i.e. the Reorder Criterion can never be satisfied.

**Table 5.4. Effects of variables on RC**

<table>
<thead>
<tr>
<th>Effect</th>
<th>E[RC]</th>
<th>P[RC&gt;0]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Linear</td>
<td>Nonlinear</td>
<td>Nonlinear</td>
</tr>
<tr>
<td>Large effects</td>
<td>$c_{\text{OOS}}$</td>
<td>$\rho, S_{\text{SL,promo}}$</td>
</tr>
<tr>
<td>Moderate effects</td>
<td>$\mu$</td>
<td></td>
</tr>
<tr>
<td>Small effects</td>
<td>$c_{\text{receive}}, c_{\text{late}}$, LF</td>
<td>LF, $c_{\text{receive}}, c_{\text{late}}$</td>
</tr>
</tbody>
</table>

**Figure 5.2. Linearity of E[RC] in $c_{\text{OOS}}$ for five different settings of other variables**

**Reorder Criterion exploration tool**

The Reorder Criterion is dependent on the setting of multiple input variables. A simple Excel-based tool was developed which provides insight into the behavior of the Reorder Criterion under user-defined input variables. Since $P[\text{RC}>0]$ was found to be non-deterministic due to randomness of $\mu_2$, the tool draws 4000 $\mu_2$-values.

**The user’s input consists of:**
- setting of values for the input variables, i.e. $c_{\text{OOS}}, \mu, LF, \rho, S_{\text{SL\,promo}}, c_{\text{receive}}, \text{ and } c_{\text{late}}$,
- selection of two of the input variables for further examination of their effect, and
- specification of the minimum and maximum values for variation of these two input variables.

**The tool subsequently produces the following output:**
- $E[\text{RC}]$ and $P[\text{RC}>0]$ for the given setting of input variables, and
- diagrams displaying the behavior of $E[\text{RC}]$ and $P[\text{RC}>0]$ over the specified ranges of the two selected variables.

This tool enables exploration of the Reorder Criterion under different input settings. If the probability of the Reorder Criterion becoming satisfied is significant, Metro should prefer OCT2 over OCT1 based on Physical Costs. On the other hand, if this probability is very low, Metro should be indifferent toward both OCT types based on Physical Costs. However, in order to make a more complete decision on OCT types, Market Mediation Costs should be taken into account as well. An impression of the Reorder Criterion exploration tool can be found in Appendix G.

**Conclusions**

$\rho$, $c_{\text{OOS}}$, and $S_{\text{SL\,promo}}$ are the most influential variables on the outcome of the Reorder Criterion. These variables mainly determine the Physical Costs, in combination with the physical cost parameters $c_{\text{receive}}, c_{\text{early}}$, and $c_{\text{late}}$. The developed tool makes more detailed examination of the behavior of the Reorder Criterion possible. It can be concluded that absolute Physical Costs are low. The next section will investigate the absolute Market Mediation Costs and Total Costs.
5.2.2 Market mediation costs and total costs

The effects of the input variables on MMC and TC in absolute terms were analyzed through ANOVA. This section discusses the effects. In order to compare the magnitude of the effects, Appendices F2 to F4 display the variables’ F-ratios and the corresponding effect plots.

Service level

MMC  Increasing SLpromo substantially decreases E[Q_{OOS}] and increases E[Q_{excess}] in case of both OCT types. A high service level of 0.98 generally leads to low E[Q_{OOS}], and minimizes the effects of other variables on E[Q_{OOS}]. E[Q_{excess}] is approximately twice as high under SLpromo=0.98 than under SLpromo=0.8.

TC  E[TC] is decreasing tremendously over SLpromo in case of both OCT types. A high service level of 0.98 generally results in low E[TC], and minimizes the effects of other variables on E[TC].

Demand characteristics

MMC  E[Q_{OOS}] and E[Q_{excess}] are increasing over μD and LF in case of both OCT types. Under OCT1, μD has a much stronger effect on E[Q_{OOS}] than LF, whereas under OCT2, LF has a stronger effect than μD. With regard to E[Q_{excess}], especially μD has a very large effect in case of both OCT types.

TC  E[TC] is increasing substantially over μD and LF in case of both OCT types.

Forecast improvement

MMC  Increasing ρ slightly increases E[Q_{OOS}] under OCT1, whereas ρ does not affect E[Q_{OOS}] under OCT2. This is caused by the way of including the forecast improvement into the model (Table 4.3). Remarkably, ρ does not have a significant effect on E[Q_{excess}]. More extreme values for the variables that affect the RC could have revealed an effect on E[Q_{excess}] (i.e. lower value for SLpromo; higher values for ρ and c_{OOS}).

TC  ρ does not have a significant effect on E[TC].

Budget inaccuracy

MMC  Budget inaccuracy plays a role under OCT2 only. Under OCT2, increasing μBI substantially increases E[Q_{OOS}] and slightly decreases E[Q_{excess}].

TC  E[TC] is increasing over μBI under OCT2.

Market share

MMC  Market share plays a role under OCT2 only. E[Q_{OOS}] is increasing over MS (only if SLpromo is low and μBI is high).

TC  MS does not have a significant effect on E[TC].

Costs of stockouts

TC  E[TC] is increasing largely over c_{OOS} in case of both OCT types.

---

1 Effects with a significance level \( p<0.05 \) are regarded as significant.
5.3 Relative performance

This paragraph discusses the effects of the model variables on performance in relative terms. Relative performance is aimed at direct comparison of OCT1 and OCT2. Section 5.3.1 describes the effects on Market Mediation Costs, and section 5.3.2 focuses on Total Costs. Since relative Physical Costs can only have four fixed outcome values, these costs will not be further examined. Section 5.3.4 presents the results of a separate analysis of the experiments with high service level only, which leads to output values and factor effects that were too small to be visible in the analysis of all experiments together. Appendices F5 to F15 contain the results of the performed statistical analyses.

5.3.1 Comparison based on MMC

This section presents the results of the analysis of MMC. In terms of expected stockout quantity, either OCT1 outperforms OCT2 or there is no statistical difference\(^1\). In terms of expected excess stock quantity, OCT2 mostly outperforms OCT1, but there are settings for which there is no statistical difference or for which OCT1 outperforms OCT2.

Service level and budget inaccuracy

\(\mu_{BI}\) and \(SL_{promo}\) are the most influential variables on both \(E[\Delta Q_{OOS}]\) and \(E[\Delta Q_{excess}]\). \(\rho\) moderates the effects of these variables on \(E[\Delta Q_{excess}]\).

As was seen before, increasing budget inaccuracy increases the expected stockout quantity under OCT2 only. Correspondingly, \(\mu_{BI}\) increases \(P[\Delta Q_{OOS}<0]\) and \(E[\Delta Q_{OOS}|\Delta Q_{OOS}<0]\), and this leads to the negative effect of \(\mu_{BI}\) on \(E[\Delta Q_{OOS}]\). \(E[\Delta Q_{excess}]\) is positively affected by \(\mu_{BB}\). The effects of \(\mu_{BB}\) are only significant if \(SL_{promo}=0.8\).

The service level affects both OCT types. \(SL_{promo}\) has a large positive effect on \(E[\Delta Q_{OOS}]\) (if \(\mu_{BB}=1.08\)). Its effect on \(E[\Delta Q_{excess}]\) is more complicated: \(SL_{promo}\) has no effect if \(\rho=0\) and \(\mu_{BI}=0.65\); \(SL_{promo}\) has a very large positive effect if \(\rho=0.3\) and \(\mu_{BI}=0.65\); \(SL_{promo}\) has a small positive effect if \(\rho=0.3\) and \(\mu_{BI}=1.08\).

Figure 5.4 displays the effects of \(\mu_{BI}\) and \(SL_{promo}\) graphically. The left diagram in Figure 5.4 shows that (1) \(E[\Delta Q_{OOS}]\) is not different from zero if \(\mu_{BI}=0.65\) or if \(SL_{promo}=0.98\), and (2) \(E[\Delta Q_{OOS}]\) is negative only if \(\mu_{BI}=1.08\) and \(SL_{promo}=0.8\). The right diagram in Figure 5.4 shows that (1) \(E[\Delta Q_{excess}]\) is negative if \(\rho=0.3\), \(SL_{promo}=0.8\) and \(\mu_{BI}=0.65\), (2) \(E[\Delta Q_{excess}]\) is not different from zero if \(\rho=0\) and \(SL_{promo}=0.98\), and (3) \(E[\Delta Q_{excess}]\) is positive in all other cases.

---

\(^1\) Every outcome is tested whether it is statistically different from zero by its 95% LSD confidence interval. In the same way, pairs of outcomes are tested whether they are statistically different from each other.
Demand characteristics

\( \mu_D \) and LF have a negative effect on \( E[\Delta Q_{OOS}] \). The effect of \( \mu_D \) seems to converge to a limit: \( \mu_D=33 \) and \( \mu_D=83 \) lead to statistically equal values of \( E[\Delta Q_{OOS}] \). LF has a positive effect on \( E[\Delta Q_{excess}] \). \( \mu_D \) increases the effects of \( \mu_{BH} \), \( SL_{promos} \), and \( C_{OOS} \) on \( E[\Delta Q_{excess}] \).

Forecast improvement

\( \rho \) does not have an effect on \( E[\Delta Q_{OOS}] \). \( \rho \) does increase both \( P[\Delta Q_{OOS}>0] \) and \( P[\Delta Q_{OOS}<0] \), but apparently, the effects of \( \rho \) on these probabilities cancel each other out. \( \rho \) has a positive effect on \( E[\Delta Q_{excess}] \) if \( SL_{promos}=0.98 \), and a negative effect if \( SL_{promos}=0.8 \). Increasing \( \rho \) increases both \( P[\Delta Q_{excess}>0] \) and \( P[\Delta Q_{excess}<0] \) largely. If \( \rho=0 \), these probabilities become very small or zero.

Market share

\( MS \) has a negative effect on \( E[\Delta Q_{OOS}] \). If \( SL_{promos}=0.8 \), \( \mu_{BH}=1.08 \) and \( \rho=0.3 \), it has a positive effect on \( E[\Delta Q_{excess}] \).

Costs of stockouts

Increasing \( c_{OOS} \) slightly decreases the probability that a difference in stockout quantity between OCT1 and OCT2 occurs. However, \( c_{OOS} \) has no significant effect on \( E[\Delta Q_{OOS}] \). \( c_{OOS} \) does have a negative effect on \( E[\Delta Q_{excess}] \) if \( \rho=0 \).

5.3.2 Comparison based on total costs

\( E[\Delta TC] \) scores are generally in favor of OCT1 (i.e. negative values). The exceptions are positive values that are so small, that they are not considered different from zero with 95% confidence. The minimum value for \( E[\Delta TC] \) equals -179.79, whereas the maximum equals 2.21. The following can be concluded on the magnitude and direction of the effects on \( E[\Delta TC] \).

Service level and budget inaccuracy

The largest effects on \( E[\Delta TC] \) stem from \( SL_{promos} \), \( \mu_{BH} \), and their interaction. If either \( \mu_{BH}=0.65 \) or \( SL_{promos}=0.98 \), the values of \( E[\Delta TC] \) are not different from zero, and the effects of other variables on \( E[\Delta TC] \) are minimized. If \( \mu_{BH}=0.65 \) and \( SL_{promos}=0.98 \), all scenarios lead to an \( E[\Delta TC] \) value of zero or higher (although statistically not different from zero), with mean 0.25 and maximum 1.34. If \( \mu_{BH}=1.08 \) and \( SL_{promos}=0.8 \), \( E[\Delta TC] \) becomes negative. Concluding, \( SL_{promos} \) has a large positive effect on \( E[\Delta TC] \) if \( \mu_{BH}=1.08 \), and \( \mu_{BH} \) has a large negative effect if \( SL_{promos}=0.8 \).

Demand characteristics, costs of stockouts, and market share

Demand characteristics \( \mu_D \) and LF, costs of stockouts \( c_{OOS} \), and market share \( MS \) all have a negative effect on \( E[\Delta TC] \). Thus, increasing the values of these variables increases the advantage of OCT1 over OCT2. There is no difference between \( \mu_D=33 \) and \( \mu_D=83 \) on \( E[\Delta TC] \), so the effect of \( \mu_D \) seems to converge to a limit.

---

1 The maximum \( E[\Delta TC] \) value of 2.21 is achieved under \( \mu_{BH}=0.65 \) and \( SL_{promos}=0.8 \).
5.3.3 Comparison with high service level only

Paragraph 5.3.1 and 5.3.2 presented the results of an analysis in which all experiments were included. In paragraph 3.3.1, it was argued that a promotional service level of 0.98 probably corresponds to the real-world system. The second input level of 0.8 was aimed to investigate the effect of the service level variable, given that the utilized service level can be lower in practice. In this section, a separate ANOVA analysis on the experiments with $SL_{promo} = 0.98$ is discussed. This separate analysis results in output values and factor effects that were too small to be visible in the analysis of all experiments together. All $E[ΔTC]$ values become statistically above zero, i.e. OCT2 always outperforms OCT1 in terms of total costs, except from the scenarios with $c_{early} = 0.39$ and $ρ = 0$. In that specific setting, the cost difference between the two OCT types is zero.

**Forecast improvement**

When $ρ$ increases from 0 to 0.3, $E[ΔQ_{OOS}]$ and $E[ΔQ_{excess}]$ are increased to values significantly above zero, i.e. the advantage in terms of MMC shifts towards OCT2. As a consequence, $E[ΔTC]$ increases over $ρ$.

**Demand characteristics**

A large positive effect on $E[ΔQ_{OOS}]$ and $E[ΔTC]$ stems from $μ_0$, again only significantly if $ρ = 0.3$.

**Costs of placing an early order**

If $ρ = 0.3$, $c_{early}$ has a weak positive effect on $E[ΔQ_{OOS}]$. $c_{early}$ has a positive effect on $E[ΔTC]$ independent of the value of $ρ$, so increasing $c_{early}$ unambiguously increases the advantage of OCT2 over OCT1.

**Costs of stockouts**

If $ρ = 0.3$ and $μ_0 = 83$, $c_{OOS}$ has a weak positive effect on $[ΔQ_{OOS}]$ and a negative effect on $E[ΔQ_{excess}]$. $E[ΔTC]$ increases over $c_{OOS}$ if $ρ = 0.3$, i.e. the advantage of OCT2 over OCT1 increases.
5.4 Other statistics

In this paragraph, an additional two statistics are evaluated, namely the probability of supply shortage and the excess stock quantity left at the supplier. Appendices F16 to F19 contain the corresponding ANOVA results and the effect plots.

5.4.1 Supply shortage

Supply shortage is measured as the probability of the delivered quantity being less than the full ordered quantity. This is referred to as the supply shortage probability (SSP). The SSP is generally much higher under OCT2 than under OCT1: the average SSP equals 0.24% under OCT1 and 2.31% under OCT2. Under OCT1, SSP is largely increased over \( \rho \). This is due to fact that the model takes the standard deviation of the early order demand forecast under \( \rho = 0.3 \) higher than under \( \rho = 0 \) (recall Table 4.3), usually leading to a higher early order quantity. Under OCT2, the largest effects stem from \( \mu_{BI} \) and \( SL_{promo} \). SSP is not different from zero if either \( \mu_{BI} = 0.65 \) or \( SL_{promo} = 0.98 \). If \( \mu_{BI} = 1.08 \) and \( SL_{promo} = 0.8 \), SSP is also increasing over MS and LF, while it is decreasing over \( \mu_D \).

\( \Delta SSP \) is mainly affected by \( \mu_{BI} \) and \( SL_{promo} \) and also MS, \( \mu_D \), and LF play a moderate role. If either \( \mu_{BI} = 0.65 \) or \( SL_{promo} = 0.98 \), \( \Delta SSP \) is not different from zero. \( \Delta SSP \) is in favor of OCT1 otherwise. The advantage of OCT1 over OCT2 increases over higher MS, higher LF, and lower \( \mu_D \).

5.4.2 Excess stock at the supplier

The expected excess stock at the supplier \( E[Q_{excess\_supplier}] \) is computed by subtracting the total quantity ordered by the retailer’s stores, \( Q_{promo} + Q^{*}_{promo} \), from the promotional production quantity \( p \). The average \( E[Q_{excess\_supplier}] \) is 6917 under OCT1 and 45851 under OCT2. \( E[Q_{excess\_supplier}] \) is mainly affected by \( \mu_{BI} \), \( \mu_D \), and LF under both OCT types. Increasing \( \mu_{BI} \) decreases \( E[Q_{excess\_supplier}] \) largely, whereas increasing \( \mu_D \) and LF increases \( E[Q_{excess\_supplier}] \) largely. \( E[Q_{excess\_supplier}] \) is also increasing over \( SL_{promo} \).
5.5 Conclusions

In this paragraph, the main conclusions from the results in paragraph 5.2, 5.3 and 5.4 are discussed. Section 5.5.1 describes the conclusions on Physical Costs. Section 5.5.2 goes into Market Mediation Costs. Finally, section 5.5.3 discusses the conclusions on the final performance indicator Total Costs.

5.5.1 Physical costs and the Reorder Criterion

Physical costs are generally low and are either in favor of OCT2 or indifferent toward both OCT types. Paragraph 5.2 discussed that the physical costs can only consist of a limited set of values, dependent on the OCT type, the values of the physical cost parameters, and the outcome of the Reorder Criterion under OCT1. If the costs of placing an early order are higher than the costs of placing a late order, OCT2 always outperforms OCT1 in terms of physical costs. If placing early and late orders are equally expensive, the probability that OCT2 outperforms OCT1 in terms of physical costs is equal to the probability that the Reorder Criterion gets satisfied. It was found that the forecast improvement coefficient ($\rho$), the costs of stockouts ($c_{OOS}$) and the service level ($SL_{prom}$) are the most important determinants of this probability. Finally, it can be concluded that the benefits of OCT2 in terms of physical costs are relatively too small compared to the total costs to make a significant difference.

5.5.2 Market mediation costs

This section will address the effects on the market mediation variables. The market mediation costs have a much larger share in the total costs than physical costs. The factors with the largest effects on market mediation costs are the service level and the budget inaccuracy, and these are thoroughly discussed in this section. The results from the analysis with all experiments together are first discussed. Subsequently, the separate analysis of experiments with a high input value for the service level is described, which results in output values and factor effects that were too small to be visible in the analysis of all experiments together.

Full analysis

A high service level results in hardly any stockouts, but it does create much excess inventory. A high service level generally leads to a low probability of stocking out in case of both OCT types. The differences between the OCT types in terms of stockout quantity are very low compared to the differences encountered under a low service level, and this makes them statistically not different from zero. The drawback of utilizing a high service level is that it leads to high excess stock quantities. A difference in excess stock quantity in favor of OCT2 appears if the forecast improvement coefficient is larger than zero.

The low input value for the service level is less likely to be applied in practice than the high input value. The effects of some factors start to be significant when the service level is low. These effects should be discussed, since they will play an increasing role in practice when the utilized service level happens to be lower than 98%.

Budget inaccuracy and market share affect the supply risk under OCT2 if the service level is low. If the utilized service level is lowered, this generally leads to higher stockout quantities and lower excess stock quantities. In addition, budget inaccuracy and market share start to affect the supply risk under OCT2 as follows:

- The supplier more often produces an insufficient quantity if budgets tend to be underestimated instead of being overestimated. As a consequence, the supplier is more often unable to deliver the full
quantity ordered by the retailer’s stores, which increases the expected stockout quantity. The average supply shortage probability under OCT2 equals 2.31%, whereas it equals only 0.24% under OCT1.

- If budgets are underestimated, a high market share creates even more stockouts, since it reduces the relative amount of inventory buffer at the supplier to fill up the gap between the production quantity and order quantity.

- On the other hand, if budgets are generally overestimated, stockouts are low under OCT2. Only minor differences in supply shortage probability and expected stockout quantity can be found between OCT1 and OCT2. More precisely, overestimated budgets create a very little advantage for OCT2 in terms of expected stockout quantity. Here we can see a remarkable worsening effect of the early order on supply risk: under OCT1, the supplier can adjust its production downwards after receiving the early order, while under OCT2, he produces the exact overestimated budget. If the updated demand forecast is higher than the early order forecast, the supplier is more probable to have enough stock available to satisfy the requested order under OCT2 than under OCT1, and so OCT2 will be better off.

It can be concluded that a low service level in combination with generally underestimated budgets leads to comparably higher stockout probability under OCT2, giving rise to a large advantage for OCT1. This advantage is magnified by increasing market share. In terms of excess stock quantities, OCT2 mostly outperforms OCT1, but it is the other way around if budgets are overestimated and the forecast improvement coefficient is larger than zero.

A higher lift factor increases the supply shortage probability, whereas a higher mean regular demand value decreases the supply shortage probability. The effects of the mean regular demand and the lift factor on the supply shortage probability are in opposite directions. A higher lift factor increases the supply shortage probability under OCT2, whereas a higher mean regular demand decreases the supply shortage probability under both OCT types. Their effects on market mediation variables are significant when the service level is low. Increasing values for the demand characteristics increase the stockout quantity as well as the excess stock quantity under both OCT types. Also, the differences in stockout quantity and excess stock quantity between the two OCT types grow larger under larger values for the demand characteristics. However, the magnifying effect of the mean regular demand on the cost difference seems to converge to a limit, where higher demand stops increasing the cost difference.

Separate analysis on high service level experiments only

A high promotional service level is most likely to be applied in practice. In paragraph 5.3.3, the experiments with a high service level were separately analyzed. This creates insight into the effects of factors which were relatively too small compared to the large effect of the service level and other factors.

The mean regular demand has the largest effect on the market mediation variables if the service level is high. The mean regular demand has by far the largest effect on the stockout quantity and on excess stock quantity under both OCT types. If there is some forecast improvement present, the differences between the two OCT types in terms of stockouts and excess stock are increased over increasing values of the mean regular demand in favor of OCT2.

Forecast improvement gives a minor advantage to OCT2 over OCT1 in terms of market mediation variables if the service level is high. If forecast improvement is present, OCT2 outperforms OCT1 in terms of both stockout quantity and excess stock quantity, but if there is no forecast improvement, no difference between OCT1 and OCT2 can be found. It can be concluded that the benefit of OCT2 in terms of market mediation depends on the existence of forecast improvement.
The cost of stockouts and the cost of placing an early order show weak effects on the market mediation variables, which are inexplicable. Under OCT1, if there is forecast improvement present and if the mean regular demand is sufficiently high, higher cost of stockouts slightly decreases the excess stock quantity. As a consequence, in terms of excess stock quantity, the advantage of OCT2 over OCT1 is decreasing over the cost of stockouts. This is counterintuitive. Since higher costs of stockouts increase the probability that the RC gets satisfied, thereby more often creating a reorder opportunity in case of OCT1, one would expect higher costs of stockouts to shift the advantage in terms of stockout quantity towards OCT1 and the advantage in terms of excess stock quantity towards OCT2.

Under OCT2, if there is no forecast improvement present, the excess stock quantity is slightly increasing over the costs of placing an early order, but if there is forecast improvement present, the excess stock quantity is slightly decreasing over the costs of placing an early order. Surprisingly, the difference in excess stock quantity between the OCT types is not affected by the costs of placing an early order, but the stockout quantity difference is. If there is forecast improvement present, it slightly increases the advantage of OCT2 over OCT1 in terms of stockouts. This is counterintuitive, since the cost of placing an early order is neither included in the RC, nor is it related to the market mediation variables in any other way.

These observations on the effects of the costs of stockouts and the costs of placing an early order can not be justified. Since both effects are very small, they will be neglected.

5.5.3 Total costs

This section will address the effects on total costs, which is regarded as the final indicator of performance. The conclusions in this section are based on a combination of the results from the full analysis and the separate analysis on high service level experiments.

Either a high service level or generally overestimated budgets result in low total costs. A high service level generally leads to low total costs, so it is wise to order abundantly. This holds for both OCT types. It also generally holds that underestimated budgets lead to low costs. Only marginal differences in costs exist between the two OCT variants if either the service level is high or the budget inaccuracy is low.

When order quantities are more scanty, costs will rise, under both OCT variants. Under OCT2, budgets and market share also start to play a role: when budgets shift from being largely overestimated towards being underestimated, costs will rise fast, and high market share starts to have a significant increasing effect on total costs. The budget inaccuracy and market share do not affect the total costs under OCT1. Due to their effect on total costs under OCT2, they do affect the costs difference between the two OCT types, in favor of OCT1.

Higher values for demand characteristics magnify total costs and total costs differences. Obviously, total costs also increase over increasing values for the demand characteristics, i.e. mean regular demand and the lift factor, because excess stock quantities and, if they occur, also stockout quantities, build up to a higher extent. Increasing the values of the demand characteristics magnifies the costs difference between the two OCT types, either in favor of OCT1 or OCT2. However, the effect of the demand variables on the cost difference seems to converge to a limit, where higher demand stops increasing the cost difference.

Decreasing the cost of placing an early order is beneficial to OCT1 in terms of total costs. Despite the counterintuitive observations w.r.t. the weak effects of the costs of placing an early order and the costs of stockouts on the market mediation variables, their effects on total costs are unambiguous. Paragraph 3.4.2 described that the high input value for the costs of placing an early order represents the situation
with the current early ordering method, while the low input value represent the situation with a redesigned early ordering method. Decreasing the costs of placing an early order increases the advantage of OCT1 over OCT2, as it makes the early order become cheaper.

**Increasing the cost of stockouts increases the total costs.** Paragraph 3.3.2 argued that the high value used for costs of stockouts is rather exceptional and aimed at investigation of the variable’s effect. The costs of stockouts lifts the total costs, simply because it makes excess stock and stockouts more expensive.

**Forecast improvement has a minor effect on total costs.** Importantly, the forecast improvement coefficient only has a minor effect on total costs. This effect can only be made visible if solely experiments with a high service level are included in the analysis. Forecast improvement is in favor of OCT2. It can be concluded that improving the forecast between the early and the late order does hardly make a difference. This can be explained as follows. Forecast improvement leads to lower excess (safety) stocks under OCT2. Excess stock is relatively cheap. Contrarily, forecast improvement does hardly lead to a difference between the two OCT types based on the relatively more expensive stockout quantity.

**OCT2 leads to an excessive amount of inventory left at the supplier.** Finally, it should be noted that the demand characteristics and the budget inaccuracy affect the excess stock quantity that is left at the supplier, under both OCT types. Overestimated budgets lead to large excess stock quantities. Also, increasing demand characteristics increase the supplier’s excess quantity. OCT2 leaves on average seven times more excess stock at the supplier than OCT1.
6 Recommendations

This chapter gives answers to both research questions. The first research question is addressed in paragraph 6.1. The second research question is answered in paragraph 6.2.

6.1 Order commitment timing

This paragraph discusses the findings on the first research question with respect to order commitment timing. The first section will summarize the conjectures developed in the simulation study. The second section will describe the recommendations on OCT for Metro, i.e. how can the developed conjectures be translated to Metro’s specific environment.

6.1.1 Conjectures

The first research question asks which factors determine the optimal choice of order commitment timing (OCT) types for Dry Food brochure articles. The factors that are mostly affecting the choice are:

1. **the service level which the retailer applies when determining order quantities**

   Costs of stockouts are relatively high compared to costs of excess stock. As a consequence, costs are generally minimized if the retailer orders abundantly. However, if the retailer orders scantily, OCT2 can be much more expensive than OCT1, since several factors increase the supply risk under OCT2 in particular.

2. **the accuracy of the budgets that are sent to supplier**

   By triggering the supplier’s production planning, budgets have a large effect on the supply risk. Especially under OCT2 when the supplier bases its total production quantity on the budget value, overestimation of budgets minimizes costs, since it secures a larger amount of supply than underestimated budgets. However, it should be noted that continuous and excessive overestimation of budgets will most probably impact the supplier’s response to the budgets in the long run (e.g. a standard decrease of the budget value for use in the production planning).

Other factors with a significant but smaller effect are:

- **the market share** of the retailer in the supplier’s product — high market share can create supply risk under OCT2 if budgets tend to be underestimated, and the utilized service level is low;  
- **the costs of stockouts** — increasing costs of stockouts increases the total costs incurred;  
- **the costs of placing early orders** — OCT1 benefits over OCT2 when costs of placing the early order are decreased;  
- **demand characteristics** — higher values for demand characteristics magnify total costs and cost differences between the OCT types. Supply shortage is more probable to occur under slowmovers than under fastmovers, whereas a higher lift factor leads to a higher supply shortage probability.

Given that all other circumstances are right, **forecast improvement** is strictly required for OCT2 to outperform OCT1 in terms of market mediation costs, but the difference can only be marginal. If no forecast improvement occurs, OCT2 can only outperform OCT1 in terms of physical costs which are generally low. It can be concluded that forecast improvement does hardly make any difference.
The optimal choice of OCT type is unambiguous. OCT1 should be chosen as the optimal order commitment timing. The two primary sources for the absence of any ambiguity are: (1) forecast improvement is found not very relevant, and (2) market mediation costs, especially stockouts, have shown to outweigh physical costs tremendously. The rationale for the choice is as follows.

Under the right circumstances, OCT2 can result in a cost saving compared to OCT1, e.g., when service levels are set high and budgets are generally overestimated. The possible savings of OCT2 for the one-store single-item situation are in the range of 0 to 2.21 with mean 0.28. This implies an average saving of approximately 95 euro per brochure (using the mean saving of 0.28 and the average number of Dry Food articles per brochure of 328), which is negligible compared to total turnover figures of a brochure.

If the circumstances are not right for OCT2, choosing for this OCT type can be hazardous in terms of costs, and the savings of choosing for OCT1 are not at all negligible. OCT2 involves risk. Defining risk as the probability of an event occurring multiplied by the impact of the event occurring, it can be stated that the probability of increased costs under OCT2 may not be high, but the impact surely is, due to the pricey nature of stockouts. OCT1 is a safer choice and is generally not much more expensive. Moreover, it is expected that suppliers are reluctant to cooperate with an OCT2 system, since their inventory levels will increase dramatically.

6.1.2 Order commitment timing within Metro

The developed simulation model is a representation of Metro’s situation. The input values used in the simulation study were based on an analysis of Metro’s data. However, some of the input values are not corresponding to Metro’s situation: the low service level value and the high market share value were aimed to investigate the effects of these variables. This has some implications. It has been found that high market share can create a supply risk under OCT2. Metro generally has a small market share in the suppliers’ products, which diminishes the supply risk significantly. Furthermore, if Metro actually orders abundantly for promotions (i.e., high service level), the total costs incurred are particularly low, and the optimal choice between OCT types loses much of its relevance.

Based on the simulation results, paragraph 6.1.1 described that the optimal choice should unambiguously be made for the early ordering variant, mainly motivated by the risk of high costs under OCT2. Metro is advised to early-order its Dry Food brochure articles as much as possible.

Currently, the people from the Dry Food sales departments choose OCT2 for some of the articles based on their own rules-of-thumb or experience. Based on their experience with the particular supplier, they are able to predict well whether the supplier is able to deal with the actual order being placed shortly before the brochure period starts, so that it will not create severe supply problems. This works fine in practice. Apparently, experience can be just as valuable as scientifically derived rules. Their main reasons for not choosing to order through OCT1 are problems with MOQ compliance (recall paragraph 1.3), and the fact that the early ordering process is time consuming. If the early ordering method is made less time consuming, for which the first redesign attempts are made in paragraph 6.2, it will stimulate the sales department people to choose for OCT1 more often. Additionally, they should be made aware of the gained insight that OCT1 is a safer choice and is generally not much less efficient.
6.2 The early ordering method

This paragraph will answer the second research question on Metro’s current working method for placing early orders. In Bückers (2009), the first steps of the Business Process Management lifecycle (Smith and Fingar, 2003) were followed. The BPM lifecycle names the different steps in analyzing and eventually redesigning business processes (Figure 6.1). The lifecycle was followed until the design step. After identifying Metro’s ordering process for dry food brochure articles as the focus process, a qualitative description of the entire process was made with corresponding process flow models1 (as-is modeling). To identify the main problems and their causes (as-is assessment), discussions were held with people who are involved in the process. Where possible, the problems were quantified in order to compare the relevance of each of them. The as-is assessment revealed the need to redesign Metro’s currently used early ordering method, the so-called Brochure Concept, and this lead to the formulation of the second research question. In this paragraph, first attempts are made to redesign the early ordering method (i.e. the to-be situation). This involves the lifecycle’s design step. Succeeding steps are outside the scope of this project.

The paragraph is structured as follows. In paragraph 6.2.1, a brief description of the as-is situation is given. Paragraph 6.2.2 summarizes the key shortcomings of the early ordering method. The applied redesign methods are discussed in paragraph 6.2.3. Paragraph 6.2.4 presents the redesign. In paragraph 6.2.5, the benefits of the proposed redesign are evaluated.

6.2.1 The current early ordering method

Currently, people from the sales departments place their early brochure orders through the Brochure Concept (BC). The Administrative Logistics Centre (ALC) of each store has a matrix printer in its office, which can be signaled automatically from the head office. At least 4 weeks before the brochure period starts, the matrix printer automatically prints out the Brochure Concept, which is an extensive list of all brochure articles with additional information (see Appendix B2). An ALC employee divides the BC into parts for each sales department, by tearing the paper into pieces. The pieces for each sales department are put in the department’s mailbox at the ALC office. Someone of the sales department has to come to the ALC office and pick them up.

The sales department fills in the early order quantities on the BC and hands the BC back to the ALC for processing before the deadline date. The sales department uses several sources of information to determine for which articles to place an early order and in what quantity, such as information from the BC, the MBS system, the brochure proof, the Commercial Bulletin, and the Commercial Display Plan2. Whether an article is placed on a promotion head or just on the regular shelves is also an important determinant of the promotional sales. Therefore, filling in the early order quantities on the BC is done in parallel with making a Heads and Squares Planning. The Heads and Squares Planning is a store-specific plan which

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1 Appendix B1 displays these process flow models. The qualitative description of the process is not included in the appendix and can only be found in Bückers (2009).

2 The decision is also influenced by the sales department person’s experience with the products, and his judgment on factors such as trends, seasonality, weather, holidays, etc.
RECOMMENDATIONS

presents the allocation of brochure articles to the available promotion heads in the store, based on the Central Display Plan composed by Metro’s central buying department. The planning gives instructions to sales employees for transformation of the store for the new brochure period.

The sales department has to determine a delivery date for each early order by taking into account the supplier’s delivery schedule. The delivery schedule is denoted as a 7-digit binary code in which each digit indicates a day of the week and whether the supplier will deliver on this day.

After the sales department has returned the BC, the ALC transcribes the early order quantities and their delivery dates to actual orders to the suppliers using their own part of the MBS system. Different from the sales department’s dispo system, the ALC can start in a blank ordering screen, choose a particular supplier, and type down the orders for a self-determined number of items.

6.2.2 Shortcomings

The Brochure Concept method is highly time and resource consuming, and causes several errors. Here is a summary of the shortcomings (Bückers, 2009):

- **Inefficient arrangement of articles**
  The brochure articles on the BC are not arranged in a way that makes it easy for the ALC to divide the BC into parts for each sales department. Each sales department receives several pieces of the BC.

- **Unnecessary tasks and resources**
  The BC has to be collected at the ALC and brought back to the ALC by someone of the sales department. After it is brought back, the ALC solely transcribes the written data on the BC into the computer. They do not perform any check and it is therefore purely a processing function. Finally, the BC is printed out twice, which consumes a lot of paper.

- **Many sources of information**
  The sales department employee has to look at a variety of sources to determine the early order quantities and switch his attention repeatedly between these sources. This consumes much of his time. In the MBS system, he has to insert article numbers manually in order to find past sales data and the current inventory level. In order to determine the right delivery date for each order, he has to look at the supplier’s delivery schedule and at the calendar.

- **Useless information**
  The option and order proposal values printed on the BC are useless.

- **Lack of automated functions**
  The BC lacks an ordering blockade function. Metro’s central buying department can assign an ordering blockade to a brochure article in the MBS system for a period in which the article can not be ordered. Blocked articles can appear on the BC, for instance when the buying department wants to sell off remaining inventories of an article. A note on the BC informs the stores not to order the article. However, it occurs frequently that stores place early orders for these blocked articles. The ordering blockade in MBS does not block orders that are placed through the processing function of the ALC.

  The BC also lacks an MOQ check function. In the dispo system, the user gets notified when the inserted order quantity does not satisfy the minimum order quantity (MOQ). The BC is a piece of paper and does not check the MOQ condition. Consequently, it occurs that orders which do not satisfy the MOQ are submitted to the suppliers. When the supplier contacts the store to inform that he will not deliver the order, it is often too late for the store to order again for delivery in time.
Finally, there is no automatic notification on the deadline of placing early orders. Stores are occasionally late with placing their early orders.

An additional note should be made on the Brochure Replenishment List (BRL). The BRL is a printed list of all brochure articles, and looks similar to the BC. It is made available to the sales departments of the store on a daily basis during the brochure period. It used to be intended for placing reorders during the brochure period, in a similar way as ordering through the BC. However, dry food sales departments do not use the BRL anymore but instead use the dispo system for this purpose. The BRL is only used as a daily overview of the brochure articles’ performance.

6.2.3 Redesign methodology

First attempts for a redesigned early ordering method are given in the next section. The actual automation of the early ordering method is outside the scope of this master project and is the follow-up step to be taken by Metro. The proposed redesign was developed in discussion with process stakeholders, and several best practices in business process redesign were used (Reijers and Liman Mansar, 2005). Business process redesign (BPR) is more of an art than a science. There is a lack of a systematic approach that can lead a process redesigner through a series of steps for the achievement of process redesign. Reijers and Liman Mansar (2005) identify a series of best practices in BPR implementation, and they evaluate the effects of each best practice based on the four dimensions of the devil’s quadrangle: time, cost, quality, and flexibility. The main objectives of the early ordering method redesign are (1) to reduce time consumption, and (2) to improve quality (i.e. fewer errors). The following four redesign best practices will be applied to the early ordering method:

1. **Task elimination.** This best practice focuses on the business process from an operation view (Figure 6.2). When unnecessary tasks can be eliminated from a business process, the speed of processing can be increased and the cost of handling an order can be reduced. A decrease of process quality due to task elimination can be prevented by the automation of tasks.

2. **Numerical involvement.** This best practice affects the organization structure (Figure 6.2). It aims to minimize the number of departments, groups and persons involved in a business process, leading to fewer coordination problems and less time spent on coordination.

3. **Task automation.** This best practice uses technology in order to redesign the business process (Figure 6.2). Automation may result in faster execution of tasks and with a better result. Several tasks within the early ordering process need to be performed by people (i.e. determining the order quantities, making the heads and squares planning, etc). Instead of fully automating tasks, an automated support of the people executing the tasks is proposed. This will increase the speed, but preserves enough flexibility through human control.

4. **Control addition.** This best practice focuses on the information which the business process uses or creates. Addition of controls to a business process leads to a higher quality of process execution and,
as a result, to less required rework. The proposed additional controls are simple and easily automated, so they will not consume extra time. Control addition contrasts with task elimination in which tasks are removed from the process.

6.2.4 Redesign

A new digital method for early ordering is proposed, which eliminates or diminishes the problems with the current method. The new method will reduce the amount of time that is consumed from sales department people, and it will omit the ALC’s processing task. The right pieces of information can be quickly accessed by the sales department, and useless information will be omitted. The digital format will enable inclusion of automated functions, such as order blockades and delivery date setting. This will prevent mistakes that are currently encountered.

The proposed method, referred to as the brochure early ordering application, has to be developed and connected to the MBS system. Sales departments can log in on the MBS Store system and go to the brochure early ordering application. Similar to the dispo system, only articles that belong to the particular department show up based on the division of the articles over MBS article categories. Also similar to the dispo system, each of the base screens that the user has to go through, displays listings of articles that belong to a single supplier.

FIGURE 6.3. EXAMPLE OF THE BASE SCREEN OF THE BROCHURE EARLY ORDERING APPLICATION

Every base screen that the user has to work through, displays general brochure information, supplier information, and a list of all brochure articles that belong to the particular supplier (Figure 6.3). The screen also contains input fields for the user to place orders (i.e. order quantity and delivery date). Additional information on a brochure article can be made visible in the bottom of the screen by putting the cursor on one of the article rows (see the yellow article row in Figure 6.3). By clicking **Other promotion details** the user accesses a new window with extra details on the promotion (Appendix H gives an impression of this screen). By clicking one of the **Ad** buttons, the user accesses a view on the brochure page where the particular article is advertised (i.e. the brochure proof). By clicking one of the **Details** buttons, the user accesses a screen with extra details on the brochure article, such as sales history of regular and promotional sales (Appendix H gives an impression of this screen).
The following *automated functions* should be integrated into the application:

- **Delivery date check.** Check whether the user’s setting of the delivery date corresponds with the supplier’s delivery scheme. Notification if the delivery date does not correspond with one of the supplier’s delivery days.

- **MOQ check.** Check whether the total order quantity satisfies the minimum order quantity (MOQ) condition. Notification if it does not comply.

- **Trading unit check.** Check whether an article’s order quantity is a multiple of the trading unit value (see *Order per* in Figure 6.3). Notification if it is not.

- **Order blockade.** Check whether an order blockade is assigned to a brochure article. Notification if an order quantity is filled in for a blocked article.

- **Early order commitment deadline.** The system notifies the sales department when the deadline for early order placement almost expires.

The following information should not be included in the brochure early ordering application: (1) order proposal; and (2) option (national level). Please note that Appendix H presents the screens that were discussed in this paragraph, and it gives an overview of the contents of these screens.

In addition to the BC redesign, the Brochure Replenishment List can be eliminated, since it is not used for reordering during the brochure period. As a substitute for the BRL, a daily overview of all brochure articles and their sales performance should be made available in a digital format.

### 6.2.5 Outlook

In Bückers (2009) an analysis was made of the man-hour consumption of the different activities concerned with ordering. Placing orders through the currently used Brochure Concept method consumes the following amounts of time:

- **Dividing the BC and the daily BRLs over the several sales departments (ALC).**
  
  *Time consumption:* [X] minutes daily, serving all sales departments. This corresponds to [XX] minutes per brochure period, and [X] minutes per BC serving only the Dry Food sales department.

- **Filling out the Brochure Concept (Sales Department).**
  
  *Time consumption:* [X] man-hours per BC per Dry Food sales department.

- **Transcribing the BC to actual orders (ALC).**
  
  *Time consumption:* [X] man-hours per BC for Dry Food articles.

- **Total time consumption:** [XX] man-hours per Brochure Concept for Dry Food articles.

The redesigned early ordering method eliminates the division and the transcription tasks of the ALC, which reduces [X] man-hours. Since all required information for determining early order quantities are easily obtained in the proposed redesign, it is estimated to reduce the time required by the sales department to place early orders by 20%, i.e. [XX] hours. Given that one man-hour costs approximately €20, the redesign will save €[XX] per brochure per dry food sales department. This implies an annual cost saving of €[XXX] for all dry food sales departments together (based on 17 Metro stores, and 27 brochures a year).
In addition, the redesign will improve the quality of the process by preventing (1) early orders for blocked articles, (2) delivery date mistakes, (3) early orders which do not comply with the MOQ condition, (4) early orders which do not comply with the trading unit and (5) early orders committed after the deadline date.

**Table 6.1. Time consumption of early ordering (As-is versus To-be)**

<table>
<thead>
<tr>
<th>Tasks</th>
<th>As-is</th>
<th>To-be</th>
</tr>
</thead>
<tbody>
<tr>
<td>Division of the BC and the BRL over the sales departments by the ALC</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Filling out the Brochure Concept by the sales department</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Transcribing the BC to actual orders by the ALC</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*per brochure, per Dry Food sales department*
7 Final conclusions

The final chapter concludes this master thesis with a review of the main findings, a discussion of the limitations, and an outlook on future research possibilities.

7.1 Review

The first challenge of this project was to create a better understanding of the factors that play a role in the decision of the optimal Order Commitment Timing (OCT) type for brochure articles. The rationale was that early OCT secures the supply, but if conditions are right, also late OCT creates enough supply security. Moreover, late OCT can benefit from increased order accuracy if demand forecasts improve over time, from decreased physical costs, and from fewer problems with MOQ compliance.

A quantitative model was developed that can simulate a supplier-retailer ordering process with a focus on order commitment timing. An Excel-based simulation tool was built. It enables the user to investigate the effects of several factors on total costs for the retailer. These costs consist of physical and market mediation costs. Additionally, the tool is able to evaluate the supplier's excess stock quantity which creates insight into the willingness of the supplier to cooperate. The tool is straightforward and easily used for experimentation with the input variables.

A set of input levels was determined based on Metro’s situation. Several performance indicators were analyzed for this set of input levels. It was found that late ordering creates a substantial risk of high costs, while its potential reduction of costs is just marginal. It was concluded that early ordering is the better choice in this environment.

The second challenge was to initiate a redesign for Metro’s current early ordering method for brochure articles. First attempts for this redesign were given. Following, Metro should start up a project in which the automation of the early ordering method is actually carried out. This involves many steps, such as meetings with users, developing a full description of the required functionality, and acceptance testing. This was outside the scope of the master project.

7.2 Limitations

The simulation model focuses on a single-item environment. In practice, orders sent to suppliers consist of multiple items. This brings up a few limitations of this simulation study.

(a) MOQ compliance problems concerned with early ordering were not investigated. Recall that large early order quantities in the pipeline can create difficulties complying with Minimum Order Quantities when late-ordering other articles from the same supplier.

(b) In a multi-item environment, whether or not placing a (late) reorder under the early OCT type also depends on other articles from the same supplier. The costs of receiving the order are fixed per multi-item order, and so a reorder can easily be placed if other articles from the same supplier are ordered as well.

The simulation model is a representation of the real-world system. A real-world system is always more complex than a model, and numerous exceptions exist that can not be captured by a model. Furthermore, many aspects of the real-world system are modeled through the perceptions of the modeler and other people who contributed to the development.
This mostly holds for the modeling of the supplier's behavior. The supplier is more or less a black box to the retailer. The retailer does not know the details of the supplier's production and inventory management, and these were therefore chosen not to be factors for investigation. The modeling of the supplier's behavior is based on information from four of Metro's suppliers, but is still fairly intuitive.

The model's goal was to give a sense of which relations are underlying the real-world system. Despite its shortcomings, the model succeeded in achieving this goal.

### 7.3 Further research

There are several possibilities for further research. This work could be extended as follows:

i. Simulation generally leads to propositions which appear true but are unproven. The simulation model developed in this thesis involved a great amount of detail, thereby making it very tailored to the specific real-world situation. Contrarily, most research on order commitment timing in the supplier-retailer environment focuses on more abstract, simple relations, which are analytically solvable and lead to proven universal rules. However, most research does not produce algorithms or heuristics that are practically usable by retailers. It is therefore valuable and challenging to develop both proven and practically usable decision rules with regard to order commitment timing.

ii. Similar research on order commitment timing could be conducted on other product categories than Dry Food. Dry Food is characterized by stable demand, an infrequently changing assortment, and low shrinkage due to deterioration. Other product categories will have different implications on order timing. For example, electronics are high-value products with long manufacturing lead times, and are often in-out articles (i.e. only sold during the promotion). This possibly increases the relevance of choosing the right order commitment timing.

iii. The simulation model in this thesis focuses on suppliers that directly deliver to the stores, i.e. a two-echelon system. Approximately 25% of Metro's Dry Food orders are delivered through a central warehouse, creating a whole different environment. Further research could be conducted on order timing issues concerned with the supplier-warehouse-retailer supply chain.

iv. A model which is made for a multi-item environment matches reality better, and could create new insights. Moreover, a reorder criterion could be developed for use in the multi-item situation. The criterion should determine whether a reorder should be placed, for which quantities of all articles of the same supplier, while taking into account the fixed costs of the multi-item order and the MOQ condition.

v. Further research within Metro could look into the tradeoff between combining and separating orders. Currently, articles of the same supplier can be divided into separate MBS groups (e.g. soft drinks versus edible grocery), and they are sent to the supplier on separate orders. This makes it easy to divide ordering responsibility to the people of a sales department, by making everyone responsible for one or more of the MBS groups. It also results in separate delivery of the goods, which makes shelf filling more efficient. The disadvantages of order separation include the increased ordering costs for Metro and the supplier, as well as the negative effect on order balance and MOQ compliance (Bückers, 2009).

In Bückers (2009), it was found that order separation is one of the major concerns with the current ordering process. Therefore, especially the last proposed research is expected to be valuable for Metro.
References


REFERENCES


Appendices