MASTER

Increasing operational performance using assortment optimization under substitution
a case study

Aardoom, J.Y.

Award date:
2014

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Increasing Operational Performance using Assortment Optimization under Substitution: A case study.

J. Y. (Jorin) Aardoom

BSc Industrial Engineering & Innovation Sciences – TU/e 2012
Student Identity Number 0661383

In partial fulfillment of the requirements for the degree of

Master of Science
In Operations Management and Logistics

Supervisors:

dr. K.H. van Donselaar, TU/e, OPAC

dr. ir. P.A.M. Kleingeld, TU/e, HPM

ir. M. Ophelders, Office Depot, Supply Chain Europe

ir. W. Vesters, Office Depot, Supply Chain Europe
Preface

This paper is the result of the master thesis project, performed at the European Supply Chain department at Office Depot, located in Venlo, The Netherlands. This master thesis finalizes my 6 years period of being a student at Eindhoven University of Technology, at the faculty of Industrial Engineering & Innovation Sciences.

While having invested a significant amount of work in both the conduction of the master thesis, and the years of studying prior to the final examination, some words of gratitude are in place. At first, I would like to thank my supervisors, both from the TU/e as well from Office Depot: Karel van Donselaar, Ad Kleingeld, and Michel Ophelders have excellently supported me from the start, back in August 2013, until July 2014. I admire their professional attitude, knowledge and friendliness along the process of conducting the master thesis.

Yet, the greatest support during my 6 years at Eindhoven University of Technology came from my family, especially my parents and brother. They were always there for me, and supported me wherever possible. A special note of gratitude goes to my brother. Together, we started Syneratio B.V. in 2012, which evidently brings along a great workload, while developing our interactive platform for researchers, students, and companies. During the months of February 2014 until June of the same year, he carried the workload practically all by himself, including the agreement with a large investor and our first big contracts. Moreover, I would like to thank Syneratio and our employees, for supporting Fabian and me in these times of high pressure, by working long hours with a very professional attitude towards our customers. Thanks, guys!!

Jorin Aardoom
Abstract

“This master thesis describes the development of a decision support tool aiming at the abstraction of a subset of items from an assortment, that do not sufficiently contribute to the overall operating performance of an organization. A case study at Office Depot has been conducted to first identify problems that may relate to a poor operating performance. Secondly, an approach is presented to provide quantitative input in the discussion of the optimization of an assortment, which is in line with the set of Key Performance Indicators that are present at Office Depot. The proposed heuristic should be integrated in the protocol of assortment reviews, being the first quantitative step prior to the assessment of individual characteristics of items, that are often compared with each other to check for sufficient diversity, when assortments are reviewed.”
Management Summary

This master thesis has been conducted in cooperation with Eindhoven University of Technology and Office Depot Europe B.V. in Venlo, the Netherlands. Office Depot (OD), founded in 1986 in the USA, is a global wholesaler in Office articles, with more than 66,000 associates worldwide and an annual turnover of approximately $17 billion. The master thesis is conducted during a five months research project at the supply chain department of Office Depot, under supervision of Michel Ophelders (OD), and Karel van Donselaar (TU/e). One of the main struggles of OD, were the high levels of inventory that were held in 23 distribution centers across Europe, with a huge amount of inventory value compared to industry averages. A significant decrease of the total value of inventories at the balance sheet, would create opportunities to reinvest millions of dollars to innovative and promising projects.

First, a problem analysis was conducted to relate all direct and indirect problems that were present at the time, that may have been driving the levels of inventory. During the problem analysis, the scope slowly changed from decreasing the total values of sales, towards an overall increase of the operating performance. Many of the interviewees at various departments, repeatedly mentioned problems and underlying suboptimal performance (behavior) of colleagues at other departments. This created a high-level perspective, that the goal of inventory reduction was not within reach as long as the operating performance was too low. In this master thesis, the term operating performance was defined as the financial ratio of profit divided by sales. Using Porras Stream Analysis (Porras, 1987), a clear overview of interconnections between 39 problem drivers was created, that all link to a poor operating performance. After diversification of the problem classes, the root cause of ‘limited standardization, harmonization and rationalization’, along with ‘the high number of SKUs in assortments’ were chosen for further analysis. Hereafter, a research objective could be stated, with corresponding research sub questions as the underlying structure of the research objective:

“How to Increase Operational Performance at Office Depot for various product families in an assortment based substitution environment?”

The elaboration on the research sub questions (RSQ) have resulted in the opportunity to unambiguously answer the research objective. The first RSQ, was to define the term ‘operating performance’. Then, for the second RSQ, the main causes of operating performance were identified.
and analyzed using a frugal cause and effect diagram, an Ishikawa diagram (1990), and Porras Stream Analysis (Porras, 1987). The third research sub question, aimed at the relation between Assortment Planning Theory and the Operating Performance. Assortment Planning theory is the field of research aiming at the optimization of the profitability of a given assortment under various constrictions. Then, for RSQ 4, the methods and frameworks for assortment planning that were applied at the time were identified and analyzed. It appeared that almost no quantitative methods were applied to assortment planning at OD, since only a verification of sufficient qualitative diversification between SKUs in an assortment was being conducted at OD. Research sub question 5 proposes the use of a constructed decision support tool, aiming at the addition of a quantitative aspect into the process of an assortment under review. The main idea behind the decision support tool, created using Microsoft Excel’s VBA®, was that the contribution of a SKU to the assortment and the operating performance as a whole, needed to be sufficient. A heuristic was implemented in the decision support tool, following four steps: the contribution to overall profit, the number of customers buying the SKU, the number of customers orders with only one specific SKU (exclusivity ranking), and the share of the sales of the SKU compared to the assortment average.

**Main findings of decision support tool**

A simulated run of the decision support tool with simulated demand of 500 customer orders, and actual data of product characteristics of 96 SKUs in the ‘electronic supplies’ assortment, resulted in an increase of Operating performance from 20.26% to 20.34%. This was achieved after the suggested elimination of 24 out of 96 SKUs that apparently do not sufficiently contribute to the assortment according to the profitability model that was included in the heuristic.

The sixth research sub question that was elaborated on in this master thesis, addressed the question whether the suggestions made in this master thesis and the decision support tool are feasible, following the set of Key Performance Indicators applied for process owners in the core business process of OD. This organizational dimension is important for the research, since the decision support tool is, as the name suggests, a support tool. According to the observations of interviewees, suboptimal performances of process owners resulted in product proliferation in the past. The high number of SKUs in the assortment increase the demand uncertainty and supply chain risk, pressing the profitability of the assortment in the end. The underlying assumption of the assortment reviewing task force, was that the assortment lacked a number of SKUs. This implied the repeated increase of the number of SKUs held in an assortment, instead of the verification whether some of the SKUs were underperforming and could be dropped from the assortment. There was a strong
belief at OD, that more sales automatically implied more profit. Cannibalization and substitution effects were not taken into account at OD, contradicting all Assortment Planning literature.

An integrated approach for the redesign of the assortment reviewing procedure has been provided, in order to cope with the aforementioned underlying assumptions that were present. After the adoption of the decision support tool, the product manager and his assortment reviewing team are required to defend their choices with arguments, whether to keep the SKUs that apparently do not sufficiently contribute to the assortment according to OD standards. By default, the list of SKUs suggested for elimination are required to be deleted from the assortment when no (quantitative) arguments are representing the defense to keep those SKUs. For instance, it could be that a product with a calculated loss is still allowed in the assortment, since OD is market leader with that specific product as its float, e.g. Office Depot Standard A4 paper.

The elaboration on the research objective is that by deleting a list of SKUs that do not sufficiently contribute to the assortment, a higher operating performance can be achieved. Shah and Avittathur (2006) states a reduced demand uncertainty and supply chain risk when the number of SKUs held in an assortment is optimized to increase the total profit. Lower levels of risk and demand uncertainty lead to lower inventory levels (Silver et al., 1998). Therefore, when all assortments are verified for underperforming SKUs using the proposed decision support tool and integration of the tool in the assortment reviewing procedure, the total value of inventory on the balance sheet of Office Depot, can significantly be decreased.
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1. Introduction

The generic retail business model operated at organizations like Office Depot Inc., can be characterized as “buying large quantities of goods and reselling these goods in smaller lot sizes, reflecting some of the cost savings made through bulk buying in the resale price”. Within the limits of this business model, it is the primary objective to increase the unit profit margin, while maintaining an overall set of competitive product prices. Therefore, a low cost organization structure with corresponding operating costs, is key to succeed this primary objective. This Master Thesis Project started with a wide review of scientific literature, and a root cause analysis to identify the most important contributors to the current poor operating performance. According to literature, a poor operating performance in the case of Office Depot, may have started at the proliferation of items in various assortments. This Master Thesis Project is the product of findings in the literature suggesting opportunities for optimization of the current assortment, versus the approach and rules of thumb that were applied at the time.

1.1 Report structure

This report is the result of a five months master thesis project conducted at Office Depot Europe B.V., located in Venlo. First, in Chapter 1, the company background and problem introduction are presented. Next, sections 2.1 and 2.2. state the formal problem definition and the corresponding research sub questions, that give structure to the research objective. The scope and deliverables of the research performed, along the selected methodology as a project approach, are discussed in sections 2.3 and 2.4. The most noticeable literature is discussed in Chapter 3, covering three important aspects for this master thesis.

In Chapter 4, the deduction of the problem statements and definition are presented, with a practical remark on the quality and availability of data. At Chapter 5, the simulation model is explained, both mathematically and in words, including the corresponding implications of the output. Finally, the results and elaboration of the research sub questions are presented in Chapter 6. Next, Chapter 7 discusses the conclusion, recommendations, and the redesign according to the findings. Some sections refer to the appendix, where figures are positioned for background information.
1.2 Company background

Office Depot was founded in 1986 in Florida, United States of America. At the time, the organization employed 66,000 associates worldwide, with an annual turnover of approximately $17 billion from multiple ventures in 57 countries. Office Depot Europe employed 9,000 associates in Europe and the Middle East, where Office Depot (OD) was the number one reseller of office products and services, through direct mail catalogs, contract sales forces, e-business and retail stores. In Europe and the Middle East, OD applied a mix of company-owned operations, joint ventures, licensing and franchise agreements, alliances and strategic partnerships. OD had, among other locations, retail activities in France, Hungary, Israel, Sweden, Saudi-Arabia, Dubai and Kuwait. The corporate headquarters of Office Depot in Europe and the Middle East, was at the time located in Venlo, The Netherlands. (www.officedepot.com, 2014).

Office Depot is a bulk-breaker and retailer in the field of office products and many product types related to this field. Office Depot Europe is a sub division within an American stock market listed public organization (NYSE:ODP), as displayed in the corporate structure shown in Figure 2 (Retrieved from www.officedepot.com, 2014). Office Depot strived to increase its share price towards pre-crisis levels, since the share value had diminished with a major 90.1 per cent from approximately $42 (mid 2007) to $4.15 (mid 2014) per share. Therefore, incentives to increase overall efficiency in order to reduce relevant costs in the complete supply chain, are initiated.

![Organization chart of Office Depot Inc.](Image)
From the perspective of Logistics and Operations Management at Office Depot Europe, there were 23 distribution centers at the time, with a total area of 500,000 square meters of warehousing space across Europe. For ocean freight, a central warehouse (CDC) replenished the regional- and local distribution centers (RDCs and LDCs), based in Eindhoven, Belgium. Figure 3 displays the geographical locations of the distribution centers across Europe. The department of ‘European Supply Chain & Inventories Planning’, located in Venlo at the European headquarters, was responsible for the (in)direct shipments of goods from distant vendors. This master thesis project has been conducted at the latter department which was, amongst other things, responsible for the timely and accurate replenishment of the CDC and the line fill rate of the CDC towards the RDCs and LDCs across Europe.

1.3 Problem introduction
Multiple interviews have been conducted with several (senior) managers of various departments, which resulted in the knowledge of presumably inefficient cross-departmental processes between procurement, merchandising, and the department of Supply Chain Operations. At the time, there were low levels of standardization and harmonization in the entire core business process starting at the long list of potential vendors, until the repeated deliveries of the selected vendors. On the one hand, there is trivial emphasis regarding the selection of new vendors at the procurement department with respect to an efficient selection procedure, rather than simply trying to decrease the purchasing price. On the other hand, the merchandising department might have been ‘pushing’ the procurement department in certain directions within the vendor selection process, making it hard to reach targeted item cost prices. Therefore, guidelines for logistics – and operations related activities were quite often one of the first protocols to be relaxed by purchasers and contractors, to reach procurement targets and thresholds. It seemed that performance indicators were not aligned towards the organization’s strategy and best interests, since contradictory incentives at departments were present. The results are lower levels of profit per item, which led to a relatively poor operating performance compared to competitors in the same field of industry, according to Steve Schmidt, president of Office Depot Europe B.V. (29 April 2014).
Office Depot proclaimed to be a *Global wholesale bulk breaker*, as their operating objective stated to “buy large quantities of goods and reselling these goods in smaller lot sizes, reflecting some of the cost savings made through bulk buying in the resale price” (Office Depot annual report, 2012, pp. 3).

Hence profits made at one department could affect the overall operational performance, stress the upstream supply chain, or decrease the bottom line profit margin per unit sold. Moreover, compared to industry standards, Office Depot had high levels of inventory in its European Division, whereas the decisions made were not based at the optimization of the average profit margin per selling unit. This resulted in a poor operating performance, along with a relatively high number of backorders, according to interviewees of various departments.

The first question that arose from this apparent multitude of problems that may relate to a poor operating performance, was how all of these problems were linked to each other. By means of an iterative search process using various problem identification methods suggested in the literature, the most important root cause identified, was “limited SKU rationalization”. The lack- and poor quality of data excluded some of the other identified problems, that also related to a poor operating performance. Consensus was reached with all supervisors of this Master Thesis Project, to analyze “rules of thumb” that were applied at the time concerning the assortment planning strategy at Office Depot, and to compare these methods with suggestions made in the literature.
2. Research Project

This chapter discusses the research methodology selected to conduct the research performed in this master thesis. Section 2.1 describes the problem definition, followed by section 2.2 that unambiguously states the research objective, structured by five research subquestions. The exact project approach, is followed by the scope and limitations in sections 2.3, 2.4, and 2.5, respectively. Then, the contribution to the literature and Office Depot will be presented in sections 2.6 and 2.7.

2.1 Problem Definition

At the start of the master thesis project, the objective was to find literature which emphasized a strategic balance between the evaluation of potential vendors, and bottom line financial benefits. Nevertheless, due to a lack of available data and the estimation of required time for the wide area of research, the problem definition changed over time. Figure 4 below, displays a typical process of the development of a problem statement with corresponding research questions, abstracted at the ‘end’ of the funnel.

![Figure 4: Development of the problem definition throughout the master thesis project](image)

The research question that was addressed after the first objective was regarded not to be feasible, was to define how problems were interconnected in order to decide which area of research should have been selected to still increase the operating performance. Chapter four describes the exhaustive search for all interconnections between the current present problems, that may directly and indirectly contribute to a poor operating performance. Steve Schmidt, president of Office Depot Europe, announced that the operating model and costs to serve the customer were inferior compared to key competitors in the same industry, e.g. Staples, Lyreco, and many others (Schmidt, 29 April 2014). Therefore, top management was aware of an absolute need for change, for which it launched the 2013/2014 Business Transformation Programme, aiming at improvements and cost...
reductions at all departments. Road maps were created and presented, to ‘change the route’ from where OD was situated at the time, towards the desired levels of performance across all departments (Schmidt, 29 April 2014). Steve Schmidt literally stated “there shall not be any sacred cows during the Business Transformation Process, like updating our current assortment and significantly decreasing the high level of inventories across all regions. Freeing up these funds could be used to enter the upwards stream of improvements, due to more investments in supporting IT infrastructure, (...)”, according to a board update at the town hall meeting of April 29, 2014.

Figure 5 displays the architecture of the product family tree, retrieved from the Retail Management System (RMS). At the time, product managers were in charge of keeping the assortment for a specific RMS Class or RMS department up to date. The number of products held in all assortments combined have proliferated with such extent, that there were no exact estimates how many SKUs were held in each assortment. Many questions might arise from this finding: How are assortments being updated, with what reasoning, algorithms or heuristics are the assortment updates supported, or how generic are these proclaimed solutions for all sales regions? Section 2.2 below has operationalized such questions towards a structured set of research questions and one overlaying research objective.

2.2 Research Objective and Structure
This master thesis project should find a balance in terms of rigour and relevance, since within the wide range of Management Sciences, the academic rigour should be taken into account considering the relevance of solving the complex problems, according to van Aken, 2005. To reach a healthy balance between rigour and relevance, the set of research objectives should be stated in an unambiguous, abstract way. Hence a structured set of research sub questions should be addressed, which will provide the elaboration of key elements in the research objective. This methodology was leading for the master thesis project, to achieve an academically valid paper that contributes to Office Depot, as well as Operations Theory as the main area of research.
The core of the research is discussed in this section. Simon Sinek (2009) proposes a set of three questions, that were addressed at each research objective that came by during the master thesis project:

- Why is the research important?
- How is the research going to be investigated?
- What exactly is going to be investigated?

Sinek (2009) deviates from conventional literature that suggests to start with answering the ‘what’ question first. The golden circle theory aims at addressing the question ‘why’ one has the need for further research, followed by the question ‘how’ to perform the research and with what kind of methodology and research objective the research will be performed. The answer to the ‘what’ question has resulted in the statement of the research sub questions, which are the core of the research within the Master Thesis Project.

The most important question according to Sinek (2009), ‘why this research is important to perform’, can be summarized in a simple explanation with a financial background. In the 2013 annual report of OD, the constantly growing level of inventory was pressing the working capital, since more investments remained stuck in the organization, while sales were decreasing (annual report, 2013). This partly caused the share value (Atrill and McLaney, 2006) of Office Depot to decrease with more than 90 per cent over a six years time span. Freeing up working capital, e.g. by increasing the operating performance and / or decreasing the costs to serve the customer, was one of the primary objectives of Office Depot, (Annual Report, 2013).

Office Depot is considered to be a bulk breaker. According to their own definitions, the main business function is to “buy large quantities of goods and reselling these goods in smaller lot sizes, reflecting some of the cost savings made through bulk buying in the resale price”. Therefore, maximizing the margin between cost price and selling price is key to Office Depot. This is in line with a new project initiated at the department of Supply Chain Operations, i.e. Operational Brilliance, aiming at the creation of opportunities that minimize costs related to every day operations in the supply chain. Among other things, inefficiencies in the decision making process, the levels of inventory and the number of order lines, are main contributors to important cost drivers. The field of Operations Research can provide solutions that may decrease these cost drivers. Replenishment policies and corresponding parameters, were automated by the inventory control software program Prime One: This inventory control software is a major overhaul of the old fashioned software combination of AS400, E3 and AWR. Since the characteristics of the software program are presumed to be the status quo, there was no incentive and / or intention for an overhaul of the inventory control software.
Nevertheless, the decision making process and input parameters are based on humanly controlled factors. Literature provides opportunities and frameworks for optimization in for example performance of the upstream supply chain, reduction of levels of inventories, and the harmonization of business processes across various departments. Solutions implemented in the aforementioned fields will possibly lead to a more efficient internal structure and supply chain optimization, and therefore an opportunity for financial benefits.

For Office Depot, the first important question that arose, was what will be defined as Operational Performance. Moreover, what were the root causes and effects of the apparent inefficient processes that result in redundant levels of inventory, and directly related, what relevant performance indicators and benchmarks were associated with Operational Performance. Continuing this logic, what does the literature suggest in order to reduce inventory levels, or the removal of items from an assortment that carry relatively high levels of costs, which could be substituted or even completely cannibalized in sales? Could the latter example reduce the risk associated with supply chain related operations, and even optimize the net profitability of an assortment? Moreover, what does the literature suggest when the proposed solution would be implemented at different departments in an organization, where discrepancies between sets of performance indicators were present? This leads to the following research objective for this Master Thesis Project:

“How to Increase Operational Performance at Office Depot for various product families in an assortment based substitution environment?”

To elaborate on the research objective, a structured set of research sub questions was required, as key elements that are nested in the research objective. The span of research of the research objective started at the identification of the decision making process, towards the opportunity to integrate the finally proposed solution to achieve financial benefits and / or an increase in operational performance:
Research sub questions:

1) How is Operating Performance defined at Office Depot?
2) What are the main causes of a poor operating performance?
3) How are Assortment Planning and Operating Performance related?
4) What methods, tools, and models are currently applied to optimize the assortment of various product families?
5) How can suggestions for optimization of the current assortment, be applied at various product families at Office Depot?
6) Are the suggestions for optimization of the current assortment, in line with the set of Key Performance Indicators at Office Depot?

This set of six research sub questions provide the milestones sequentially needed in order to provide a scientifically sound elaboration on the research objective. The next section, will discuss the project approach applied to this master thesis project.

Project approach

2.3.1 Sagasti & Mitroff

Sagasti and Mitroff (1973), and Mitroff et al.’s (1974) Research Methodology model is based on the initial approach used when operations research emerged as a field. The model consists of four phases, explained briefly below. Figure 6 displays the research model by Sagasti and Mitroff (1973) and Mitroff et al. (1974).

![Diagram of Sagasti and Mitroff's Research Model](image-url)
In the **Conceptualization** phase, a conceptual model of the problem is formed, decisions on which aspects are relevant and irrelevant and which variables need to be included in the model are made. The conceptual model also represents a further degree of abstraction from reality and is capable of generating one or more scientific models. In the **Modeling** phase, the quantitative simulation model is made by defining causal relationships between the variables precisely in operational terms. The result is a formal representation of both reality and the conceptual model, in the shape of the scientific model. **Model Solving:** In this phase the scientific model is solved for the particular situation in scope, whereas the **implementation** phase is providing the solution linked back to reality. Based on the implementation, conclusions are drawn and recommendations are provided.

This methodology is suitable for research where a scientific simulation model is being constructed to elaborate the research questions. Yet, the methodology used to elaborate on the research objective, can be found primarily in the structured spread of the key elements of the research objective, denoted as research sub questions in section 2.2.

### 2.3.2 Regulative cycle by van Strien

The implementation phase in the framework of Sagasti and Mitroff (1973) provides the solution linked back to reality. This process is not as standardized as the methodology would suggest, since the implementation should be regarded more as an integration or redesign of the found solutions. Therefore, the regulative cycle by van Strien (1997) was substituted for the implementation phase of the framework described in section 2.3.1. This is the case when the proposed solution in this master thesis can be integrated and implemented ‘on top of’ the protocols or procedures that were already actively used. Figure 7 displays the regulative cycle, often used in literature for the redesign including an intervention based on a plan of action. The characteristic element of the regulative cycle by van Strien (1997), is the link between the evaluation step and the initiation of the problem definition, since the redesign of a certain procedure may be evolving over time. See van Strien (1997), or van Aken (2005), for more details concerning the regulative cycle and other alternative methodologies.

![Figure 7: Regulative cycle (van Strien, 1997)](image-url)
2.4 Scope
The decrease of the total value of inventory held was one of the main targets of Office Depot. Inventory is a significant parameter at the balance sheet that can affect the operating performance, according to the management of OD. At OD, inventories were diversified into several stock buckets with different root causes. The overall goal to reduce inventories in Europe was operationalized by OD into six stock buckets, of which three were in scope: non-Promotional Excess stock (MOQ Stock), Replenishment stock (cycle stock), and Safety stock, since these three stock buckets account for the majority of total European inventories.

The proposed model, discussed in Chapter five, will function as a decision support tool rather than an incentive to overhaul the current inventories management system *Prime One*, developed by *DemandSoft*. The model constructed during this master thesis project can only be regarded as a supporting tool for the decision making process, in order to start the conversation with various stakeholders in the supply chain how to optimize the profitability of an item. Formulas, algorithms and heuristics are noted by DemandSoft as intellectual property. The result is that the leading replenishment theory / policies are not known. Therefore, theory regarding inventory control is assumed to be non-influenceable for this master thesis project. This does not imply that output from Prime One cannot be added to the simulation model. Cost parameters or output data could still be inserted into the profitability model after the successful launch of Prime One in all active sales region, since at the time of this research, the software was not yet fully operational in all regions.

Transportation was considered to account for approximately two-thirds of the European Supply Chain department its budget. Nevertheless, OD did not expect to significantly decrease costs of transportation, since goods are delivered DDP (Delivery Duty Paid) to OD, which implies a built-in transportation cost factor in the initial purchase price from the perspective of Office Depot. The outbound logistics strategy of OD is not unified across all sales regions, since the differences between regions are too great to compare the outbound logistics costs with each other. Further analysis of the statement that ‘transportation’ is out of scope, is elaborated in section five.

In the literature, Vendor Managed Inventory is often described as an important opportunity to increase levels of operational efficiency in the (upstream) supply chain, popularized by Walmart and Proctor & Gamble in the late 1980s, according to Waller et al. (1999). Previous endeavors of Office Depot did not result in a successful implementation of Vendor Managed Inventory (VMI), with large sunk costs as a consequence. Therefore, VMI is considered out of scope as an opportunity to increase operational efficiency in the supply chain, and decrease inventory levels locally.
2.4.1 Business Entities involved
The business entities that were involved in this master thesis project were the European procurement department, Merchandising department, Business Intelligence department, and European Supply Chain department. The latter department was directing operations, the planning and supply of the Central Distribution Centre, which transferred part of the inventory to a subset of the 23 regional and local distribution centers in Europe.

2.4.2 Product groups involved
Office Depot Europe constructed its internal structure according to several dimensions. For instance, six regions were active in Europe which are getting more standardized over time, e.g. by implementing Inventory control software program Prime One in all regions. Moreover, products are divided into several categories, ranging from completely customized by the customer, to standardized products or ‘own brand’ items from Office Depot. A product group may therefore be the product of a certain product category in a specific region, e.g. all toners and cart ridges in France.

2.5 Deliverables
The deliverables of this master thesis project:

1) A detailed process model of the end-to-end vendor selection process until the initial delivery of the selected vendor;

2) A cause and effect diagram with interconnections of problems relating to a poor operating performance, graphically represented in a clear overview.

3) An easy to use decision support tool for the quantification of assortment planning, and the impact of reducing the number of SKUs in the product category its assortment.

4) An addition to the literature with insights in the relationship between the rationalization of SKUs, and the expected increase of operating performance.

5) A Master’s thesis.

2.6 Contribution to the literature
When browsing for literature during the preparation phase of the master thesis project, various specific research areas have been glanced through. Among other subjects, the vendor selection process, inter departmental KPI assessment, and advanced Inventory Management algorithms and heuristics have been analyzed during the identification of interconnections of problems. Finally, consensus was reached for SKU Rationalization as the in-depth Master Thesis Project area of research. In the literature, SKU Rationalization is predominantly known as Assortment Planning, which has links to Product Variety theory, and Product Proliferation. Most articles are dated pre-Internet era, therefore possibly not applicable in the special case of Office Depot. In those times,
brick-and-mortar stores were the most important sales channels, leading to other modeling characteristics and restrictions in assortment planning theory, compared to the set of possible restrictions that are applicable to web based sales channels. Sales channels for Office Depot are mainly catalogue- and Internet (web) based, according to van Deijck (2013).

The contribution of this Master Thesis Project to the literature, is the initial case study that addresses the poor operating performance, linked to the theory of Assortment Planning and Product Proliferation, for the sales channels that Office Depot operates with. In the literature, it is often assumed that retail companies have aisles with limited tangible shelf space as sales channels, therefore, it cannot be assumed that suggestions made for the optimization of the Assortment Planning Problem, can be applied black and white in the case of Office Depot. This master thesis contributes to the literature with an alternative approach to optimize assortments, independently whether web based sales or brick-and-mortar stores are applied as sales channels.

Another contribution to the literature is the identification of relevant contributors to various symptoms that relate to a certain topic. Among other things, frugal problem analysis, Ishikawa diagrams (Ishikawa, 1990), and Porras Stream Analysis (1987) were not unambiguously helpful. When the number of problems exceeds 15 cases, the number of interconnections are increasing rapidly, resulting in a multitude of problems. My suggestion to create a synoptic overview of interconnected problems was derived from the theory of Porras Stream Analysis (Porras, 1987), yet with an iteration of the second degree symptoms which directly influence the primary problem identified. The complete description of the search for a suitable method for problem identification can be found in Chapter 4.

2.7 Contribution to Office Depot Europe
A cross-validated effect – cause – effect diagram has provided awareness for actors at various departments in the process of operational inefficiencies. Along with an identified set of Key Performance Indicators (KPIs), this master thesis project has provided knowledge of Office Depot’s own Standard Operating Processes of their core business. This has been achieved by conducting interviews and creating drawings of the corresponding operating models, and by suggesting a redesign for the integration of the proposed heuristic into the approach that was leading at the time.

Moreover, sacred cows, e.g. the Rationalization and Harmonization of items in the assortment, was considered a very sensitive subject at Office Depot, which repeatedly returned in conference rooms. The most important contribution to Office Depot, would be the reduction of the total value of
inventories, while securing total sales. From a finance perspective, a reduction of booked inventories directly results in the possibility to reinvest the value of unlocked current assets, or to let it increase the total equity, according to (Atrill and McLaney, 2006). An increase of the total equity, divided by an assumed equal number of shares outstanding, implies the increase of the share value of the European Division of Office Depot. Since approximately 90 per cent of the share value of Office Depot has been depleted since pre-crisis levels (2008), it can only be assumed the findings in this Master Thesis can be of great help to achieve the primary objective of a public company, which is to maximize the shareholder’s value (Atrill and McLaney, 2006).
3 Literature Review

This chapter discusses headlines from literature that are significant for this research and its research objectives. Three research disciplines are important for this master thesis project. The basis for the construction of the decision support tool, its practical implications, and the underlying theory, should be found in literature. Therefore, operating performance, performance management, and assortment planning literature have been analyzed, of which sections 3.1 through 3.3 present the key findings that played a central role as the foundation of knowledge and theory applied in this master thesis.

Section 3.1 discusses the (term) operating performance, whereas section 3.2 discusses the performance management systems. Section 3.3 is partitioned into four subsections. After the general discussion of literature findings in the field of Assortment Planning, four consumer choice models and its implications are presented in sections 3.4.1 through 3.4.4.

3.1 Operating Performance

Three broad categories of managerial activities can be distinguished within the overall corporate strategy, being strategic planning, tactical planning, and operational control, according to Anthony (1965). Silver et al. (1998), state that there is a second type of integration of decisions, that is important in the context of multistage production operations. They state “at the operational level, one must ensure that there is proper coordination of the input streams of the various raw materials, components, subassemblies, and so forth” (Silver et al., 1998, pp. 538). Multiple significant developments have passed over the recent years, from MRP-I towards ERP and PLM (Chituc, 2014, pp. 4), “in order to control, automate and integrate the majority of an organization’s business processes”. Barber and Lyon (1995) even proposed a method to assess the relative power of operating performance between multiple organizations, using various Return-On-Assets measures.

Operating Performance is often defined in terms of the financial ratio of operating performance, i.e. the ratio of profitability divided by the total sales value (Atrill and McLaney, 2006; Barber and Lyon, 1995). The operating performance can be influenced by many factors, both internally as well externally related, e.g. in the supply chain. Mentzer et al. (2001), define a supply chain as “a set of three or more entities (organizations or individuals) directly involved in the upstream and downstream flows of products, services, finances, and/or information from a source to a customer”. Hendricks and Singhal (2005) studied the impact of supply chain related glitches upon the Operating Performance, by assessing a sample of 885 identified glitches over a time span of seven years. The main viewpoint of Hendricks and Singhal (2005, pp. 695) is that “Efficiency, reliability, and
responsiveness are key drivers of a firm’s profitability”. Their quantitative assessment of 885 supply chain glitches upon operating performance, was targeted more at the reliability and robustness of the general operating performance, rather than the conventional literature describing impact upon efficiency.

Hence operating performance can be influenced by numerous factors, including the efficiency of personnel. This type of efficiency, often mentioned as Performance Management, is described at section 3.2 below. Both for Office Depot and this master thesis, the operating performance is defined following the terminology of Atrill and McLaney (2006), as the ratio of profit over the total sales value.

### 3.2 Performance Management Systems

“The ability to measure the performance of operations can be seen as an important prerequisite for improvement, (…) and performance measurement becomes even more important in the context of a supply chain”, according to Fawcett and Cooper (1998). Three important terms are described in literature, that should not be confused with each other, according to Lohman et al., 2004:

- **Performance Indicator (PI):** A variable that quantitatively expresses the effectiveness and / or efficiency, of a part of or a whole process, or system, against a given norm or target;
- **Performance Measurement (PM):** The activity of measuring performance using PIs;
- **Performance Measurement System (PMS):** A system to execute PM in a consistent and complete way.

De Haas and Kleingeld (1999) found evidence that management should consider compatibility in two ways, i.e. vertical and horizontal consistency of organizational PMS’s. Vertical consistency dictates that strategic priorities must be unambiguously reflected in financial and non-financial PIs of the PMS, whereas horizontal consistency dictates that management should develop a cross functional view of the contribution of each individual work unit in the integrated value chain of primary and supportive processes (Algera and de Haas (2002)).

Kennerly and Neely (2003) focused at the question how organizations (can) manage their measurement systems so that they continually remain relevant. Latter authors demonstrate that “a complex range of factors can facilitate or inhibit this evolution and present a framework that provides an understanding of how evolution can be managed” (Kennerly and Neely, 2003, pp. 215). This can be done by grouping capabilities under the categories of process, people, systems, and
culture. This enables organizations to cope with the changing environment and modify their performance measurement system accordingly, according to Kennerly and Neely (2003).

A typical development process of a PMS can then be described according to the nine steps procedure of Neely et al. (1995):

1) Clearly define the firm’s mission statement;
2) Identify the firm’s strategic objectives using the mission statement as a guide, e.g. profitability, market share, quality, cost, flexibility, dependability, and / or innovation;
3) Develop an understanding of each functional area’s role in achieving the various strategic objectives;
4) For each functional area, develop global performance measures capable of defining the firm its overall competitive position to top management;
5) Communicate strategic objectives and performance goals to lower levels in the organization, and establish more specific performance criteria at each level;
6) Assure consistency with strategic objectives among the performance criteria used at each level;
7) Assure the compatibility of performance measures used in all functional areas;
8) Use / Execute the PMS;
9) Periodically re-evaluate the appropriateness of the established PMS in view of the current competitive environment.

Lohman et al. (2004), conceptually separate the development of a PMS into three relevant aspects of performance: Resources, output, and flexibility. A firm should install processes that ensure continuous review of the PMS (Beamon and Ware, 1998; Bourne et al., 2000; Medori and Steeple, 2000).

3.3 Consumer Choice models & Assortment Planning
“Assortment planning has been the focus of numerous industry studies, mostly concerned with the question of whether assortments were too broad or too narrow” (Kök and Fisher, 2007, pp. 1001). Conventional brick-and-mortar stores have limited shelf space capacity and are required to make an informed decision what products to sell, where in the shelf to position the product with a limited number of facings, and how many comparable items should be sold from a specific category. When a product is considered not available (at the moment) for a customer, she may choose to substitute her preferred product, with one that sufficiently covers her requirements from the initial product desire. In the literature, there are two substitution models identified what happens in these
situations. Stockout-based substitution is the switch to an available variant by a consumer when her favorite product is carried in the store, but is stocked out at the time of her shopping. The second option of substitution, is assortment-based substitution, which is the switch to an available variant by a consumer when her favorite product is not carried in the store (Kök and Fisher, 2007; Guadagni and Little, 1983; Bernstein et al., 2013). Consumer responses to stock outs, measured across eight categories of retailers worldwide, are displayed in Figure 8 below (Gruen et al., 2003).

![Figure 8: Consumer responses to stock outs, Gruen et al., (2003)](image)

Kök, Fisher, and Vaidyanathan (2008), provide a thorough and extensive review of assortment planning literature. They academically define the Assortment Planning Problem, as “the formulation of an optimization problem, with which to choose the optimal set of products to be carried and, possibly, the inventory level and price of each product. Moreover, products are interdependent because products are linked in considerations such as shelf space availability and substitutability” (Kök et al., 2008, pp. 3). According to Honhon (2013), assortment planning requires a tradeoff between three elements of an assortment: The Breadth, Depth, and Inventory. The breadth determines how many different categories the retailer is carrying, the depth determines how many SKUs the retailer is carrying for each assortment, and the inventory determines how much stock is held for each SKU. For instance, there are 500 types of shampoo at Walmart or 15 versions and types of Colgate toothpaste at a supermarket (Byrne, 2007). Toothpaste is regarded to be a homogeneous product, therefore offering 15 alternatives from even one brand, can be an overkill for consumers. Byrne (2007) even mentioned Office Depot as the resemblance of one of the worst examples of product proliferation, by offering too many irrelevant alternatives in an assortment, e.g. 80 varieties of black pens.

Starting in the 60s of the last century, the era of ‘customer focused innovation’ started. Henry Ford’s famous marketing campaign – *You can buy the T-Ford in every color, as long as it’s Black* – was not longer sufficient, since consumers started to desire the exact product they had in mind. Mass
customization was the result, which led to the effect known as SKU proliferation (Byrne, 2007). Profits can be increased with significant results, according to Honhon (2013): Kök and Fisher (2007) report a potential 50% increase in profit by applying their assortment planning optimization methods at Albert Heijn, Chong et al. (2001) denote a profit improvement of 25.1% across eight food categories and five stores, whereas Yunes’s (2007) research at Deere & Company identified a potential profit increase of eight to eighteen per cent. Moreover, Honhon (2013, pp. 5) states that “variety is costly: A broader assortment implies less demand and inventory per product, which can lead to slow selling inventory, poor product availability, higher handling costs, and greater markdown costs”.

In order to decide whether the addition of an extra item to an assortment will result in a profit increase or decrease, the behavior of the consumer needs to be represented first. Various consumer choice models have been analyzed in literature, of which four are presented in sections 3.3.1 to 3.3.4.

- Multinomial demand model;
- Exogenous demand model;
- Locational choice model;
- Ranking–based model.

For an extensive literature review and corresponding case studies following one of the four consumer choice models, see to Kök et al. (2005), Mahajan and van Ryzin (1999).

### 3.3.1 Multinomial Logit model

Guadagni and Little (1983) provide an axiomatic view with a choice at alternative $k$ from a specific set of SKUs $S_i$, chosen by customer $i$. Both $k$ and $S_i$ are in terms of SKUs, where $k$ can be conceptualized as an alternative for a comparable item that is carried in an assortment. This alternative will be chosen following three main assumptions, described in Guadagni and Little (1983):

1. Alternative $k \in S_i$ holds a utility $u_k = v_k + \epsilon_k$, with $v_k$ as the deterministic component of $i$’s utility, and $\epsilon_k$ as a random component.

2. Customer $i$ chooses the product from the assortment with the highest utility $u_k$ on the occasion, where the probability of choosing alternative $k$ is $p_k = P\{u_k \geq u_j, j \in S_i\}$.

3. The random component $\epsilon_k$ follows an Double Exponential distribution at the interval $-\infty < \epsilon < +\infty$, according to Montgomery and Runger (2007).

“How the Multinomial Logit Model (MNL) computes the probability of choosing an alternative as a function of the attributes of all the alternatives available”, according to Anupindi et al. (1998). Latter authors provides a case study with coffee purchases using Point-Of-Sales data to calibrate the MNL.
model. In the literature, MNL is often challenged at one of its assumptions when the ratio of choice probabilities for alternatives $i$ and $j$ are independent of the choice set $S$, known as the Independence of Irrelative Alternatives or IIA. In summary, the probabilities of the selection of an alternative is changing, when irrelevant alternatives are added to the set $S_i$, e.g. offering three more green-color variants of ballpoint pens, when the customer is choosing between purchasing either a pencil or a ballpoint pen. Van Ryzin and Mahajan (1999, pp. 1498) suggests the “MNL model should be restricted to choice sets containing alternatives that are in some sense equally dissimilar”. Moreover, van Ryzin and Mahajan (1999) provide a description of aggregate demand, determined by the collection of decisions made by all customers. They state that aggregate demand under the MNL model, can be either following the independent population model, or the Trend-following population model (see Kök et al. (2005), Marvel and Peck (1995), or van Ryzin and Mahajan 1999, for more details). For Office Depot, the MNL model is not very suitable because of the IIA assumption: Irrelevant alternatives are redundantly present in many of the assortments.

3.3.2 Exogenous Demand model

The exogenous demand model has been elaborated by Anupindi et al. (1998), using the example of a soda vending machine, with two products to choose from, A and B, e.g. Coca-Cola or Pepsi. The ED model assumes that demand arrives following a Poisson process with rate $\Lambda$ with inter-arrival times exponentially distributed with mean $1/\Lambda$. Three main assumptions are present when the Exogenous demand model (ED Model) is applied, according to Anupindi et al. (1998):

1) Every customer has a favorite product from the set of potential SKUs with size $n$; the probability that product $j$ is a customer its favorite product is $p_j$;

2) In case the customer’s favorite product is not available, she substitutes to a certain variant $k$ with probability $a_{jk}$, denoted in the substitution matrix $A$ with $n \cdot n$ elements.

3) At most one substitution attempt is allowed; if the substitute product is not available, the sale is lost.

Using estimates for substitution probabilities in case one of the two products runs out, the most likelihood estimator $L$ for purchase probabilities $p_A, p_B$ and inventory levels $s_A, s_B$ can be found solving for

$$
\max_{p_A, p_B, a_{AB}, a_{BA}} L = \prod P_1(S_A, S_B) \prod P_2(S_A, S_B) \prod P_3(S_A, S_B) \prod P_4(S_A, S_B) \prod P_5(S_A, S_B)
$$

Such that $0 \leq p_A, p_B, a_{AB}, a_{BA} \leq 1$. Yet in the case of Office Depot, this model is not very convenient since there would be too many variables to be estimated, and the corresponding cases are too large in case $n \gg 2$. 

20
3.3.3 Locational Choice model

The Locational Choice model was originally developed by Hotelling in 1929, yet extended by Lancaster (1966), used for horizontal differentiation, where a customer corresponds to her most preferred combination of attributes. With the Locational Choice model (LC model), the property of the IIA does not hold, compared to the MNL model. Yet, the model can be used for substitution between products with characteristics that are close to each other. In literature, milk is often used as a fine example of the LC model, where a customer has a set of preferences ranging from skim to whole milk. Each customer is assumed to have an ideal product within that range. According to Honhon (2013), “the purchase probability of product \( j \), i.e. \( P_j(S) \) can be calculated by taking the integral of the consumer taste density over the market segment of product \( j \).” The range of products a consumer can choose of is too broad to apply the LC model as the consumer choice model at OD.

3.3.4 Ranking Based model

Farias et al. (2013), describes the Ranking based model (RB Model), with consumer types. Honhon (2013, pp. 51) defines the RB model as “each consumer type has a ranking of the set of offered alternatives in the category set \( S \), where she can choose not to include one or more of the offered alternatives in her ranking list. The probability of a consumer picking product \( j \) from assortment \( S \), i.e. \( P_j(S) \), can be described once the permutations (rankings) \( \sigma \) of all alternatives in \( S \) has been associated for a particular customer”.

Therefore, the customer prefers product \( i \) over \( j \), when \( \sigma(i) < \sigma(j) \). Note, that with respect to the earlier three consumer choice models described at section 3.3.1 through 3.3.3, Farias et al. (2013) somewhat deviates from the standardized notation, since they use \( \mathcal{M} \) instead of the alternative \( k \), in the offered set \( \mathcal{N} \) instead of \( S \). Mathematically, a customer purchases following

$$\arg \min_{k \in \mathcal{M}} \sigma(i)$$

Then, the exact choice model is defined as

$$p(j|\mathcal{M}) = \sum_{\sigma \in S_j(\mathcal{M})} \lambda(\sigma) \triangleq \lambda^j(\mathcal{M})$$

Where \( \lambda: S_N \rightarrow [0,1] \), and \( S_N \) denotes the effective set of all possible customer types since every customer is permutated (ranked), which uniquely determines her behavior. The \( \triangleq \) operator, i.e. \textit{delta equal to} operator, decides \( \lambda^j \) is defined as \( \lambda^j(\mathcal{M}) \). This holds under the important model assumption that “at a given point in time, a customer possess rational preferences over all alternatives”, (Farias
et al., 2013, pp. 7). Note, that a customer only needs to be aware of her preferences from set \( \mathcal{N} \), and not from all offered alternatives in the complete set.

The most important addition from the RB model compared to the MNL model, is the overcoming of the IIA assumption using a Nested Logit Family (Farias et al., 2013). The authors simply state the universe of products, \( \mathcal{N} \), to be partitioned into \( L \) mutually exclusive subsets, i.e. nests, denoted as \( \mathcal{N}_1, \mathcal{N}_2, \ldots, \mathcal{N}_L \), such that \( \mathcal{N} = \bigcup_1^L \mathcal{N}_\ell \) and \( \mathcal{N}_\ell \cap \mathcal{N}_m = \emptyset \), for \( m \neq \ell \).

Following the derivation of Ben-Akiva and Lerman (1985), along with a set of assumptions on the error terms \( \xi_{j,\ell} \sim \text{Gumbel}(0, \rho < 1) \), then we can derive the probability that product \( j \) is purchased when offered assortment \( \mathcal{M} \) as:

\[
\Pr(j|\mathcal{M}) = \Pr(\mathcal{N}_\ell|\mathcal{M})\Pr(j|\mathcal{N}_\ell, \mathcal{M}) = \frac{(w(\ell,\mathcal{M}))^{\rho}}{\sum_{\ell=1}^L (w(m,\mathcal{M}))^\rho} \frac{w_j}{w(\ell,\mathcal{M})}
\]

Where the factor \( w(\ell,\mathcal{M}) \) is defined as the sum over \( w_j \), or \( \sum_{i \in \mathcal{N}_\ell \cap \mathcal{N}_m} w_i \). This approach does require however, to partition the items in a nest such that items sharing unobserved attributes lie in the same nest. For further details, see Farias et al., (2013); Marzano and Papola, (2008); and Vovsh, (1997).

\[\blacksquare\]
4 Deduction of Problem Statements & Definition

This section describes the search for the set of problems that can be influenced, and provides sufficient space for an in depth theoretical analysis. Section 4.1.1. describes the findings from the frugal method used at the start of this master thesis project. This method is the result of multiple interviews, meetings, and read-throughs of documentation provided by various process owners and managers of the departments and processes in scope. Section 4.1.2. describes the Vendor Selection Process, adhered from interviews and meetings with the Business Transformation Operations team, and Business Intelligence team. Section 4.1.3 describes the Ishikawa diagram (Ishikawa, 1990), drawn based on the frugal cause and effect diagram displayed in section 4.1.1. The last subsection, 4.1.4, describes the Porras Stream Analysis (1987), used to identify specific underlying root causes, subsets of problems and symptoms addressed to three main problem drivers of the present poor operating performance at Office Depot. Some references for background materials can be found in the Appendix.

4.1 Frugal cause and effect diagram

In this subsection, references are made to Figure 9 below, and appendix A, where the full list of names and corresponding functions of interviewees are displayed. The list of interviewed employees contains several organizational layers. At the time, OD had seven layers of management incorporated, including the Board of Executives at the global headquarters in Boca Raton, FL, USA (Annual Report OD, 2012). Process owners, directors, and other staff from the first five layers of OD, have been interviewed for their knowledge about certain processes, problems, and / or relations between those problems. Moreover, a visit was paid to an actual distribution center in Zwolle, the Netherlands, to verify some of the proclaimed statements about certain problems. Interesting enough, consensus was found between all interviewees: OD needs to transform its business processes, either to survive for the coming years, or to provide and support a sustainable business model.

To create a first view of the possibly relevant problems that may drive the current poor operating performance, a frugal cause and effect diagram has been drawn, based on the statements made by the interviewees. The cause and effect diagram is stated to be frugal, since there is very little literature reviewed to create the initial list of problems, since they are predominantly both identified and connected according to the statements of the interviewees. Being able to adhere a set of concluding statements, some thought should be given to provide a clear overview, while knowing
1 = Too many operating systems for management & control
2 = No standardized unique SKU identification numbers
3 = No strong position of Office Depot in the market
4 = Large set of SKUs (> 100,000)
5 = Limited standardization and harmonization of SKUs
6 = Bonuses solely focused on EBID, Sales, Cash flows
7 = Limited quality of data
8 = Limited availability of data
9 = Merchandising assumes zero costs for storage
10 = COGS & Rebates are no robust KPIs
11 = New Products are poorly specified (BOM) to vendors
12 = Very limited understanding of other department’s targets, struggles, KPIs, and benchmarks
13 = Conservative perspective at the optimization of existing processes
14 = Lack of generic procurement processes
15 = Very limited communication between departments
16 = Strong presence of external attributions
17 = ‘Main’ procurement cost price driven incentives
18 = No penalties for late deliveries
19 = Vendor audits and social compliance tests are expensive
20 = Very limited knowledge of standard Operations Theory

21 = Benefits at the Procurement Dept are counter-productive for Operating Costs
22 = Very limited involvement of Supply Chain Operations Dept. in vendor selection process
23 = Merchandising Dept. practically determines a-priori the vendor for a new product
24 = (End of the year) Rebate offers are accepted
25 = No overlap in leading and lagging KPIs
26 = MPA after audits with selected vendor
27 = Very inaccurate decision parameters
28 = Low scores for OTC (On-Time-to-Comply) and OTR (On-Time-to-Request) planned deliveries
29 = Lack of a dual sourcing procurement strategy
30 = Outdated (1999) cost parameters (old currency)
31 = Far East vendors cause long lead times
32 = Far East vendors cause much risk in SC
33 = MOQs and MOVs are accepted
34 = High levels of Safety Stock
35 = High levels of Replenishment & Excess Stock
36 = Balanced Joint Replenishment order cycle
37 = Unsustainable high levels of inventory
38 = No bottom line profit margin per item calculated

Figure 9: Frugal cause and effect diagram
what problem originates from which other problem, and vice versa. Therefore, in the cause and effect diagram as displayed in Figure 9 above, colored arrows, denoting the links / relationships, between identified problems, were added to the diagram. Now it can easily be viewed where in the diagram a certain problem relates to, yet, a clear overview still has not been provided. As a rule of thumb, problems that are situated more at the left of the diagram, are in general more often stated as a root cause of other problems, because there are more arrows leaving the problem, than entering. The more a problem is situated at the right, the more a problem is a result of root causes and other problems in between. Finally, the unacceptable high levels of inventory, and the fact that decisions were being made that are not based on the potential impact at the actual bottom line profit margin on an item aggregation level, together with a presumed high level of backorders, were considered the three most important drivers of poor operating performance in the case of Office Depot, according to interviewees.

This frugal approach for problem analysis, applied primarily to have a broad overview of the relationships between the set of identified problems, made it very clear that almost every problem relates to at least one or more other problems. In turn, these problems relate to other problems, and iterative problem routes may occur, such as process deadlocks. The relatively high number of process deadlocks in the cause and effect diagram implicate the need for another problem analysis method, which is further elaborated on in sections 4.3 and 4.4. Hence, concise conclusions regarding direct drivers, possible problem subsets, or departments cannot be drawn solely from this frugal cause and effect diagram.

4.2 Vendor Selection Process
An interesting observation during the interviews and meetings that were held to draw the frugal cause and effect diagram, was the presumed ownership of many problems by the procurement department, according to the majority of the interviewees. Specifically the creation and / or addition of new vendors or products of a vendor, was named multiple times. Therefore, after requesting for Standard Operating Procedures (SOPs) of these business processes, it seemed there was no such SOP present. In a second round of interviews with procurement officers and the staff from the Business Intelligence department, a basic flowchart following the notation of Dijkman (2013) has been drawn, including a zoomed in sub-process of the “Tendering Process”. This process model have been drawn since many of the problems mentioned by interviewees, were linked to the Procurement department or the performance of the officers with functions related to procurement.
As mentioned earlier, one of the main goals of the problem analysis, was to identify what function or department is responsible for which stream of problems. Nevertheless, when deadlocks occur it is a very exhaustive and complex search which function is exactly responsible as initiator of the problem due to external attributions (Landy and Conte, 2008). Yet, when drawing a specific process flowchart, a Responsibility Assignment Matrix (RAM) can be linked to the flowchart. Every step in the process, no matter how detailed, can be linked to either one of the four roles, adopted from PMBOK (PMI, 2004). RAM is widely adopted in project management for, amongst others, Human Resource Planning. It is a convenient method for delegation of tasks in a business process, since everyone will understand what needs to be done. This methodology holds, when the delegated actions are actually being performed by the assigned officer. Note that not all four roles, i.e. Responsible, Accountable, Consulted, and Informed (PMI, 2004), need to be allocated for every action. Therefore, some of the roles in the RACI matrices of the vendor selection process, are not filled in.

From an Operations Management perspective, it is noticeable that the Supply Chain department is being informed and consulted just once, only in the sub-process flowchart of the Tendering Process. The second round of interviews, set up in order to gain some feedback on the constructed process models, provided awareness of importance of the role of the Supply Chain Department in the improved situation of the SOP, but in practice the Supply Chain Department is almost never being informed or consulted. This does not immediately imply a wrong SOP being executed by the process owners. Nevertheless, it can be stated to be fair logic that a Supply Chain Manager has a better understanding of implications and effects in terms of costs, variance, and risk with respect to contract specific numbers and figures to the supply chain, than an officer with a set of performance indicators aiming solely at the improvement of either increasing sales or decreasing the cost of goods sold.

### 4.3 Ishikawa diagram

Since the conclusions and results from the vendor selection process are marginal, another method should be selected to conduct a thorough problem analysis with a clear overview. Now, the level of specificity is lowered to a departmental aggregation level. Problems that may drive a poor operating performance, were allocated to five swimming lanes (Dijkman, 2013) in the Ishikawa diagram (Ishikawa, 1990). Figure 10 below displays the Ishikawa diagram, which is based on the frugal cause and effect diagram described in section 4.1 above.

All problems that somehow relate to a poor operating performance, link to the red line literally in the middle of the diagram. One can easily observe that the Ishikawa diagram provides a clear overview of
all problems relating to the poor operating performance. Nevertheless, clear distinctions between
direct and indirect problem drivers or relationships cannot be made. Moreover, the clear overview in
the diagram originates from the lack of interconnections between problems. Therefore, an Ishikawa
diagram is not the best option for a clear overview of the interconnections between root causes, and
direct- and indirect drivers of a poor operating performance.
Figure 10: Ishikawa diagram, (Ishikawa, 1990).
4.4 Porras Stream Analysis

To be able to visualize interconnections and relationships concerning the subject of poor operating performance, Porras Stream Analysis (Porras, 1987) was selected as an approach for this particular case. “The Stream Analysis approach can be used for diagnosing organizational problems, planning change activities, and tracking the intervention process that unfolds” (Porras 1987, pp. 14). The organizational problem diagnosis technique was performed using this method in the project.

From the previously applied methods for problem analysis, we already obtained the process wise swimming lanes (Dijkman, 2013) in terms of responsible departments, and the numerous interrelationships between problems. The terminology of Porras (1987) distinguishes three types of problem categories when drawing a Stream Analysis Diagram:

- **Root causes**: Problem classes with only arrows leaving the box;
- **Problems**: Problem classes with both arrows entering, and leaving the box;
- **Symptoms**: Problem classes with only arrows entering the box.

In Figure 11 below, the complete Stream Analysis for this particular case is displayed. The legenda denotes red boxes to be root causes, the blue boxes to be problems, and the green boxes to be symptoms. Due to the high number of interconnections, almost all problem entities are denoted as ‘problems’, that may lead to a poor operating performance. A clear diversification of the term ‘operating performance’, though briefly described at section 3.1, is required in order to create a better overview of problem classes. Recall we stated the three main drivers of a poor operating performance representing to be:

A. An unacceptable high level of inventories;
B. Decisions made are not based on the bottom line impact on profit margins;
C. An abundant number of missed order lines.

The number of problem entities that do not directly influence either A, B or C, were deleted in order to have Porras’ problem classification clearly observable. The three individual problem storylines that have been distinguished, have an interesting deviating classification of problem categories. For each main driver A, B and C, the problems classified as root causes or symptoms are described below. Note that the particular problem corresponding to the number in the overview, can be found in Figure 12 below. Next, the stream analysis storyline of main driver A is described below, and appendices E and F display the corresponding second degree Porras Stream Analysis (1987) diagram for the direct drivers of poor operating performance B and C.
Figure 11: Porras Stream Analysis: Full graphical display with interconnections
A. An unacceptable high level of inventories:

Root Causes: 4, 5, 8, 14, 26.
Symptoms: 10, 20, 23, 32, 33.

B. Decisions made are not based on the bottom line impact on profit margins:

Root Causes: 4, 6, 22.
Symptoms: 5, 20, 24, 34.

C. An abundant number of missed order lines:

Root Causes: 1, 4, 6, 14, 15, 22.
Symptoms: 5, 33.

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| 1 | = Too many operating systems for management & control |
| 2 | = No standardized unique SKU identification numbers |
| 3 | = No strong position of Office Depot in the market |
| 4 | = Large set of SKUs ( > 100,000 ) |
| 5 | = Limited standardization and harmonization of SKUs |
| 6 | = Bonuses solely focused on EBID, Sales, Cash flows |
| 7 | = Limited quality of data |
| 8 | = Limited availability of data |
| 9 | = Merchandising assumes zero costs for storage |
| 10 | = COGS & Rebates are no robust KPIs |
| 11 | = New Products are poorly specified (BOM) to vendors |
| 12 | = Very limited understanding of other department’s targets, strategies, KPIs, and benchmarks |
| 13 | = Conservative perspective at the optimization of existing processes |
| 14 | = Lack of generic procurement processes |
| 15 | = Very limited communication between departments |
| 16 | = Strong presence of external attributions. |
| 17 | = Mainly ‘procurement cost price’ driven incentives |
| 18 | = No penalties for late deliveries |
| 19 | = Vendor audits and social compliance tests are expensive |
| 20 | = Very limited knowledge of standard Operations Theory |
| 21 | = Benefits at the Procurement Dept. are counter-productive for Operating Costs |
| 22 | = Very limited involvement of Supply Chain |
| 23 | = Merchandising Dept. practically determines a-priori the vendor for a new product |
| 24 | = (End-of-the-year) Rebate offers are accepted |
| 25 | = No overlap in leading and lagging KPIs |
| 26 | = MPA after audits with selected vendor |
| 27 | = Very inaccurate decision parameters |
| 28 | = Low scores for OTC (On-Time-to-Commit) and OTR (On-Time-to-Request) planned deliveries |
| 29 | = Lack of a dual sourcing procurement strategy |
| 30 | = Outdated (1999) cost parameters (old currency) |
| 31 | = Far-East vendors cause long lead times |
| 32 | = Far-East vendors cause much risk in SC |
| 33 | = No valid / trustworthy forecast calculations |
| 34 | = MOOs and MOVs are accepted |
| 35 | = High levels of Safety Stock |
| 36 | = High levels of Replenishment & Excess Stock |
| 37 | = Balanced Joint Replenishment order cycle |
| 38 | = Unacceptable high levels of inventory |
| 39 | = No bottom line profit margin per item calculated |

Figure 12: List of all identified problem states with corresponding identifiers.

The decision has been made to only include the direct relationships with the main problem drivers, therefore excluding the indirect drivers, for example problem number 24, i.e. the lack of overlap in leading and lagging KPIs across various departments. This is an indirect, although important, driver of for example the unacceptable high levels of inventories, but it does not directly drive the high levels of inventory. According to van Weele (2008), the tactical and operational level of procurement processes should be aligned, since benefits achieved at e.g. Cost of Goods Sold reductions, could be counterproductive for lot sizing and ordering frequencies (van Weele, 2008). Lot sizing and ordering frequencies have an impact on the service level, and therefore the required levels of inventory to cope with the risk in the supply chain for possible stock outs, according to Silver et al. (1998). Hence the influence of problem number 24 has an indirect impact only, although important, at the high levels of inventory, and is therefore excluded from e.g. the storyline of main problem driver A.
**Storyline of main driver A**

The stream analysis of main driver A is graphically displayed in Figure 13 at the next page. The large set of SKUs in assortments [4], together with the limited standardization and harmonization of SKUs [5], both result in the conservative perspective at the optimization of existing processes [12]. Since the previously used methods for the management of assortments have resulted in large turnovers in the past, process owners hold on to their methods and approaches and keep adding more items to the assortments to drive the turnover. As a result, the *Master Purchase Agreements* (MPAs) have no clear penalties for late deliveries [17]. Therefore, low scores for On-Time-to-Complete (OTC) and On-Time-to-Request (OTR) deliveries [27], and vendors causing long lead times and high levels of risk in the supply chain [30], together cause forecast calculations not to be valid [31]. [31] causes the need for a balanced Joint Replenishment order cycle [33] as a replenishment policy (silver et al., 1998). [30], the long lead times and risk perceived by vendors, and [32], the vendor specific high MOQs and MOVs that were being accepted, also relate to the presence of the balanced Joint Replenishment order cycle [33].

One of the most important, direct drivers of the high level of inventories, is [8]: The merchandising department that assumed zero costs for storage. Some employees had a strong believe that “since we already have those warehouses, we can better fill them up: it will not cost us more money” (interviewed employee, *anonymous*, 13-03-2014). Logically, this implies [32], that vendor specific high MOQs and MOVs were accepted at the time. The inaccurate decision parameters [26], accepted forward buying options [23], low OTC and OTR scores [27], lack of clear delivery tardiness penalties [17], and longer lead times and higher levels of risk in the supply chain perceived by vendors [30], all contribute to [32].

The limited communication between departments [14], resulted in the fact that benefits perceived at one department was sometimes counterproductive for other departments [20], and the limited involvement of the Supply Chain department in the vendor selection process [21]. [21] Results in the acceptance of rebates and forward buying options [23]. Five symptoms for main problem driver A can now be distinguished: [10], [20], [23], [32], and [33].
Direct Drivers of “Unacceptable high levels of Inventory” (a)

Office Depot in General
- (4) Large set of SKUs in assortment
- (5) Limited standardization and harmonization of SKUs
- (14) Limited communication between departments
- (26) Inaccurate decision parameters

Procurement
- (20) Benefits at one department may be counter-productive on other departments
- (23) Reliability & Forward Buying others are accepted
- (25) Limited involvement of SC OPM in vendor selection process
- (32) Vendor specific high MOQs and MOVs are accepted

Supply Chain Operations
- (27) Late storage of OTS and OTR (planned delays)
- (31) No valid and reliable forecast calculations
- (32) Asian/Far East vendors cause long lead times & high levels of risk in the supply chain
- (33) Balanced Joint Replenishment order cycle

Merchandising
- (10) Poor new product specification & BOM
- (11) Merchandising assumes zero costs for storage
- (17) No penalties for late deliveries
- (30) No valid and reliable forecast calculations

Figure 83: Porras Stream Analysis: main driver A.
According to Porras (1987, pp. 17), “a theme is a set of core problems that, (...) although not formally interlinked, all speak to some common issue. These predominantly macro-level problems should be identified because they require integrated actions for solutions”. According to OD’s directors of the Procurement, Merchandising, and Supply Chain Department, the “Rationalization and Harmonization of SKUs”, is the most important theme that would imply the most downstream solutions for all direct and indirectly interlinked problems and symptoms.

To conclude, using Porras Stream Analysis (1987), a comprehensive overview what root cause could or should be selected has been constructed in order to create the in depth analysis of a specific subject, that would contribute to Office Depot and Operations Theory both. This problem analysis approach has resulted in the selection of a problem state that is present in the storylines of all three main problem drivers. Moreover, it is a root cause for the high levels of inventory, and a symptom for both main problem drivers B and C. The stream analysis is the starting point for the exploration of possible solutions to the selected problem state(s) (Porras, 1987). SKUs that affect the operating performance, via either problem drivers A, B, or C, could be quantified into their respective level of profitability or contribution to the overall profit of an assortment. A decision support tool can identify which SKU contributes significantly to an assortment, and which SKUs does not. When this question is answered following the output of a certain heuristic or algorithm, a quantification method to assess the profitability of a SKU, and its contribution to a better operating performance could lead to a rationalized assortment.

Two important assumptions of conducting Stream Analysis

Porras (1987) discusses two key assumptions when an action plan would be addressed, e.g. based on the storylines of direct drivers A, B, and C: “A good process facilitator would substantially improve the quality of problem identification and analysis, and can provide expert insight and implications of planned actions”, according to Porras (1987). Nevertheless, Porras (1987) clearly states, “Stream Analysis can and has been conducted without the help of a skilled professional consultant: It has worked, and worked reasonably well!”. The second assumption of Porras Stream Analysis, is the required final consensus regarding an effective diagnosis of the problem being addressed. All contributors to the Change Management Team (CMT), although possibly (in)extreme in their statements and perspectives, should never be suppressed in the drive towards consensus.
4.5 Data Quality & Availability
Office Depot has initiated several IT projects in the past years, with Project One, as its float. This initiative aimed at “developing a re-usable business process blueprint that supports the integrated multi channel growth strategy in Europe” (Office Depot, 2012). One of the main ideas linked to Project One, was to unify the majority of business supporting (software) systems into one SAP platform, that could serve as a large data cube following the logic of Big Data (Shan et al., 2011) for the optimization of internal processes. Albeit a good initiative – stated by the majority of the interviewees – the project was terminated in the first quarter of 2014 after six years of preparation. Another $15M was required to finish the project, without any guarantee of finalizing the project with this extra time and funds, having invested already more than $30M in the previous six years the project was running. After the termination of the project, the search for the required, valid, and correct data was exhaustive. Due to time constrictions of a master thesis project, the model described in section 5 is for some parameters based on probability distributions and randomized data.

Actual historical transactional data, specific item related numbers and figures, supply chain routings, and many more cost driving parameters would be required to realize a (more) complete model of ‘total cost of ownership’ and / or ‘cost to serve’ model, and many other performance indicators of a random assortment that could be rationalized. Nevertheless, when process owners were asked to provide the data needed to construct a sound model or framework, the majority systematically neglected the requests until their negligence was communicated and escalated to higher management. There is some doubt whether all required data for such a model is actually available, yet the antagonizing and delaying behavior of employees made it very hard to create a good overview of which data is present, and which is not.
5 Model and Framework

This chapter presents the design, construction and output of the simulation model, created in Microsoft® Excel Visual Basic for Applications (VBA) as the leading programming language. The functional heuristic is based on findings and suggestions mentioned in the literature, and the technical construction of the application has been constructed from scratch. A simulation model was chosen, since important data such as demand per item, or historical transactional data per customer, was not available. Therefore, a simulation model was constructed with input parameters and probability distributions estimated and verified by interviewees and process owners. It is the best suitable alternative when coping with a lack of data to provide an example of input and output from the solution proposed in this master thesis.

First, section 5.1 discusses the objectives of the rationalization model, the availability of data, and the probability functions generating parts of the required data for the simulation model. Section 5.2 presents the profitability model, both in words and mathematically, whereas section 5.3. discusses the discrepancy and improvement versus the current methods, protocols, and approaches applied at Office Depot.

5.1 SKU Rationalization model
A certain SKU within an assortment can have an abundant number of variables with a potential impact on the profitability of that SKU. Described in section 3.3 are some of the insights found in the literature within the field of Assortment Optimization, the independence of irrelevant alternatives, etc. The Product Manager has a central role as the leading officer during line reviews, i.e. refreshing the current assortment following his approach and remaining in line with the corporate strategy. In short, the product manager checks his RMS group (see Figure 5 in section 2.1), for sufficient diversification of qualitative characteristics of comparable items. This method of line reviewing is compared to findings and implications from the model suggested in this master thesis, in section 5.3.

5.1.1 Objectives
Different approaches of optimizing an assortment can be compared with each other by means of a simulation tool. In this thesis, it should be regarded more as a decision support tool, which aimed at the initiation of the discussion at OD whether the method of line reviewing applied at the time, is correct and profitable. Before stating the current line reviewing strategy and the decision support tool proposed in this master thesis, some definitions are required for clarity due to the presence of several multi-interpretive terms, according to Rouwenhorst et al. (1999). When constructing a
simulation tool, a set of objectives should be stated first to set a clear target for the tool and its design. The objectives of the model are:

- Identify a cost model to assess the profitability model of a SKU in an assortment, including cost parameters that are both relevant and common for all SKUs in that assortment;
- Identify a set of SKUs that could be rationalized or dropped from the assortment due to its low contribution to the assortment;
- Opt for the possibility of future addition of actual historical transactional data and other significant cost parameters that may influence the profitability of the SKU in the assortment;
- Identify key differences and opportunities between the current applied method of SKU rationalization, and the method proposed in the model.

At the time, the product manager as an expert of his assortment, has to back up his decisions with his knowledge of product characteristics, when adding or deleting items from his product portfolio. The proposed heuristic in this master thesis, opposes and improves upon this method by creating a list of SKUs that does not contribute enough to the assortment where it is part of. Based on the earlier work of Byrne (2007), the exact heuristic will be described in section 5.2, after the specification of definitions and terminology used and applied in the simulation model.

5.1.2 Definitions and Terminology

The terms decision support tool, simulation tool, model, and SKU rationalization model are fully interchangeable within this document. A Product is a type of good, e.g. a soda bottle of a specific brand, whereas an item is the specific individual bottle. The terms item and Selling Unit (SU) are fully interchangeable in this section, whereas a Stock Keeping Unit (SKU) refers to the unique product, where multiple selling units may be present as part of the inventory. A customer order is a (unique) client that may place an order containing several order lines, where each order line contains exactly one SKU, ordered in a specific quantity of selling units (one or more). The customer order sheet is the set of all customer orders within a range of time combined, creating a complete list of all customers, that have placed an order with a specific quantity for that SKU. Volume refers to the measurements in cubic centimeters of an item. A Twenty-foot Equivalent Unit (TEU) is a standard cargo capacity of a shipping container, which is used at Office Depot for inbound logistics purposes at warehouses. Different sizes of TEU could be used, yet for simplicity it is assumed a standard 2TEU with a volume capacity of approximately 77m³ is always used for inbound logistics. A case pack is a SKU specific quantity of items that can arrive in a box, crate, or on a pallet.
5.2 Model Design
The multi-interpretive terms have been defined in the previous section. Now, the specific behavior of e.g. demand and the number of order lines per customer order, needs to be described to continue with the description of the proposed decision support tool. A screen capture is displayed in appendix I, to observe what the graphical user interface (dashboard) looks like.

5.2.1 Characteristics of simulated demand
Due to the lack of available data at the time as described in section 4.5 above, several merchandisers and officers from the sales department (appendix A) have been interviewed, who did not have a background in, or sufficient knowledge of, probability distribution functions or even advanced statistics as a whole. By drawing the characteristic density function of some of the most accepted probability functions as a graph during the interviews, an assumption could be made which function best describes the customer behavior as the simulated demand. Interviewees were confronted with, amongst others, the negative binomial distribution, a normal distribution, the exponential distribution, the Poisson distribution and the gamma distribution. For detailed information about the characteristics and applicability of these probability distributions, see Montgomery and Runger (2007), van Berkum and di Bucchianico (2007), Hopp and Spearman (2008). Assuming that the merchandising officers made a well informed choice of the probability function, it can be assumed it was the best option available at the time when creating a decision support tool in an environment with poor data opportunities. Further research at Office Depot should verify for the fit of the applied probability distributions with actual sales- and transactional data of customer demand behavior.

According to the interviewees, the Normal Distribution had the best fit for the number of order lines per customer order. Leading parameters of this function, i.e. $\mu$ and $\sigma^2$, have been estimated applying the rules of thumb derived from Montgomery and Runger (2007): “Both 34% left and 34% right of the area around the mean $\mu$ is approximately between $(\mu - \sigma)$ and $(\mu + \sigma)$”. The average number of customer order lines is known with a value of $\mu = 25$. Therefore, to be within the range of 68% of the area around the mean, $\sigma^2 = 100$. Figure 14 displays the density function of the Normal distribution with

![Figure 9: Normal distribution for customer orders, with $\mu = 25$ and $\sigma^2 = 100$](image-url)
\( \mu = 25 \) and \( \sigma^2 = 100 \). Note that the number of order lines per customer order are Normally distributed on domain \([2, 1000]\), since a greater customer order than 1000 order lines is presumed to be practically impossible. A customer order with a single order line occurs often, since some of Office Depot’s customers specifically shop there to buy a certain exclusive product, e.g. an uncommon ink cartridge for an old fashioned printer model. Therefore, \( x = 1 \) is excluded from the domain. Moreover, since negative demand is not possible, the density function is cut off at the left bound value of 2.

For the amount ordered per order line, i.e. the demand of a specific item within a customer order, the Gamma distribution tended to be the most suitable according to the interviewees. The Gamma distribution is commonly accepted in literature as a probability function to describe demand, since special cases of the Gamma distribution are the \( \chi^2 \) distribution, or the Erlang- and Exponential distribution (van Berkum and di Bucchianico, 2007). Characteristic parameters for the Gamma distribution are the mean, \( \frac{\alpha}{\beta} \) and variance, \( \frac{\alpha}{\beta^2} \). Now, parameters \( \alpha \) and \( \beta \) needed to be estimated, which was more difficult than the rules of thumb estimation procedure for the parameter estimates of the Normal Distribution shown above. The only known figures the interviewees could provide, were the average order line quantity of “slightly more than three (approximately) units”, and that “almost none of our customers order more than 30 selling units at a time”. Figure 15 displays the density function of the Gamma distribution with \( \alpha = 6 \) and \( \beta = 1.8 \). Note that the density function looks very similar as the Normal Distribution in Figure 16, since the Gamma distribution is a somewhat skewed and shifted version of the Normal distribution, depending of the parameter values (Montgomery and Runger, 2007).
5.2.2 Shared responsibilities & model procedure

As mentioned earlier, there is no quantitative model applied at Office Depot as input for the rationalization of SKUs in an assortment. Moreover, none of the interviewees had knowledge about the influence of cannibalization- and substitution effects, which can affect the profitability of a SKU and the profitability of the assortment as a whole (Mason and Milne, 1994; van Ryzin and Mahajan, 2001). An extra item added to an assortment, “simply implied that there would be more sales, and therefore automatically more profit”, according to several employees of Office Depot. Since the performance management system allowed bonuses to be distributed, based solely at the increase of total sales of an assortment, this belief of ‘more sales means more profit’ was even corporately justified. The design of the decision support tool must not ‘declare war’ to the installed bonus parameters, yet, it should follow an approach mentioned in de Haas and Kleingeld (1999, pp. 256): “As a consequence of shared responsibilities for deployed result indicators, multiple constituencies are discussing the same performance variables, albeit in a language that is meaningful for the organization level at which individual constituencies are acting. A language spoken in terms of the constituency’s own process indicators over which it has maximum controllability.” The solution to overcome resistance following the applied performance management system at the time, was to drive the Product Manager’s process indicators with lists of SKUs that could be rationalized following the output of the proposed decision support tool. From this list, the product manager should provide arguments why the particular SKU at the list should stay in the assortment, therefore, stating what its exact contribution to the assortment is. During this discussion with his line reviewing taskforce, the start for dropping or adding an item to the assortment, should be found in the output of the simulation model. Hence awareness will be created of the fact that extra sales do not imply extra guaranteed profits, which results in the consequence of shared responsibilities for the deployed result indicator (de Haas and Kleingeld, 1999), namely sales and profit generation.

The terminology has been clarified and the probability functions for the simulation and generation of demand are described, therefore, the exact procedure of the decision support tool can now be discussed. Byrne (2007) states there are two important elements that should be taken into consideration when optimizing an assortment: Identify which SKUs serve unique sales channels, and suggest to eliminate the low-volume SKUs. The model suggests a subset of SKUs that could be rationalized, after the stepwise execution of the following heuristic.
Model Procedure (heuristic) in four steps:

1) Conduct a Pareto analysis based on the absolute profit at the SKU-aggregation level. If the SKU is in the ‘80% tail’ of the Pareto chart, place the SKU at list1.

2) Conduct a Pareto analysis based on the number of (unique) customers that have bought the SKU. If the SKU is in the ‘80% tail’ of the Pareto chart, and the SKU is present at list1, place the SKU at a new list2.

3) Of all the SKUs present at list2, compute the number of unique customers that specifically buys one SKU only, i.e. a single order line in a customer order. The higher this exclusivity-percentage for this SKU, the stronger the argument that implies a strategic advantage to keep the SKU in the assortment (Byrne, 2007). Information is only printed next to items at list2: no SKUs are further being eliminated from list2.

4) Of all the SKUs present at list2, compute the significant contribution of the SKU as a percentage of the demand, from the total demand of the assortment. A cut off value for the term ‘significant contribution as a percentage’ could be e.g. one hundredth of the average demand of all SKUs in the assortment. This information is only printed next to items at list2: no SKUs are further being eliminated from list2.

The first step of the modeled procedure, ranks the contribution of the SKU according to the highest total profit, to its assortment in descending order. The search for input variables of the profitability of a SKU is exhaustive, and requires a lot of data. Hierarchically high level assumptions are required to simplify the profitability of a SKU, in order to sustain the design and creation process in a feasible time span. For instance, according to officers within the supply chain department of OD, the deliveries of goods to a warehouse were based on a Delivery Duty Paid (DDP) policy. This procurement contract approach implies the cutoff point of inclusive incurred transportation costs of the goods, which were set at the moment the goods are unloaded from the ship at the truck, which drives towards the (central) distribution center. This means that the stake of transportation at the overall profitability of a SKU is already included in the procurement price. Derivative transportation costs and fees, e.g. duties payments, partner allowances, markup percentages, or exchange rates, are therefore out of scope for the profitability in this model. Since there is no unified outbound logistics approach in terms of transportation, this parameter is also left out of the model. This model is constructed to provide an overall view of the profitability of an assortment, where the transportation costs are not relevant for this cause. In general, the development of transportation as a cost bucket when an assortment is optimized by reducing the number of SKUs, will not increase in total. Yet, when an equal total volume of demand for the assortment would be assumed, the transportation costs to be allocated to a specific SKU would inevitably increase. Nevertheless, this
factor would be outweighed by the reduced supply chain risk, assortment profitability, outstanding
inventory value, and most importantly, the increased sales volume per SKU (Shah and Avittathur,
2006).

5.2.3 Profitability model
Office Depot Europe spends a significant budget each year at Supply Chain Operations. Approximately two third of this budget is transportation related, and out of scope for the model. The interesting cost parameter to include in the model, is the remaining 33 per cent of the supply chain budget, which is allocated to warehousing. Appendix H displays the results of a 17-weeks (85 working days) time-series analysis of a warehouse in Ashton, United Kingdom, in order to specify which warehousing operation demands the most labor hours. The warehouse in Ashton is a typical Office Depot warehouse, very similar to the one in Zwolle, which was visited in April of 2014. For example, order picking is optimized using a pick-by-light architecture for items with small measurements, and fast moving consumer goods, such as ink cartridges, are constantly replenished using a put-to-light architecture. Items with larger measurements, such as furniture, are positioned in conventional European pallet sized racks.

In order to create a profitability model with factors that may have a sufficient impact on the profitability of a SKU, given a certain demand behavior, the most important cost factors of the warehousing cost structure were selected, i.e. those that are applicable to every assortment and every warehouse. Sortation is an operation that is not uniformly carried out in every warehouse, and therefore it is not included in the model. The five relevant cost parameters that are included in the model with the highest impact on total warehousing activity costs, with most of the definitions derived from Rouwenhorst et al. (1999) are:

- **Receiving**: the first process encountered by an arriving item. It is assumed that products arrive solely via trucks with a 2TEU capacity. Part of the receiving operation, incurred in the cost figure, is the unloading of the incoming shipments and immediate administrative checking whether the goods have fully arrived.

- **Split case picking**: the retrieval of items from their storage location, partly performed manually. Different and more expensive than the full case picking, since an extra activity is performed, that relatively incurs great amounts of time. The split case picking costs are decreasing over an higher number of selling units that are picked per time the employee needs to travel towards the exact picking location, since Drury (1988) estimated about 55% of the picking job costs are driven by travelling time. Yet, there are no exact figures or
percentages found in literature for the share of operations while picking orders using a pick-
by-light system, such as the stake of the walking distance per pick.

- **Full case picking**: The retrieval of full case packs, i.e. not items, from their storage location, 
  partly performed manually. Different and relatively cheap versus the split case picking costs, 
  since the travelling time during the picking job, can be diversified over the number of selling 
  units that are present in the case pack.

- **Checking**: All operations throughout warehousing, where the items are checked for damage, 
  as well the item itself and the box. Items can be damaged when e.g. falling of the conveyor 
  belt, or while placing a pallet with items in storage, etc. Estimates are that ten per cent of all 
  case packs are ad hoc selected, and checked for damages throughout the process.

- **Replenishment**: Items retrieved at the end of the inbound logistics process, need to be 
  positioned at the correct location for replenishment. The pick-to-light system architecture 
  does not allow much storage space for items, therefore, a constant replenishment team 
  makes sure almost every pick location is sufficiently replenished. Moreover, part of 
  replenishment processing costs is the restacking of pallets due to an allowed variety of SKUs 
  at one pallet. This implies waiting stock for this extra operation, which is allocated to the 
  replenishment cost bucket, according to the Ashton warehouse time series analysis data set 
  (2013).

These five warehousing cost parameters were selected by representing a larger than six per cent 
stake of warehousing operations costs allocated. Section 5.2.4. explains the exact profitability model 
of each SKU. Once again, let it be mentioned that there are numerous more parameters that could 
have a significant impact on the profitability at the item aggregation level, but the required data was 
insufficiently available to accurately estimate and implement these extra cost parameters.

In 2013, a time series analysis was conducted at the warehouse of Ashton, United Kingdom. During 
85 working days, every employee’s actions were timed and written down. By dividing the total 
accumulated time in hours spent on a certain process by the number of working days (85), the 
average daily hours spent per operation have been computed. Next, the hourly rate of a warehousing 
employee is €15.46 per hour, following the June 2014 exchange rate of British Pounds Sterling upon 
European Euros of £1 = €1.253. Note that this is the hourly rate for warehousing employees 
excluding management and cleaners, since these cost parameters were not relevant for the 
simulation model. The average number of cartons processed during the 17-week time-series analysis, 
was 28,023 case packs in total. Then, we can compute the costs per processed Unit of Measurement
(UOM), as the product of the daily hours spent at a process and the employee rate, which is divided by the average number of UOMs processed per day.

These costs figures appear to be too general for warehousing costs parameters at first sight, since one can argue that each average figure must have a certain variance in daily volume totally processed, or hours spent per process, productivity rates, unexpected overtime, etc. According to internal communication with Ashton warehouse management, the number of employees with a fixed contract is fairly high, and there are very little efforts placed at implementing dynamic scheduling and planning of the weekly workforce. Therefore, the figures can be regarded as the best estimate per UOM at the moment. It should be noted though, that a UOM is not always equal to a case pack, for example the split case picking cost parameter. These costs are in function of the number of individual selling units that are picked during a single travel / walk to the picking location, instead of the full case picking cost parameter that is in function of the number of case packs that are picked during a travel.

5.2.4 Mathematical notation of profitability model

Following the model description of the latter sections, the mathematical profitability model can be written down as:

\[
\begin{align*}
W_i &= \text{Profit per selling unit of SKU } i; \\
F_i &= \text{Selling price of a selling unit of SKU } i; \\
R_i &= \text{Purchase price of a selling unit of SKU } i; \\
v_D &= \text{Number of elements in a vector with non-zero demand; } v_D \sim \text{Normal}(\mu = 25; \sigma^2 = 100); \\
A^b &= \text{The set of SKUs in the selected assortment group } b, \text{ with } A = \{A_1, A_2, ..., A_n\}; \\
n &= \text{The number of arbitrarily SKUs in assortment } A; \\
G &= \text{The set of unique customers placing an order, with } G = \{\text{client}_1, \text{client}_2, ..., \text{client}_m\}; \\
m &= \text{The number of arbitrarily arrived customer orders over a certain time span;} \\
\bar{s}_i &= \text{Case pack size of SKU } i, \text{ i.e. the number of selling units that are packed together in a box / crate.} \\
D_{i,j} &= \text{The customer order line for SKU } i, \text{ placed by customer } j. \text{ It denotes a vector with } n \text{ elements, of which } v_D \text{ elements are stored with non-zero demand. } D_{i,j} \sim \text{Gamma}(\alpha = 6; \beta = 1.8), \text{ with } \\
&\text{Gamma}(\alpha, \beta) \text{ as the continuous Gamma distribution with mean } \alpha/\beta \text{ and variance } \alpha/\beta^2. \text{ For } \forall D_{i,j} \neq s_i, \bar{D}_i \text{ denotes the sample mean of all demand per selling unit not equal to the case pack size } s_i.
\end{align*}
\]
For confidentiality reasons, all five cost parameters have been scaled in percentages of the sum of the five cost parameters together.

\[ c_R = \text{the costs associated with receiving one case pack from inbound logistics,} \]
\[ c_R = 11.8\% \]

\[ c_c = \text{The costs associated with checking one case pack across all warehouse related operations, with} \]
\[ c_c = 15.3\% \]

\[ c_{scp} = \text{The costs associated with the order picking operation where } D_{i,j} \neq s_i, \]
\[ c_{scp} = 19.8\% \]

\[ c_{fcp} = \text{The costs associated with the order picking operation where } D_{i,j} = s_i, \]
\[ c_{fcp} = 18.0\% \]

\[ c_s = \text{The costs associated with replenishing a case pack in either the pick-by-light region or the pallet size racks.} \]
\[ c_s = 35.2\% \]

\[ K_i = \text{The vector with } h \text{ relevant cost parameters for each SKU } i \text{ in the state space, denoted as } K_i(h), \text{ with } h = \{1,2,3,4,5\}. \]

**Now, we denote the five leading cost parameters as**

\[ K_i(1) = \text{Receiving costs:} \quad \frac{D_{i,j}}{s_i} c_R \quad \text{for } i \in A \]

\[ K_i(2) = \text{Checking costs:} \quad \frac{D_{i,j}}{s_i} c_c \quad \text{for } i \in A \]

\[ K_i(3) = \text{Split case picking costs:} \quad \frac{1}{D_i} \sum_{j=1}^{G} D_{i,j} c_{scp} \quad \text{for } i \in A, j \in G, D_{i,j} \neq s_i \]

\[ K_i(4) = \text{Full case picking costs:} \quad \frac{p_i(2)}{s_i} c_{fcp} \quad \text{for } i \in A, j \in G, D_{i,j} = s_i \]

\[ K_i(5) = \text{Replenishment costs:} \quad \frac{D_i}{s_i} c_s \quad \text{for } i \in A \]

**Which results in the statement of the profitability of SKU } i \text{ denoted by variable } W_i \text{ following**}

\[ W_i = F_i - Q_i - \left( \sum_{h=1}^{5} K_i(h) \left( \sum_{j=1}^{m} D_{i,j} \right) \right) \]
Adoption of Decision Support Tool:
This model has been programmed such that the addition of new identified significant cost parameters to vector $K$ can be added to the simulation model by an employee with just novice skills in Excel VBA as the programming language of the model. The list of rationalizeable SKUs will increase in its accuracy, when the number of significant cost parameters added to the profitability model will increase. In case the accuracy of the profitability model is sufficient in the perspective of the product manager, the decision support tool will be adopted and integrated in the line reviewing protocol.

5.3 Model output
Following the objectives stated in section 5.1.1., the output of the model is a list of SKUs that are identified not to contribute sufficiently to the assortment. The proposed model cannot check for irrelevant alternatives due to the qualitative nature of the data involved to conclude such statements. For instance, within an assortment of writing equipment, it could be that the simulation model selected all variants of green ballpoint pens. It is therefore always the task of the product manager, to qualitatively deselect these specific items from the output list of rationalizeable SKUs. Yet, the product manager should note that the overall contribution to the assortment is not sufficient to ‘pass the quantitative bar’, making his view at the list of rationalizeable SKUs non-optional. Therefore, this model should be regarded as quantitative input for the product manager, to further elaborate this input with his knowledge as the expert of the assortment.

An example simulation has ran, creating a list of potential SKUs that could be rationalized. In this section, the following descriptive statistics are present:

<table>
<thead>
<tr>
<th>Description</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>#Customer orders:</td>
<td>500</td>
</tr>
<tr>
<td>Assortment:</td>
<td>Electronic Supplies</td>
</tr>
<tr>
<td>SKUs in assortment:</td>
<td>96</td>
</tr>
<tr>
<td>Average order value:</td>
<td>€ 7.231,62</td>
</tr>
<tr>
<td>Maximum order value:</td>
<td>€ 28.620,09</td>
</tr>
<tr>
<td>Minimum order value:</td>
<td>€ 1,96</td>
</tr>
<tr>
<td>Customer order size distr.:</td>
<td>Normal(25 ; 100)</td>
</tr>
<tr>
<td>Demand (item level) distr.:</td>
<td>Gamma(6 ; 1.8)</td>
</tr>
<tr>
<td>Total Simulation runtime:</td>
<td>45m45s</td>
</tr>
</tbody>
</table>

Figure 16: Descriptive statistics of customer orders.
The assortment group taken as an example, is *Electronic Supplies*, an assortment carrying 96 SKUs. Demand has been generated following the procedure described earlier in Chapter 5, with 500 customer orders of which the customer order descriptive statistics presented in Figure 16 above. For this selection and generated demand, the stepwise heuristic performed provides us with the following output:

**Figure 17: Pareto chart of Profitability of the SKU**

**Figure 18: Pareto chart of the number of unique customers buying the SKU**
Figures 17 and 18 above are the results of a run of the heuristic. The Pareto charts denote the cumulative contribution of the SKU as a percentage of the total. The secondary axis are in terms of percentages, which are increasing in cumulative profit for Figure 17, and increasing in the number of unique customers that buys the product in Figure 18.

The last two columns of the output of the simulation run, are the exclusivity and category loyalty, which denote the third and fourth step of the heuristic described in section 5.2.2. From the final list of rationalizeable SKUs as output from the tool, the product manager is required to address his expert knowledge of specific characteristics per item. The total contributed profit from this list of potentially rationalizeable SKUs, not more than €27,000,- of total profit from these items will be lost when they would be dropped from the assortment. There was no knowledge at the time of substitution effects and rates, although it can be assumed by logic reasoning that there is a strong substitution effect in this product category. Therefore, the adoption of sales of the remaining SKUs in the assortment of the dropped SKUs could be significant. Some of the items at the list are bought by more than 60 customers of the total base of 500 customers simulated in this run, yet some SKUs are bought by merely eleven customers. A product manager could conclude now, that it was not very profitable to keep these items in the assortment.

Nevertheless, for the items with SKU ID number A96 and A77, there is a particular high percentage of exclusivity for the item in this simulation run, representing the number of customers that specifically only order that particular item. One can assume, that the reason here is that Office Depot is the only supplier for this item, for its customers. Although the contributed profit is not very high, the product manager could therefore choose not to drop the item from the assortment. Yet, for SKU A96, the item is presumed to be exclusive, but it reports a loss of nine cents for every selling unit that is being sold. The advice for this example should be, to definitely drop this item from the assortment.

An extra step could be added to the heuristic, prior to the four steps described earlier. The proposed decision support tool assumes that every product is actively being sold, and that inventory is present in the warehouses. It could be the case for some regions, that a product is held at stock but it is not being sold anymore, or vice versa, that there is demand for the specific item, but there is systematically no stock available. In case a SKU deviates from the fact that there is stock present, and / or it is not being actively sold, it could be added to the list of SKUs under review. The product manager should absolutely discuss these kind of items with his line reviewing taskforce, since those situations are far from optimal assortment planning and management.

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5.4 Improvement versus current protocol

The current method for assortment optimization applied at the time, mentioned as a *line review process* at Office Depot, is to a large extent different from the approach and results presented above. At the time, there was no quantitative method applied to check for underperforming SKUs, since the leading assumption of product managers during a line review, was that the product variety could be increased in the assortment, instead of dropping some items. The typical procedure a product manager may follow, supported by a taskforce of lead category managers, merchandisers, and procurement officers, is described below. Preceding the protocol below with a quantitative step first, such as the output of the decision support tool, would be an improvement to the line reviewing protocol:

- For every region where the assortment, or some of its particular items, are actively being sold, write down the actual net sales figure of this period, and the period before, along with a calculated change in total sales in the region;
- Perform a segmentation analysis of the assortment’s characteristics across all active sales regions, where the following parameters are taken into account:
  - Material type; Shape; Color; Size; Floor Surface; Brand;
  - Note that different parameters for product characteristics may be applied for other assortments, e.g. technical specifications of laptops and computers.
- Perform a key competitors analysis per segment identified in the previous step, where Office Depot (and Viking) are being compared to Staples, Lyreco, JM Bruneau, Printus, and Otto Office, where the following parameters are taken into account:
  - Number of pages nominally allocated to the assortment in the catalogue;
  - Number of SKUs carried in the assortment, across active sales regions;
  - Pricing of SKUs carried in the assortment;
  - Features that may be present at SKUs carried in the competitor its assortment, rather than Office Depot’s;
- Search for possible innovations of SKUs carried in the current assortment, e.g. Anti-allergic items, long-life warranties, significant improved designs, fashionable items, etc.
- Construct the ‘Map of Tactics Recommendation’: A two-dimensional map for considerations of assortment repositioning following the previous steps. Considerations are categorized under either Product, Pricing, Promotion, or Placement.

An example of the result of a protocol like this can be found in appendix G, for the category of *Metal filings*. Green cells denote the item is carried in the assortment in the specific region, which are
divided over several columns. Note that a partial copy of the analysis has been displayed in the appendix, due to the length of the original document. In summary, from 197 items officially carried in the assortment where inventory is present, there are just 17 items actively being sold in one or more regions. Metal filings are items with a substantial volume, that are more easy to sell from brick-and-mortar stores, than online. These stores as sales channels are present in France only, and not in the rest of Europe. The reason that the Metal filings assortment was not line sufficiently reviewed, is that there ought to be ‘no problem’ from a sales perspective. Thousands of selling units are annually being sold from this assortment: Although in France. The decision support tool proposed in this master thesis, can also be used to discuss quantitative differences between selling regions. When data of the Metal Filings assortment would be added from France, a completely different suggestion for the rationalization of SKUs would be provided, compared to a region without brick-and-mortar stores.

The proliferation of items added to an assortment, after running the protocol above that aims at adding more and more products to an assortment in order to presumably ‘serve the customer’, leads to a complete overgrowth of items, leading to demand uncertainty according to Shah and Avittathur (2006). The identification of a number of items that do not contribute enough to an assortment in terms of profit, sales volume, and the service to unique sales channels, are important input for the discussion of line reviews. Assortments can be rationalized by not only stressing the addition of items to an assortment that drives product proliferation, but to stress out in advance of these additions, which items should be dropped first from the assortment.

**Flexibility of decision support tool and its characteristic parameters**

The decision support tool is modeled such that every cost parameter, cut off value, or characteristic parameters of the simulated demand distributions can be adapted when new insights are available. As mentioned earlier, cost parameters can be added to the vector $K_1(h)$ by any user of the tool with just novice programming skills in Excel VBA. Every user with standard spreadsheet knowledge of changing cells in Excel, can adapt (and improve) the values of the current cost parameters and probability distributions when there is an incentive to change these values. This element of model flexibility is an important feature for adoption of a decision support tool by the product manager and his line reviewing taskforce. See Appendix I for a screen capture of the dashboard of the decision support tool.
Comparison in Operating Performances

Operating Performance is defined in section 3.1, as the ratio of Profit over sales. The example simulation run with one assortment group at section 5.3, i.e. *Electronic Supplies*, had an initial sales volume of €3,194,183.02, and a resulting profit of €647,193.00 over the *unrationalized* assortment with 96 SKUs, when the simulation model ran. After the heuristic ran, a list of 24 SKUs have been identified that could be rationalized. Let’s assume for simplicity that all SKUs would be deleted from the assortment, and no substitution effect is present. Then, the sales volume of the remaining 72 SKUs would be €3,043,071.02, versus a profit of €619,245.46. Now, the operating performance of both sets of SKUs, can be compared since the profit and sales values are known. The operating performance of the *full* assortment is 20.26%, whereas the operating performance of the *rationalized* assortment is 20.34%. This is a significant increase of operating performance, since there were no cannibalization or substitution effects assumed: The profitability of an assortment will increase after assortment optimization under substitution effects (see section 3.3), creating the opportunity for a further increase of operating performance.
6 Discussion

This section presents the conclusive elaboration of the research sub question, leading to the opportunity to elaborate the research objective stated earlier in section 2.2. All statements and conclusions follow the literature, models and frameworks discussed in Chapters 1 to 5.

6.1 Results & Elaboration of research sub questions

Sections 6.1.1 to 6.1.5. discusses the conclusions per research sub question:

6.1.1 Research sub question 1
- How is Operating Performance defined at Office Depot?

Operating performance, is a term that is widely used in different contexts. Chapter 4 discussed the triptych of operating performance in the case for the supply chain department, as a diversification of inventory, backorders, and the decision making process. Corporate wide, the financial definition is used, that was also followed in this master thesis: Operating performance is the ratio of profit divided by sales.

6.1.2 Research sub question 2
- How are problems interconnected, that relate to a poor operating performance?

Chapter 4 described the search for a convenient cause and effect diagram that is easy to read and provides a clear overview of the current set of interconnected problems at Office Depot, that contribute to a poor operating performance. Sections 4.1 to 4.4 display the output of this search quest for the convenient overview, which was found using Porras Stream Analysis (Porras, 1987). A set of 39 problems were identified that relating directly or indirectly to a poor operating performance. A single core process-bottleneck problem state cannot be pointed out, since each individual problem had a slightly different background, or problem class type in the diagram. Problems have been classified as either a root cause or symptom, or in between, a problem. Differences between the problem classes are the number of arrows entering and arrows leaving a specific problem state. When zero arrows depart from the problem state, it is regarded as a symptom. In case zero arrows arrive in a problem state, it is regarded as a root cause. Problem states with both arrows entering and leaving the state, are simply denoted as a problem. This methodology has been developed by Jerry Porras in 1987, who proposed a fine solution for cause and effect diagrams with less than fifteen problem states.

Nevertheless, the complexity of interconnecting 39 problem states in a diagram increases rapidly, compared to an average of 15 problem states in literature, as the number of interconnections between problem states grow quickly when the number of problem states increase. Therefore, as
displayed in section 4.4, a Stream Analysis following Porras’ theory has been conducted three times, while having diversified the term ‘Poor Operating Performance’ into three elements for the supply chain department, as the direct drivers of the poor operating performance: High levels of inventory, a relatively high number of backorders, and the decision making process that is not based on the bottom line impact on the profit margin per SKU. These three direct drivers of a poor operating performance, along with the diversification of problem ownership at four departments that denote the process model its swimming lanes, are the best available solutions to provide a clear overview of the status quo at Office Depot regarding its poor operating performance. For this master thesis, the seemingly obvious root cause of the limited SKU rationalization and the high number of present SKUs, has been selected for further research. This cause and effect analysis can be used to initialize more research topics at Office Depot, since the result of this master thesis is not the entire solution of all identified and present problems. Although, there are an abundant number of interconnections and even iterations between problem subsets, which implies the solution provided in this document contributed (thoroughly) to many of the problems currently present at Office Depot. Further research could estimate these effects quantitatively, whether the analyzed relations had a direct, moderating, or mediating role in a statistical model.

The problem states are interconnected like a ball of strings, e.g. the effect of problem one causes a magnitude of problem two, which leads to an increase of problem one again via problem three, and so on. The operating performance is therefore spiraling down, and without an intervention, this effect will not be put to a halt. The share price decline of 90% in just six years, is the direct effect of the poor operating performance. One could ask, why no one has put a halt to this spiral, that is circling down. The reason appears to be centrally located in the cause and effect diagram, are the Key Performance Indicators (KPIs) that do not overlap between departments with one true leading KPI, e.g. overall profitability. Bonuses are still administered, since they are dispensed solely based on sales, or in some instances also EBID and cash flows. This leaves space for employee malpractices, while still receiving their bonus or premiums. Note that malpractices are not always deliberately exercised, since subsets of KPIs found at various departments could also be simply contradictory.

6.1.3 Research sub question 3
- **How are Assortment Planning and Operating Performance related?**

As displayed in chapter 4, problem states 4 and 5 denote the limited SKU rationalization and the high number of SKUs in the assortments, which lead via various ways towards a poor operating performance. These relationships have been found using Porras Stream Analysis, of which the interconnections between problems have been explained earlier.
Assortment Planning is the field of research that aims at the maximization of profit, of a given assortment with options for substitutes and or cannibalization effects of consumer behavior. The sum of profits gained over optimized assortments, would result in an overall increase of profit. Assortment Planning theory aims at the control of the costs allocated for carrying items and their corresponding inventory levels, while retaining consumer behavior methods.

The operating performance is for this master thesis defined as the financial ratio of profit over sales. When optimization of assortment planning is thoroughly conducted, it can easily be deducted that profits will increase, and assuming the sales will remain at an equal level, the ratio of operating performance will increase.

6.1.4 Research sub question 4

- What methods, tools, and models are currently applied to optimize the assortment of various product families?

At Office Depot, the product manager is in charge of keeping the current assortment up to date. He or she should be fully aware of what range of products are being sold in all regions, what the functional characteristics of the products in his portfolio are, and what the corresponding prices of the product are. Assortment optimization is commonly referred to as ‘line reviewing’, and is a process lead by the product manager, and concluded by a joint session with officers from the merchandising and procurement department. Slightly different approaches are applied for each assortment group, since the position of the assortment should be aligned with the leading strategy that is implemented from higher management. For instance, the strategy of Office Depot is to be ‘the first supplier to think of’, when a potential customer needs to buy any type, size, or quantity of paper category products.

The Office Depot own brand category penetration in an assortment, ranges from 33 to 60 per cent of the complete assortment group, including irrelevant alternatives such as size- and color differences. This figure of ‘own brand penetration’ is determined by higher management, limiting the options of the product manager to find an ideal point in assortment optimization. Office Depot its own brand is further diversified across six brands, i.e. Foray, NiceDay, RS, Ativa, Office Depot, and Viking.

The trigger for a line review can be either scheduled in function of the time, or via a significant development from a financial perspective. Latter trigger is applied most of the time across the
assortments. The protocol applied at the time by the line reviewing task force led by the product manager, is discussed in section 5.4.

After these steps, the most important question arises in the Line Review taskforce, where Office Depot deviates from literature described in Chapter 3. The question addressed: “Which SKUs should be added to the assortment in each region, in order to complete the gaps in listing per region, to extend full portfolio relevance”. The underlying assumption from the line review taskforce, is that the assortment under review lacks a subset of SKUs, instead of keeping a more open perspective that questions the expanding proliferation of items. To conclude, no quantitative models, frameworks or customer perspectives were structurally used when reviewing assortments. After the construction of a list of new SKUs that needed to be added to the assortment, simple calculations were made what the sales potential of the extra items would be. The sales potential ‘calculation’ was a direct copy from last year’s total sales of the item that could be compared best to the new item, while not adjusting for cannibalization effects.

6.1.5 Research sub question 5

- How can suggestions for optimization of the current assortment, be applied at various product families at Office Depot?

First, it should be noted that it is practically impossible to propose a unified answer for the subject addressed in this research document: Simply constructing a simulation model that optimizes an assortment is not sufficient, since performance indicators that allow for suboptimal decisions of responsible officers of various departments, could affect the opportunities created. Therefore, the solution of the general problem statement is divided into two parts: A more theoretical suggestion for assortment optimization will be presented in this section, and in section 6.1.6 the somewhat more practical proposition how to apply this theory at Office Depot, (albeit) keeping in mind the diversified set of KPIs that are present throughout the organization. Hence this section will elaborate further on the question how the element of quantitative modeling can be applied in the best suitable way for various product families of Office Depot.

Moreover, a follow-up project at Office Depot aiming at the optimization of Assortment Planning, should start with the search for all relevant data that is required to improve the accuracy of the simulation model, preferably with transactional and product-characteristic data. The simulation tool including the proposed heuristic that has been constructed in this master thesis, has been programmed and modeled dynamically using Excel Visual Basic for Applications, such that extra available data can easily be added to the profitability model. Each cost parameter added to the
model is an extra element in the vector determining the profitability per SKU. One of the first steps of applying Assortment Planning theory at Office Depot, is therefore to insert all relevant data that could be of influence at the overall profitability of the assortment. This step in the process can only be performed when a model improvement with more relevant cost parameters included is made that may have an impact at the overall profitability, e.g. end-to-end transportation costs, substitution- and cannibalization matrices, promotions, or even technical, economic and political forces.

After the required data has been collected and inserted in the simulation model, a complete overview of the profitability of each SKU can be calculated. From a strategic perspective, Office Depot can select assortments at which it sets its targets for being market leader. While carrying more than 42 different assortment groups with thousands of SKUs per group, the position of being the continuous market leader in all 42 assortment groups at the same time, would be an unreal objective.

The constructed decision support tool could be extended by adding a module that works in reverse by ‘answering’ the following question: The addition of one extra SKU with its corresponding data and cost parameters, in the current assortment: Will this increase the overall profitability of the assortment?

**Big-bang implementation approach**

Quick wins are also an option for Office Depot, to pool the first reactions of the line review taskforces on the proposed heuristic. Product managers, merchandisers, and procurement officers have already been informed of the possibilities of the proposed method, as an addition to the current protocol of line reviews, as described in section 5.4. In case the trigger for a line review is financial in nature, i.e. a quantitative trigger, the first step should be to check the profitability and the number of unique customers, of each SKU in the assortment. Each SKU can then be placed in perspective versus other SKUs in the assortment. This would imply that the underlying assumption of the line reviewing taskforce, stating ‘there must be gaps in the assortment that need to be filled’, will not be as strong in its presence as previously assumed. The taskforce could now start to drop certain SKUs from an assortment, when the profitability and number of unique customers buying the item, are outside the expected range. This big-bang implementation strategy could be a quick win for Office Depot, by adding the two figures to the protocol of the line review taskforce.
**Substitution effects**

The literature described in chapter 3, suggests to include substitution effects to optimize the profitability of the composition of an assortment. At the time, Office Depot assumed no presence of any substitution- or cannibalization effects, since new items planned to be added to an assortment were simply expected to create an equal contribution to total sales like the best comparable item, without any loss of sales of that comparable item. To cope with substitution and / or cannibalization effects, customer behavior and buying preferences are required to be known, which could be different for every assortment group. The Nested Logit family (NL model), as described in section 3.3.4, could be an interesting model for Office Depot. It is a first attempt to overcome the Independence of Irrelevant Alternatives effect, which is a shortcoming to other models mentioned in literature, e.g. the Multinomial Logit model.

According to the product family tree in Figure 5, there are 619 RMS classes, divided over 42 assortment groups. The Nested Logit model, described in section 3.3.4, could as a first step be applied for each of 619 RMS classes, by positioning the items of each RMS class in a nest $N_i$. This model however, assumes partitioning of items in just one nest $N_i$. Vovsh (1997) suggest the Cross Nested Logit model (CNL model), where items can belong to more than one nest. For instance, the ‘item’ of a no purchase option evidently exists for a retailer in every RMS class. Moreover, a chair could be combined as e.g. a combi pack with a chair mat and a matching desk, during a certain promotional activity which may have an impact on the consumer choices made.

This type of promotional activities would imply the possibility of an item to be part of multiple assortments. Therefore, the Cross Nested Logit model (Vovsha, 1997), would be an improvement versus the NL model due to this extra feature. The downside of this extra feature, according to Marzano and Papola (2008), is that it cannot capture all possible types of correlations among products. Nevertheless, it is always an improvement of the assumption that substitution or cannibalization effects do not exist within the assortments that Office Depot offers to its customers.

Applying the CNL model in the decision support tool when substitution matrices are known, is therefore a good opportunity / suggestion for optimization of the current assortment for various product families. For more information about characteristics and implementation of the CNL model, see Vovsha (1997), and Marzano and Papola (2008).
6.1.6 Research sub question 6

- Are the suggestions for optimization of the current assortment, in line with the set of Key Performance Indicators at Office Depot?

The current set of active performance indicators at Office Depot, displayed in appendix J, are not in line with the overall profitability of the assortment. The following example, somewhat exaggerated, will provide insight at an actual scenario that is possible at Office Depot:

“When the merchandising department aims predominantly at an increase of the total amount of sales generated in all regions of Europe, completely un-harmonized and un-rationalized assortments throughout all active sales regions could maybe generate the expected higher total sales value. Yet as a result, it would be accompanied by higher levels of demand uncertainty and corresponding higher levels of inventory (Shah and Avittathur, 2007). The objective of merchandising could be accomplished, but in case the sales are generated by for example setting the selling price per SKU relatively low, which could be somewhat closer to the procurement price than expected. In between are numerous cost drivers that decrease the profitability, such as the increased storage costs due to the higher levels of inventory, as a result of the increased total sales value arranged by the merchandising department. Nevertheless, the procurement department had already accomplished its targets by decreasing the Cost of Goods Sold as a performance indicator, along with the supply chain department that had accomplished its minimum On Time Delivery performance indicator.”

According to this exaggerated example, every department has performed very well and accomplished its KPIs. Nevertheless, the annual report presented some time later, reports massive losses instead of expected profits since every actor in the core process of Office Depot has managed to accomplish his or her set of KPIs. Every department at Office Depot is required to communicate with other actors in the core process. This requirement was already present at Office Depot, but it was not being executed often. Following the review of literature discussed at section 3.2, and the results described in sections 6.1.1. through 6.1.4.,

Lohman et al. (2004) specifically notes that the “availability of data is one of the considerations in the design process”. The availability of data, or more accurately stated the lack of available data at Office Depot, is presumed to be a hurdle when following the nine step framework of Neely et al. (1995). Lohman et al. (2004) provide suggestions to overcome this problem, by proposing various approaches that can be used to design the PMS, e.g. asking or interviewing of process owners, prototyping, planning methods, and using existing reports.
6.2 Research objective
Shah and Avittathur (2006) found that “Demand uncertainty increases with an increase in customized extensions”. Moreover, they state the demand forecasting accuracy of SKUs is being reduced with the increase of the demand uncertainty. This, at its turn, implies higher possibility of stock outs or oversupply.

The operational performance at Office Depot can be increased by using and analyzing the output of the decision support tool. The tool is based on implications of Assortment Planning theory, rather than actual consumer choice models of substitution probabilities between SKUs. This data should be constructed from actual historical and transactional sales data, instead of the simulated demand that was implemented in the tool to make it more accurate. The accuracy of the simulation model is leading for the adoption of the decision support tool by product managers, during line reviews. It should be noted that there may be more cost parameters added to the simulation model, in order to create a profitability model per SKU that has more solid foundation to conclude an item as one with not sufficient contribution to the assortment it is part of. The underlying assumption from the line reviewing taskforce, is that the assortment lacks a certain diversity of SKUs, since ‘only then more sales and therefore automatically more profits’, can be generated. The decision support tool shows, that an elimination of a subset of SKUs that do not contribute sufficiently to an assortment, can lead to an increase of operating performance.
7 Conclusion, Limitations and Recommendations

This section presents the overall conclusion of the findings, and discusses opportunities for both additions to literature and improvement of processes at Office Depot. Section 7.3 discusses options for integration and implementation.

7.1 Conclusion
This master thesis aimed at the increase of operational performance, by constructing a decision support tool and suggesting a framework for implementation. After an extensive search for interconnections between 39 problems that somehow relate to a poor operating performance, the main subject for research was selected. The rationalization of the Stock Keeping Units (SKUs) in an assortment would imply an optimization of three identified direct drivers of a poor operating performance. Since the majority of the problems were linked via a misalignment of Performance Indicators, theoretical aspects of Performance Management theory were added to the master thesis. Malpractices of officers in the core process of Office Depot could still result in individual bonuses to be received, where improvements of one department could be completely counterproductive for the targets set at another department.

A simulation model has been constructed as a decision support tool for the product manager and/or his task force during a line review. The model follows a four-step heuristic, based on a profitability model with various relevant cost parameters, and two Pareto analyses. The improvement versus the current approach applied by the product manager, can be found at the supplementary quantitative dimension that suggests a list of possibly rationalizeable SKUs, based on their (lacking) contribution to the assortment. The accuracy of the profitability model of the decision support tool could be expanded with more relevant significant cost parameters, due to a dynamic programming architecture that allows for more data to be inserted.

7.2 Limitations and recommendations
The simulation model, described both in words and mathematically, is a first attempt to start creating a model addressing the total profitability of a SKU in an assortment. Numerous dimensions that affect the profit per selling item could still be included, such as transportation routing per SKU or the influence of substitution effects between items. These possible add-ons at the current simulation model requires many data entrances, which incurs a huge effort since the search for the data is difficult and exhaustive. Further research could be aiming at the improvement of the accuracy of the profitability model.
Another suggestion for further research, that could be specifically conducted at Office Depot, can be found at the interconnections between problem states in the diagrams mentioned in Chapter 4. Measurements of the power and significance of all relationships in the cause and effect diagrams could provide more knowledge and insight of difficult processes. For each of the most significant problems selected by e.g. the director of Supply Chain Operations, projects could be initialized for more research to be conducted regarding these problems.

7.3 Redesign, Integration and Implementation
After the results and the solutions presented earlier, a suggestion for implementation should be regarded. The redesign and integration of the approach suggested in this master thesis, follows the regulative cycle by van Strien (1997), as the methodology for the implementation phase in the leading methodology of Sagasti and Mitroff (1973). Next, a helicopter view will be presented as reflection, looking back at the steps taken to create this master thesis, and what data entries are suggested to implement in the decision support tool to improve its accuracy and contributions.

7.3.1 Redesign
The decision support tool and corresponding optimization heuristic suggested in this master thesis, can be integrated in the protocol for line reviews that was actively used at the time. The regulative cycle can cope with the addition of extra cost parameters and data in the simulation model, since there is a link in the framework that connects the entities ‘evaluation’ and ‘problem (re)definition’. Note that the solutions provided in this master thesis must be considered as an addendum to the protocol that was already present, since the decision support tool cannot cope with qualitative characteristics and diversification between alternatives in an assortment. There is no incentive to overhaul the qualitative aspects of the line reviewing process, since interviewees and process owners stated that the verification for sufficient diversification between alternatives in an assortment was thoroughly conducted, which I agree on.

In order to increase the operating performance and reduce product proliferation, the decision support tool with the corresponding heuristic should be integrated in the line review protocol, prior to the qualitative verification of the assortment. Previously, the underlying assumption of the line reviewing taskforce, was fed by the belief that the assortment lacked a number of SKUs, which needed be added in order to increase sales, and therefore automatically profit. The proposed decision support tool shows that the elimination of a list of SKUs from an assortment, can increase the operating performance. Moreover, using the decision support tool, the product manager is now in the position where he needs to defend his position and arguments whether to still keep the selected list of SKUs in the assortment. This defense of arguments, should be performed in presence
of a line reviewing taskforce, that has process owners and officers from all three core business process departments: Merchandising, Procurement, and Supply Chain Operations. Each department will strive for the accomplishment of its own goals and targets (KPIs), by discussing the impact of elimination of the SKU(s) at the performance of their own department. Hence a constructive discussion can be created, knowledge and perspectives can be shared cross-departmental in order to align with the leading strategy of Office Depot: Maximizing the shareholders value, by increasing the average bottom line profit margins per SKU.

7.3.2 Reflection on master thesis

The call for change was considered to be too great, to demand three complete departments to overhaul their structure of performance indicators, and possibly even the bonus structure linked to the performance indicators. Generally, bonuses were based on total sales value, rather than bottom line profit margin. For future research at OD, I suggest to analyze all applied performance indicators for opportunities of cross-departmental malpractices, and the allocation of bonuses in case cross-departmental counter-productive decisions have been made. As long as the incentive of maximization of total sales value will lead to a higher salary or bonus for a process owner, incentives for maximization of bottom line profit margins will be suppressed.

Another key point of reflection during the conduction of the master thesis, is the availability of data. The only efficient approach to receive relevant data for the construction of the decision support tool, was to escalate the withholding employee such that he was forced to provide the data. In some occurrences, even escalation was not a successful method, resulting in the necessity of an element of simulation into the decision support tool. Further research should therefore include transactional data and improve the accuracy of the profitability model per SKU, by collecting the following sets of data:

- Historical transactional data per customer for a time span of three years;
- All relevant qualitative characteristics per SKU, e.g. size, color, and brand, etc.;
- End-to-end transporting routings for every SKU;
- Substitution matrices for comparable in all assortments;
- Inventory and demand data per SKU per active selling region;
- Profitability model with differences for SKUs in every selling region’s warehousing costs;
- Overhead costs, since interviewees mentioned there is a substantial error rate for standard core business operations from initial procurement to routine customer deliveries.
Glossary

Throughout the document, abbreviations were used. Below is the full list with corresponding explanation, sorted by appearance:

OD: Office Depot Europe B.V.
AS400: Previously applied Inventory control software program;
AWR: Previously applied Inventory control software program;
E3: Previously applied Inventory control software program;
Prime One: Inventory control software program applied at the time;
CDC: Central Distribution Center;
LDC: Local Distribution Center;
RDC: Regional Distribution Center;
SKU: Stock Keeping Unit
KPI: Key Performance Indicator;
MRP-I: Materials Requirements Planning - 1
ERP: Enterprise Resource Planning;
PLM: Product Lifecycle Management;
PI: Performance Indicator
PM: Performance Management;
PMS: Performance Management System;
MNL model: Multinomial Logit Model
ED model: Exogenous Demand Model;
LC model: Locational Choice model;
RB model: Ranking Based model;
IIA: Independence of Irrelevant Alternatives – assumption;
RMS: Retail Management System;
TEU: Twenty-foot Equivalent Unit.
References

- Algera, J. A., Haas, M. de, 2002. Performance management at Different Organizational Levels, Improving organizational Performance with the productivity measurement and enhancement system: An international collaboration, Ch. 7, Nova science publishers Inc.


• Kleingeld, P.A.M. (1994). Performance management in a field service department: Design and transportation of a productivity measurement and enhancement system (ProMES). Ph.D.

masked for confidentiality in the best interests of Office Depot.