Raw Materials Sourcing Optimization in the Tire Industry

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Dissertação de Mestrado

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Mestrado Integrado em Engenharia e Gestão Industrial

2017-06-26

"The information revolution is sweeping through our economy.
No company can escape its effects."
Michael Porter

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Abstract

This project was developed on the scope of the inbound supply chain department of Continental AG, an automobile industry company, and was focused only on the tire division. Its aim was to analyse the sourcing process, the management of raw materials' supplies, and to propose a solution, that would come up with an improved approach to supplier-related decisions.

In the automobile industry, purchasing of raw materials typically represents more than half of the total cost of goods sold and consumed (Gobetto, 2014). Hence, any savings in this field have a significant impact on the financial results (EBIT), which justify the relevance of the project. Opportunities for improvement were diagnosed in the purchasing process, mainly related to sourcing: unstructured information regarding plants, suppliers, packaging and raw materials; the inexistence of a standardized analysis, before negotiations with suppliers, of the sourcing options; operational incompatibilities of the conditions in which the materials are sent from the suppliers to the plants; possibility to increase control over environmental damage caused by the sourcing of raw materials. All of these topics were addressed in this project, as it was believed that they could bring a positive financial impact to the company.

The design of the approach to the raw materials sourcing optimization was divided in three phases: building up a database with the necessary variables for costs calculation; defining a mathematical model for the strategic constraints, in order to optimize quantities allocated from suppliers to plants; implementing a business case, with key previously chosen raw materials, in order to test the system and the model. It optimizes a cost function regarding operational, financial and holding costs and then presents the relevant information regarding supplier performance and sustainability, including environmental impact. Although the business case was only applied to two families of materials, the model is flexible enough to integrate the analysis of any other raw material, which allows purchasers to make an analysis before and after contract establishment with the supplier.

This approach allowed a better understanding of the costs involved in the sourcing decisions, both from the operational and sustainable point of view. Firstly, the value to be paid for more sustainable sourcing options was calculated. Secondly, the effect of payment terms and consignment on total spent of raw materials purchasing was computed, proving that longer payments terms and/or establishing stock on consignment with suppliers attains better results, depending on the number of days of the payment term, and on the percentage of total demand that is under consignment. The effect of other operational conditions (space, handling, transport and feedstocks fluctuations) on total spent was also analysed. Moreover, the price to pay for strategic manoeuvres of risk mitigation was calculated. For all of the mentioned situations, it was also possible to obtain the optimum allocation of suppliers to each of the plants, the respective quantities and demand splitting.

Acknowledgement

Firstly, I would like to acknowledge the opportunity given by the Inbound Supply Chain department at Continental Tires, not only to develop this project but also to implement it through a real business case. Especially, I would like to thank Michael Okon, head of the inbound supply chain department, for trusting on my capacities, for giving me the chance to go three times to Hannover, to work directly with the key users of the implemented solution, and always guiding the project on the right path. Secondly, I would like to thank Philipp Felbinger and Georg Schwarz for the time spent with me to develop the business case of the project. Thirdly, I would like to thank all the others, that with their experience and specific knowledge on different fields, contributed with constructive opinions and suggestions: Michael Harmmeyer, Wolfgang Kock, Silke Kroemer, Jan Schmidt and Milena Dibucchianicco, Thomas Bannert, Alexej Rosnatovskia, Tomas Lukac, Burkhard Schaefke, Kai Roesseler, Dierk-Carsten Harries, Daniel Zalesak.

At Continental-ITA, where the project was developed, I would like to thank Diogo Silva, for the patience, the guidance, the avid discussions and brainstorming, the sharing and for always challenging me, even when I thought I was already doing my best. I would also like to acknowledge Manuel Pinheiro and Eduardo Diniz for the opportunity to work at C-ITA (Continental Industria Têxtil do Ave) and the availability to cooperate every time necessary, also Marcela Silva and Duarte Sá for their eagerness to help. At Continental Mabor, I would like to thank Cláudia Monteiro, Sandra Ribeiro and Maricilde Reis, for their availability to spend time with me and answer all my endless questions about the tire production.

At FEUP, I would like to acknowledge the guidance and the availability to support of Professor Bernardo Almada-Lobo, all along the project.

On the personal side, I wholeheartedly thank my parents who, no matter how distant, have always supported, cared and believed in me and in my conquers. The last but not the least, I would like to thank my flatmate, Cristina, for the fellowship during these four months of hard work; my friend and colleague Nuno, for all the lessons learned about algorithms and programming; my friend Rita, for all the advice about finance and accounting; and my friend and colleague, Sofia, with whom I shared bright ideas and songs to inspire my work, cheering up the greyest and celebrating the happiest days.

Index

Acronyms 3

Index of Figures 4

Index of Tables 5

1 Introduction 6
- 1.1 Framework and motivation of the project 7
- 1.2 Opportunities for Improvement 8
- 1.3 Objectives of the project 9
- 1.4 Project Planning 9
- 1.5 Structure of the Thesis 10

2 Background 11
- 2.1 Inbound Supply Chain Management 11
  - 2.1.1 Performance measurement in purchasing – Financial approach 14
  - 2.1.2 Packaging as part of the inbound supply chain management 15
  - 2.1.3 International Trade 16
- 2.2 Sustainability Management in the Inbound Supply Chain 16
- 2.3 Information Systems Management 18
- 2.4 Sourcing Strategy: Portfolio of Suppliers Approach 20
  - 2.4.1 Risk Management in the supply chain – How many suppliers to use? 20
  - 2.4.2 Suppliers Performance Measurement – Operational approach 21
- 2.5 Competitors Benchmark 22

3 Diagnosis of the Current Situation 23
- 3.1 General Overview of the Inbound Supply Chain at Continental 23
  - 3.1.1 Purchasing Process 24
  - 3.1.2 Risk assessment 28
  - 3.1.3 Suppliers Performance measurement 28
  - 3.1.4 Opportunities for Improvement in the Inbound Supply Chain Management 29
- 3.2 Packaging Situation 30
- 3.3 Sustainability Management at Continental 32

4 Solution Proposed 34
- 4.1 Database development 34
  - 4.1.1 User Requirements 34
  - 4.1.2 Formulas Specification 35
  - 4.1.3 Other remarks about data gathering 36
- 4.2 Mathematical Model for Costs Optimization 37
- 4.3 Business Case Implementation 43
  - 4.3.1 Assumptions 43
  - 4.3.2 Scenario Analysis 44
  - 4.3.3 Results Analysis Discussion 44
  - 4.3.4 Notes on the purchasing process 48
- 4.4 Other implemented solutions 48

5 Conclusion and Future Works 50
- 5.1 Expected improvements 50
- 5.2 Results Summary 51
- 5.3 Future Works 51

References 54

APPENDIX A: Levers of purchasing in terms of return on capital employed - (Kotula et al. 2014) 56

APPENDIX B: The extended supply chain - (Beamon 1999) 57

APPENDIX C: Evaluation criteria for a green supply chain - (Beamon 1999) 58
APPENDIX D: Examples of Supplier's Performance Metrix (Wisner, Tan, and Leong 2014) 59
APPENDIX E: Current and past supplier selection criteria - (Cheraghi, Dadashzadeh, and Subramanian 2011) 61
APPENDIX F: List of packaging and plants' codes 62
APPENDIX G: Tire Production Process and Raw Materials 63
APPENDIX H: Table of Raw Materials' Families and Sub-Families 64
APPENDIX I: Incoterms 65
APPENDIX J: Types of Packaging at Raw Materials' Warehouses 66
APPENDIX L: CVC Calculation Rational 68
APPENDIX M: EcoVadis Sustainability Assessment Criteria 69
APPENDIX N: Core Processes of Tire Division Purchasing 70
APPENDIX O: Purchasing Strategy of Tires Division 71
APPENDIX P: Suppliers' Codes Hierarchical System 72
APPENDIX Q: Gantt Diagram for Project Planning 73
APPENDIX R: Information Scheme for the Database Development 74
APPENDIX S: Raw Materials Sourcing Decision Criteria Applied 75
APPENDIX T: Allocation Output Report 76
APPENDIX U: Questionnaire for Packaging Ecological Impact Assessment at the Plants 77
APPENDIX V: Suppliers' Packaging Requirements Manual Template 78
APPENDIX X: Results Analysis – Scenarios Table 80

Acronyms

AHP	Analytical Hierarchy Process
C-ITA	Continental Indústria Têxtil do Ave
CE	Capital Employed
CFC	Chlorofluorocarbon
AG	*Aktiengesellschaft*
CVM	Conti Vendor Master
CVC	Continental Value Crated
DAP	Delivered at Place
DAT	Delivered at Terminal
DDP	Delivered Duty Paid
EBIT	Earnings Before Interests and Taxes
EDI	Electronic Data Interchange
EVA	Economic Value Added
FAS	Free Alongside Ship
FCA	Free Carrier
FOB	Free On Board
GIT	Goods In Transit
IBC	Intermediate Bulk Container
INCOTERMS	International Commerce Terms
ISCM	Inbound Supply Chain Management
ISO	International Standardization Organization
IT	Information Technology
KPI	Key Performance Indicator
LCA	Life Cycle Analysis
MAUT	Multiattribute Utility Theory
OECD	Organization for Economic Cooperation and Development
PO	Purchasing Order
R&D	Research and Development
RFQ	Request For Quotation
ROCE	Return On Capital Employed
SDS	Sourcing Decision Sheet
SPM	Supplier Performance Measurement
SR	Synthetic rubber
SRM	Supplier Relationship Management
TCO	Total Cost of Ownership
WACC	Weighted Cost of Capital
WTO	World Trade Organization

Index of Figures

Figure 1 – Continental Corporation Divisions, sales and employees - (AG 2015) 7
Figure 2 – Continental Tire Plants Locations Worldwide (AG 2015) 7
Figure 3 - Purchasing Process Scheme - (Presutti 2003) 12
Figure 4 - The transportation table - (Gobetto 2014) 19
Figure 5 – Purchase portfolio matrix explained - (Gelderman and Van Weele 2003) 20
Figure 6 – Raw materials used for a standard tire 23
Figure 7 – Families of raw materials 24
Figure 8 – Information provided by material code 24
Figure 9 – Raw materials purchasing flowchart 25
Figure 12 - Effect of the variation of 50% of the BdEU feedstock on total spent for material synthetic rubber 3 ..... **Erro! Marcador não definido.**
Figure 13 – Changes in allocation of suppliers (% of total demand) for the material synthetic rubber 3 due to BdEU fluctuations ..... **Erro! Marcador não definido.**
Figure 14 – Effect of synthetic rubber 3feedstocks fluctuations on total spent **Erro! Marcador não definido.**
Figure 15 – Differences in allocation of suppliers to the material synthetic rubber 3, due to feedstocks fluctuations 47
Figure 16 – Extra total spent and allocation due to capacity restrictions for material synthetic rubber 1 47
Figure 17 - Effect of strategic constraints split on cheapest option and comparison with 2016 allocation for SR2 47
Figure 18 – 2016 suppliers' allocation validation 48

Index of Tables

Table 1 – Sourcing opportunities for improvement....8
Table 2 - Negotiation terms....27
Table 3 – Solution representation of the problem....39
Table 4 – Step 2 of the allocation rational....39
Table 5 – Final result of the allocation....40
Table 6 – Capacity penalization calculation....42
Table 7 – Deliveries penalization calculation....42
Table 8 –Strategic spreading penalizations calculation....43
Table 9 – Feedstock values considered for analysis....46

1 Introduction

In this chapter, a brief introduction to procurement is provided, followed by a presentation of the framework of the project and a diagnosis of the main opportunities for improvement. The methodology and structure of the thesis will be presented at the end.

The five competitive forces that shape strategy, proposed by Michael Porter (Porter 2008), tell us which external factors can majorly influence the competitiveness of a company in a certain business. One of those forces is the so called bargaining power of suppliers. As explained by the author, powerful suppliers shift costs to the following industry participants or rise prices, which turns into a problem when the company is somehow supplier dependent. In order to avoid that, the company must be flexible enough to rapidly change suppliers if necessary, or at least to have means or information to decide upon making that decision. Regarding information technology, Porter also tells us that it is hard to overestimate its strategic significance, there are three specific ways that it affects competition: it alters industry structures, it supports cost and differentiation strategies, and it spawns entirely new businesses (Porter and Millar 1985). This supports the need for quality assessment of the available information and its proper organization, in order to get competitive advantage.

However, changing suppliers can be difficult in terms of operations, due to specialized equipment or even plant location, which reinforces the idea that strategic management decisions impact all areas of a company (Weber, Current, and Benton 1991). Hence, an approach to deal with sourcing decisions and allocations is, first of all, a strategic decision, which represents significant importance in a company's business: "While ordering decisions are tactical in nature, the allocation decision is strategic." (Tomlin 2006).

The choice of suppliers together with the allocation, contract establishment and purchasing are all part of the procurement process. For Continental AG (*Aktiengesellschaft)*, the purchase of raw-materials represents more than a half of the total cost of a finished good, which is consistent with the average values for the automotive industry (Weber, Current, and Benton 1991). Hence, any opportunity for cost savings in this area can consequently have a great impact on the profit and loss balance sheet. Weber also refers that vendor selection decisions are complex due to a big number of criteria involved, which also change significantly accordingly to the raw material. The same complexity was found at the inbound purchasing department at Continental when the As-Is analysis of the process was ran.

Although the initial scope of the project was solely related to packaging optimization, that is which packaging optimizes costs for each material, soon it was understood that such an operational issue works hands in hands with strategical and supplier related decisions. So, and since the strategic positioning for the purchasing department in 2016 was Sustainability and in 2017 Digitalization, it was under this drive that the project rose and that its scope got wider. This approach brings an operational and sustainable perspective to the sourcing decision process, while being flexible to adapt to many kind of raw materials inside the company.

Along this chapter, both the company and the relevance of the project will be contextualized, in order to make clearer how it can contribute to the challenges mentioned above.

1.1 Framework and motivation of the project

The corporate group Continental AG, where the project took place, despite being mainly recognized by its tire division, is also a major player on the automotive business. The company is composed of two groups: Automotive and Rubber. These are in turn divided into five divisions and 28 business units, depending on product group and region. The Rubber group itself is divided into Tires and ContiTech, which generates around 40% of consolidated sales as shown in figure 1.



Figure 1 – Continental Corporation Divisions, sales and employees - (AG 2015)

The project is focused on the Tires division, whose product portfolio includes tires and rubber products. The tire manufacturers had at the time of this report, 19 locations, as seen in the figure 2, supplied by 1800 other companies.



Figure 2 – Continental Tire Plants Locations Worldwide (AG 2015)

As in any automotive industry, the supply chain of the tires division is quite complex and demanding, however, for this project, the focus is on the inbound supply chain, where the approach to raw materials sourcing will be implemented. In order to perform the pilot project (explained in chapter 4), there was direct contact with the corporate purchasing department, specifically with the Central Inbound Supply Chain Management. Several personal contacts were performed with the team in Hannover, with lead-buyers, controlling and IT team members, where the headquarters of the company are located, in order to get information and to understand what were the opportunities for improvement and to get feedback as the project was developed.

The ISCM (Inbound Supply Chain Management) has a development strategy of giving visibility to plants and suppliers, of managing risk and warehouses. This project was triggered by the ISCM, however, its development lead to a tight collaboration with the purchasing department as well. It is responsible, among other functions, for buying raw materials from suppliers and for designing the upper level of the supply chain, which means, all the relations among suppliers and plants. This activity represents more than a half of the total costs of finished goods. The raw materials are divided into families of chemicals, textile and steel reinforcements and rubber, which are bought from many locations around the globe and packed accordingly to the supplier preferences (and not according to what should be the best option available).

Therefore, the main objective of the project is to allow the lead-buyers to decide upon which suppliers to choose and what quantity to allocate to the plants, and at what costs, for a certain material. This is mostly useful for the stage of supplier selection and negotiation of the purchasing process. The new feature of this approach, in comparison to what was done before, is that hidden costs are also considered for the analysis, such as operational costs (handling of raw materials, space occupation, packaging conversion), together with financial indicators. Moreover, information about supplier performance and environmental impact, which was already being collected by the company but not integrated into the decision process, will be displayed together with the allocation indications. The main constraints for the optimization are strategic and will be explained in more detail in chapter 4.

Finally, Continental is facing a strong competition and uncertainty, since the whole automotive industry is facing major changes and shakes, such as the evolution of market and vehicle usage conditions, the availability of new technologies, and safety and environmental restrictions (Gobetto 2014). Companies in this sector need to be able to decide fast and accurately, in order to deal with changes in the market and to react to them faster than the competitors (Martínez Sánchez and Pérez Pérez 2005). Hence, focus on supply chain optimization and continuous improvement is crucial. In order to cope with that, adding flexibility and agility to supplier related decisions is predicted to attain strong advantages. It is established that the dimensions of flexibility in the Supply Chain include number of products, volume of production, routes, deliveries, lead-time, trans-shipments, postponements, sourcing, responsiveness to target markets, launch and distribution flexibility (Martínez Sánchez and Pérez Pérez 2005). The new approach here presented can contribute simultaneously to many of the dimensions previously mentioned: deliveries, lead-time, sourcing and responsiveness to target markets. It is based on a database and changeable strategic inputs, allowing the introduction of new information and also the filtering of the criteria considered in the choice of suppliers for a certain raw material: its features are flexible in order to work as a strong support for supplier related decisions.

1.2 Opportunities for Improvement

After analysing the current sourcing procedure of the company, opportunities for improvement were found, as summarized in table 1. It provides an insight about the problems found, what their effect on performance is and which stakeholders are involved. Details are provided in sections 3.1.4, 3.2 and 3.3.

Table 1 – Sourcing opportunities for improvement

No.	Topic	Problem	Effect	Stakeholders
1	Operations	Plants' diversity of infrastructures	Incompatibilities on handling of raw materials - losses or extra spends	Purchasers, raw materials warehouse managers

2	Operational costs related to sourcing decisions	Sourcing decisions without an analysis of their impact at plant level – operational costs not being assessed at central level before purchasing	Negative overall financial impact (sourcing decision is not optimized)	Purchasers, central controlling, local plants
3	Sustainability	Sustainable practices and performance of suppliers is assessed but not considered as a decision criteria	Poor performances might be ignored due to attractive prices, consequences in the long-term specially at production sites	Purchasers, strategic and corporate purchasing
4	Information growth management	Unstructured information regarding suppliers, raw materials and packaging, extracted from different systems, organized independently by each of the lead-buyers	Replication of efforts, unstandardized and non-efficient process of data gathering and storage, reporting information to corporate purchasing becomes a too time-consuming task	Purchasers, strategic and corporate purchasing
5	Environmental management	There wasn't a holistic evaluation of the ISCM sustainability practices, with potential to extend it to inbound logistics and packaging	Best sustainable solutions are not identified and might be neglected due to unattractive price rates, inexistence of a trade-off cost analysis	Corporate and strategic purchasing
6	Process standardization	Economic scenario analysis of sourcing options and allocation of suppliers to plants is not performed systematically before and after negotiations	Sourcing decisions might not be accurately evaluated and manual allocation might not be the optimal	Purchasers

1.3 Objectives of the project

The main objective of the project is to develop, implement and analyse the results of a new approach to supplier sourcing decisions, that can address successfully the opportunities for improvement described at the top and enhance packaging solutions, sourcing procurement and raw materials purchasing. As said before, three phases were conducted: database and interface development, mathematical model optimization and business case implementation.

Regarding the technical approach, Excel and VBA were the main software interfaces used for the development; SAP (software system company) information was used for data sourcing. In terms of scientific approach, an optimization algorithm was applied, based on operations research methods, to simulate different hypothetic scenarios (likely to happen in a practical context) and perform a what-if analysis. Moreover, halfway of the process, there was personal contact with corporate purchasing departments: controlling, ISCM and lead-buyers, aiming to confront the future users with the new approach and to get feedback on its interface and features. The point is that the output of the calculations work as guidance for decision making, not replace it, because there is also qualitative output and soft facts that, if integrated in a cost function, could bias the output result.

The main expected result is a versatile and flexible approach, which can support lead-buyers decisions during the main phases of negotiation, as well as during the whole sourcing process. In the long run, after it is implemented, several operational advantages are expected: faster and more reliable decision making, savings, stronger and more effective coordination among suppliers.

1.4 Project Planning

As already explained, the first objective of the project was to analyse only different packaging alternatives for each of the raw materials and to find an optimized solution. However, as the project went by, it was made clear that it was impossible to deal with

packaging alternatives without dealing with suppliers and plants as well. Regarding that change, the following methodological approach was applied to the project:

1st month: Learning background know-how of Continental's packaging structure - get overview of different packaging types used in the tire plant and all plants worldwide. Analyse current situation and identify opportunities for improvement.

2nd month: Development of a mock-up for the database and interface, as well as for the mathematical model for strategic constraints and costs improvement.

- ➔ First milestone: presentation of the mock-up at Hannover to lead-buyers and sustainability responsible.
  - Output: feedback from target users about new features to introduce and others to discard. Mock-up more adapted to the process.

3rd month: Focus on 3 key raw materials with potential for analysis. Development of the mathematical model and improved solution methodology, collection of data needed for simulation and database fulfilment. Definition of the approach for the sustainability information.

- ➔ Second milestone: simulation running and testing in Hannover directly with lead-buyers (key users). Getting approval from controlling for the financial evaluation, from sustainability for the packaging ranking and from quality for packaging requirements definition.
  - Rational of the approach approved and ready for simulations with higher number of input variables.

4th month: Final improvements on the simulation. Result analysis and discussion. Improvements on the user interface. Definition of future works.

- ➔ Third milestone: presentation of the final project at Hannover.
  - Project delivery.

1.5 Structure of the Thesis

After this introductory chapter, a literature review of the state of the art will be presented, in chapter 2. Information will be provided regarding the main topics that ground this project: inbound supply chain management (ISCM), sustainability in the ISCM, information systems management and sourcing strategy. In the end of the chapter, a benchmark of the competitors, regarding the mentioned

In chapter 3, an SPS analysis is performed (situation – problem – solution). For that, an AS-IS analysis of the purchasing process is done, together with the main problems identified and solutions proposed (TO-BE analysis).

In chapter 4, a more detailed overview of the solution implemented and its main steps is presented, together with a discussion of the results of the simulations of different scenarios. The choice of the scenarios was agreed upon with the key users, in order to evaluate practical situations that happen both at strategical and tactical levels.

Finally, in chapter 5, conclusions and possible future works related to the project are found, together with a perspective of the future steps of the implementation of the project at the company.

2 Background

After understanding the framework of the project in chapter 1, a review of the literature will now be presented. Information will be provided regarding the main topics that ground this project: inbound supply chain management (ISCM) and sustainability at the ISCM, where the main opportunities for improvement were found; information systems management, relevant for the sourcing optimization approach developed; sourcing strategy, the main constraint that shapes the output of the implemented system, described in chapter 4. In the end of this chapter, also a benchmark of the competitors, regarding raw materials sourcing optimization, is provided, in order to position Continental's competitiveness.

2.1 Inbound Supply Chain Management

This project aims to provide a solution to sourcing optimization, hence, the following topics will specify concepts related to inbound supply chain management: performance measurement – decisive for the choice of suppliers; packaging - a key factor influencing tactical sourcing decisions; international trade - it regulates the flow of raw materials from suppliers to plants.

The Council of Supply Chain Management Professionals defines supply chain management as: "The planning and management of all activities involved in sourcing and procurement, transformation of goods and all logistics management activities" (Wisner, Tan, and Leong 2014). Information technology represents a major catalysis to the competitiveness of a company on all its fields of action, including inbound supply chain management (Russell and Taylor-Iii 2008).

Sourcing, part of ISCM, involves all the processes needed for supplier selection and contracting, starting with procurement and followed by purchasing. Purchasing can be divided into two broad categories: direct materials (inputs for manufacturing, subject to transformation and assembly operations, composing the final product) and indirect products (needed for other operations, such as maintenance, for instance). In the automotive industry, raw materials are considered direct materials. They are purchased by weight volume from industry specific suppliers, due to its uniqueness and particularities of each business.

A typical purchasing department is responsible for procuring agreements, selecting and strengthening a set of suppliers, applying evaluation criteria, coordinating technical and economical comparisons, leading negotiations, making orders, maintaining contract relations with suppliers and for assuring best market conditions. Purchasing structure can be centralized or decentralized. Centralized purchasing has a single purchasing department that makes all the decisions (order quantity, pricing policy, contracting, negotiations, supplier selection and evaluation). Decentralized purchasing has local departments, usually at plant level, that make their own purchasing decisions regarding technical requirements, target industrial initiatives and choice of local suppliers. The current trend is toward a hybrid purchasing organization: centralization for procurement and purchasing of higher volume commodities, in order to attain economies of scale advantages (quantity discounts, less-costly volume shipments, favourable purchase terms and bargaining power) and decentralized for the rest of the

materials (Wisner, Tan, and Leong 2014). However, this decision depends on the size and geographical spread of the company.

The major steps of a typical purchasing process are represented in figure 3. In this task, suppliers, a cross-functional team with engineers, representatives from operations and marketing are involved. A supplier manager will then develop a list of prequalified suppliers, request proposals and make a final decision by taking into account the established selection criteria. Afterwards, terms and conditions agreed upon result in a final formal contract, which contemplates transaction-processing guidelines. Once the process is established, performance measurement should also be implemented, to assure the supplier is contributing to the company's competitive position (Presutti 2003).

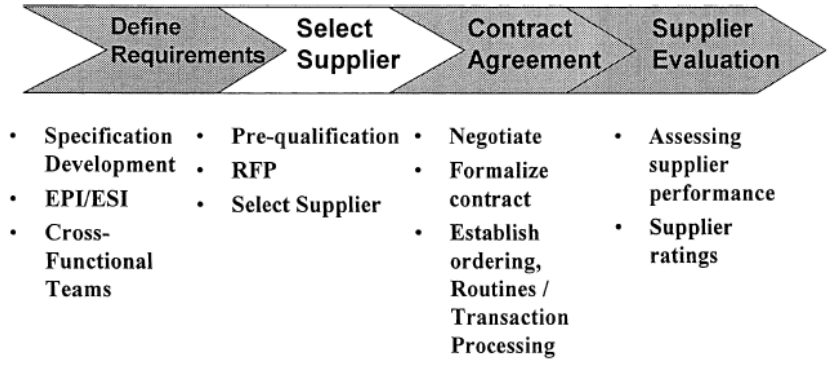


Figure 3 - Purchasing Process Scheme - (Presutti 2003)

Suppliers can be directly contacted from purchasers, after a market screening is performed. During negotiations, the buyer tries to obtain a detailed proposal about costs in order to perform a benchmark analysis, however, usually the professional operates in relation to well defined cost targets, defined by the department (Gobetto 2014). Usually, the purchasing and delivery of goods is a planned activity, taking place in specific periods of the year. However, each time a material is not available in the warehouse, a requisition to the purchasing department can also be triggered.

After a first contact with the potential suppliers, an RFQ (request for quotation) is issued to a pool of pre-qualified and approved suppliers. When a suitable option is found, the buyer issues a PO (purchasing order) and it is sent to the best option. Terms and conditions are agreed upon, such as technical specifications, quality control methods, delivery dates and transportation. In the end, a contract is established. Here, the obligations of the supplier are stated, such as the required production capacity, the quality level based on technical specifications, the delivery conditions (delivery dates and packaging) and the prices maintained for the agreed-upon period. At the same time, the purchaser agrees on certain obligations, for instance sharing the production planning and paying under the established conditions. Usually the payment term is defined by the purchaser. It is a source of financial advantage and should be considered as a tactical decision – to be taken accordingly to lead time between the delivery and the accounting of remuneration. In case of international trade, incoterms should be defined, as well as optimal location for delivery and stock availability, as explained under the topic "International Trade".

The pre-qualified and approved suppliers must go through a complex process of testing, also dependent on the industry and materials used. Raw materials, for instance, can largely influence the quality and performance of the finished goods, thus, checking the material requirements compliance through samples is a common procedure when choosing a new supplier. (Wisner, Tan, and Leong 2014)

Once the goods are bought to suppliers, delivery procedures can vary from industry to industry and from company to company. Usually suppliers make frequent, partial deliveries. Although they are more difficult and expensive to manage than larger batches, they represent a solution that doesn't increase largely the company's inventory. At the same time, they provide the company flexibility and reaction speed to sudden market changes. This procedure is named as continuous replenishment: "supplying orders in short periods of time according to a predetermined schedule". To deal with products arriving from worldwide locations, buffers are admitted and delivery plans are dependent on transportation methods and lead-times. Sometimes, to cope with uncertainties or to reduce the effect of holding costs, producers require their supplier to manage their warehouses with stock on consignment. When the supply is mainly done offshore, warehousing costs can represent a significant percentage of the total costs, because of the necessity to hold higher levels of stock. The holding costs can be computed by taking into account the capital cost (physical stock cost, i.e., the opportunity cost of tying up capital that could be invested elsewhere), service costs, risk costs (dependent on the time of recovery of the supplier) and storage costs (including cost of space and handling) (Rushton, Croucher, and Baker 2014). All this costs will be used as key references for the construction of the sourcing optimization as explained in chapter 4.

The ability to assure best market conditions is obviously influenced by the bargaining power of suppliers, determined by the offer/demand ratio. The bigger the number of alternatives in the market compared to the whole demand, the more likely it is to get better supply conditions. On the other hand, the buyer is at big disadvantage when the demand overcomes the foreseen dimension of the offer, which might sometimes result into single sourcing dependence, which, as further will be discussed, can represent a high risk for the company's business.

Summing up, a purchasing department is a linking point between the company itself and the suppliers, dealing closely with top management, in order to prevent sourcing interruptions (Gobetto 2014). Its core objectives are settled in order to improve the company's competitive position, and the following topics are usually contemplated: developing purchasing strategies that support and match a common business strategy and organizational goals; maintain supply continuity; obtain and develop suppliers and manage sourcing processes efficiently and effectively. In order to comply with those objectives, the professionals have to make decisions regarding which and how many suppliers to use and where they are located, which materials to use, when and how much inventory to purchase, who holds the inventory and when the transfer of ownership is done (Leon 2015). This project aims to add value to the decision making process related to these questions.

Before discussing performance measurement in the purchasing process, in the next section, it is important to understand what the supply costs are and what they include. First of all, they include the supply direct costs (purchasing price, usually including packaging and duties), indirect costs for logistics management (transport to final delivery point, warehousing and transferring of material to manufacturing systems), costs due to lack of quality (defect materials) and costs due to lack of service (interruptions in production process due to delays in delivery) (Gobetto 2014). Supply costs usually account for a high percentage of the production costs. In automotive industries, this value can go up to 50% of the total production costs. These costs can easily rise if materials are delivered with delay, or if they present low quality levels – in this case the company is forced to maintain large and costly inventories to prevent shortages and production from stopping. Smart procurement, the process of finding the right supply for materials, can avoid such situations, which justifies its importance and its crucial strategic role in the supply chain.

2.1.1 Performance measurement in purchasing – Financial approach

Nowadays, purchasing staff must be viewed as strategical internal suppliers of the organization, so it is recommendable to periodically monitor the sourcing performance against standards, goals or industry benchmarks (Wisner, Tan, and Leong 2014). Numbers support the relevance of corporate purchasing: a company's sales would have to increase 33% in order to achieve the same results as a reduction of 4% in the cost of raw materials (Kotula et al. 2014).

Effectively presenting purchasing performance is not always simple - any methodology across companies and industrial sectors has so far been established. The common practice is to measure the savings impacting operating results or the financial value created. However, this approach doesn't consider the effect that other sourcing decisions would have on the financial results, because a comparison of different strategic choices (more or less suppliers, in different locations, with different service quality level and order volumes) is not performed. This is exactly where improvement potential exists.

Notwithstanding, procurement and purchasing savings might sometimes be shadowed by external factors. Market fluctuations, volatile demand, lost sales, interdependencies with other corporate functions and decisions, such as the strategical ones, if not isolated from the performance analysis, might gloss the savings obtained through purchasing. It is essential that measures are established in a way that the different effects of the external factors are taken into account properly. Several other factors can influence performance measurement: organizational structures, management guidelines on purchasing, supply chain strategy and constellation of the procurement market (market power of the company vs. market power of the supplier). To cope with that plurality of factors, a holistic system of purchasing performance measurement should be implemented. This includes a value-oriented measuring model (procurement value added – financial approach) and a management-oriented implementation approach (purchasing balanced scorecard – operational approach).

One of the main factors affecting the purchasing performance is the price of materials, which is usually the major portion of the sourcing costs. It can be influenced by the negotiating skills of the purchasing team, quality of the goods, detailed knowledge of the product, availability of the product for purchase, distance of the supplier (influence through transportation costs) and economic trends (Rushton, Croucher, and Baker 2014). This last factor, usually results on significant price fluctuations, affecting specially raw materials (commodities) prices, which, in turn, are the main contributors to production costs, as already mentioned (Kotula et al. 2014). Regarding the distance of suppliers, in recent years, due to low costs of labour and production, there is a trend to source supply in Asia. Though this strategy provides price competitive advantage, when sending material to European plants, it might compromise other factors such as high transportation expenses and long replenishment lead times (Rushton, Croucher, and Baker 2014). On top of the factors mentioned, the market position of active and potential suppliers has a complex influence on purchasing performance. This topic will be further mentioned under the tab "Sourcing Strategy: Portfolio of Suppliers Approach".

In practice, the most used ratio for procurement value added measurement is the ROCE (return on capital employed), which can also be combined with WACC (weighted cost of capital) to calculate the EVA (economic value added): EVA$= (ROCE - WACC) \times CapitalEmployed$. ROCE ratio can be calculated as explained in Appendix A. The numerator, EBIT (earnings before interests and taxes), represents the profit and loss, the denominator, CE (capital employed) is computed via the balance sheet. Purchasing can influence these items into an extent described in Appendix A. As already mentioned, please note that material price has a direct influence in the cost of goods sold. Together with ratio calculation, qualitative performance measures are usually taken into account: service level, risk assessment, quality of deliveries, delivery period (lead-times), sustainability orientation

and requirements conformity (Gobetto 2014). This is important, because usually "non-conformance" or extra operational costs, due to inadequate purchasing decisions, are allocated to production cost centres instead of purchasing, representing a hidden cost and consequent misinterpretations. The qualitative performance measures will be further discussed.

To compare several direct materials sources, using ratios, qualitative indicators and other cost-based methods, an accounting system might be unable to process all the data required for calculation, especially in what it takes to hidden costs (Gobetto 2014). A well implemented database, linked to several sources of data, can fix this problem.

2.1.2 Packaging as part of the inbound supply chain management

Packaging plays a major role in inbound logistics for many reasons. Its shape, size and material can have a big influence in the handling of materials. For instance, transportation in containers has a limited space, so the shape of the packaging will determine how many units can be stored. A cylindrical-shaped product is unlikely to fill a cubic capacity and will leave much empty space, consequently, fewer units per container can be transported, more trucks will have to travel and higher will be the cost. So, filling empty spaces effectively is of major importance, since it will decrease unitary transportation costs and also reduce the environmental impact, since less travels are necessary.

This issue becomes even more relevant when packaging requires return to the origin for reuse, in this case, it is also important that empty packaging can be stored in a clever way, to increase the returning coefficient. A higher returning coefficient will mean that returnable packaging will have to be sent less times, and more units can be sent back per truck than received. If the packaging is not returned, then, it is considered waste or it can be reused inside the company. This type of packaging, that can't or isn't returned, can sometimes become a problem of inverse logistics, since waste packaging needs to be returned up to the supply chain or dealt with (Rushton, Croucher, and Baker 2014), as explained in Appendix B. This topic will be further discussed into more detail in section 2.2, entitled "Sustainability Management in the Inbound Supply Chain".

Besides that, packaging has an important function in protecting the goods from damage, preserving the materials and providing information. During transit, storing and production, its design has consequences on its handling, which represents a cost. Usually each supplier decides upon the way on how to pack the goods. However, buyers should try to negotiate or intervene in this matter, in order to match the plants handling requirements and facilitate the supply. For example, if plastic film gauges are optimized to an absolute minimum, in order to realize savings, this may result in an increase of returns due to low quality delivery or damages. In that case, significant additional costs will result: extra transportation and possible production stoppages (Kotula et al. 2014).

Packaging is considered to have different levels: primary (directly enclosing the product) and secondary (the several other layers that contain the primary packaging). The secondary packaging must be conceived in a way that matches the orders, so that units of product can be easily manoeuvred, picked and dispatched in a cost-effectively way. The common unit of loads are pallets. A pallet is a flat platform, made out of wood, plastic, steel or other material, on top of which products are placed and into which truck forks can be inserted to lift or move. They have several standardized sizes, accordingly to the geographical place in the world. These variations, even if sometimes small, can represent problems in international transport and in the design of racking equipment in the warehouse. The most common size in Europe is 1200mm by 800mm. Besides pallets, and accordingly to the industry, other types of unit load can be used: cage and box pallets, for goods that might otherwise fall, that can be stacked over each other and consequently save warehousing space; IBCs (intermediate bulk containers), used for transporting liquids and solid particulate products (Rushton, Croucher, and Baker 2014).

2.1.3 International Trade

Analysis of purchasing markets requires knowledge of macroeconomic and financial aspects, by characterizing geo-political areas (Gobetto 2014). Firms usually expand their sourcing to foreign suppliers, seeking lower prices of materials, energy and workforce, better quality, faster delivery to foreign units, tax concessions, social and political context favorable to industrial development, or better technologies. In this case, the costs involved in identifying, selecting and evaluating suppliers are higher. Moreover, if the supplier has a distant location, duties, customs, transportation and lead-times play important roles that might turn a certain option unacceptable, which has to be analyzed.

Foreign markets are not homogeneous and require customized service in terms of packaging and labelling. Other issues might affect worldwide commerce: high volume of documentation, cargo insurance, letters of credit, bills of lading, regulations for import and export, tariffs, duties, landing costs and shipping modes. The International Chamber of Commerce created a standard set of rules called INCOTERMS (International Commerce Terms), to simplify international transactions of goods and the related shipping costs, risks and responsibilities of both parts involved (buyer and supplier) (Wisner, Tan, and Leong 2014). The world trade organization (WTO) regulates the tariffs and duties between countries, ensuring that trade flows as smoothly as possible among the members (Russell and Taylor-Iii 2008).

2.2 Sustainability Management in the Inbound Supply Chain

The United Nations environmental programme has defined sustainability as "development that meets the needs of the present, without compromising the ability of future generations to meet their own needs". Creating a sustainable global supply chain has become an important goal of most companies. Pressure by stakeholders is making environmental issues less likely to be ignored by corporations, sourcing departments and their suppliers are starting to be involved in the implementation of resource conservation programmes, aiming to reduce energy use, greenhouse gases, water usage and dispose of hazardous materials.

This is a new challenge to manufacturing corporations worldwide: "environmental, social and economic dimensions must all be considered in order to select a well-rounded sustainable supplier" (Govindan et al. 2015). However, when it takes to social responsibility, numbers aren't always clear, and total cost of ownership gets hard to link to sustainability (Wisner, Tan, and Leong 2014). The first step to meet this challenge is to redefine the basic structure of the entire supply chain, by accommodating environmental concerns of waste and resource usage minimization. Producing, packing, storing, repacking, delivering and returning or recycling products, represents a significant threat to the environment, because discarded packaging, scrapped toxic materials, carbon monoxide emissions, noise, traffic congestion and other forms of industrial pollution are produced (Wisner, Tan, and Leong 2014). Appendix B explains how complex waste management can become, and the importance of its reverse logistics (Beamon 1999).

Regarding the environmental dimension of sustainability, the ISO (international standardization organization) has defined, in response to more stringent environmental regulations, the ISO 14000 Series. The objective of this regulation is to encourage an internationally common approach to environmental management and strengthening companies' ability to improve and measure environmental performance through audits.

On top of the increasing awareness of the general public for environmentally friendly businesses, is the growing cost of natural resources: wood, oil and natural gas. Strategies to compete under these conditions include using recyclable materials, returnable and reusable packaging and packaging materials, managing returns along the supply chain, designing smart

transportation, managing warehouse space and using environmental management systems along the supply chain. These procedures will lead to lower system costs, fewer duplicate activities, marketing advantage, less waste and great customer satisfaction (Wisner, Tan, and Leong 2014). However, regarding procurement and purchasing, a target conflict may occur between the most economical price and compliance with sustainability criteria. In case of doubt, the target with higher weight should be previously defined. In other words, the company should define until what value it is available to pay for sustainability, after computing the costs of both choices. In order to perform those calculations, it is necessary to identify suppliers with top ecological performances and with the required certifications. Other topics related to social sustainability, such as child labour or unsocial labour, disrespect for worker's rights, unsafe working environments, should be taken into account, so performance regarding these aspects should be monitored as well, especially in case of procurement from growing economy nations. Although the responsibility for sustainable damage is related to the supplier, the buyer can also suffer from the decision to supply from environmental non-compliance companies, since damage in reputation is expected (Kotula et al. 2014).

To cope with this kind of problems, a system can be set up in order to manage suppliers' environmental performance. This way, it can be formally monitored through an auditing process, that will identify when to and how to implement corrective actions to be taken. This auditing can be done internally, or outsourced by another company's service. Some examples of evaluation criteria were proposed by Beamon (1999), as it can be seen in Appendix C. It allows a commitment to continuous improvement in environmental management, and ensures the organization won't be exposed to falling to meet its legal and ethical obligations (Rushton, Croucher, and Baker 2014).

Packaging materials and transport suppliers are also regarded in these programmes, since improving the amount of packaging and the routing can both help the environment and reduce operating costs (Leon 2015), as explained in the following topic.

Packaging and transportation as part of a Sustainable Supply Chain

As mentioned above, packaging and the waste that it generates needs to be dealt with, when managing the supply chain. To help on this task, a life cycle assessment is a specific tool which is used to assess the environmental impacts of a product packaging, from design through production and use until disposal. It takes into account energy and water usage, emissions and its disposal pattern. Several articles mention this tool as a way to compare different options of packaging. Wooden packaging, for instance, requires less energy to produce and is less process intensive. On the other hand, plastic pallets require manufacture of plastic resins, thus creating environmental burden due to the extraction of crude oil. In conclusion, it was found that plastic pallets incur in larger carbon footprints as opposed to wooden pallets that are relatively greener (Philip 2010).

Another critical factor that determines the impact of a pallet throughout its life is the pallet life time: the total number of round trips a pallet makes before it is broken down or disposed of. Studies favour pooled pallets (the ones with possibility to be returned to the sending company, for reuse) against one way pallets. Studies also reclaim that one-way pallets have to be used several times in order to represent the same performance as pooled ones (Bengtsson and Logie 2015).

Regarding IBCs (intermediate bulk containers), reuse and recycling of the packaging is obviously favoured. Drums made out of steel are the best option in terms of material, due to high recycling rate worldwide. Unless recycling rates of plastic are high, which doesn't happen worldwide, since it is only recycled in order to produce energy, plastic should be avoided. Composite drums should be as less used as possible (Manuilova 2003).

Regarding criteria, in order to decide upon what is the best packaging to use, (Pirjo 2013) suggests the following:

- Using already existent packaging instead of buying or producing a new one.
- Look for an end-to-end solution, an alternative that can be used through as much steps of the supply chain as possible.
- Recyclable materials should be used.
- Materials with wider reuse potential should be used.
- Though corrugated board has high potential for recycling, it has low potential for reuse. Thus it should be avoided.
- Design packaging in order to have a minimum amount of material that ensures goods protection during carriage and storing. This minimizes material usage and consequently costs and environmental impact.

Regarding transportation, results show that trucking is preferred when time is the primary constraint. However, when cost, energy and emissions are regarded, ship freight are dominantly preferred on a cost basis, when compared to rail and trucking (Corbett et al. 2013). The environmental impact of air delivery is much higher than any other delivery mode. (Pirjo 2013)

2.3 Information Systems Management

The supply chain is composed of linkages of activities that affect the cost or effectiveness of others, resulting in a trade-off of performance among them, which should be optimized. These linkages require that activities are coordinated carefully, since they might bring competitive advantage. Information technology affects both activities and linkages, through information flows within and outside the company (Porter and Millar 1985) and "it has become the most important enabler of effective supply chain management" (Russell and Taylor-Iii 2008). Supplier relationship management (SRM) has gained increasing attention among companies.

SRM includes procurement, sourcing analytics (such as spend analysis), sourcing execution, payment, supplier evaluation and performance monitoring. Basically, SRM streamlines the processes and communication between buyers and suppliers, in order to manage it more efficiently and effectively. It provides vital insights into the supply base and purchasing history, automates processes, integrates information from multiple departments and software applications, gets hidden costs visible, allows collaboration, optimizes processes and decision making through enhanced analytical methods, with possibility of migration towards more dynamic tools in the future. With analytic SRM, an organization can assess how it was performing yesterday, where it stands today and up until where it can go in the future, in order to meet its strategical goals. Work collaboration is this way facilitated due to elimination of repeated tasks of data gathering and organizing. Its storage requires a previously defined structure, documented sources (or other already built databases) and original data (got on the work floor, for instance). Other advantages of having such a system consist on access to the same data from different people, the same structural models available, in the same environment or platform, and availability of quality and up-to-date information. Consequently, these points allow a closer monitoring of the processes involved, economic analysis (scenarios simulation running for cost-effects), solutions benchmarking and also a systematic measurement of its performance. Moreover, there is minimization of costs related to information and administration in purchaser/supplier relationships.

Though, the great challenge is gathering all the data: sourcing and purchasing require information from different already implemented systems, or even information that was never recorded before (Wisner, Tan, and Leong 2014). Moreover, difficulties found in the

implementation are due to the characteristics of pre-existing information technology systems and data protection issues (Gobetto 2014).

Trends in Optimization Algorithms for Sourcing Decision Support

Treating supplier selection as an optimization problem requires the formulation of an objective function, typically of cost minimization. This function, can take into account total inventory costs (quality, responsiveness, flexibility) or simply purchasing costs. However, qualitative consideration, abundant in supplier selection, should also be considered. In order to compute the objective function mentioned, Total Cost of Ownership (TCO) models are used. The TCO models include all the costs incurred in the supplier choice, throughout the purchased item's life cycle and are usually computed by a unit of good (De Boer, Labro, and Morlacchi 2001).

An Analytical Hierarchy Process (AHP) and linear programming is the often used solution to address both quantitative and qualitative criteria – supplier selection is a multi-criteria decision-making process, since criteria and suppliers' performance are usually conflicting. The advantage of the AHP is its ability to act as a feedback mechanism for the decision makers to review and revise their judgements – the output of the AHP is a relative importance weighting of criteria and sub-factors (Ho, Xu, and Dey 2010). Another common approach is the Multiattribute Utility Theory (MAUT), a mathematically decision-making method. Independently of the method chosen, it is important to determine the criteria used to measure suppliers performance, topic that is discussed under the theme "Sourcing Criteria" (Huang and Keskar 2007).

Regarding the allocation of quantities of goods from suppliers to plants, a transportation model can be adapted to establish the relations, while minimizing costs. Though this is not complex enough to model the whole current situation, the rational followed is useful to build an initial feasible solution for the problem. In the original model, a product is transported from a number of sources, to a number of destinations at the minimum possible cost. Each source is able to supply a fixed number of units of the product and each destination has a fixed demand for the product. The problem consists on determining how many tons of product to transport from each source, to each destination, while minimizing the total costs of transportation (or all the costs associated). Transportation model is usually solved with the help of a transportation table as shown in figure 4.

from \ to	*Chicago*	*St. Louis*	*Cincinnati*	**Supply**
Kansas City	6	8	10	150
Omaha	7	11	11	175
Des Moines	4	5	12	275
Demand	200	100	300	600

Figure 4 - The transportation table - (Gobetto 2014)

Transportation problems can be balanced (demand equals capacity) or unbalanced (more realistic scenarios). Unbalanced problems should be applied together with penalizations of the objective function. Restrictions should be applied to model, in order to prevent capacity from being surpassed, or a service level above 100%. Prohibited routes, i.e., transportation routes over which goods cannot be transported, should be assigned to higher costs, so that there aren't materials allocated to it (Russell and Taylor-Iii 2008).

2.4 Sourcing Strategy: Portfolio of Suppliers Approach

A larger set of options, more severe consequences of poor decisions, higher speed and transparency required, and a larger set of criteria have increased the complexity and importance of the purchasing approach (De Boer, Labro, and Morlacchi 2001). To minimize vulnerabilities and make the most of the potential buying power, collecting data, forecasting supply scenarios, identifying available purchasing options and developing individual supply strategies for critical items and materials, has to be part of the strategic approach.

First, purchased materials have to be classified in terms of profit impact (percentage of total purchase cost, impact on product quality or business growth) and supply risk (availability, number of suppliers, competitive demand, storage risks and substitution possibilities). They are sorted out into four categories, as shown in figure 5: leverage items, strategic items, non-critical items and bottleneck items. Each of them requires different purchasing approaches, as complex as the strategic implications, including analytic techniques, market analysis, risk analysis, computer simulation and optimization models.

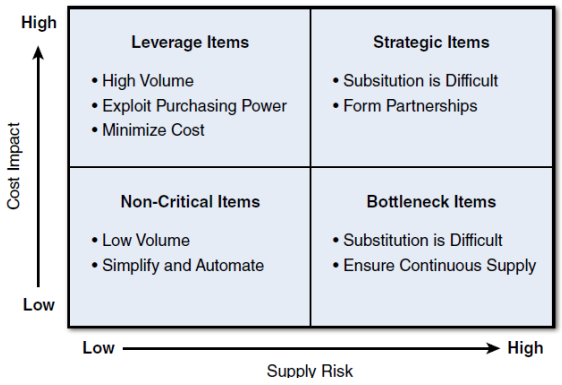


Figure 5 – Purchase portfolio matrix explained - (Gelderman and Van Weele 2003)

Secondly, the market for those materials is analysed, then overall strategic supply position is determined: the company weights its bargaining power against the power of the suppliers. For this analysis, topics such as supplier's capacity utilization (risk of supply disruption), annual volume purchased and expected growth in demand and potential cost in the event of non-delivery or inadequate quality (difficulty in rapidly changing supply), should be evaluated.

In the last phase, the company should explore different supply scenarios where different options of short-term and long-term supply, respective risks, costs and returns are analysed. For the preferred option, objectives, steps, responsibilities and contingency measures should be approved and implemented (Kraljic 1983). Finally, material strategies and action plans are implemented.

2.4.1 Risk Management in the supply chain – How many suppliers to use?

The number of elements that should constitute the portfolio of suppliers is a matter that varies from industry to industry. The high costs associated to supply have been driving companies to reduce the number of suppliers and to maintain closer relations and partnerships with the ones who perform best and with the ones who can do business globally. This way they can, for instance, implement EDIs, to reduce the cost of purchasing (Rushton, Croucher, and Baker 2014). However, companies might miss opportunities to improve competitiveness by underestimating the customer-supplier flexibility capabilities, and by focusing on a smaller number of collaborations.

The factors that contribute to a company's risk supply include vendor mix, contractual coverage, regional spread of supply sources and availability of materials. Unacceptable risks

should be eliminated by implementing strategic actions, to deal with events that might lead to an interruption of the flow of goods (Kraljic 1983). These events might include: unexpected rising demand, port closures, labour strikes, terrorism, natural disasters, supplier failure, quality and political uncertainty. A simple risk management program includes four steps: map and understand the supply chain, identify and manage the critical paths and infrastructure and improve supply chain visibility. Then, risks should be categorized from devastating to inconsequential. The higher the value at risk, the more attention should be given to this specific risk element (Leon 2015):

$$Supply\ Chain\ Value\ at\ risk = value\ lost\ if\ event\ occurred * probability\ of\ occuring$$

Summing up, this decision is a strategic one of major importance to the company and must represent a trade-off between flexibility, risk and partnerships (Martínez Sánchez and Pérez Pérez 2005). As a general rule, if commodity items, using more suppliers to promote competition to lower prices is appropriate. For more technical components, fewer suppliers is often the most viable option (Leon 2015). As discussed here and in the following chapters, purchasing function will continue to be viewed as a major strategic contributor to supply chain cost reduction, through better supplier evaluation techniques and decisions (Wisner, Tan, and Leong 2014).

2.4.2 Suppliers Performance Measurement – Operational approach

"You can't manage what you can't measure" (Kaplan and Norton 1996), is particularly true for buyer-supplier alliances. Measures related to quality, cost, delivery and flexibility have been used to evaluate how well suppliers are doing. They should be understandable, easy to measure and focused on real value-added results for both buyer and supplier. By evaluating suppliers, organizations identify suppliers with exceptional performance, improve supplier communication, reduce risk and manage the partnership based on an analysis of reported data (rewards can be implemented for top performance suppliers). By monitoring suppliers' operational performance, sourcing decisions can be made based on facts and not on perception of the suppliers' capabilities. The needed data should be collected from the different plants and also from central purchasing services, if existent. Wisner, Tan and Leong (2014) propose seven areas of operational performance measurement, as shown in Appendix D. Dickson (1996) is known as one of the most reviewed publications on sourcing criteria. His findings allowed to identify 23 top used criteria, mostly by manufacturing companies, ranked by popularity. Meanwhile, the study has been revised and ranking was changed in terms or order and new criteria. The current top 5 criteria are Quality, Delivery, Price, Repair Service and technical capability. New factors such as reliability and flexibility have entered the ranking. This ranking can be analysed into more detail on Appendix E.

Nevertheless, certain measures might be more important than others, depending on the industry and business. The weighted criteria evaluation system includes selecting the dimensions of performance, monitor and collect data, assign weights to each of the dimensions - based on their relative importance (sum of the weights = 1), evaluate each measure on a rating between zero (fails to meet) and 100 (exceptional meeting) and multiply the dimension ratings by their respective importance weights, to get an overall weighted score. In the end, suppliers should be classified accordingly to their overall scores. Audits should be implemented to perform a certification review (Wisner, Tan, and Leong 2014). On the level of multi-criteria purchasing performance measurement, it is difficult to aggregate monetary, quantitative and qualitative values up to a top ratio. A typical issue of multi-criteria performance measurement is the determination of optimum order volumes. The definition of criteria, even if coordinated among different departments, must be coherent with Top Management Purchasing Policies and strategic placement.

2.5 Competitors Benchmark

Benchmarking, the practice of analysing what other businesses do best, is an effective way to improve sourcing practices and supply chain performance (Wisner, Tan, and Leong 2014), while having a better understanding of its competitive environment and its customer's needs (Rushton, Croucher, and Baker 2014). Published information from 3 competitors (Michelin, Pirelli and GoodYear) was consulted, to collect benchmark information for this report, in order to position the competitiveness of Continental regrading sourcing.

Regarding the environmental assessment of sourcing, i.e., how the suppliers behave in terms of sustainability, when the Sustainability at Corporate Purchasing project was implemented at Continental, benchmark studies were conducted for the main competitors. It was understood that most were showing actions towards sustainability evaluation and participating, for instance, in the Dow Jones sustainability index.

Moreover, in the Michelin's annual report (Michelin 2016) is stated that in 2005, Michelin had defined an environmental performance indicator, called Michelin Environmental Footprint. It includes data about consumption of resources (water, energy and waste), emissions of CO2 and waste dumped into landfills. The company has also defined environmental targets, such as reduce CO2 emissions by 20% until 2030 and 50% until 2050; and invested 60 million euros for environmental performance improvement projects. 400 main suppliers were also evaluated regarding sustainability with the objective that 7% of them would improve their performances to reach the Michelin standard values. Social responsibility of the suppliers is also evaluated. Regarding sourcing management, Michelin segments sourcing risk regarding impact of product, turnover, business criticality, suppliers' dependence, length of the relationship with the supplier and its evaluation. Then, an assessment is performed, which might be supplemented by a documented audit. Moreover, Michelin has implemented a Total Cost of Ownership approach, which enables the company to include environmental, social and ethical requirements in the internal clients' specifications. The objectives of Michelin's purchasing include establishing an active and high-quality working relationship with suppliers, suited to Michelin's requirements and challenges. The main elements of the strategy, upon which their SRM works, are discussion, cooperation, transparency and responsibility on the market, now and in the future. The collaborative work with suppliers allows long-term effects by drawing adapted improvement plans.

Pirelli assesses the risk for business interruption, for the most important suppliers, in order to implement mitigation measures and reduce the vulnerability of the supply chain. One of them is the extension of the approved plants for each supplier and the approval of alternative suppliers. Also, the environmental impact of the suppliers is monitored, in order to request them to adopt the same standards as Pirelli (Pirelli 2016).

For Goodyear, Natural rubber, synthetic rubber and carbon black, materials linked to oil, are considered as a factor of uncertainty in the cost structure of the group, given their strong price volatility and their impact of the cost of finished good. Price scenarios are constantly simulated at Pirelli, in relation to the historical values, or best information available in the market. For that, purchasing of raw materials is centralized, in a global procurement department in order to leverage purchasing power (Goodyear 2016).

3 Diagnosis of the Current Situation

After reviewing literature related to inbound supply chain, sourcing and strategy, sustainability and information systems in the previous chapter, it is now important to apply the gathered concepts to the specific case of the tires division of Continental. In this chapter, an AS-IS analysis of the current sourcing process is performed, as well as a diagnosis of the main problems and opportunities for improvement that triggered this project.

3.1 General Overview of the Inbound Supply Chain at Continental

A wide range of raw materials (direct materials are the focus of this approach) and semi-finished products are used at Continental. Its purchasing volume goes to more than 15 billion € per year. Natural rubber and oil-based chemicals such as synthetic rubber and carbon black are the key raw materials for the Rubber Group. In Figure 6 other materials that take part of a tire and the respective percentages are explained.

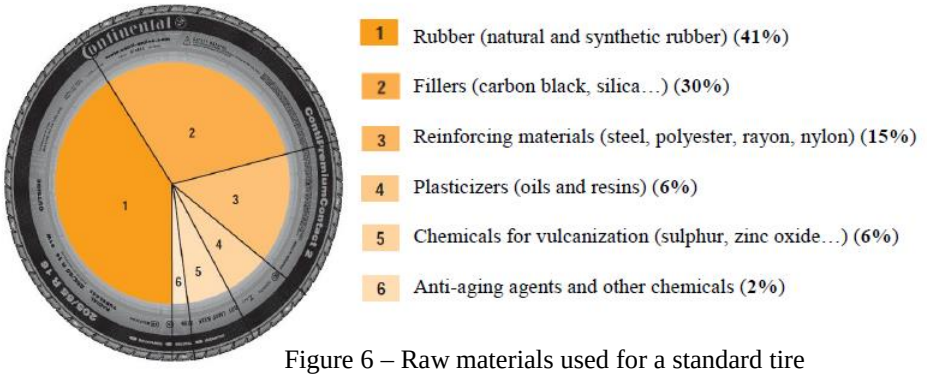
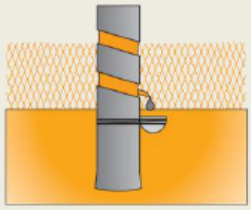


Figure 6 – Raw materials used for a standard tire

The raw materials presented in figure 6, belong to four different families. Each of them is further described, in figure 7:

Rubber extraction



Source: Continental AG

Natural rubber is found as a milky fluid (latex) in the bark of the rubber tree (*Hevea Brasiliensis*). The liquid latex is mixed with acids that cause the rubber to solidify. It is then cleaned with water and pressed to squeeze out excess water and form the rubber into sheets. The sheets are dried and pressed into solid bales of easier transportation and storage.

Chemical industry



Source: Continental AG

Supplies synthetic rubber, produced from the polymers found in crude oil, and materials which, when mixed with rubber and then heated, produce specific tire characteristics such as wear reduction and grip increase.

Textile industry  Source: Continental AG	Supplies base materials (rayon, nylon, polyester and aramid fibres) for the manufacture of cord which serves as a reinforcing material in tires.
Steel industry  Source: Continental AG	Supplies high-strength steel which serves as the starting material for the manufacture of steel belts (steel cord) and bead cores (steel wire).

Figure 7 – Families of raw materials

Accordingly to this classification, and together with producer and packaging indications, the following rules are applied to define material codes. They consist of a set of ten characters which identify each raw material. The first two characters indicate the family (Rubber, Chemicals, or Reinforcements). Adding two more characters, information on the sub-family is provided - a detailed list of the codes is shown in Appendix H. The last two characters indicate the packaging in which the raw material is stored, according to a table showed on Appendix F. The interpretation of a material code is demonstrated by means of an example in figure 8.

Material Code	Family	Sub-family	Packaging
CA12020110	Chemicals	Accelerators	Bag

Figure 8 – Information provided by material code

Some of the mentioned raw materials may integrate the production process of the tire in different stages. Appendix G explains the different phases of the process, as well as the different steps where materials are integrated. A granted continuous flow of material into production is a result of the coordination of activities of many departments: production planning, warehousing and purchasing, however, the focus of this work will be on the purchasing and sourcing activities.

Each Continental Tire plant is identified via a four digit code in SAP. The list of the plants' codes can be found also on Appendix F. However, suppliers' codes are defined in a more complex hierarchical system, as explained in Appendix P. The reason for this definition is motivated by the different necessities from purchasing, accounting and research and development departments, which all work with different entities of the suppliers. For the approach developed, the identification code for suppliers used, was simply the information provided by the ten-digit material code, for simplification purposes, and since the analysis is focused only on suppliers' location sites and not on vendor entities.

In the rubber group, most suppliers are established globally due to the specific nature of the business, so local sourcing is not always viable. The rubber group specifically, is supplied by 1800 suppliers of production materials, with the following share of purchasing volume: Europe 53%, Asia 20%, North/Central America 25,5% and other countries 1,5%. The sourcing decision and purchasing processes are following described.

3.1.1 Purchasing Process

The corporate purchasing of direct materials has a centralized department at the headquarters of the company in Hannover. Sourcing negotiations take place in an annual basis, as described in figure 9. Every year supplier relations are revised, evaluated

(accordingly to criteria explained in chapter 3.1.4) and new negotiations are performed. Other processes take place at this department, as explained in Appendix N.

Continental defines sourcing as "a number of procurement activities aimed at finding, evaluating and engaging suppliers of products". The main inputs for the sourcing process are the raw materials budget forecast (how much money the company is available to pay for), the raw materials quantities forecast (based on the previous years' estimations and market trends) and the raw materials group strategy (suppliers' location, number of suppliers, suppliers' requirements and capacity utilization of the supplier).

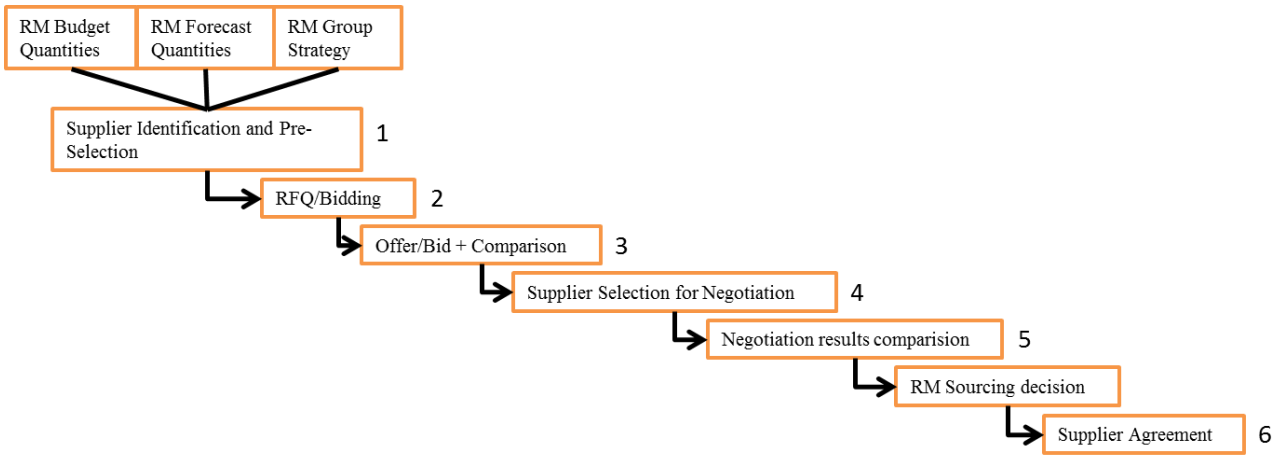


Figure 9 – Raw materials purchasing flowchart

The potential suppliers are identified by a market screening [1]. In this phase, previously established contacts and outsourced services to specialized companies (some belonging to Continental's group) are important to reach good potential sourcing options. A pre-selection of the suppliers will be completed once they are approved in terms of quality and requirements, as will be explained further [1].

Once the list of pre-selected suppliers is ready, each lead-buyer, usually responsible for a family of raw materials, is going to place an RFQ (request for quotation) to the suppliers [2], which means that the lead-buyer is going to ask for a price per a defined unit of raw material. Sometimes they can also propose an accepted price and answer to suppliers questions. After receiving the suppliers' quotes and conditions proposal, the purchasing team performs a CVC (Continental Value Crated) comparison [3]. This method will be further explained. A final selection of the supplier or portfolio of suppliers for negotiation and a pre-allocation to the plants are made [4]. Continental states that [5]: "The decision is to be based on full commercial as well as technical evaluation of Offers and Negotiation Results and under consideration and evaluation of quantitative and qualitative aspects, foreseeable risks and strategic considerations. The decision is to be done in favour of the supplier with the lowest total cost under compliance with the specification(s) and taking into consideration the defined strategy, capacities, technical and logistical constraints of the locations and other applicable requirements."

Before closing contract, negotiations are performed, not only in terms of raw materials price, but also in terms of transportation costs (via benchmark analysis as explained afterwards), delivery terms, packaging and allocation from producers to plants. Different options are compared. Finally, a raw materials sourcing decision is performed [6] and a supplier contract agreement is established and recorded into the SAP system, with all the data relevant to the sourcing. All the lead-buyers have, in the end, to report a standardized accounting file, called SDS (sourcing decision sheet), were they state the spends, discounts and CVC effect, for controlling purposes.

Approval of new suppliers, CVC comparison, transportation costs benchmarking and allocation from suppliers to plants will now be further explained.

To approve a new supplier, it has to undergo an approval process, starting with the supplier self-assessment. Then, there is a supplier site assessment, where the manufacturer site facilities are evaluated in terms of technology, supply capacity, quality and cost/finance. Only when the site is approved, can the supplier become an approved source of supply. Moreover, other prerequisites such as ISO 9001, ISO 14001 and agreement with Continental's Suppliers' Code of Conduct are required. Secondly, material needs also to be approved by the research and development department. A sample of the material is asked to the supplier and tested in a laboratory and in a trial production. The extent of the testing is decided by the Material Development department at Continental. The approval of the material and of the supplier may be limited to certain applications or to certain production sites of Continental, depending on the criticality of the material. The list of approved suppliers of a certain material is stored in specific files that indicate the status of the process.

CVC (Continental Value Created) is a calculation applied by the company in order to measure the economic value added by its operations. Value is created every time the return on investment (ROI or ROCE – return on capital employed) overcomes the cost of capital, usually set to a value of 10% (WACC – weighted average cost of capital). The CVC calculation is based on the rational presented on Appendix L. As it can be seen, raw materials' purchasing influences CVC in two ways: variable costs (EBIT) and current assets (operational assets). The operating assets, or working capital, are essential in order to ensure that the company can operate, cover upcoming operational expenses and satisfy short-term debt, and it has a direct impact on the value created – bigger the working capital, lower the value created. The working capital management has the target to minimize inventory (minimize the time period between start of production and sale of products, with the trade-off of losing operational flexibility or availability), minimize average receivables (minimize time period between sales and incoming payment, by pressuring customers) and maximize average payables (by maximizing the time period between purchase of products and outgoing payment), in order to maximize the value created (CVC). The CVC analysis is used in order to understand how much value create the different options of supply, in order to support the lead-buyers with financial decision support criteria.

Regarding the transportation costs benchmarking, usually price negotiations with suppliers occur by bidding on F-term prices. As explained in chapter 2, international trade requires the establishment of incoterms between the intermediaries, where insurance, risk, duties and transportation costs are whether of the responsibility of the buyer or of the vendor, depending on the term agreed upon. An F-term price, means that the company is negotiating based on F-term incoterms: Ex-Works, FCA (free carrier), FAS (free alongside ship) or FOB (free on board). Details about these different terms can be found on Appendix I. This way, the buyers are simply negotiating the original price of the raw material, composed of three summed values: material fee (the actual price of the material), feedstock (value based on market trends of commodities) and packaging price. All the other costs, transportation, duties and insurance will be determined accordingly to Continental's benchmarking values. These prices, if unknown, can be obtained by a dedicated department, which optimizes land and sea freights and routes (and also determines the necessary lead-times). This way, both sides benefit from the best market prices and, at the same time, Continental ensures that a supplier won't charge more for the raw material, due to avoidable transportation, duty or insurance expenses. Then, after an agreed price, expenses are assigned to buyer and vendor, accordingly to the incoterm defined on the contract. Usually, the incoterm used among transactions is D-term: DAT (Delivered At Terminal), DAP (Delivered At Place) or DDP (Delivered Duty Paid). Thus, risk is minimized, tracking and tracing is possible, there is an increased flexibility in shortage situations, optimized logistics costs are achieved and working capital

effect is positive, as it was explained before. Summing up, the extent of the negotiation takes place as explained in table 2.

Table 2 - Negotiation terms

<table>
<tr><td colspan="3">RM Price</td><td colspan="3">Freight Cost</td></tr>
<tr><td>Fee</td><td>Feedstock</td><td>Packaging</td><td>Duties</td><td>Insurance</td><td>Transport</td></tr>
<tr><td colspan="3">Negotiated with supplier.
Paid by Continental.</td><td colspan="3" rowspan="2">Minimum benchmark value obtained by Continental is applied.
Payment depending on incoterm.</td></tr>
<tr><td colspan="3">F-Term</td></tr>
<tr><td colspan="6">D-Term</td></tr>
</table>

The allocation of suppliers to plants, after negotiating values for the aggregated total demand (annual demand of the 19 plants) with suppliers, is done accordingly to transportation costs minimization, except for prohibited routes or specific cases where other constraints play an important role: high duty prices, quality requirements or a necessity to ensure both local and international suppliers for the same plant destination (due to long lead times and high risk of supply disruption). Detailed delivery plans, on shorter term-basis, are a result of a scheduling between central corporate purchasing and local purchasing, as further will be explained.

Local purchasing departments exist at a plant level, so, the purchasing structure of Continental is classified as hybrid. Here, buyers place POs (purchasing orders) according to SAP indications – they are responsible for the continuous replenishment. The system analyses the production planning, with a daily drill-down, and tells the buyer the exact day when the order has to be placed, by material and producer, by taking into account the total lead-time. At least one approved supplier should exist four months before the first required delivery date.

The target is that the demand forecasted by each plant, matches the orders placed on a monthly basis. However, in cases where the same material in a certain plant is supplied by more than one producer, time for order placement has to be managed manually in a separate file, due to system constraints and operational limitations (for instance, carbon black silos can't store material from different suppliers). Every time the plant requests more or less than forecasted, KPI penalizations are applied in every case. The plants don't intervene on what supplier to order from, they simply follow indications from central corporate purchasing, regarding which suppliers are approved to the plant and how many suppliers to source from.

However, some events might change this scenario. For instance, unexpected production changes or unaccepted lots due to quality problems, might require an extraordinary order. In this case, the buyer can contact directly the supplier and ask for anticipated delivery. In case this is not possible, due to capacity restrictions or too long lead-time, then a close enough plant (lead-time constraint) from the Continental group can send available stock. In the worst case scenario, the same supplier can source a similar material approved by R&D (Research and Development) or another supplier will have to be approved and be placed a PO (Purchasing Order). Sometimes, local purchasing can also identify opportunities for commercial changes and suggest the central purchasing the change of the contract: have stock on consignment, change supplier (quality or delivery problems) or ask the supplier to change the packaging due to poor quality, etc.

Continental has grown over the past 25 years mainly due to the acquisition of other companies. However, when those companies were merged, there was not a standardization of the spaces, machines, equipment and warehouses. Thus, each plant location has very particular operational constraints. This issue has a special effect on raw materials. The receiving of goods is affected by space availability, dimensions of the warehouses (height,

maximum weight load per square meter), handling equipment (for instance fork lifts) and distance to production site. Thus, packaging units and format play here an important role, as further will be explained in chapter 3.2. Secondly, mixing rooms, as explained on Appendix G, receive most of the raw materials (rubber and chemicals). Different plants have different layouts and mixing rooms' installations, and produce different types of tires. Hence, the way raw materials are introduced into the production process changes from plant to plant. Moreover, since the plants don't have the same production volumes of different products, stock turnover and average inventory time vary, even for the same material.

3.1.2 Risk assessment

Risk management is one of main topics of purchasing strategy, as explained in Appendix O, and it comes hand in hands with TCO (total cost of ownership) management, as will be further explained. Potential risks of supply chain disruption due to purchasing practises include: additional regulations that restrict or limit car traffic (causing significant decrease in car sales, which adversely affects Continental's products and services), production cutbacks due to changing climate conditions, bottlenecks in the availability of raw materials, extreme fluctuations in temperature and natural disasters. These events may result in production downtimes or interruptions in the supply, if not managed properly.

Regarding the bottlenecks in the availability of raw materials, Continental tries to spread sourcing risks by two means: spreading the purchasing of a specific raw material into different vendors, even if paying more for their services, – the wider the spreading, the more the spending, the less the risk – and by ensuring Continental is not the only buyer of a certain producer (to reduce the dependence of the producer from Continental – fair business practices). In some cases, when the supplier is located far away from the plant, with a lead time that can go up to 3 months, the lead-buyers usually assign a local and an international vendor to the plant, with different delivery percentages, in order to cover possible delays or urgent necessities.

Special attention should be paid to materials considered as critical for risk assessment. These are considered as so, due to monopoly supply, low number of alternative suppliers, application to critical products, high demand/offer market ratios, number of production sites of the supplier, unclear demand (or volatile demand). These factors can lead to production stopping, tight quality or legal requirements or significant cost increase. In order to avoid this kind of situations, Continental identifies new approval needs, implements contingency plans, supports shortage handling centrally (support to plants), monitors quarterly the status of these materials and the applied measures.

3.1.3 Suppliers Performance measurement

Prior and during supplier relationship, suppliers are also reviewed regarding delivery capability, technological, financial and general corporate issues. Satisfaction, quality requirements and supplier code of conduct are also assessed. For that, 40 audits per year are held at the supplier's production sites. A supplier relationship can be suspended in extreme cases of non-compliance with Continental working standards.

Continental has implemented a system of performance measurement of the suppliers. For each supplier, plants supplied by, and central purchasers dealing with, answer an annual questionnaire. Moreover, data automatically extracted from information systems is used for calculations and measurement. However, this assessment is only applied to 300 suppliers annually, strategically chosen by the lead-buyers. Critical suppliers, usually related to critical materials (with higher expenses, volumes or quality levers), are among the most common choices, together with suppliers that might be undergoing severe complaints from plants. The evaluation is performed by CVM (Conti Vendor Master), which means, by vendor company,

which makes it impossible to understand how different producer's locations sites are performing.

Comparing both operational performance measurements, the one suggested by (Wisner, Tan, and Leong 2014) – appendix D – and the one applied by Continental - the main differences are the following:

- From quality perspective, Continental is not evaluating continuous process improvement and warranty. In terms of business metrics, Continental is not measuring total cash flow and rate of return on investment of the suppliers. **Regarding total cost of ownership, cost of special handling, cost of defects, rework and problem solving associated with purchases is not being measured;**
- Continental is, however, adding innovative measures: supplier strategy (regional and global availability, long term business plan, organization of strategic areas), stabilized organization, risk management (danger of force majeur, ownership stability, market structure), samples (availability, quality, traceability, technical capabilities for in-house testing), system support (EDI ratio, self-invoicing ratio, RFQ electronic participation), cooperation (ability to track goods in transit, acceptance of small volume deliveries, capability of handling global supply chains, order confirmation rate), quality (quality score of deliveries, severe complaints), payment terms agreement, delivery terms agreement, stock reduction initiatives and cost improvement programs;
- Environmental issues will be further discussed in chapter 3.3.

Although SPM analysis is implemented at Continental tires, it is not a sourcing decision criteria. Integration of the SPM evaluation in the purchasing process is suggested in chapter 4.1.3.

3.1.4 Opportunities for Improvement in the Inbound Supply Chain Management

Even though the project started by the necessity to evaluate the operational impact of the use of different kinds of packaging, soon it was understood that it was impossible to perform this task, without evaluating the sourcing decision itself - packaging is, by now, totally dependent on the suppliers' choice. By working closely with lead-buyers, who perform the sourcing decisions, it was possible to understand that one of the main needs was the implementation of an SRM information system. Repeated tasks of data gathering, undefined data storage structure and consequent lack of control over information growth, insufficient operational and packaging data – of poor quality and not up to date –, non-standardized strategic approach to purchasing scenario analysis and losses due to operational incompatibilities among plants were the main opportunities for improvement found.

It was identified that each lead-buyer would extract the needed data from different systems or directly from suppliers, and store it in their own excel files . Information about previous sourcing decisions also wasn't structured, the only common document used by all the lead-buyers was the Sourcing Decision Sheet, where financial results of the contracts were sent to the controlling department. Hence, business is dependent on the expertise of lead-buyers, a skill which is hard and time-consuming to transmit inside the company. As referred on chapter 2, the main advantages of a SRM match the current needs of the corporate purchasing department. On top of that, closer and systematic monitoring of the process performance (by integrating the already existent SPM system into decision making) and an economic analysis (cost-effects scenarios) can be implemented.

Moreover, regarding the financial impact of the sourcing decision, CVC calculation was only performed after a pre-selection of suppliers. Due to the complexity of the non-automated task, it was too much time consuming to perform this analysis before a pre-selection. Consequently, good financial options could be discarded. By automating the CVC

calculation into the sourcing system, value contribution of any option could be easily integrated into the first pre-selection of suppliers.

Regarding materials phase in and phase out processes, the main problem identified in the process is the sourcing capacity not aligned with real demand after phase in process has started and lack of local supply to cover urgent unexpected necessities from plants. Also, systems lack integration into raw materials direct purchasing information, set-up of SAP contracts takes longer that needed and information is sometimes incomplete. Hence, the new approach suggested gives an important contribution to the communication processes between research and development, corporate and local purchasing, which is a big step further into solving the problems mentioned.

Regarding the risk assessment, not all the raw materials purchases were complying with a risk mitigation strategy, due to the major necessity of costs reduction. However, it is important to analyse what will be the spending trade-off between mitigating risk (i.e. sourcing from different suppliers, even if more expensive ones) and incurring into probable recovering expenses of supply chain disruption (sales losses, setup costs, losses due to delay, etc.). This kind of scenario analysis is going to be explored in section 4.3.3.

Another important aspect to improve, is the lack of bargaining power against monopoly or close-monopoly suppliers. As explained by local purchasing, some very specific materials can only be sourced by one supplier worldwide, turning the offer/demand ratio unfavourable for Continental. In this case, negotiating prices and operational aspects (consignment, packaging, payment terms) is a hard task. By having a sourcing decision support tool, buyers can have more information in hand, in order to have a more accurate basis for the negotiation step of purchasing. Also, when a new material is used into production, there is a need for assessing acceptable prices for sourcing, which can be estimated or benchmarked by the use of the sourcing optimization system. Summing up it needs to be flexible enough in order to integrate different phases of the purchasing process.

Finally, the complication of the purchasing process that originated this project was the difficulty to assess the operational and financial costs impact of different choices of suppliers. By developing a database and a SRM, it is possible to simulate cost scenarios and evaluate operational spends, which were before assigned to warehouse and production cost centres: feedstocks fluctuations, packaging changes, different payment terms or incoterms, different levels of risk spreading, etc. Moreover, the contribution in percentage of these costs to the TCO (total cost of ownership) can be evaluated. In chapter 4, the solution proposed to optimize the decision making regarding sourcing will be further explained, which will bring a new approach by including new operational factors into the TCO analysis (instead of only financial), as suggested by literature.

3.2 Packaging Situation

Although the suppliers decide on which type of packaging to use, the choice depends, first of all, on the raw material properties (physical, chemical, size of the lot). However, different kinds of packaging can be used for the same material - a summary of the types used at Continental Raw Material Warehouses can be found on Appendix J. Moreover, each plant's warehouses have different constraints regarding space, maximum weight load, distance from production, buffers and handling equipment. So, packaging area, dimensions, stack ability and maximum load play here an important role.

Continental Supplier's Requirements Manual defines some rules for packaging:

- "Full metal boxes or crates have to be used for shipment of natural rubber and synthetic rubber and the devices have to be light weight, easy to handle, stackable and

foldable. Exceptions have to be approved by Continental prior to shipment or in supply contract.";

- "Metal or plastic pallets should be used for chemicals and fillers.";
- "Wooden pallets are not preferred but accepted. Wooden pallets have to be covered by a plastic or cardboard sheet before loading.";
- For reinforcements (steel cord, bead wire and textiles) requirements are described in specific documents (provided to the supplier upon request);
- "Metal or plastic pallets have to be used. Packaging has to be clean before usage.";
- "Packaging material and devices with damages (strong deformation, holes, splinters etc.) which could damage or contaminate the material must not be used for packaging/transportation.";
- "Material or plant specific individual packaging requirements have to be agreed between the respective plant and the supplier on case to case basis.".

The requirements defined allow, however, exceptions and regard special agreements between plants and suppliers. For instance, though wood is forbidden in the production area, due to quality issues, the suppliers are not prohibited from sending raw materials in wood pallets. Instead, conversion of the pallets is done at the arrival to the warehouse, representing an added cost of equipment and employees.

For the specific case of carbon black and silica, silos are used for storage instead of warehouse packaging (except for safety stock and, for some plants, they are stored in the warehouse in big bags). Each plant can have one or more silos for different kinds of carbon black, and materials coming from different suppliers can't be mixed in the same silo. The loading of the silos is done by a truck, coming to the plant as regularly, as the consumption of the material. However, silo trucks with carbon black, if not available from a close point of origin, can become too expensive (for instance, normal truck from supplier A to Lousado 80€, silo truck 190€). In order to cope with this problem, some plants receive carbon black in big bags, transported in a common truck, which is afterwards transferred into silos. Silo handling and warehouse handling have different costs and don't require the same people and equipment. A further analysis of this topic will be performed in chapter 4.

Packaging costs are usually part of the price offer made by the supplier. However, in some cases Continental leases the packaging to companies such as GPS or Goodpack. These companies are responsible for sending the metal crates to the supplier and then of picking them up at the plants, when they are empty and ready for reuse at another location. In these cases, payment may not be included in the raw material price and can vary, accordingly to the utilization conditions defined by the contract, established with the packaging company. The advantage of having such service is the uniformity of packaging in the warehouse, their easiness in production and other physical characteristics such as stack ability and weight load capacity. Another special case, are the returnable pallets. In some cases, wooden or plastic pallets, spools and creels have to be returned to the supplier. This represents an extra cost, since transportation has to be provided. However, it is a more environmental friendly option, as will be discussed in chapter 3.3.

Opportunities for Improvement regarding Packaging

Since no specific requirements are defined for each family of materials regarding packaging, except for reinforcements, this is the first opportunity for improvement found. The storage space and handling procedures of raw materials constraint the type of packaging that each plant is able to use. As an example, rubber, one of the main raw materials for tire production, is sent to the plants from different suppliers in different kinds of packaging with different sizes. Not all the plants, for technical or dimensional reasons could process all these variants. At the same time, no cost assessment is performed and, consequently, no proper analysis of the impact of choosing different kinds of packaging for rubber was taken into

account. Moreover, warehousing space optimization is directly affected by the space occupied by the packaging, its stack ability and weight load. If these factors are taken into account and privileged during sourcing decisions, suppliers' choice can contribute to this topic. Also, wood conversion and carbon black transfer from big bags to silos represent an extra cost (defined as conversion cost) that is not being taken into account when choosing a supplier. For instance, there is a need to compare between the option of sending big bags and silo trucks of carbon black, by comparing handling costs of both options, something that can be performed with the approach suggested.

Dealing with packaging implies dealing with suppliers, since when those are chosen, extra operational costs due to packaging reception and processing are incurred. In the end, these costs are hidden in the warehousing cost centres of each plant, which can significantly rise every time there is some kind of incompatibility or change of supplier/packaging. Having this kind of data in hand, it is possible to negotiate with the supplier what is the preferable packaging to use, that complies with the pre-defined requirements, or, in some cases, it might even be possible that the operational costs of some packaging won't compensate the lower values of raw materials, changing the sourcing decision. It is this kind of analysis that will be done in chapter 4.

3.3 Sustainability Management at Continental

Sustainable management and corporate social responsibility are among Continental's fundamental values. Climate change and shortage of raw materials turn into opportunities to the company and result in product innovations, seen as competitive advantage. Continental expects its suppliers to demonstrate their social, environmental responsibility and commitment, to quality consistent with the principles of Continental.

For the suppliers that Continental already has contracts with, the company regularly assesses the level of certification according to ISO 14001. This information is incorporated on the internal assessment system, described in chapter 3.1.4. 73% of the suppliers in the Rubber Group had an environmental management certified according to ISO 14001. Projects have been implemented with the objective to improve their environmental performance: training, consultation, knowledge transfer of the best practices and preparation and support for the ISO 14001 certification. Regarding new suppliers, Continental evaluates its environmental performance prior to the placement of order, by applying a questionnaire. This questionnaire includes: energy consumption, packaging, workplace hygiene, safety data, environmental certification and contingency management. In the procurement area, Continental has defined the goal that 100% of the strategic suppliers, by 2020, would meet the requirements of ISO14001, in cooperation with the Purchasing and Supplier Development departments.

Regarding the social aspect of sustainability, in 2015, 65% of all production materials were procured from companies with headquarters in states belonging to the OECD (Organization for Economic Cooperation and Development). It is expected that problems respected to human rights and bad work practices won't occur. All the suppliers and service providers are required to compromise with the Supplier Code of Conduct, which regards ten points related to: compliance; law and legal regulations; respect for human rights; antitrust and competition law compliance; anti-corruption; safety, health and environment; data protection, confidential information and intellectual property; export and import regulations; violations of the supplier code.

Continental itself is submitted to environmental audits and standards by KPMG (consulting company), where direct and indirect energy consumption, CO2 and other sources of greenhouse gases emissions, water consumption and waste generation are measured. Inbound logistics represents 7,8% of the total CO2 emissions and materials represent the major part, with a percentage of 82,3% of the total CO2 emissions.

Opportunities for improvement in Sustainability Management in the Inbound Supply Chain

Though waste generation, inbound logistics (transports) and materials environmental impact are measured, there is no assessment of this impact regarding suppliers sourcing. However, there is an increasingly demand for transparency and details about the supply chain sustainability by stakeholders: labour practices and human rights violations/avoiding actions, environmental issues, stopped or at risk commercial relationships due to the factors mentioned, etc. To cope with this problem, Continental Tires has recently integrated a new project which aims to evaluate suppliers' performance regarding sustainability. The service is outsourced to a company which performs audits to the suppliers: EcoVadis. Some of the main competitors are already requesting the services of the company, so data resources access is facilitated (some companies share suppliers). The company audits the suppliers by applying a questionnaire, regarding the 21 criteria described on Appendix M. Comparing these criteria with the ones defined by Beamon (1999), EcoVadis introduces an innovative approach to the social and ethical sustainability categories. This represents an advantage for Continental since a significant part of the suppliers of the company are located in developing nations were respect by fair work practises has to be closely monitored. Regarding the environmental criteria, EcoVadis complies with what is suggested by Beamon (1999). The output of the EcoVadis assessment are 6 percentages, indicating the performance of the supplier divided by different areas: commercial and finance, quality, supply, technology, company and overall. A first phase of the project has already been implemented, and carbon black suppliers are already assessed. However, rubber suppliers aren't yet in this process and will be integrated in a following phase. The ultimate milestone of the project is that this evaluation can be integrated with the SPM data, all suppliers are evaluated at production location level, average scores are all above 60% and that this evaluation is part of the supplier strategy and selection process.

When choosing different kinds of packaging, which represent a significant flow of materials in and out Continental, also no environmental assessment is performed. So, there is a necessity to understand, what the role of packaging in sustainability issues is. The supplier requirements manual already defines some indications regarding packaging: "Packaging materials have to be reusable or recyclable. Packaging materials have to be without CFC's (chlorofluorocarbon), chlorine-free, chemically inactive, groundwater neutral and nontoxic when incinerated." Since data regarding waste generation and conversion of environmental impact into a cost was not feasible, this information was not possible to integrate into the optimization process. The solution found for this problem was an environmental ranking for packaging will be further will be explained in chapter 4.

Regarding the inbound logistics environmental impact, information regarding CO2 emissions, of each of the routes used for raw materials transportation, is available (the companies responsible for the transportation have to report their CO2 emissions and other environmental data). However, this data is not being stored or analysed. The information could be integrated together with transports costs information and displayed when selecting the delivery routes, bringing an advantage regarding sustainable practices.

By integrating sustainability data into procurement software analysis, as a qualitative factor, there is an opportunity for decision making influence. For instance, even if a supplier quotes a very cheap offer, but it has a poor sustainability classification, lead-buyers can analyse "how much they want to pay" (how much they will spend by purchasing from a more expensive supplier) for a better environmental option.

4 Solution Proposed

In the previous chapter, opportunities for improvement regarding inbound supply chain management, packaging and sustainability were diagnosed. The solution here proposed aims to cover the needs and gaps identified in the sourcing management, by suggesting an optimization approach. The implementation process went through three phases. Firstly, a database was developed - in order to do so, main variables related to suppliers, plants, packaging and materials were defined, as well as the relationships among them. Secondly, the problem was modelled into mathematical expressions for the sourcing optimization. Finally, a business case was applied and different cost scenarios were evaluated. The three steps will be explained in the following topics. The phases didn't take place in a chronological order, since the input information for the database is complex and was gathered all along the project. The business case application was done when all the information for simulation was available. The materials chosen for the business case were three kinds of synthetic rubber and one kind of carbon black. The innovative point further explained is the integration of operational costs and sustainability into sourcing strategic decisions.

4.1 Database development

The main variables and relationships included in the database are explained in Appendix R. The definition of the required fields and main keys was performed by taking into consideration user requirements. Some of the fields, marked with a grey shadow, are automatically calculated according to the formulas further explained, while the other fields need manual input or connection to other information systems, to be extracted. All the needed variables for the calculation are included in the database. In order to gather the needed input information, many methods were applied: extraction from existing systems (SAP, GUTS - Growing Up Thinking Scientifically, software system), direct contact with lead-buyers and other experts, physical measures at the warehouse, visual inspection of packaging documents and controlling reports. This information will be further detailed whenever necessary.

4.1.1 User Requirements

Regarding the initial necessities of improvement and the first direct contact with key users (lead-buyers), user requirements were defined. By a matter of comprehension, each of them is going to be identified by a capital letter, in order to be related to the formulas mentioned in the following topic.

The first requirement [A] agreed upon was the necessity to consult data about packaging, as well as its specifications. Secondly, it was also relevant to gather information regarding inbound supply chain logistics [B] (transportation, lead-times, incoterms, payment terms, consignment and feedstocks), in order to simulate different scenarios and respective cost-effects for all of them. All the data stored should be possible to update and in case of new materials or suppliers, it should also be possible to insert new entries [C]. Moreover, scenarios for different operational concepts, to implement in the inbound supply chain, should be able to be tested [D]: transport carbon black in silo trucks or big bags; use wood pallets and

perform wood conversion, versus other type of packaging with higher cost; among others. The ultimate requirement [E] agreed upon, was to use all the information gathered and stored, in order to apply an optimization algorithm, for allocation of raw materials, from suppliers to plants. The allocations should be stored with detailed information about costs and date [F], in order to be possible to analyse the choices made in the past. Evaluating the sustainability impact of the different options of suppliers was also one of the agreed requirements, together with the integration of the SPM and Ecovadis rating [G] in the process.

4.1.2 Formulas Specification

In order to calculate the necessary costs for optimization with a mathematical model, as will be explained in the next topic, formulas had to be defined. All the fields shadowed in grey, in Appendix R, result of formulas calculation.

In order to perform operational comparisons between transporting carbon black in silo trucks and big bags - requirement [D], the mathematical model will take into account the handling costs of the different options analysed. In order to perform that, silo handling and warehouse handling costs had to be computed. The mathematical expressions applied to calculate silo handling are described by the formulas (4.1) and (4.2). The results of these calculations were compared to the handling cost of the raw materials warehouses in those plants.

$$Silo\ Handling\ (€/silo/year) = \frac{Average\ Unitary\ Silo\ Cost}{Silo\ Lifetime\ (years)} \tag{4.1}$$

$$Silo\ Handling\ \left(\frac{€}{TON}\right) = \frac{Silo\ Handling(€/silo/year) * Silo\ Number}{Annual\ Demand} \tag{4.2}$$

In order to test different packaging options for the suppliers (requirement D), the following concepts had to be defined: area occupied by the packaging at the warehouse – formula (4.3) and maximum stack ability - formulas (4.4), (4.5), (4.6) and (4.7).

$$Area\ (m^2) = Width * Length \tag{4.3}$$

$$Max.Weight\ p.SQM(ton/unit/m^2) = Max.Weight/Area \tag{4.4}$$

$$Max.Stackability\ Weight\ Plant\ (units) = \frac{Max.Weight\ Plant}{Max.Weight\ p.SQM} \tag{4.5}$$

$$Max.Stackability\ Height\ Plant\ (units) = \frac{Height\ Plant}{Height\ Packaging} \tag{4.6}$$

$$Max.\ Stackability\ (units) = Min[\ Individual\ Max.Stackability; Max.Stackability\ Height\ Plant; Max.Stackability\ Weight\ Plant] \tag{4.7}$$

Please note that the individual maximum stack ability represents the technical limitation (depending on the type of packaging), that defines the maximum number of units of packaging that can be stacked.

In order to calculate inbound supply chain ecological impact, as mentioned in the requirement [G], the following rational was applied – formulas (4.8), (4.9), (4.10) and (4.11).

$$Ecological\ Impact\ (€/km) = ton\ CO2/km * €/tonCO2 \tag{4.8}$$

$$Units/Load = \frac{20TON}{Max.Weight} \tag{4.9}$$

$$Returning\ Coefficient = \frac{Units/Load}{Units\ Returned} \tag{4.10}$$

$$EcoImpact\ Transport(€/TON) = Distance * EcoImpact\frac{€}{km} * (1 + Returning\ Coefficient) \quad (4.11)$$

The conversion of the ecological impact of transportation into a monetary value, is going to be combined with SPM, EcoVadis and packaging rating, in order to complement the optimized allocation decision with qualitative criteria, as further will be explained – requirement [G]. It is not going to integrate the sourcing optimization. This decision was taken, since it was agreed with the inbound supply chain department, that this was not a direct cost which should influence the result. Moreover, the materials analysed in chapter 4 are all delivered via sea freight, whose ecological impact cannot be calculated as described above. Further details will be given regarding this in the following topic.

4.1.3 Other remarks about data gathering

In order to meet requirement [A], physical characteristics of the packaging were obtained by visual inspection and measurement, as well as contact with managers at Lousado's raw materials warehouse. Standardized measures were used in the circumstances where this could not be applied. In some cases, such as individual stack ability, information was provided whether by the supplier or by the company leasing the packaging, via official documentation. In order to calculate the units loaded by truck, it was assumed an average net truck weight of twenty tons. By comparing the tables named "Packaging" and "Material_Packaging" in Appendix R, with the original table about packaging shown in Appendix F, it is clear to see that the information stored before the implementation of this approach was insufficient.

Information about plants and raw materials warehouses (such as number of silos, silos' capacity, cost and lifetime, maximum height, maximum weight) had already been gathered for the development of other raw-materials' related projects and was also used as an input in this case. Exceptions such as square meter cost, warehouse handling price, wood conversion and decanting were obtained via direct contact with warehouse managers. When data was not available, once again, Lousado's plant was used as benchmark value.

Regarding sustainability information, EcoVadis assessment, the data related to these evaluations was only available, until the moment of the report, for carbon black materials, and it was provided by a sustainability manager. Packaging ecological performance ranking information is obtained by the classification further described on chapter 4.4. SPM information was extracted from business warehouse systems, with the help of the SPM coordinator. Regarding inbound logistics environmental impact, sea freight CO2 emissions are mainly dependent on speed. On the other hand, speed used for transportation is not always the same, due to price variations and urgency on the transportation. Hence, it was agreed that from now on, CO2 emissions information provided by the logistics operators could also be stored in this database, in order to perform a 360º degrees evaluation of the sustainability performance. For the other kinds of sea freight, the formulas described in the previous topic are applied.

These sustainability indicators, will be displayed after the allocation is optimized, in order to provide an insight of qualitative indicators of the supplier's performance – requirement [G]. This means that qualitative criteria won't influence the optimization (technically, they won't be part of the objective function to be minimized, as explained in the following topic), rather they are going to complement it.

In order to comply with the requirement of updating information and register new entries, a user interface was created with a connection to the database. This way, the user can run simulations (by varying conditions of the inbound logistics, for instance – requirement

[B]), extract reports of the simulations, create new entries (new materials, packaging, suppliers, plants, etc.) and access all the data stored – requirements [C] and [F]. For example, the user can search for reports of the choices made in the past and understand under what conditions they were taken.

4.2 Mathematical Model for Costs Optimization

A mathematical model for sourcing optimization will be proposed in this topic, which, in the end, gives an output of the best allocation of suppliers to plants for a certain material – requirement [E], together with qualitative performance and sustainability indicators of the supplier chosen. Linear programming was the most suitable approach found in this case. Qualitative factors are integrated into the sourcing decision and, at the same time, only cost-related data is considered for scenario analysis.

The mathematical model for optimization is based on the application of an algorithm developed in VBA. The rational used to construct an initial solution is similar to the Transportation Model referred in chapter 2. There is a set of plants, each of them with an assigned demand (for the specific material to be analysed). The total demand of all the plants computes the aggregated demand. These values can be extracted from Business Data Warehouse systems. On the other hand, each supplier has a defined capacity. However, it is known that suppliers might produce more than one product at the same time. So, it is very important to store the exact capacity of the supplier for that material - it is this value that is going to determine the maximum volume that the supplier will supply. By comparing demand and capacity, it is possible to determine whether the problem is going to be balanced, which means there is enough capacity to fulfil all the demand, or unbalanced, which means that some of the demand won't be delivered to the plants.

The definition of the main variables and constraints for the optimization algorithm implemented was applied as follows. The hard constraints are all the restrictions that define the feasibility of the initial solution found. The adaptation of the transportation model to optimize allocation, as following will be explained, will only work with these constraints.

Indices	Description	Parameters	Description
p	plant (p = 1, …, P)	d_p	demand from plant p
s	supplier (s = 1, …, S)	c_s	capacity of supplier s

Variables	Description
q_{sp}	quantity produced at supplier s to plant p

The assigned deliveries cannot overcome suppliers' capacity, as ensured by constraint (4.12):

$$\sum_{p=1}^{p} q_{sp} \leq c_s \; \forall \; s \in \; S \tag{4.12}$$

Constraint (4.13) forces the demand to be fulfilled, unless total capacity is insufficient.

$$d_p \leq \sum_{s=1}^{s} q_{sp} \forall \; p \in \; P \tag{4.13}$$

The main difference, to the transportation model, is that instead of considering only transportation costs for the allocation, a set of other costs is also taken into account, as is described on Appendix S. The sum of the financial, operational and holding costs, computes the Total Cost value – formula (4.14), which the algorithm is going to optimize, in order to perform the allocation.

$$Total\ Cost\ (€/TON) = Delivered\ Price + Operational\ Costs + Holding\ Costs \quad (4.14)$$

Operational costs – formula (4.18) - include: space occupied in the raw materials warehouse – formula (4.15); handling costs of raw materials (silo handling or warehouse handling depending on the way they are stored) – formula (4.16); conversion costs (wood conversion of the pallets - wood is not allowed in production, hence they have to be converted - or if carbon black is transported in big bags, they have to be decanted into silos) – formula (4.17).

$$\begin{aligned} Space\ Costs(€/TON) \\ = €/sqm/month * PackagingWeight * Area \\ * Average\ Inventory\ Time\ (months) * \left(\frac{1}{MaxStackability}\right) \end{aligned} \quad (4.15)$$

$$Handling\ Costs\ (€/TON) = Warehouse\ Handling + \ Silo\ Handling \quad (4.16)$$

In order to obtain the warehouse handling prices, raw materials warehouse managers from five plants were contacted: Lousado (benchmark value for the other values), Sumter (E.U.A.), Puchov (Slovakia), San Luis Potosi (Mexico) and Aachen (Germany). Specific elements for handling cost evaluation were defined: salaries, overtime salaries, maintenance, equipment (renting and depreciation), supplies (plastics, paper and any other needed material) and cleaning. Rent was excluded from the analysis. In order to obtain a handling cost per TON, consumption from the respective warehouses was extracted form SAP, and warehouse handling costs were divided by it.

$$Conversion\ Costs\ (€/TON) = WOOD\ Conversion + Decanting \quad (4.17)$$

$$Operational\ Costs\ (€/TON) = Space\ Costs + Handling + Conversion \quad (4.18)$$

Financial costs – formula (4.19) include: material fee, feedstock value, transportation costs, packaging costs and duties. The sum of these values constitutes the delivered price. Material fee is negotiated with the supplier, feedstocks vary due to market trends, transportation costs are determined by the benchmarking method explained in chapter 3.1.1, duties are defined by WTO and packaging varies depending on the existence of a leasing contract.

$$\begin{aligned} Delivered\ Price\ (€/TON) \\ = Fee + FeedStock + Transportation + Duties + Packaging \end{aligned} \quad (4.19)$$

On top of that, holding costs are also calculated via an adaptation of the CVC analysis. The point is that the different payment terms, incoterms and consignment options can be evaluated, by comparing the advantage of having the material before payment with having the equivalent money invested with a return of 10% (WACC=10%). The conditions of the payment terms, are summarized by controlling in a table that indicates, for each of the payment terms' codes, how many days to consider. The rational applied for these calculations is described in the following formulas – formula (4.20) to (4.28). GIT stands for Goods In Transit.

$$GIT\ (TON) = \frac{Consumption}{360} * LeadTime \quad (4.20)$$

$$Average\ Inventory\ Stock\ (TON) = \frac{Annual\ Demand}{12} * Average\ Inventory\ Time\ (months) \quad (4.21)$$

$$Stock\ (TON) = \frac{Consumption}{320} * Average\ Inventory\ Time\ (days) \quad (4.22)$$

$$Annual\ Purchasing\ Volume\ (€) = Consumption * Delivered\ Price \quad (4.23)$$

$$Average\ Payables(€) = AnnualPurchasing\ Volume * \frac{DaysPaymentTerm}{360} \quad (4.24)$$

$$Average\ Inventory(€) = (Stock + GIT) * Delivered\ Price \quad (4.25)$$

$$Net\ Working\ Capital(€) = Average\ Inventory - Average\ Payables \quad (4.26)$$

$$Net\ Working\ Capital\ per\ TON\ (€/TON) = \frac{Net\ Working\ Capital}{Consumption} \quad (4.27)$$

$$Holding\ Costs(€/TON) = Net\ Working\ Capital\ per\ TON * WACC \quad (4.28)$$

The calculation of the holding is an adaptation of the CVC analysis explained in chapter 3.1.1. It was performed since CVC calculations, as they were done originally, didn't match the cost-effect per ton that this approach aims to standardize. Moreover, always a reference value for sourcing had to be used, which in this case is not the approach followed.

Finally, the total cost of assigning a supplier of a certain material to a plant, is computed as stated in formula (4.14).

The solution representation of the problem is a dual entry matrix, were suppliers' packaging combinations are stated in columns, while plants are displayed in lines. Each cell has an associated Total Cost (grey cells), as previously described. An example is shown on table 3.

Table 3 – Solution representation of the problem

	Supplier 1 + Packaging 1		Suplier 1 + Packaging 2		Supplier 2 + Packaging 1		Supplier 3 + Packaging 1		Demand
Plant A		50		45		20		30	3000
Plant B		30		25		50		20	2000
Plant C		20		15		30		50	2500
Capacity	1000				5000		3000		

The algorithm implemented is going to start by choosing the cheapest total cost (in this case, cell C1.2), and allocate quantity until: not enough capacity available, OR, plant demand satisfied. When a quantity is assigned, both demand and capacity should be discounted. Table 4 describes the expected result.

Table 4 – Step 2 of the allocation rational

	Supplier 1 + Packaging 1		Supplier 1 + Packaging 2		Supplier 2 + Packaging 1		Supplier 3 + Packaging 1		Demand
Plant A		50		45		20		30	3000
Plant B		30		25		50		20	2000
Plant C		20	1000	15		30		50	~~2500~~ 1500
Capacity	~~1000~~ 0				5000		3000		

In this case, total demand (7500 tons) is inferior to total capacity (9000), so delivery problems won't occur. In the end, following the described rational, the final output should be as described in table 5.

Table 5 – Final result of the allocation

	Supplier 1 + Packaging 1		Supplier 1 + Packaging 2		Supplier 2 + Packaging 1		Supplier 3 + Packaging 1		Demand
Plant A	-	50	-	45	3000	20	-	30	0
Plant B	-	30	-	25	-	50	2000	20	0
Plant C	-	20	1000	15	1500	30	-	50	0
Capacity	0				500		1000		

The result is that plant A is going to receive 3000 tons from supplier 2 in packaging 1, pant B is going to receive 2000 tons from supplier 3 in packaging 1 and plant C is going to receive 1000 tons from supplier 1 in packaging 2 and 1500 tons from supplier 2 in packaging 1. The total spent can be computed by multiplying the quantities assigned by the total cost. For the case represented in table 5 the total spent calculation would be equal to 160.000€ (1000*15+3000*20+1500*30+2000*20).

However, in real case scenario, sourcing allocation is not such a simple procedure to be solved with the method described. Strategic constraints play an important role, which not all the lead-buyers take into consideration, due to the difficulty of analysing their effects, without proper data organization. In order to include strategic constraints in the sourcing decision approach, the same mathematical model mentioned in the beginning of this topic is applied - equations (4.12) and (4.13). On top of that, soft constraints are defined, as well as an objective function and respective penalizations. In this case, as further will be explained, Excel Solver will optimize the allocations by minimizing this objective function, instead of applying the algorithm previously mentioned (the adaptation of the transportation model).

Continental applies two main strategic restrictions to sourcing allocations: total dependence on supplier should be avoided (monopoly sourcing), in order to spread risk; total occupancy of supplier capacity should be avoided (reduce dependence of the supplier). The variables and hard constraints applied are the same as in the previous method. New variables, soft constraints and respective penalizations are added to the model, as following explained.

New variables:

T_{sp}: Total cost of the raw material sent from supplier s to plant p – formula (4.14)

Δ_{1s}: Variation between the assigned quantities to supplier s and strategic capacity occupation - formula (4.31)

Δ_{2p}: Variation between the delivered quantities and the demand of the plants - formula (4.32).

Δ_{3s}: Variation between the assigned quantities to supplier s and strategic demand split - formula (4.33)

New parameters:

p_d: percentage of the total demand assigned to supplier s, strategically pre-defined before allocation

p_c: percentage of utilization of capacity of the supplier s, strategically pre-defined before allocation

f_1: Flexibility rate for capacity strategic constraints

f_3: Flexibility rate for demand split strategic constraints

The defined strategic percentages must compute a total of 100%, as shown in formula (4.29):

$$\sum_{s=1}^{s} p_d = 100\% \tag{4.29}$$

The objective function will be computed as shown in formula (4.30). Each penalization is calculated based on the multiplication of a variation to the expected values (Δ_{1s},Δ_{2p} Δ_{3s}), a flexibility value and a numerical value, as explained in the expressions (4.31) to (4.33) and (4.36).

$$\begin{aligned} &Objective\ Function \\ &= Total\ Spent + Penalization\ 1 + Penalization\ 2 \\ &+ Penalization\ 3 \end{aligned} \tag{4.30}$$

$$\Delta_{1s} = \frac{\sum_{p=1}^{p} q_{sp}}{c_s} - p_c \tag{4.31}$$

$$\Delta_{2p} = \sum_{s=1}^{s} q_{sp} - d_p \tag{4.32}$$

$$\Delta_{3s} = \frac{\sum_{p=1}^{p} q_{sp}}{\sum_{p=1}^{p} d_p} - p_d \tag{4.33}$$

Soft constraints:

Percentage of total quantities assigned to supplier s, from total demand, should match the strategic percentage defined - formula (4.34).

$$\sum_{s=1}^{s} [\Delta_{3s}] = 0 \tag{4.34}$$

Capacity utilization should be inferior to the strategic percentage defined - formula (4.35).

$$\sum_{p=1}^{p} q_{sp} \leq c_s \times p_c \quad \forall q_{sp} \in [0, c_s] \tag{4.35}$$

The objective function will be penalized by the variations from the soft constraints - formula (4.36). The flexibility values, allow the simulation of different scenarios, according to the expected capacity of negotiation with supplies. In other words, users should set the flexibility to lower values if they expect that sourcing decision will be mainly driven by strategic constraints. On the other hand, they should set flexibility values to higher values, if they believe that sticking too much to strategic constraints won't allow seeking the best options regarding costs. Summing up, these values determine how flexible the strategic constraints should be.

Please note that penalization will only apply toΔ_{1s}, if the capacity utilized overcomes the strategically defined capacity percentage (p_{cs}), which means, only if Δ_{1s} is positive. Also, regarding demand and deliveries, since hard constraints determine that deliveries can never surpass demand – formula (4.13), the penalization will only apply if deliveries are inferior to demand, which means, if Δ_{2p} is negative. Finally, in the case of strategic demand split, penalization applies every time there is a deviation from the defined percentages.

Objective Function:

$$\sum_{s=1}^{s}\sum_{p=1}^{p} T_{sp} * q_{sp} + \sum_{s=1}^{s}\left(\frac{\Delta_{1s} + ABS(\Delta_{1s})}{2} \times (1 - f_1) \times Penalization\right) + \sum_{p=1}^{p}\left(\frac{ABS(\Delta_{2p}) - \Delta_{2p}}{2} \times Penalization\right) + \sum_{s=1}^{s}\left(ABS(\Delta_{3s}) \times (1 - f_3) \times Penalization \right)$$

(4.36)

Total spent is calculated as previously explained (table 5). Penalization 1, is obtained by multiplying the variation between % of capacity assigned to the supplier and % defined by strategic purchasing, by the flexibility and the penalization value, as explained in table 6. Please note that the values are only penalized if the capacity assigned overcomes the defined value, in case it is a lower value, no penalization applies. In this case, flexibility was defined as 90%.

Table 6 – Capacity penalization calculation

	Supplier 1	Supplier 2	Supplier 3
Defined %	80%	80%	80%
Assigned Capacity	90%	85%	70%
Variation	10%	5%	-10%
Penalization	=0,1*0,9*Penalization	=0,05*0,9*Penalization	0

Penalization 2 is related to service level. As already mentioned, demand is a hard constraint, so the algorithm won't assign more quantity than the demand. However, due to lack of capacity of suppliers or a very expensive supplier option, cases might happen where the assigned deliveries are inferior to demand. The point of penalization 2 is to minimize these differences, as explained in table 7.

Table 7 – Deliveries penalization calculation

	Plant A	Plant B	Plant C
Demand	10.000	5.000	7.500
Deliveries	10.000	4.000	7.000
Variation	0	-1000	-500
Penalization	0	=1000*0,9*Penalization	=500*0,9*Penalization

Penalization 3, works similarly as penalization 1, but it is applied to strategic splits of supplier. The percentages to assign to each supplier are previously defined by strategic purchasing, then they will be compared to the total assigned deliveries and variation is calculated, as explained in table 8. Penalization is applied whether the value is under or above the defined percentage. The point of this strategy constraint is risk mitigation, by spreading dependency of suppliers among several entities, as mentioned in chapter 2.5 – Portfolio of Suppliers approach.

Table 8 –Strategic spreading penalizations calculation

	Supplier 1	Supplier 2	Supplier 3
Defined %	50%	30%	20%
Assigned Deliveries	53%	27%	20%
Variation	+3%	-3%%	0%
Penalization	=0,03*0,9*Penalization	=0,03*0,9*Penalization	0

In the end, quantities allocated from suppliers to plants are reassigned in order to minimize the objective function. The solution obtained with solver, by taking into account the strategic constraints, is expected to be more expensive than the one obtained by the algorithm. However, cost scenarios can be run, in order to evaluate whether how much does Continental spend more due to strategic constraints.

After allocation is performed, an output report is triggered based on a model defined. Here information about sustainability and supplier performance is provided as well. An output report model can be found on Appendix T. This kind of reports will be analysed for the business case implementation, in the following topic.

4.3 Business Case Implementation

The raw materials chosen for the business case implementation were three types of synthetic rubber and one type of carbon black. These families of materials represent a significate part of purchasing expenses, which can go up until a fifth of the total volume purchased of production materials - any savings can have a big impact on company's results. Both families of materials have a great number of suppliers, located worldwide, using different kinds of packaging and offering the products with small price differences. This way, operational cost-effects play a bigger role on sourcing decision - they have to be properly evaluated and measured. At the same time, information was available, or could be extracted from the information systems, and lead-buyers were eager to cooperate by providing the necessary inputs.

4.3.1 Assumptions

In order to implement the approach to real business case scenarios, the following assumptions were made:

- It was assumed that all packaging units were filled until the maximum weight;
- Each truck load carries 20 tons;
- Duties are included in the material fee;
- All lead-times were considered as 30 days, though sea freight manager was able to provide data for all the combinations of suppliers and plants, it was impossible, until the moment of delivery of this report, to obtain the addresses of the producers, needed for lead-time calculation;
- Weighted average cost of capital reference value was considered to be 10% and debt cost 5%;
- Average inventory time was estimated in agreement with lead-buyers;
- Maximum height and weight data of the raw materials warehouses was not available for all the plants. For the missing data, seven meters were defined as maximum height and ten tons were defined as the maximum weight per square meter;
- In order to simulate if it would compensate to store carbon black in silos, for the plants where they don't exist, it was assumed that the plant would have 1 silo of an average 70 tons capacity;

- Usually transportation costs depend only on the origin, destination and type of freight. However, for carbon black, silo trucks or common trucks carrying big bags, have different prices. Since this price difference was only available for a few cases, it was considered that the delta (delta= Transportation in Silo truck – Transportation of big bags in normal truck) would assume the value of 100€, by lead-buyer's recommendation.

4.3.2 Scenario Analysis

In order to meet the requirements defined on chapter 4.1.1, and by discussing the topic with the head of inbound supply chain management, cost-effect scenarios were agreed upon. Thus, the features of the approach implemented can be tested and the value added to the process can be understood. The following scenarios were applied to the four key raw materials, used as a pilot for the project:

i. Trade-off analysis between mitigating risk and having supply chain disruptions (for the specific cases were monopoly sourcing applies). This can be done by comparing the cost of spreading the demand between many suppliers (which probably will result in higher costs) with the cost incurred due to shortages – losses due to disruption, setup costs, delayed delivery costs, etc.

ii. Analyse the break-even point where allocation of suppliers and packaging changes, for the following factors (in order to meet requirements [B] and [D]):

a. Payment terms;
b. Consignment;
c. Feedstocks;
d. Capacity of supplier;
e. Space costs;
f. Handling prices;
g. Conversion prices;
h. Transportation prices;

iii. Analyse what is the effect on total spent, of having low and high scenarios for the same factors as mentioned above;

iv. Analyse what is effect on total spent of choosing the best possible options regarding sustainability;

v. Validate the purchasing data of the four key materials in the year of 2016, by analysing the effect on total spent of manual allocation versus optimized allocation.

In order to compare the effect of the variation of these factors in total spent and allocation, a "neutral" simulation is performed initially, known as BASIC. In this case, no strategic constraints are applied, nor any variations to the input data. In the following topic, a detailed analysis of each of the scenarios will be discussed.

4.3.3 Results Analysis Discussion

Appendix X provides a detailed analysis, of the individual expected effects, of each of the analysed factors, on the total spent. In order to perform this analysis, all the scenarios were compared to BASIC, as mentioned in the end of the previous topic. Each factor is varied at a time, in order to isolate its effect, though the system is flexible enough to vary more than one simultaneously.

Regarding the comparison between incurring in shortage costs and spitting demand, it is important to explain that it would be more relevant to analyse cases of monopoly supply (where it is more likely to happen a shortage), to understand what is the trade-off between mitigating risk (splitting demand) and having shortage costs. Since any of the four materials chosen had mono supply, the splitting was performed by adding one more supplier to the current situation. Also, it is important to mention that shortage costs were calculated based on data provided by the company (extra transportation costs, material change costs, tire losses and process impact). However, as the situation is now, it is more likely that the material that

will benefit more from demand splitting will be synthetic rubber 3, since shortage costs are very close to the total spent of demand splitting.

Regarding space costs, it can be observed that the break-even points that change packaging allocation are high, considering that in the BASIC scenario internal space valuation prices (benchmark value) range from 2 to 15€/sqm/month, with the biggest percentage of the values under 7€/sqm/month. Hence, it is not expected that many changes would occur from the BASIC scenario, since such an increase in space costs is not expected. It was also possible to determine the break-even costs, for Lousado plant and carbon black, where the choice of receiving silo trucks with carbon black, or big bags in a common truck, would change: 59€/ton for warehouse handling costs (although it is believed that such a high value won't be reached), 57€/ton for conversion costs (decanting), and 67€/ton for transportation. Regarding the effect of high and low scenarios of the factors analysed, it can be seen that the highest impact on total spend is due to the variation of the feedstocks values.

For a better understanding of what is the effect on allocation of suppliers and packaging, as well as on total spent, of the mentioned factors, several scenarios were chosen for a more detailed analysis. Firstly, it was calculated that Continental would have to invest 13% more in sourcing of carbon black, in order to supply all the demand from the best sustainability option, as shown in figure 10. Secondly, regarding payment term and consignment, as shown in figure 11, the variation of the number of days of payment term can have a significant impact on the total spent. A break-even point for payment term, that equals the value of the total spent of having all the stock on consignment, can be calculated. For material synthetic rubber 2, a payment term of 120 days, at all the plants, would attain as much savings as negotiating consignment with all the suppliers. By analysing appendix X, it can also be concluded that this break even value can be found with the shortest payment term for carbon black, and with a longest one for synthetic rubber 3.

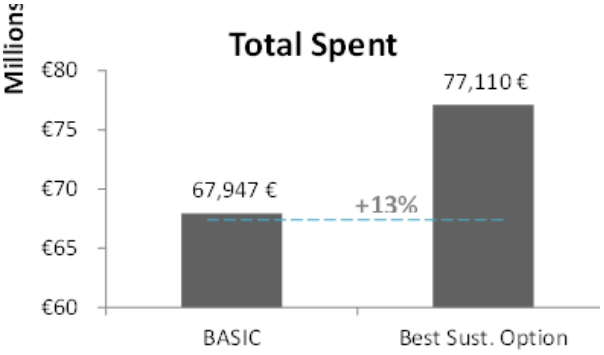


Figure 10 - Sustainability analysis for carbon black

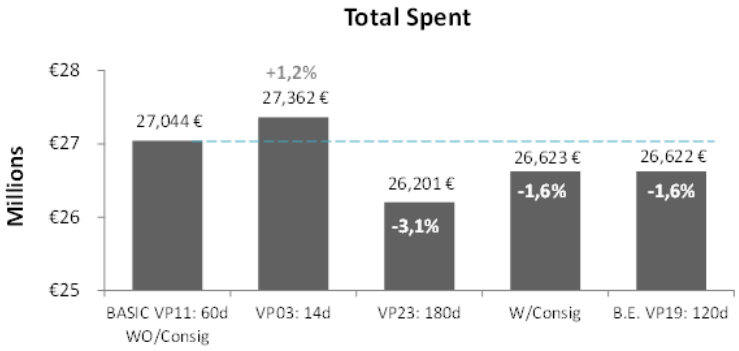


Figure 11 - Payment term effect on total spent of material SR 2

Regarding feedstocks, it is important to analyse not only the effect on total spent, but also the changes in the allocation. Synthetic rubber 3 price is affected by 3 different Butadine feedstocks: BdEU (Europe), BdAS (Asia) and BdUS (United Stated of America). The effect of an increase or decrease of 50% of the BdEU on the total spent of this material is shown in figure 12. In order to cope with these variations, also allocation of suppliers has to be changed, in order to obtain optimized values, as shown in figure 13. It can be seen that the fluctuation of feedstocks can determine the inclusion of new suppliers in the sourcing decisions, or simply changing the split of demand among them.

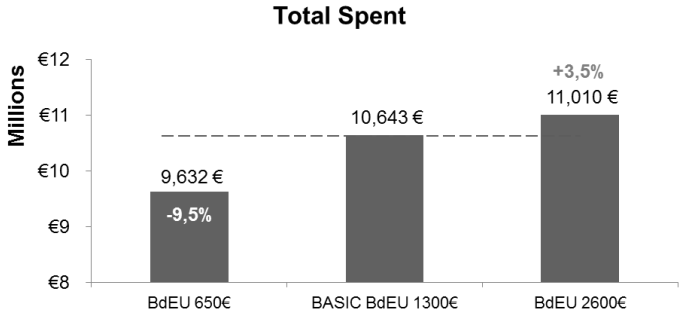


Figure 12 - Effect of the variation of 50% of the BdEU feedstock on total spent for material synthetic rubber 3

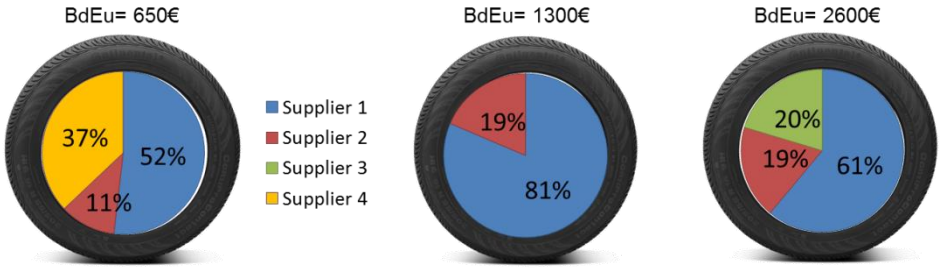


Figure 13 - Changes in allocation of suppliers (% of total demand) for the material synthetic rubber 3 due to BdEU fluctuations

However, it is known that in a real case scenario all the feedstocks fluctuate along the time, varying according to market trends. So, in order to make a more realistic analysis, the evolution of these three feedstocks values, during the last year, was analysed. Two points of time were chosen for analysis: February 2016, when feedstocks reached the lowest values and were very close from each other; March 2017, when feedstocks' values had a spike rise, and were very different from each other. These values can be found at table 9 (provided by the company), and the effect can be seen on figure 14.

Table 9 – Feedstock values considered for analysis

Feedstock (€/ton)	Minimum Value Feb. 2016	Maximum Value Mar. 2017	BASIC
BdEU	500	1750	1300
BdAS	627	2598	1450
BdUS	493	2150	1400

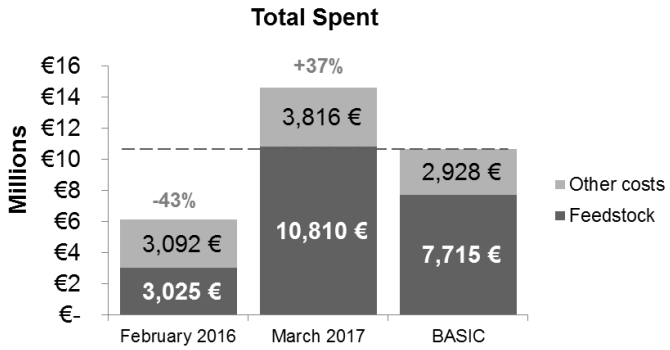


Figure 14 - Effect of synthetic rubber 3 feedstocks fluctuations on total spent

It is clear to understand that, the higher the feedstocks values, the bigger is its contribution to the total spent. However, this analysis should be complemented with the ideal allocation, in order to deal with the fluctuations of the values, as seen in figure 15.

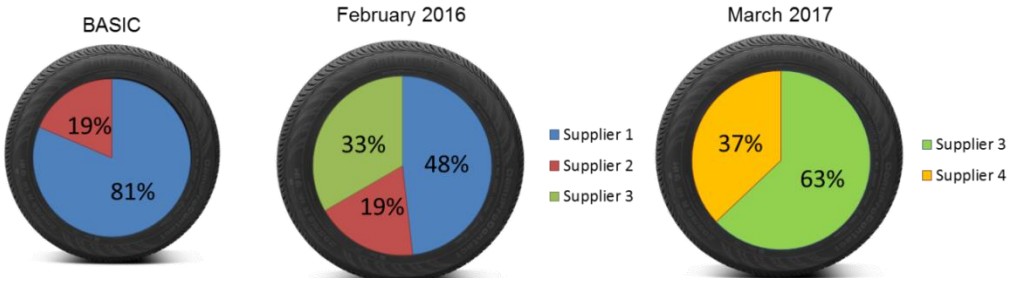


Figure 15 – Differences in allocation of suppliers to the material synthetic rubber 3, due to feedstocks fluctuations

Regarding the capacity constraints, it was also possible to assess, for material synthetic rubber 1, how much would have to be the investment on strategy, in order to occupy solely 30% of the capacity of the suppliers (figure 16). This extra investment is explained by the allocation of a higher percentage of the total demand to more expensive suppliers, as seen underneath.

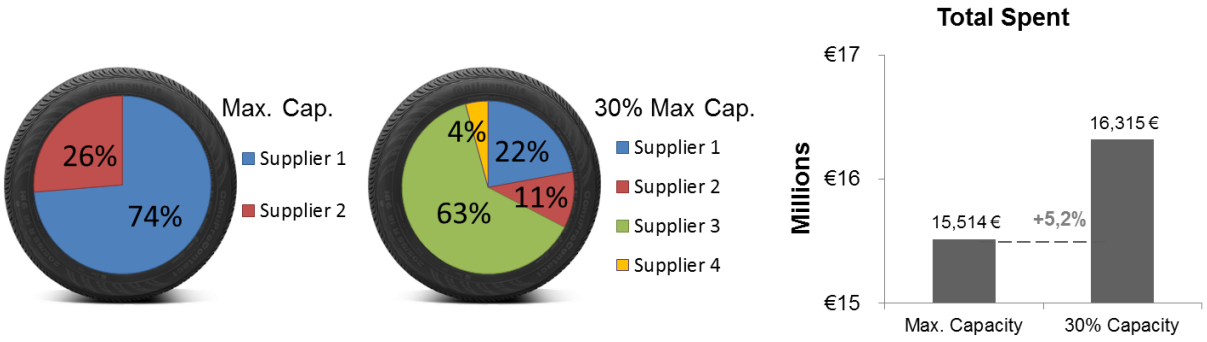


Figure 16 – Extra total spent and allocation due to capacity restrictions for material synthetic rubber 1

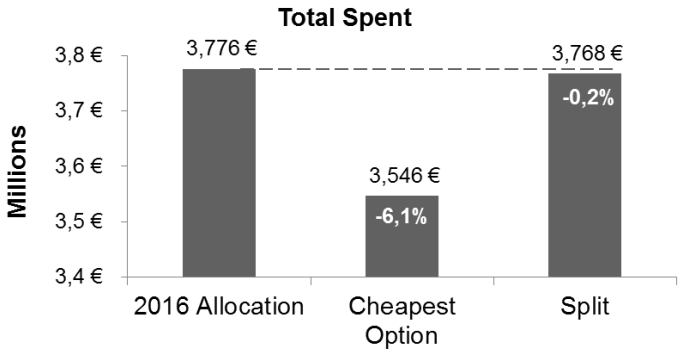


Figure 17 - Effect of strategic constraints split on cheapest option and comparison with 2016 allocation for SR2

Finally, it is important to discuss the validation of the system implemented. Appendix X shows that, by comparing the manual allocation performed in 2016, to the one obtained by the algorithm for the same sets of data, it is possible to understand that the maximum variation obtained in the total spent was of +1%. For synthetic rubber 3 and synthetic rubber 2 even better results could be obtained, due to small changes on quantities allocation, as seen in figure 18. Synthetic rubber 2 presented savings of 0,2% on the total spent, by applying the strategic constraints to the cheapest option allocated by the algorithm, as presented in figure 17.

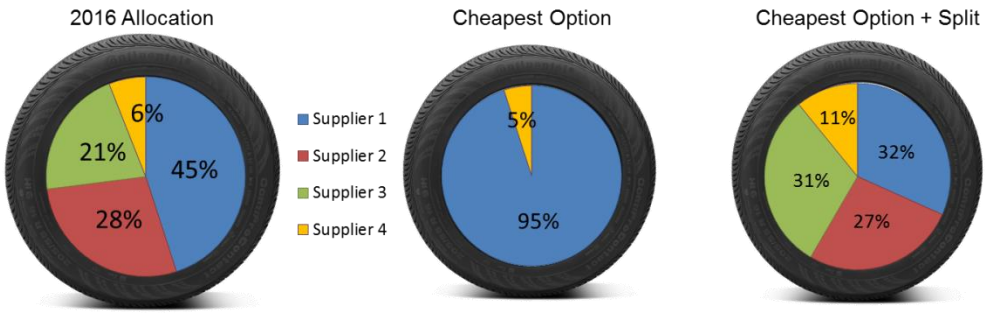


Figure 18 – 2016 suppliers' allocation validation

This proves the potential of the implementation of this system as a support decision approach to sourcing. Along this topic it was proved more than once that there are still opportunities to improve the achieved results in corporate purchasing, which can be accomplished by the implementation of this approach in the purchasing process. Some notes on that will be presented in the following topic.

4.3.4 Notes on the purchasing process

The approach proposed can be integrated and add values in different phases of the purchasing process. Simulations can be performed before and after negotiation, in order to compute the negotiation savings, usually stated at the SDS (sourcing decision sheet). Yearly savings can be calculated as well. KPIs can also be implemented regarding these savings, as will be suggested in chapter 5.3.

Although the tool is designed for the lead-buyers as key users, in order to perform tactical decisions about purchasing (which supplier to choose, which packaging to send, access data regarding previous costs, etc.), it is also ready to provide input for ideal strategic decisions:

- Mitigate risk;
- Define capacity to occupy from suppliers.

The split of demand among suppliers, known as portfolio share of suppliers is a measure applied to avoid dependency of suppliers. Hence, from a strategic point of view, it might also be important to understand how the portfolio share of suppliers changes along the years. Capacity occupancy definition is important to define the extent into which the supplier is dependent of the company's demand.

4.4 Other implemented solutions

Apart from the database and mathematical model, other solutions were implemented regarding packaging. In order to understand its ecological impact, evaluation criteria were defined together with the director of environmental protection from Tires division, as suggested in chapter 2.3.1: returnable or non-returnable; reusable or non-reusable; waste generation; end-to-end solution; weight of the packaging versus weight of the content; material.

Though the criteria mentioned cover most of the environmental issues mentioned by literature, the ideal scenario would be to perform a LCA (life cycle analysis) of the packaging. This way, all its impact, since production until disposal, could be properly assessed. Due to the limited time frame of the project and insufficient resources and information available, it was not possible to implement such solution. Instead, a questionnaire was developed, as shown in Appendix U. The objective is that every plant can answer eight questions regarding the kinds of packaging at use there. In the same file, according to the answers, the rating of

the specific combination, of material and packaging, is calculated and stored. Therefore, the rating is afterwards converted into a percentage, by comparison with the other options, which provides the user an insight about its ecological performance. This result can be then inserted into the main database, in order to run the desired simulations. When applying this questionnaire, it was proved the existing lack of data regarding packaging. As shown in appendix F, the existing list of packaging doesn't provide any information about the material, or the several items that might compose it. Therefore, since the combinations of items and other characteristics are important for ecological impact calculations and operations management, it was found a necessity to have this data on the packaging database, as a new entry, stating the components and their respective material, for instance: "big bag on wooden pallet", "big bag on plastic pallet", etc.

Regarding the packaging quality concerns, the implemented supplier's requirements manual at the tires division, as described on chapter 3.2, is far from enough, since many exceptions are allowed and only very general statements are defined. Each type of raw material has very specific characteristics, and consequently packaging requirements, which are hard to generalize for all the materials. Hence, the solution found was to do an internal benchmark analysis at the company's group. Automotive division provides a detailed manual to suppliers, with packaging specifications. Every time a new material or supplier takes part of Continental inbound supply chain, the supplier is informed about the packaging requirements, being provided a specific manual and motivated to strictly comply with it. The point is that, at Continental Tires division, the same method can be applied, by providing a similar document to the suppliers. A template of the manual to send to suppliers was developed and is provided in appendix V. This way, losses due to packaging noncompliance (extra spends at the plants related to processing unwanted packaging), can be from now on calculated and compared with the option of negotiating packaging changes with the supplier. Moreover, suppliers can be assessed regarding compliance with these requirements. For that purpose, KPIs can be implemented, or a new topic can be added to the SPM analysis. It is important to perform this analysis at a plant level, since different plants might require different kinds of packaging specifications.

5 Conclusion and Future Works

The main objective of the project was to develop, implement and analyse the results of a new approach to supplier sourcing decisions at the tire division of Continental. The trigger of the project was the identified necessity of integrating operational costs into the sourcing decision. However, supplier selection, as a systematic process, has been approached with different frameworks and techniques, not yet standardized for any industry sector.

In this project, supplier selection was considered as a multi-criteria decision problem. To attain the proposed milestones, a holistic system of purchasing performance measurement and supplier allocation was implemented. This includes a value-oriented simulation model and a management-oriented qualitative classification. Its practical execution required the development of a database and the construction of an optimization mathematical model. The purchasing process was reformulated, on a tactical level, and the approach created also input data for strategical decisions regarding purchasing.

In the following, the expected improvements of the approach implemented will be summarized and future works, that couldn't be executed due to the limited time frame of the project, will be proposed. Also, the main results of the business case are summarized.

5.1 Expected improvements

The implementation of a supplier relationship management system is expected to provide standardization into the process, insights of historic registers, integration of information coming from different systems (and thus facilitating communication between research and development, corporate and local purchasing), more flexible decision making and facilitated collaboration among lead-buyers. This is expected to facilitate the processes of new material or new supplier approval as well. Another important aspect is the regular review and update of information, as well as the consequent positive impact on information quality.

Since operational costs were also included in the optimization process, these will no longer be "hidden" at plants' costs centres and corporate purchasing will be able to visualize them and implement tactical actions in order to reduce them (at a central level). Economic analysis of cost-effect scenarios will also be possible: feedstocks fluctuations, packaging changes, payment terms days negotiation, different levels of risk spreading, etc. For that, CVC calculation was adapted to working capital cost effects, allowing its integration into the economic analysis.

Packaging quality requirements, an issue until now totally dependent on supplier's choice, are now defined (only for the materials chosen for analysis, with the perspective of expanding the concept to the other raw materials in the long-term). This is expected to result on the avoidance of operational handling problems at the plants.

The introduction of the SPM system into the sourcing decisions, will allow a closer and more systematic monitoring of the whole purchasing performance. Monitoring of packaging requirements can also be possible from now on, since they are already defined. This topic could be included in the SPM questionnaire sent to plants: supplier's compliance with

packaging requirements, number of complaints due to packaging irregularities, etc. Measures can also be defined and implemented in order to deal with this kind of situations.

Input information for strategical corporate purchasing decisions (such as risk mitigation spends versus supply chain disruption expenses), is now available and possible to work with. This is especially important for monopoly sourcing cases, where Continental has to face a huge bargaining power of suppliers. Moreover, shortage handling and critical materials management is facilitated, since the approach allows a faster and more flexible supplier comparison, both in phase-in and phase-out processes.

The integration of sustainability information into sourcing decisions allows simulating costs-effects of sustainable choices of suppliers. This is the first step towards answering the question "How much to pay for sustainability?".

5.2 Results Summary

The main results, obtained by the application of a business case to the scenarios mentioned in topic 4.3.2, were validated at the headquarters if the company in Hannover and allowed to conclude that:

- For the current level of shortage costs, demand splitting wouldn't improve the total spent. However, if shortage costs would raise 1%, 4%, 15% and 0,19% respectively for materials synthetic rubber 1, synthetic rubber 2, carbon black and synthetic rubber 3, then demand splitting should be considered.
- When consignment cannot be negotiated with suppliers but they are flexible on payment term, it is possible to calculate the number of days of payment term that equals the effect of consignment.
- Feedstock effect is among the ones with highest impact on total spent. The company should minimize the effect of its fluctuations, by using the system as a way to predict what should change in allocation, in order to deal with different assumptions of feedstock values.
- Lower capacity occupation of the suppliers leads to the choice of more expensive options, raising the total spent. Strategic purchasing must decide upon the amount of money to be invested in this case, then optimal allocation can be determined.
- By varying space, warehouse handling, conversion and transportation costs, optimal packaging allocation changes. Break-even points when packaging should be changed can be calculated.
- Although sustainability information is still only available for carbon black family of materials, it was possible to calculate that changing the allocation to the best sustainability option would rise the total spent in 13%. The inverse analysis can be computed by defining firstly a budget for sustainable sourcing and then finding the best allocation.
- The system was validated using data from 2016. Since total spent and allocation matched the historic data, with variations no bigger than 1%, it can be stated that the approach was successful.

5.3 Future Works

The main objectives of the project were attained: develop, implement and analyse results of a new versatile approach to sourcing of raw materials. However, since the project was limited to 4 months, some topics were not possible to address within the time frame, or, in other cases, simply there was not enough information, or favourable conditions to do so.

One of the remarks noted right in the beginning by the lead-buyers, was that for specific materials, some plants require the establishment of a contract with both a local and an international suppliers, in order to avoid supply disruptions. This is particularly important for critical materials supplied by producers with lead-times longer than 3 months, which is quite

common since for rubber materials, a significate part of the suppliers is located in East Asia, sending the products to Europe and America. However, this requirement is only applied to a small number of materials. Since the task was too time consuming, it was decided to apply this constraint in the next stage of the project.

Regarding the proposed mathematical model, it would also be important to analyse the effect of different values of the penalization in formula 4.36, in order to understand the behaviour of the objective function.

Since performance measurement of the purchasing-related activities is now possible, due to the standardized storage of information, a scorecard can now be defined for the process. KPIs can be agreed upon for corporate purchasing, such as historic savings, lead-buyers performance, operational savings, shortages etc. This is the expected following step, in order to implement the mentioned holistic system of purchasing performance management. The starting point of this evaluation should be an assessment of the current situation regarding avoidable expenditures and losses, due to the identified opportunities for improvement.

Though the project was for now limited to 4 key raw-materials, due to input data related time-consuming activities, there is a high potential for application to other materials. However, one of the limitations of developing the system in Excel and VBA, is the limited number of variables that can be processed at a time. Because of that, it is technically not recommended to maintain such a database on this kind of software (combinations of materials, plants and suppliers can go up to thousands of entries). So, as a future work, it would be interesting to maintain all the variables and data in another system. This way, before starting an analysis, the user could select the material to analyse, as well as the suppliers and plants. Then, all the related information could be extracted to a database structured as suggested in this report, and the optimization algorithm could work as already described. This would improve the algorithm running time and allow the user to process and interpret only relevant information for the desired purposes.

If a new support system could be implemented, instead of working with Excel and VBA, the project could also be taken to another dimension of complexity. As it is developed now, each material is analysed individually. This represents a gap whenever more than one material is produced at the same supplier location and its capacity is shared. Hence, when simulating different scenarios for suppliers' capacity occupation, it would be possible to take into account how much capacity is already occupied by other materials, also bought by Continental. An integration of a new dimension into the problem, or in other words, simultaneously analysing several materials, would require adaptations to the mathematical model and also a more robust software system support. For instance, it would be interesting to apply an AHP procedure, as mentioned in chapter 2.3, in order to integrate also the qualitative information, such as sustainability, into the model.

Finally, the following stages of the implementation of the project were defined together with the inbound supply chain and corporate purchasing departments:

- Project take-off: August 2017

1. Identifying more potential materials for analysis;
2. Linking the database to the existing systems;
3. Nominating people at the plants and at the purchasing department in order to update the data related to plants and suppliers, making the information system sustainable;
4. Testing the system during the negotiations period;

- First milestone: November 2017

5. Upgrading the system to a more robust software, in order to fasten the required time for information processing, due to the integration of more materials into the analysis.
6. Decide upon implementing a more complex model of simultaneous analysis of materials, as described in the previous paragraph. Make a decision based on the trade-off

between time/resources employed and value-added of this improved model concept. To be discussed and decided by corporate purchasing.

- Second milestone: improved model - November 2018; current model – April 2018.

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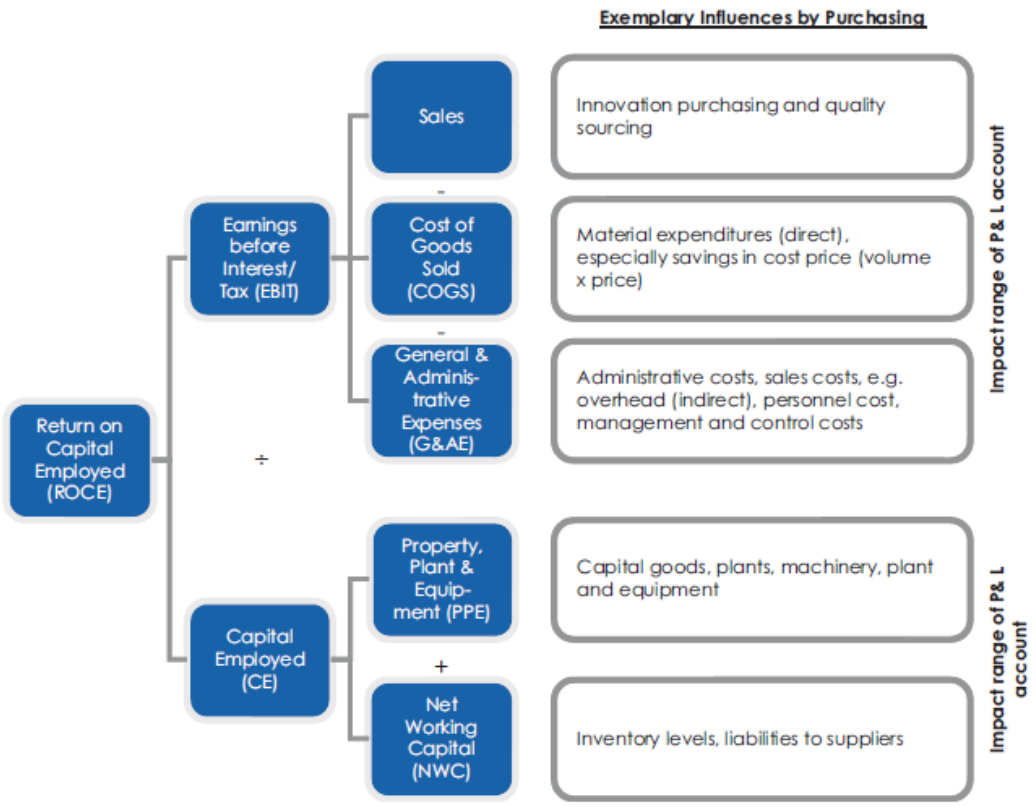
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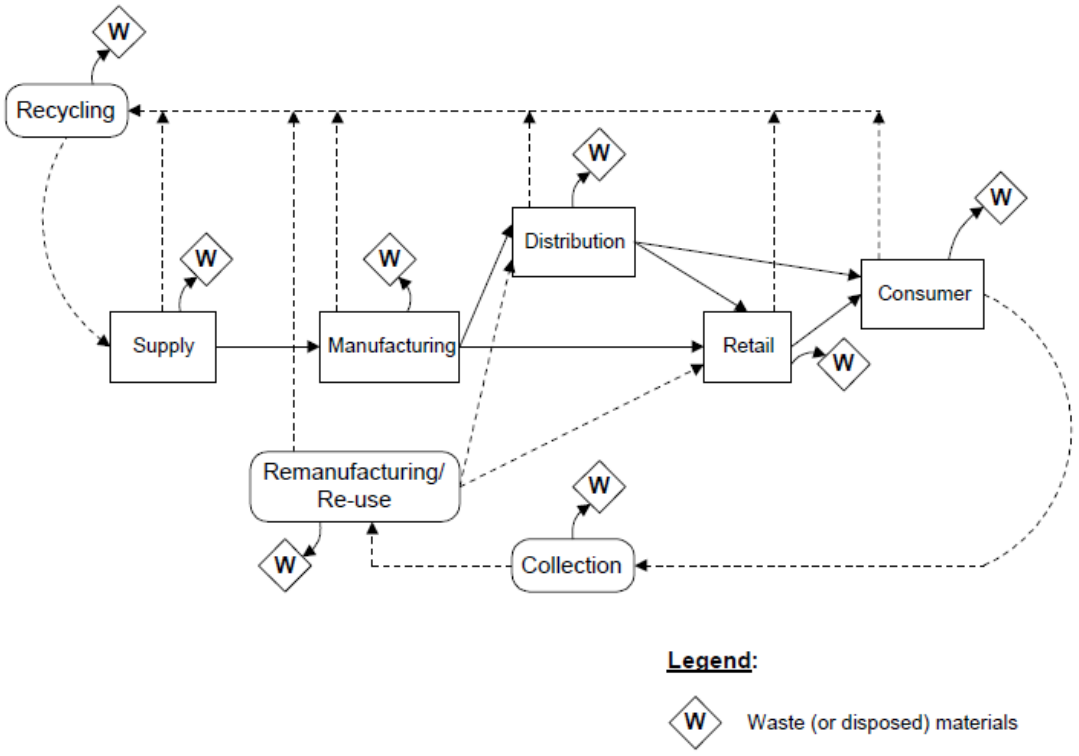
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APPENDIX A: Levers of purchasing in terms of return on capital employed - (Kotula et al. 2014)



APPENDIX B: The extended supply chain - (Beamon 1999)



APPENDIX C: Evaluation criteria for a green supply chain - (Beamon 1999)

Performance Measure Classification	Performance Measure (Measured over Product and Process Life Cycle, except where indicated)
Resource Use	Total energy consumed Total material consumed (e.g., water, timber, steel, etc.)
Product Recovery **Remanufacturing** **Re-use** **Recycling**	Time required for product recovery % recyclable/reusable materials (volume or weight) available at end of product life % product volume or weight recovered and re-used Purity of recyclable materials recovered % recycled materials (weight or volume) used as input to manufacturing % product disposed or incinerated Fraction of packaging or containers recycled Material Recovery rate (*MRR*)[1] Core Return Rate (CRR)[2] Ratio of virgin to recycled resources Ratio of materials recycled to materials potentially recyclable Materials Productivity: economic output per unit of material input
Product Characteristics	Useful product operating life Total mass of products produced
Waste Emissions and Exposure Hazard	Total toxic or hazardous materials used Total toxic or hazardous waste generated Solid waste emissions % product (weight or volume) disposed in landfills Concentrations of hazardous materials in products and by-products Estimated annual risk of adverse effects in humans and biota Waste ratio[3]: the ratio of wastes to all outputs.
Product Characteristics	Useful product operating life Total mass of products produced
Waste Emissions and Exposure Hazard	Total toxic or hazardous materials used Total toxic or hazardous waste generated Solid waste emissions % product (weight or volume) disposed in landfills Concentrations of hazardous materials in products and by-products Estimated annual risk of adverse effects in humans and biota Waste ratio[3]: the ratio of wastes to all outputs.
Economic	Average life-cycle cost incurred by the manufacturer Purchase and operating cost incurred by the consumer Average total life-cycle cost savings associated with design improvements
Economic/Emissions	Ecoefficiency[4]: adding the most value with the least use of resources and the least pollution. Generally, "The ability to simultaneously meet cost, quality, and performance goals, reduce environmental impacts, and conserve valuable resources"

APPENDIX D: Examples of Supplier's Performance Metrix (Wisner, Tan, and Leong 2014)

1. Quality
    a. Zero defects
    b. Statistical process controls
    c. Continuous process improvement
    d. Fit for use
    e. Corrective action program
    f. Documented quality program such as ISO 9000
    g. Warranty
    h. Actual quality compared to: historical quality, specification quality, target quality
    i. Quality improvement compared to: historical quality, quality-improvement goal
    j. Extent of cooperation leading to improved quality
2. Delivery
    a. Fast: $Reorder\ Cycle = Time\ for\ trigerring\ the\ order + delivery\ time + ime\ for\ inspection\ and\ warehousing$
    b. Reliable/on-time
    c. Defect free deliveries: $Error\ Rate\ (\%) = \frac{Faulty\ deliveries}{Total\ deliveries}$
    d. Actual delivery compared to promised delivery window (i.e., two days early to zero days late)
    e. Extent of cooperation leading to improved deliver
3. Responsiveness and Flexibility
    a. Responsiveness to customers
    b. Accuracy of record keeping
    c. Ability to work effectively with teams
    d. Responsiveness to changing situations
    e. Participation/success of supplier certification program
    f. Short-cycle changes in demand/flexible capacity
    g. Changes in delivery schedules
    h. Participation in new product development
    i. Solving problems
    j. Willingness of supplier to seek inputs regarding product/service changes
    k. Advance notification given by supplier as a result of product/service changes
    l. Receptiveness to partnering or teaming
4. Environment
    a. Environmentally responsible
    b. Environmental management system such as ISO 14000
    c. Extent of cooperation leading to improved environmental issues
5. Technology
    a. Proactive improvement using proven manufacturing/service technology

   b. Superior product/service design
   c. Extent of cooperation leading to improved technology
6. Business Metrics
   a. Reputation of supplier/leadership in the field
   b. Long-term relationship
   c. Quality of information sharing
   d. Financial strength such as Dun & Bradstreet's credit rating
   e. Strong customer support group
   f. Total cash flow
   g. Rate of return on investment
   h. Extent of cooperation leading to improved business processes and performance
7. Total Cost of Ownership
   a. Purchased products shipped cost-effectively
   b. Cost of special handling
   c. Additional supplier costs as the result of the buyer's scheduling and shipment needs
   d. Cost of defects, rework and problem solving associated with purchases

APPENDIX E: Current and past supplier selection criteria - (Cheraghi, Dadashzadeh, and Subramanian 2011)

Current Rank	Previous Rank	Factor
1	3	Quality
2	2	Delivery
3	1	Price
4	10	Repair Service
5	5	Technical Capability
6	4	Production Facilities and Capacity
7	9	Financial Position
8	7	Management and Organization
9	New	Reliability
10	New	Flexibility
11	8	Attitude
12	13	Communication System
13	10	Performance History
14	6	Geographical Location
15	New	Consistency
16	New	Long-Term Relationship
17	14	Procedural Compliance
18	12	Impression
19	13	Reciprocal Arrangements
20	New	Process Improvement
21	New	Product Development
22	New	Inventory Costs
23	New	JIT
24	New	Quality Standards
25	New	Integrity
26	New	Professionalism
27	New	Research
28	New	Cultural
29	8	Reputation and Position in Industry
30	13	Labor Relations Record
Passé	11	Operating Controls
Passé	11	Packaging Ability
Passé	13	Training Aids
Passé	14	Desire for Business
Passé	15	Amount of Past Business
Passé	15	Warranties & Claims Policies

APPENDIX F: List of packaging and plants' codes

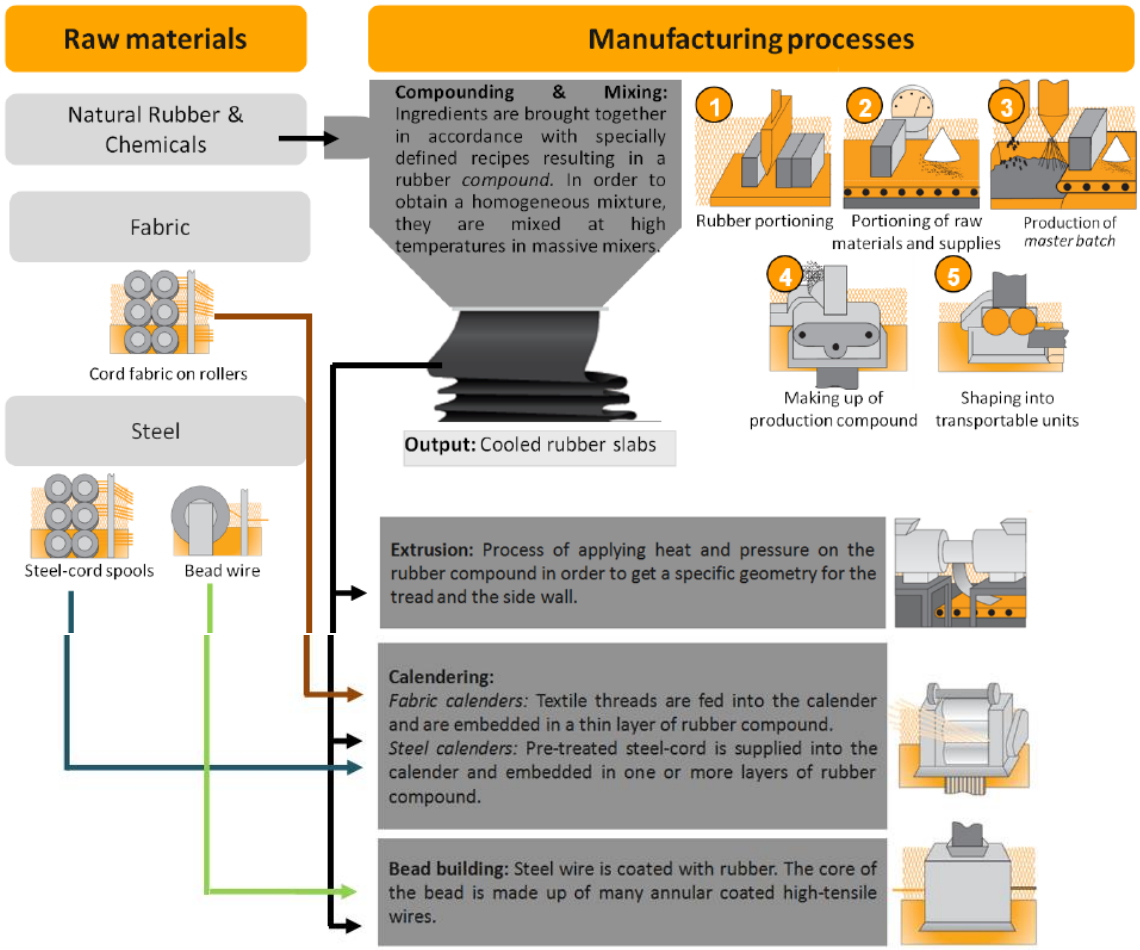
Packaging



Plants' Codes and Plant Location

0200	Aachen
1000	Puchov
1200	Mount Vernon
1600	San Luis Potosi
2200	Timisoara
2300	Kaluga
2500	Port Elizabeth
2600	Sumter
2900	Alor Setar
3000	Stoeken
3300	Cuenca
4000	Korbach
4800	Camaçari
5500	Sarreguemines
6600	Otrokovice
7700	Petaling Jaya
8200	Lousado
9200	Hefei
9300	Meerut

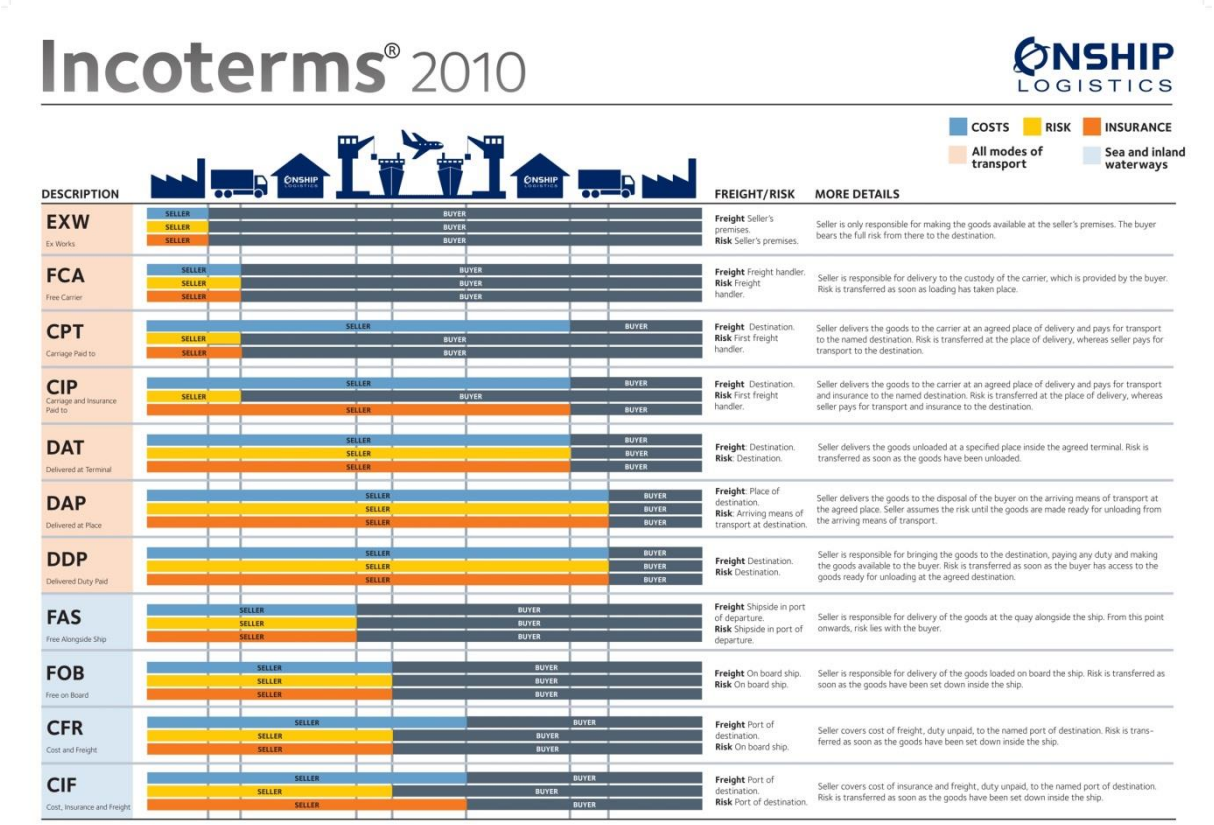
APPENDIX G: Tire Production Process and Raw Materials



APPENDIX H: Table of Raw Materials' Families and Sub-Families

XXXXXXXXXX	Family	XXXXXXXXXX	Sub-family
CA	Chemicals	CA11-39 CA40, CA56-59 CA41-42 CA55 CA61-70	Accelerators Oxides/Activators Fatty acids Silanes Antidegradants/Antioxidants
CB	Chemicals		Bonding agents
CC	Chemicals		Carbon black
CE	Rubber		Synthetic Rubber
CF	Chemicals		White fillers
CN	Rubber		Natural Rubber
CP	Chemicals	CP01	Peptizers
CR	Rubber/Chemicals	CR10-12, CR18, CR31 CR13-14, CR20, CR30 CR40-63 CR-80	Performance resins Tackifiers resins Reclaims Retarders
CS	Chemicals	CS10-12 CS20-26 CS40-79	Silica Solvents Softeners
CV	Chemicals	CV10	Sulfur
CW	Chemicals		Waxes
CZ	Chemicals	CZ09-13 CZ14-CZ18	Production aids Release agents
R0	Reinforcements		

APPENDIX I: Incoterms

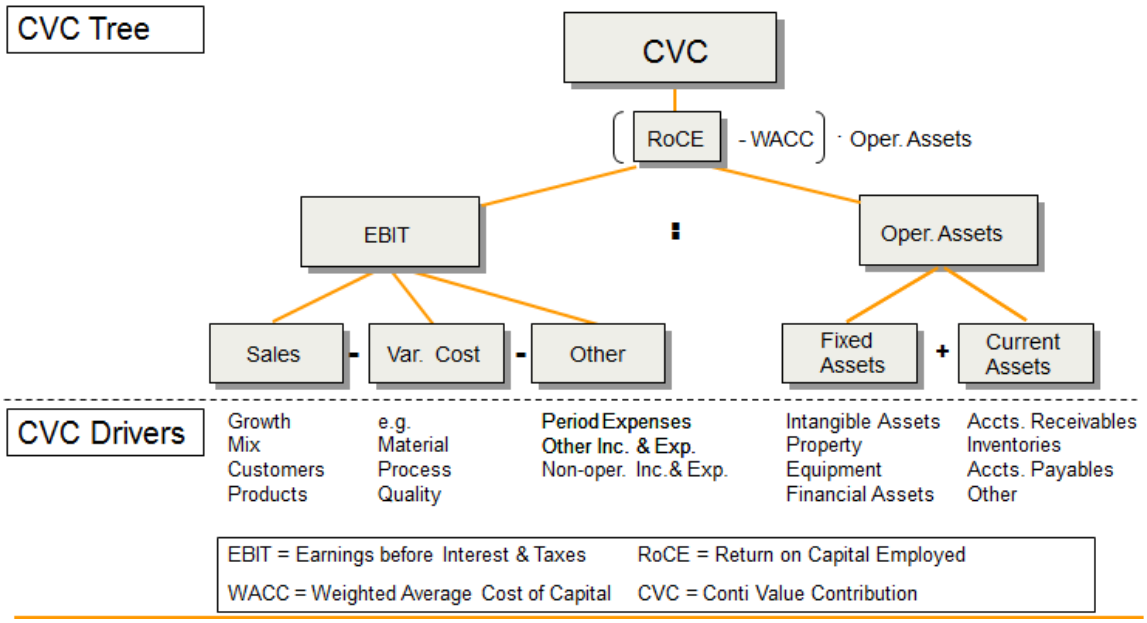


APPENDIX J: Types of Packaging at Raw Materials' Warehouses

Supplier industry	Material category	Packaging	Handling unit	Picture
Rubber extraction/ Chemical industry	Natural/synthetic rubber	Metal or plastic box	Box	 
Chemical industry	Liquid chemicals	Rigid IBC	Container	
Chemical industry	Various chemicals	Flexible IBC (or *Big bag*)	Pallet	
		Small bags		
Textile industry	Textile reinforcements	-	Roll	

Steel industry	Steel-cord	Cardboard box	Pallet	
Steel industry	Bead wire	Rack structure	Rack structure	

APPENDIX L: CVC Calculation Rational



APPENDIX M: EcoVadis Sustainability Assessment Criteria

EcoVadis 21 Criteria



21 CSR Criteria

ENVIRONMENT

Operations
- Energy & GHGs
- Water
- Biodiversity
- Pollution
- Materials & Waste

Products
- Product Use
- Product End of Life
- Customer Safety
- Advocacy

SOCIAL

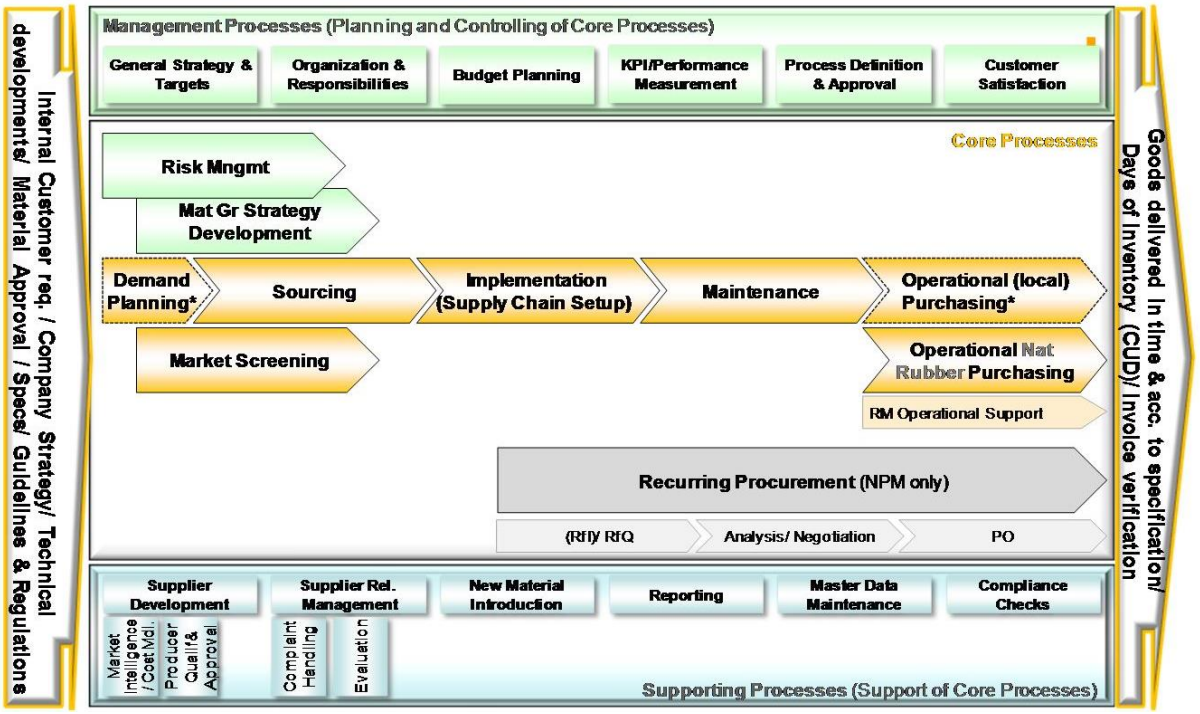
Human Resources
- Employee Health & Safety
- Working Conditions
- Social Dialogue
- Career Management & Training

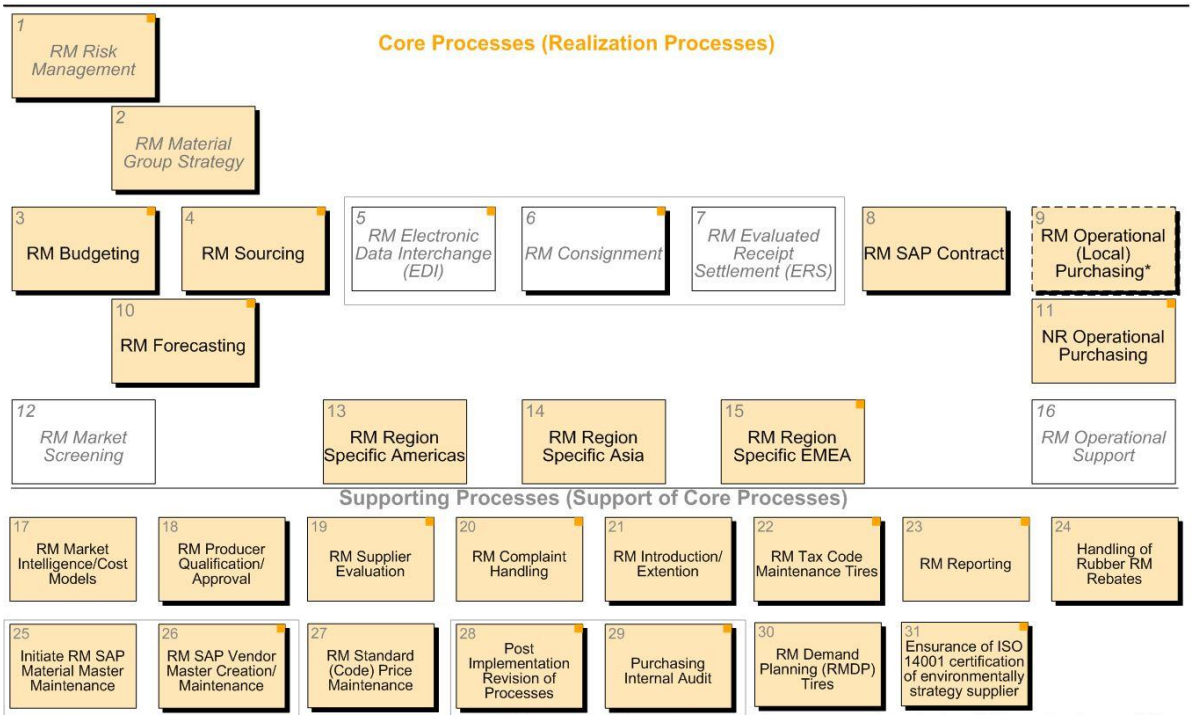
Human Rights
- Child & Forced Labor
- Discrimination & Harassment
- Fundamental Human Rights

ETHICS
- Corruption & Bribery
- Anti-competitive Practices
- Data Security

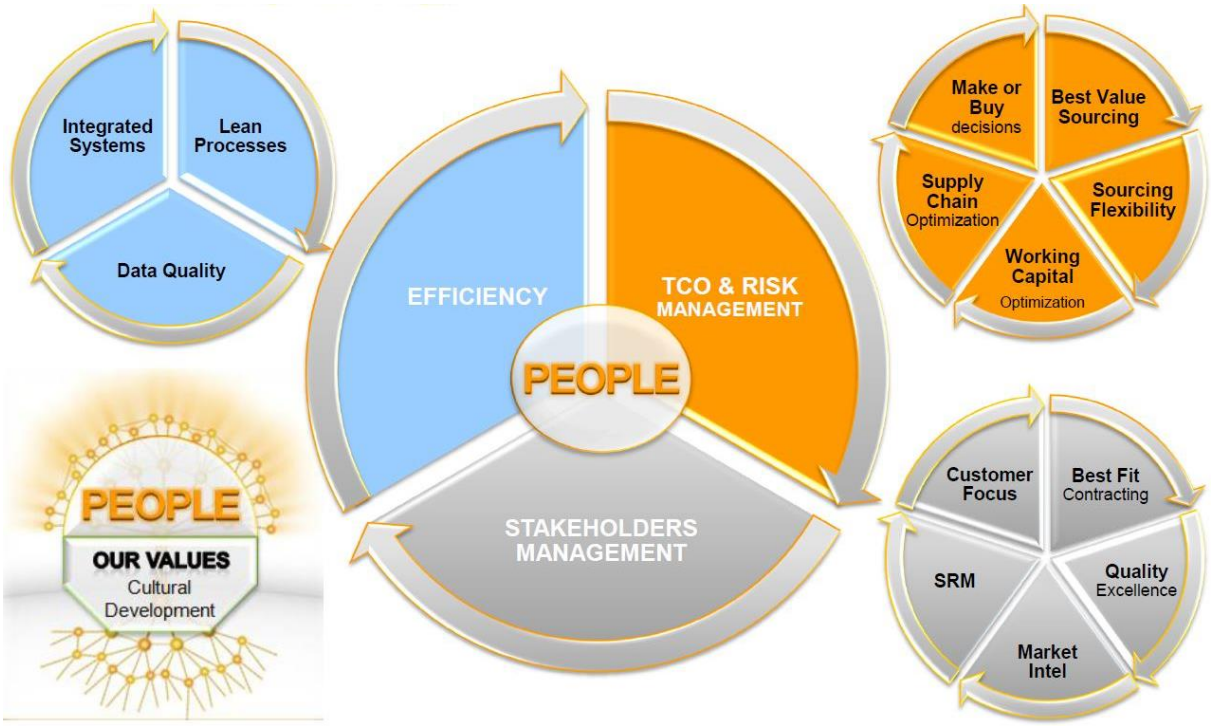
SUSTAINABLE PROCUREMENT
- Supplier Environmental Performance
- Supplier Social Performance

APPENDIX N: Core Processes of Tire Division Purchasing





APPENDIX O: Purchasing Strategy of Tires Division

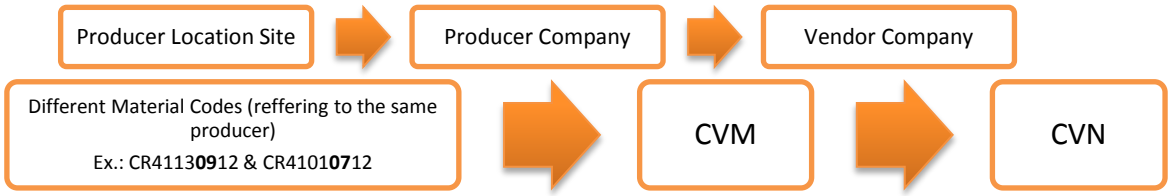


APPENDIX P: Suppliers' Codes Hierarchical System

Example 1 – Basic scenario, for each producer company 1 CVM, each vendor 1 CVN.

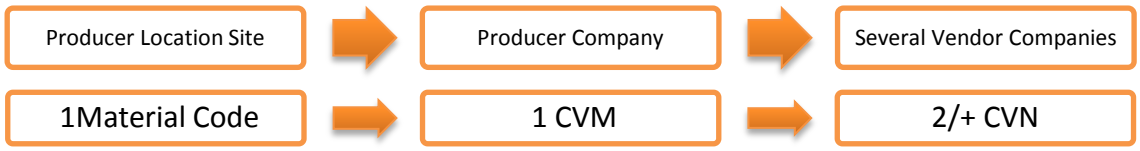


Example 2 – same producer company supplying different materials, sold by 1 vendor.



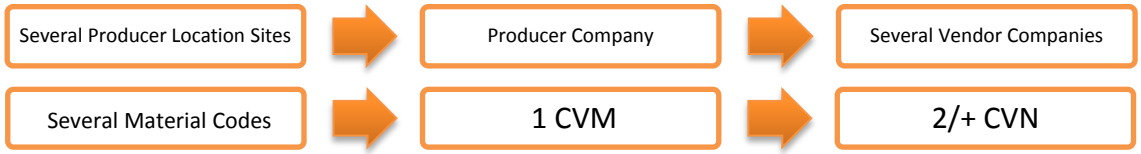
Though both material codes refer to the same producer location and company, it is the 7th and 8th digits of the code, together with the 6 first digits, that define it, and not the 7th and 8th digits alone, as it happens with packaging (see example above).

Example 3 – several different vendor companies are selling from the same producer the same material.



In this situation, usually the selling price is the same. This situation happens for trade purposes. In some cases the producer might be located in nations with unfavourable trade conditions, and the vendor might be located, for instance, in Europe, allowing facilitated commercial relations (for instance, consignment agreements).

Example 4 – Different vendors selling from the same producer company, with different production site locations.



In this situation selling price varies. Since the production location is not the same, different feedstocks, transportation and packaging prices may apply, changing the delivered price to the customers.

APPENDIX Q: Gantt Diagram for Project Planning

Time Plan:	**W01**	**W02**	**W03**	**W04**	**W05**	**W06**	**W07**	**W08**	**W09**	**W10**	**W11**	**W12**	**W13**	**W14**	**W15**	**W16**
Workshop Health & Safety																
Visits to Mabor Plant																
Variables Definition																
Database Mock-up Construction																
Interface Mock-up Development																
Discussions with Lead-Buyers																
Mathematical model mock-up																
1st Milestone																
Data Collection																
Costs improvement method development																
Sustainability approach definition																
2nd Milestone																
Improvements on user interface																
Simulations and results analysis																
3rd Milestone																

APPENDIX R: Information Scheme for the Database Development

Material
Code
Name
Family
CPMG
Participation Tire

Packaging
Code
Type
Material
Returnable (Y/N)
Units/Container Returnable
Leasing (Y/N)
Company

Plant
Code
Name Plant
Address Plant
€/sqm/month
Max. Height
Max. Weight
WOOD conversion €/unit
Country
Decanting €/TON
Warehouse Handling €/TON
Silo Lifetime
Average Silo Cost
Silo Handling

Vendor
Code
CVM
Producer Name
Producer Address
Country
Company
EcoVadis Total
EcoVadis Environment
EcoVadis Labour Practices
EcoVadis Fair Business Practices
EcoVadis Sustainable Procurement

Type of Transport
Code
Type
tonCO2/km
€/tonCO2
€/km

Material_Packaging
Key
Length
Width
Height
Max. weight (ton/unit)
Units/load
Returning Coefficient
Individual Stack
Area
EcoImpact
Max. weight (ton/unit/sqm)

Material_Plant
Key
Annual Demand
Silo Handling €/TON
Silo Number
Average Capacity/TON

Material_Vendor
Key
€/TON fee
Capacity
Minimum Order
Maximum Capacity Utilization
SPM Overall
SPM Company
SPM Technology
SPM Supply
SPM Quality
SPM Cost and Finance
EcoVadis

Plant_Vendor
Key
Distance
Type of Transport
Full Lead-Time
Incoterm Lead-Time

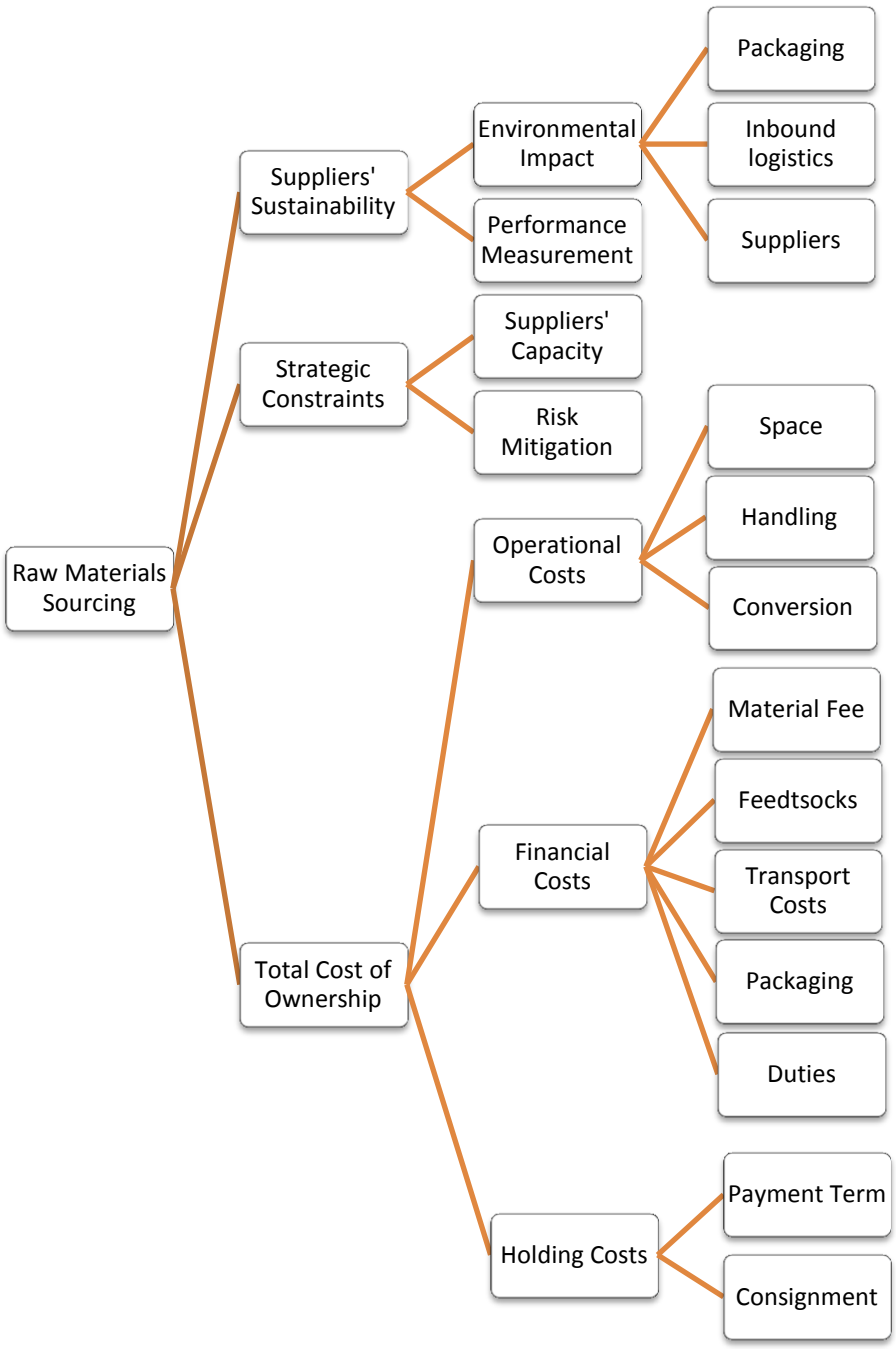
Material_Plant_Vendor
Key
Consignement
Incoterm
Duties
Payment term
Transport €/TON
FeedStock
Average Inventory Stock
Average Inventory Time (days)
Average Inventory Time (months)

Material_Packaging_Plant
Key
Max. Stack
Wood Conversion €/ton
Decanting
Conversion Price
Handling Price

Material_Packaging_Vendor
Key
Packaging €/unit
Packaging €/TON

Material_Packaging_Plant_Vendor
Key
Delta Silo
Delivered Price
EcoImpact Transport
Space Costs
GIT
Stock
Annual Purchase Volume
Average Payables
Average Inventory
Net Working Capital
Net Working Capital / TON
Holding Costs
WACC

APPENDIX S: Raw Materials Sourcing Decision Criteria Applied



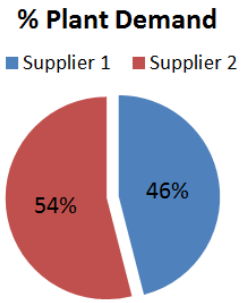
APPENDIX T: Allocation Output Report

Company	Supplier 1	Supplier 2	Supplier 3
Supplier Site	A	B	C
Packaging	0002	0002	0002
8200 Lousado	0	20368	23528
0200 Aachen	5267	4733	0
4000 Korbach	502	0	0
2500 Port Elizabeth	0	0	20000
2600 Sumter	0	635	0
1000 Pushover	1494	0	0
1200 Mount Vernon	0	0	2156
1600 San Luis Potosi	1284	0	0
2200 Timisoara	1614	0	0
3300 Cuenca	787	0	0
4800 Camaçari	1968	0	0
6600 Otrokovice	2084	0	0
5500 Sarreguemines	0	0	370

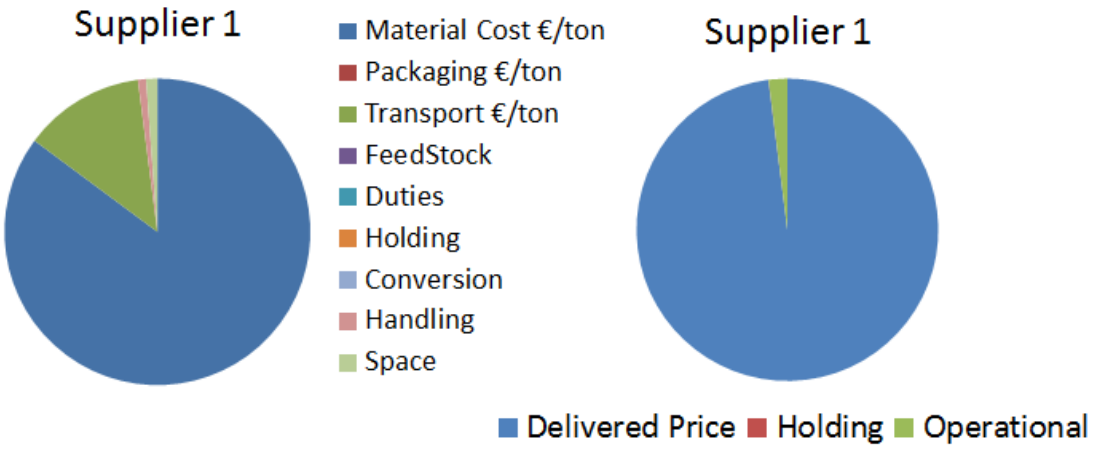
Sourcing Report - Lousado

Material: SR 2 **Date:** 22.06.2017
Lead-Buyer: Marta S. **End:** 31.12.2017

Supplier 1	Supplier 1	
Quantity	20368 ton	
SPM	87	
EcoVadis	60	
Packaging	Plastic Pallet	N
Supplier 2	Supplier 2	
Quantity	23528 ton	
SPM	92	
EcoVadis	55	
Packaging	Plastic Pallet	N



Sourcing Report: Supplier 1 to Lousado



APPENDIX U: Questionnaire for Packaging Ecological Impact Assessment at the Plants

Packaging Ecological Impact Ranking

Material Master	Packaging Code	Final Score	
CR7801	0005	#N/D	Calculate

How many main items compose the packa: 2

1	2	3	4	5

Please select the materials of each of those items.

Wood	Synthetic Fit	-	-	-

Which items of the packaging are returnable? (Y/N)

Y	N			

note

Which items of the packaging are considered waste? (Y/N)

For the Non-Waste, Non-Returnable ones, which ones have reuse potential? (Y/N)

If there is reuse potential, how many times can they be used in the plant? (No=0, Yes=number of

How much does the packaging weight? (total in kg)

How much material does it carry? (total in kg)

End of questionnaire, please check the score.

Example

Please fill in the questionnaire for a new packaging on the left side, as shown in the example underneath.

Material Maste	Packaging Code
CB1000	0032



How many main items compose the packaging?

2

1	2	3

Please select the materials of each of those items

Plastic	Synthetic Fit	

Which items of the packaging are returnable? (Y/N)

Y	N		Please leave empty the non-used fields

Which items of the packaging are considered waste? (Y/N)

N	Y		If returnable, Waste=N

For the Non-Waste, Non-Returnable ones, which ones have reuse potential? (Y/N)

N	N		If it is possible to use them again, even if outside Continental (selling).

If there is reuse potential, how many times can they be used in the plant?

0	0		One time meaning one process.

How much does the packaging weight? (total in 70

How much material does it carry? (total in kg) 1000

End of questionnaire, please check the score.

APPENDIX V: Suppliers' Packaging Requirements Manual Template

PACKAGING MANUAL

Version 0.1
Material: synthetic rubber 1
Plant: Mabor Lousado
Supplier: A
Comments: Example

1. General requirements

When selecting packaging, standard packaging material from the receiving plant shall be considered first as it meets the following requirements and has already proved its effectiveness in practice. Generally, packaging should be:

- Easy to open and close
- Easy to repack
- Reusable
- Environmentally compatible
- Safe

The supplier is responsible for the quality and delivery of the products and therefore also for compliance with these packaging requirements. It is the responsibility of the supplier to provide individual and/or collective packaging for the goods. The packaging provided by the supplier shall ensure that the goods reach their destination in sufficient condition.

This norm shall apply to all worldwide activities of Continental and all deliveries to worldwide destinations of Continental. This norm is part of the currently valid purchasing agreement between the supplier and Continental and states binding requirements for logistic processes and procedures. Except otherwise explicitly laid down in the currently valid purchasing agreement, the supplier shall undertake to meet the requirements stated in this norm.

2. Packaging definition procedure

Continental-plant specific demands/requirements are to be agreed with the logistics department of the receiver's plant directly. Packaging must be approved during material approval process from the plant. If the option provided is not accepted, due to non-compliance with the requirements here mentioned, another solution has to be agreed among both parts.

3. Technical requirements

It is of responsibility of the supplier to provide the packaging under the following conditions:

- Damage free
- Stackable, slip-resistant
- Standard for automatized handling
- Designed to form lots and save space
- Maximum gross weight of _____(specify weight) kg per pallet
- Maximum gross weight of 15kg for manual handled loading unit
- Load capacity for distributed static preferably minimum _____ (specify weight) kg each pallet
- Load capacity in stack for distributed load static minimum 4000kg each pallet
- Charpy impact strength minimum 10KJ/m2

- Metal or wood pallets shouldn't have paint
- Pallet construction: 4-way-pallet with minimum 3 runners, height minimum 140mm, height for forks minimum 100mm.
- (etc.)

4. Packaging design improvements

Non-returnable/ expendable packaging should be avoided where possible. If non-returnable packaging is preferred to returnable packaging for economic reasons, only packaging, ancillary packaging and loading packaging approved by Continental may be used. All such materials shall be environmentally compatible and recyclable and shall be marked with the „RESY- symbol"(only for domestic Europe). These materials are defined in "Approved Materials".

5. Approved materials

- Metal
- Plastic (…)

6. Non-Approved materials

- Wood (…)

7. Securing devices

In order to ensure safe handling (in accordance with accident prevention and other regulations) and smooth operations, it is essential for all goods to be delivered in accordance with the requirements stated in this section.

- Temperature resistant
- Corrosion resistant
- Chemically neutral
- Shockproof
- Tear-proof

Corrosion protection should be applied, however, hazardous materials should be avoided. Straps or other security systems should be applied when packaging is not rigid. PET is the recommended material for straps.

(etc.)

8. Accepted and non-accepted pallets/loading units

Example 1: Stackability of Loading Units
Unacceptable condition:

- 2-way pallets
- Presswood-pallets
- Stretched single cartons
- Single cartons with no outer cardboard box

Acceptable condition:

- 4-way-free-entry block-pallet
- The loading unit is strapped with PP- or PET- straps
- The loading unit is stackable

(etc.)

9. Pallet standards

Container Optimized Wood Pallet L1108 1140x790x140 98-4525-0108-0-00
Container Optimized Wood Pallet L1110 1140x980x140 98-4525-0110-0-00
Plastic-Light-Pallet 1200x800x150 98-0348-1285-0-00
Plastic-Heavy-Pallet 1200x800x160 98-0789-1103-1-00
(etc.)

10. Contacts

Any doubts or complaints should be sent to: packaging@example.email.conti.de

APPENDIX X: Results Analysis – Scenarios Table

Scenario	Expected Effect	Synthetic Rubber 1	Synthetic Rubber 2	Carbon Black	Synthetic Rubber 3
i	Demand split amongst more expensive suppliers should compensate the **shortage cost** effect on total spent.	Splitting demand is 1% more expensive than paying for shortage costs.	Splitting demand is 4% more expensive than paying for shortage costs.	Splitting demand is 15% more expensive than paying for shortage costs.	Splitting demand is 0,19% more expensive than paying for shortage costs.
Conclusion	For the current level of shortage costs, there is no point in performing demand split. However, in case these costs raise 1%, 4%, 15% and 0,19% respectively for each of the materials represented, splitting demand should be considered.				
ii. a	The longer the **payment term**, the lower the total spent.	Valid	Valid	Valid	Valid
ii. b	The bigger the percentage of the demand with stock on **consignment**, the lower the total spent. Break-even point when effect on total spent of payment term equals consignment effect.	Valid B.E. 105 days	Valid B.E. 120 days	Valid B.E. 90 days	Valid B.E. 135 days
ii. c	The higher the **fluctuation of the feedstocks**, the bigger is its participation on total spent, and the higher is its variation.	Not applicable	Not applicable	Valid	Valid
Conclusion	Feedstocks fluctuations forecast should be as accurate as possible, in order to proceed with the necessary sourcing decisions, to minimize their effect on total spent.				
ii. d	By using lower values of **capacity occupation** of the supplier, more expensive options of suppliers will be assigned to plants, raising total spent.	Valid	Valid	Valid	Valid
ii. e	When **space costs** rise, more efficient packaging is chosen, even though if its price is higher. Break-even value for space costs will change the optimum packaging option.	Valid B.E. 12€	Valid B.E. 18€	Valid B.E. 76€	Not applicable. Only 1 type of packaging analysed.
ii. f	When **warehouse handling prices** rise, alternative storage systems are chosen, such as silos. There is a break-even value for handling costs that changes optimum warehousing conditions.	Not applicable. Only 1 type of warehousing analysed.	Not applicable. Only 1 type of warehousing analysed.	Valid B.E. 59€	Not applicable. Only 1 type of warehousing analysed.
ii. g	The same situation applies to **conversion costs of packaging**, provoking	Not applicable. Packaging	Not applicable. Packaging	B.E. 57€	Not applicable. Packaging

	changes in packaging choices. Break-even values can also be found.	analysed doesn't require conversion.	analysed doesn't require conversion.		analysed doesn't require conversion.
ii. h	**Silo truck transportation costs** can increase in such an amount that it is preferable to send big bags in normal trucks instead. A break-even point for this change can be found.	Silo transportation not applicable.	Silo transportation not applicable.	B.E. 67€	Silo transportation not applicable.
Conclusion	Each of the factors analysed has a very particular effect on total spent and allocation (analysed in more detail in chapter 4.3.3). However, it can be seen that the system is complying with the expected results.				
iii	Payment Term Long/Short (180/14 days)	-3,22% /+1,35%	-3,12% /+1,18%	-3,31% /+1,27%	-2,41% /+2,22%
	Consignment Yes/No	-1,11% /+0,17%	-1,56% /0%	-0,93% /+0%	-1,35% /+0,36%
	Feedstocks +/- 50% (all feedstocks included)	Not applicable.	Not applicable.	+30,85% /-22,80%	+13,73%/-36,29%
	Capacity occup. 30%/95%	+5,17% /+0,1%	Not enough capacity /0%	+5,34% /0%	0% /0%
	Space Costs High/Low (100€/1€)	+4,26% /-0,67%	+11,28% /-2,62%	+3,25% /-0,15%	+2,37 /-0,14%
	Handling High/Low (100€/1€)	Not applicable.	Not applicable.	+3,25% /-0,39%	Not applicable.
	Conversion High/Low (100€/1€)	Not applicable.	Not applicable.	+0,46% /-0,35%	Not applicable.
	Silo Truck Transp. High/Low (150€/50€)	Not applicable.	Not applicable.	+0% /-0,25%	Not applicable.
iv	More sustainable options can force the algorithm to choose more expensive suppliers, raising the total spent.	Not available data.	Not available data.	+13%	Not available data.
Conclusion	It is possible now to calculate how much it has to be invested in order to choose more sustainable options. On the other hand, sustainability investment budget can be defined, then optimal allocation can be defined in order to match those values.				
v	Variation between manual allocation done in 2016 and algorithm allocation with strategic constraints.	+1%	-0,21%	Not available data.	-0,34%
Conclusion	Since small variations between manual allocation and algorithm strategic splitting are found, it can be said that the system is validated.				