A Supplier Selection and Evaluation Methodology as a Procurement Strategy

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Abstract

The growing need to assure competitive advantage in today's dynamic market is putting high pressure in companies to focus on their internal value-adding processes. Companies are acquiring more products and services from external sources which is resulting in higher supplier dependency and demanding an effective management of their supply chain.

Through literature review, it was possible to understand the importance of purchasing in companies and of the application of supplier management approaches. Strategies for selection, evaluation and development of suppliers were studied and analyzed for a possible application to the company where this dissertation was developed, ADIRA.

This dissertation emerges during a period of reorganization, where ADIRA's processes are being reviewed as a way of turning them as efficient and effective as possible. The focus of this work is supplier management processes, through a detailed analysis of what is currently done and its performance and consequences in the company.

The project targets three key processes of supplier management: selection, evaluation and development of suppliers. Initially, it has been proceeded an analysis of the existing processes in the company, where opportunities for improvement were identified as well as solutions were proposed regarding the main problems detected.

One of the proposed methodologies consists in the creation of a formal and structured supplier selection model, through the use of the analytic hierarchical process and weighted scoring model, based on a set of previously defined criteria. Another proposal relates to the improvement of the current process on supplier evaluation, where the evaluation structure and methodology as well as the requirements on suppliers' performance were defined. Finally, it is proposed the structuring of the supplier development and relationship management strategies in order to ensure the continuous improvement of supplier performance.

Keywords: purchasing and supply management, supplier management, supplier selection, supplier evaluation, supplier development, supplier relationship management.

Resumo

A crescente necessidade de assegurar vantagem competitiva no mercado dinâmico atual obriga, cada vez mais, as empresas a concentrarem-se nos processos internos criadores de valor. Com isto, as empresas estão a adquirir mais produtos e serviços a entidades externas, aumentando a sua dependência de fornecedores e exigindo uma gestão eficaz da sua cadeia de abastecimento.

Através da revisão da literatura foi possível compreender a importância do papel das compras nas empresas e da aplicação de estratégias para a gestão de fornecedores. Estratégias de seleção, avaliação e desenvolvimento de fornecedores são analisas e estudadas para uma possível aplicação na empresa onde foi desenvolvida esta dissertação, a ADIRA.

A presente dissertação, surge num período de reorganização da ADIRA, onde os processos estão a ser revistos a fim de torna-los o mais eficientes e eficazes possíveis. O foco deste trabalho são os processos relacionados com a gestão de fornecedores, através de uma análise detalhada do que é feito atualmente e do seu desempenho e consequências na empresa.

O projeto incide em três processos chave da gestão de fornecedores: seleção, avaliação e desenvolvimento dos fornecedores. Inicialmente, procedeu-se a uma análise dos processos da empresa onde foram identificadas oportunidades de melhoria e feitas propostas de soluções para os principais problemas detetados.

Uma das metodologias propostas consiste na criação de um sistema formal e estruturado de seleção de forncedores, através do método *analytic hierarchical process* e o modelo de pontuação ponderada, tendo por base um conjunto de critérios previamente definidos. Outra proposta relaciona-se com a melhoria do processo atual de avaliação de fornecedores, onde se definiu a estrutura e a metodologia de avaliação, bem como os requisitos de desempenho dos fornecedores. Por último, propõe-se a estruturação das estratégias de desenvolvimento e gestão de relações com fornecedores de modo a assegurar a melhoria contínua do desempenho dos fornecedores.

Palavras-chave: gestão de compras e fornecimento, gestão de fornecedores, seleção de fornecedores, avaliação de fornecedores, desenvolvimento de fornecedores, gestão do relacionamento com fornecedores.

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Last but not least, to all my friends, for growing up alongside me, for all the support, and above all for their great friendship.

"The proper function of men is to live, not to exist."

Jack London

Contents

Acronyms and Symbols

AHP	Analytic Hierarchical Process
BI	Business Intelligence
BOM	Bill of Materials
CI	Consistency Index
CON	Consumable
ELE	Electrical
ERP	Enterprise Resource Planning
KPI	Key Performance Indicator
MCDM	Multi-Criteria Decision-Making
MEC	Mechanical
MRP	Material Requirements Planning
NCF	Non-Conformities
OTD	On-Time Delivery
PSM	Purchasing and Supply Management
QMS	Quality Management System
RI	Random Index
RM	Raw Material
SCM	Supply Chain Management

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Chapter 1

Introduction

The present work was developed under the Dissertation course of the Integrated Master in Engineering and Industrial Management of the Faculty of Engineering of the University of Porto. It was developed under the scope of purchasing and supply management, in the Purchasing & Logistics Department of ADIRA Metal-Forming Solutions S.A..

In this chapter, the project itself is further explained with the presentation of its motivation and objectives. The company description and the structure of the document are also presented.

1.1 Context and Motivation

In today's highly competitive business environment, companies are more willing on developing purchasing functions since the purchase of goods and services can affect company performance (Prasad et al., 2016). In addition, intense competition in the market, increasing customer demand and the development of the latest technologies have forced companies to commit themselves to higher quality, better lead times and lower costs (Imeri et al., 2015). These changes have led to a more transparent and systematic attitude towards supplier selection (De Boer et al., 2001) and to a more objective evaluation of suppliers' performance (Imeri et al., 2015).

Efficient supplier evaluation and selection processes can help on achieving cost savings and performance improvement as well as mitigating risks (Gordon, 2008), translating in high potential profitability of a company (Imeri et al., 2015). Moreover, it is also a powerful tool in identifying and reducing poor quality costs which, in some industries, can make up to 50% of total costs (Gordon, 2008).

The present dissertation, developed in the Purchasing & Logistics Department of ADIRA Metal-Forming Solutions S.A., had its focus on the development of the procurement process, as a way of minimizing late deliveries and poor quality purchases so that production is not jeopardized by the company's suppliers. At the same time, reducing purchasing costs and enhancing supplier relationships are also among the motives for developing this research.

To tackle this challenge and to support medium to long term strategy, the creation of a supplier selection framework, the development of the current supplier evaluation process, and a structured strategy on supplier development, were proposed.

1.2 Company Background

With more than 60 years of history, ADIRA is a Portugal-based company operating in the engineering and manufacturing of machine tools for the metal forming industry, mostly for customers outside Portugal. With this in mind, the company desires to evolve from "Iberian Leader" to a multi-continental structure in order to establish closer relations with each customer.

The range of ADIRA's products includes laser cutting machines, hydraulic press brakes, shears, robotized bending cells, automatic sheet metal transforming systems, and in more recent years additive manufacturing solutions. The company is recognized as technologically dynamic and strong committed to innovation and R&D investments. This has allowed ADIRA to earn different awards, such as an innovation prize in 2017 awarded by COTEC-ANI (Portuguese Innovation Agencies).

The company's mission statement is to listen to its costumers and supply them innovative and customized solutions for efficient sheet cut and forming, with the highest international standards. In 1994, ADIRA became the first European machine-tool manufacturer to be certificated by ISO 9000, and the first worldwide to have all its products with CE certification. To this days, ADIRA's quality management system (QMS) is in accordance with the requirements of the standard ISO 9001:2015.

In June 2017, Sonae Capital SGPS S.A. acquired 100% of the share capital and voting rights of ADIRA. This led to an organizational restructuring so that the company got integrated into Sonae Capital's reality.

1.3 Objectives of the Dissertation

To keep up with the growing pace of ADIRA's business, supplier management has become a natural part of the purchasing process. The main concern comes to the level of selecting and evaluating suppliers in order to avoid damage to the company's revenue or reputation as well as minimizing risks.

Everyday high quantities of non-conforming supplies and delayed purchase arrive to ADIRA's warehouse. Consequently, there are constantly missing components on production leading to disruptions, which is currently one of the critical dilemmas of ADIRA. Due to the lack of defined processes on managing suppliers, nothing structured and standardized is being done about it. With that being said, the main goal of this dissertation is concerned with the development of supplier selection and evaluation methodologies.

In the context of this dissertation, the following research questions were selected:

- RQ1: How to properly identify the best-fit supplier to an identified need?

- RQ2: What supplier performance evaluation process would fulfill ADIRA's requirements and needs?
- RQ3: How can ADIRA better develop their suppliers?

Answering this questions requires analyzing, describing, defining, and comparing different supplier selection and evaluation methodologies through a literature review. Moreover, it also calls for an analysis of the current situation of the company, the identification of improvement opportunities and the choice of the relevant methodologies to be applied.

1.4 Methodology

The methodology adopted during this project can be divided into three main moments: data collection, AS-IS analysis, and TO-BE process.

The first moment consisted on collecting all relevant data and information on how procurement worked in ADIRA. Data was obtained through the company's internal database, Enterprise Resource Planning (ERP), and also from internal Business Intelligence (BI) software. The analysis of the data was a time-consuming process due to not only the extensive amount of evidences but also inaccurate information. Over this first moment, it was also developed a intensive literature research to better understand the problem and to get familiar with suitable methodologies for the case.

Secondly, an AS-IS analysis was developed. By analyzing existing documents and direct interacting with the company's purchasers it was possible to model the current processes of ADIRA. Moreover, after cleaning and preparing the data collected for this work, the problems associated with purchasing were quantified and the path for the work defined.

The last moment involved the design of potential improvement actions on the matter of opportunities identified. The key features of the proposed processes are defined and clear instructions for each one were prepared.

1.5 Document Structure

The structure of this dissertation is divided into five chapters. It is outlined as follows.

In the current chapter the subject of this dissertation was introduced. Firstly the motivation and context of the dissertation was presented, followed by a description of ADIRA, the company where this dissertation was developed. The methodology used in the dissertation was also described in this chapter.

Chapter 2 presents a literature review about purchasing and supply management with special focus on supplier selection and development and how it is related with supply risks. The aim was to understand the impact of this concepts in the company's performance. In addition, this chapter also reviews potential techniques for dealing with suppliers as well as current discussion topics such as Procurement 4.0.

Chapter 3 focus on describing the current situation of ADIRA. First, it analyses how the Purchasing and Logistics Department is organized. After, the processes inherent to suppliers are specified. Finally, the main problems are highlighted and improvement proposals identified.

In Chapter 4 it is proposed a model for selecting and evaluating suppliers' performance. The model is in relation to the problems found on the current situation of the company, and aim on satisfying the identified needs for improvement. In the end of this chapter the results and a brief discussion are presented.

Finally, Chapter 5 summarizes the main findings of this project, and hints future research directions.

Chapter 2

Literature Review

Purchasing and Supply Management (PSM) has been an increasing area of interest over the past years. Many professionals have realized that purchasing, and consequently supplier relationships, represent a noticeably field for improvement.

In the present chapter the theoretical concepts, theories and methods that serve as a base for this dissertation are introduced. Relevant contents related to PSM including agile procurement, supplier selection, evaluation and development as well as decision approaches and performance measurement techniques are encompassed in this literature review.

Over this document, the terms "purchasing and supply management" and "procurement" will be interchanged.

2.1 Purchasing and Supply Management

Supply Chain Management (SCM) entails activities as planning, supply management, manufacturing, transportation, warehousing and distribution in its management efforts (Wook, 2006). As a part of the SCM, PSM is a strategic mechanism for managing suppliers while assuring the acquisition of the company´s current and future needs (Trent, 2007). Over the years, its focus shifted from a transaction-oriented function to a strategic capability (Gordon, 2008). This means that companies are less focused on sales only and more oriented to employ competitive advantages to its business. According to Gordon (2008), the reasons behind this transformation include globalization, the increased dependence on outsourcing goods and services, and the need for enhancing market responsiveness.

To this days PSM is considered a crucial factor on flexibility and responsiveness (Monczka et al., 2016) as well as a key component of a firm's short-term financial stability and also of the long-term competitive advantage (Van Weele, 2010). The development of its strategy is capable of having an impact on the quality of a product or service, of increasing the customer value and of improving product and process designs (Monczka et al., 2016). Finally, and due to the fact that purchasing costs may represent around half of a company's sales turnover, it can also help on reducing costs (Van Weele, 2010).

The concept of purchasing goes far beyond the idea of merely obtaining goods or services in order to satisfy a customer's need. It requires buying the products or services at the right price, from the right source, at the right specification, in the right quantity, and to be delivered at the right time and at the right internal customer (Monczka et al., 2016).

Factors as quality and delivery time are becoming increasingly critical and fundamental to the competitiveness of an organization. Additionally, challenges as focus on the service level, research productivity and efficiency, and increasing integration with suppliers in the value chain, are continually increasing the pressure on a company's performance and on how to handle purchasing processes (Nicoletti, 2018).

2.2 Procurement Process

The procurement process generally identifies user requirements, effectively and efficiently evaluates the need, identifies suppliers, ensures payment occurs correctly, confirms that the need was effectively met, and push forward continuous improvement (Monczka et al., 2016). In a more detailed way, the authors present the process as follows:

1. Forecast and plan requirement: identification of a need (requirement);
2. Need clarification: communication to purchasers what is needed and for when it is required;
3. Supplier identification and selection: choice between fulfilling the need by a supplier that has an existing contractual relationship with the buying company or by a new supplier;
4. Approval, contract, and purchase order generation: definition of quantity needed, material specification, quality requirements, price, delivery date, method of delivery, ship-to address, purchase order number, and order due date;
5. Receipt and inspection: transmittal of purchase requirements to the selected supplier;
6. Invoice settlement and payment: issue an authorization for payment to the supplier;
7. Records maintenance: identification of critical events associated with the purchase to identify trends or patterns in supplier performance;
8. Continuously measure and manage supplier performance.

In a similar way, Nicoletti (2018) includes a list of different activities in the procurement process, which are schematically illustrated in Figure 2.1. It starts with an assessment, where it is required a decision of making in-house or outsourcing. After reaching the decision of buying a product or service, it is necessary to determine the supply mean by choosing the right suppliers. The next steps involve defining rules and a management system for the supply base, and also reaching strategic decisions regarding procurement.

The procurement process can be highly complex. It includes strategic, tactical and operational activities and implies informational, physical and financial flows over the many stakeholders involved (Nicoletti, 2018).

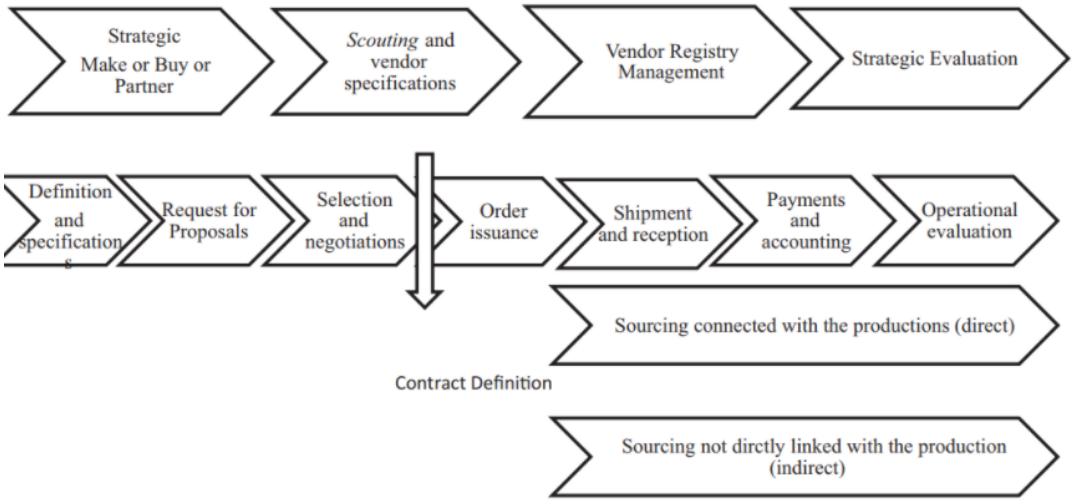


Figure 2.1: Agile procurement processes. Source: Nicoletti (2018)

As procurement evolve, companies start looking beyond traditional areas of tactical supply assurance and price. They are currently spending more time on the strategic part of the business which requires coordination and collaboration not only with suppliers but also with internal stakeholders. As shown in Figure 2.2, the value of procurement is much more than a mere buying function, it has become a consulting and changing agent (The Hackett Group, 2018).

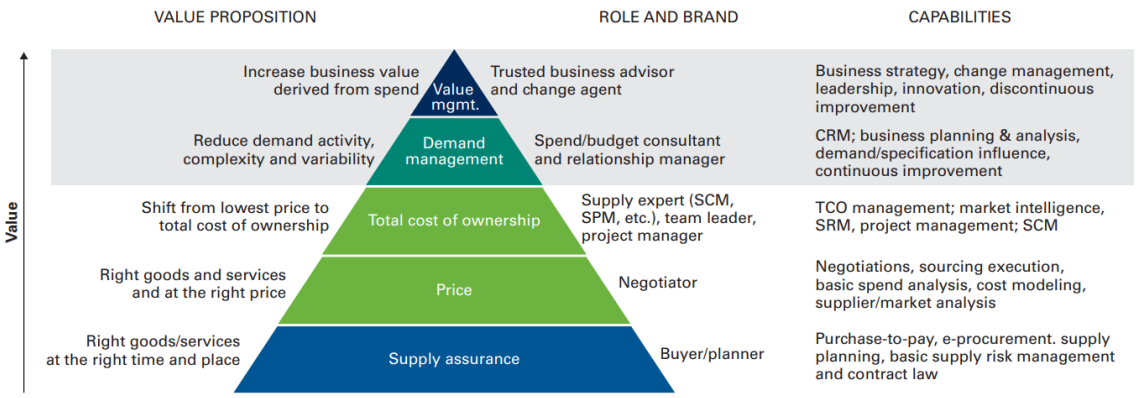


Figure 2.2: Procurement value pyramid. Source: The Hackett Group (2018)

For 2018, The Hackett Group (2018) identifies different critical procurement development areas that companies should take into account. It includes the alignment of procurement skills and talent with changing business needs, measurement and management of procurement performance and business value, acquirement of more value from existing suppliers through relationship management, and obtainment of more value from existing categories through category management.

2.2.1 Supplier Selection

One of the crucial steps of the procurement process identified by Monczka et al. (2016) is supplier selection. The authors go into further detail in the subject and develop a seven-step methodology, outlined in Figure 2.3.

Overall, supplier selection consists on identifying, evaluating and contracting a supplier among a list of potential ones for a determined need (Beil, 2010). It aims not only on reducing risks but also on maximizing value to the buyer (Monczka et al., 2016).

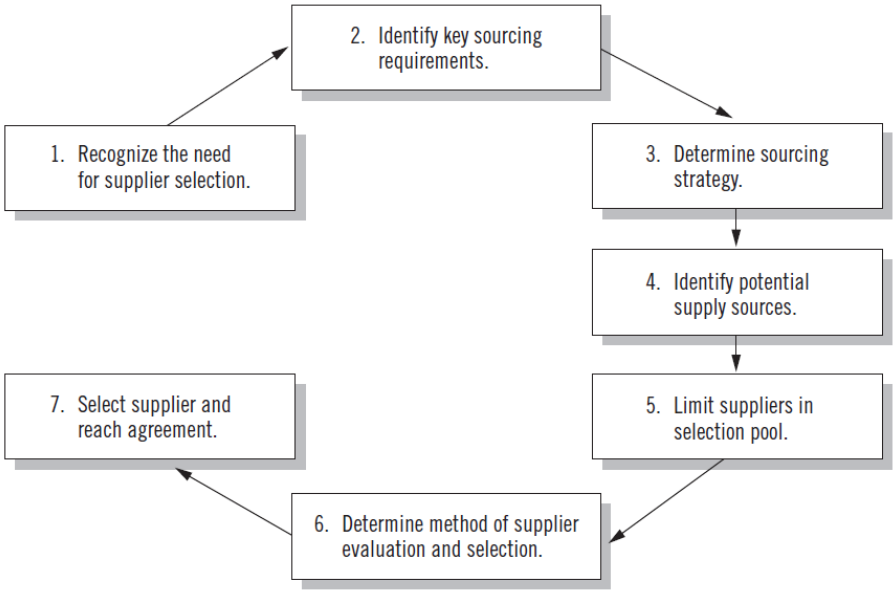


Figure 2.3: Supplier selection and evaluation process. Source: Monczka et al. (2016)

Supplier selection is commonly considered and solved as a Multi-Criteria Decision-Making (MCDM) problem. This means that the decision of selecting a supplier involves conflicting factors and requires a trade-off among several criteria (Shukla, 2016). These criteria are the aspects the buyer must consider when selecting a suitable supplier (Monczka et al., 2016).

Since the 1960s that the set of criteria for the selection process has been discussed. One of the pioneers in this matter was Dickson (1966) who identified 23 criteria that companies found important at that time. Out of these 23 factors, Dickson (1966) set quality, delivery and performance history as the three most important criteria. Later, Weber et al. (1991) reported that quality and delivery performance were still among the most important criteria, followed by price. This shows the variation that might exist on different situations, and that the formulation of criteria for the selection process is highly individual for different companies and should be defined according to its own objectives (De Boer et al., 2001).

Over the years, several approaches have been studied to determine an effective supplier selection process. Chai et al. (2013) developed a literature review on decision making techniques connected to supplier selection, and determined that the most frequently used is the Analytic Hierarchy Process (AHP). This technique is followed by Linear Programming, Techniques for Order

Preference by Similarity to Ideal Solution, the Analytic Network Process, and Data Envelopment Analysis. Besides this, the authors also denote that there are other perspectives in addition to MCDM techniques such as mathematical programming, artificial intelligence and integrated approaches.

The focus of this dissertation combines the use of AHP with a simple weighting-rating method.

2.2.1.1 Analytic Hierarchy Process

AHP was developed by Thomas L. Saaty during the 1970s and is an effective tool for handling with MCDM problems. It involves a pairwise comparisons between a set of criteria and alternatives, from which they are evaluated and weighted to reach a final decision (Nawara et al., 2017).

Saaty (2008) decomposes the decision process into four steps:

1. Clearly define the decision problem;
2. Break down the decision into a hierarchy that includes the goal, criteria and alternatives;
3. Create the pairwise comparison matrices, by performing comparative judgments. It aims on measuring the relative importance of the criteria and alternatives to the overall goal;
4. Weight the priorities of each criteria and alternative, and obtain the global priority.

In order to compute the priority weights for the different criteria, AHP starts creating a pairwise comparison $m \times m$ matrix $\mathbf{A}$, with m being the amount of criteria considered. Each entry a_{ij} of the matrix $\mathbf{A}$ represents the importance of the ith criterion relative to the jth criterion. If $a_{ij} > 1$, then the ith criterion is more important than the jth, while if $a_{ij} < 1$ is the other way around. If two criteria have the same importance, then the entry a_{ij} is equal to 1. Moreover, the constrain $a_{ij}.a_{ji} = 1$ must be satisfied, as well as a_{ii} obviously equals to 1 (Saaty, 1980).

Once the matrix $\mathbf{A}$ is built, it is possible to derive from it the normalized pairwise comparison matrix A_{norm} by making equal to 1 the sum of the entries on each column. Finally, the criteria weight vector w, an m-dimensional column vector, is built by averaging the entries on each row of A_{norm} (Saaty, 1980).

For computing the matrix of option scores, a $n \times m$ real matrix $\mathbf{S}$ is created, with each entry s_{hi} representing the score of the hth alternative with respect to the ith criterion. In order to derive such scores, a pairwise comparison matrix $\mathbf{B}$ is first built for each of the m criteria. $B^{(i)}$ is a $n \times n$ matrix, where n is the number of alternatives evaluated. Each entry $b_{hl}^{(i)}$ of the matrix represents the evaluation of the hth alternative compared to the lth alternative with respect to the ith criterion. If $b_{hl}^{(i)} > 1$, then the hth alternative is better than the lth alternative, while if $b_{hl}^{(i)} < 1$, then the hth alternative is worse than the lth alternative. If two options are evaluated as equivalent with respect to the ith criterion, then the entry is equal to 1. Moreover, the constrain $b_{hl}^{(i)}.b_{lh}^{(i)} = 1$ must be satisfied, and $b_{hh}^{(i)}$ equals to 1 (Saaty, 1980).

Then, AHP applies to each matrix $B^{(i)}$ the same two-step procedure described for the pairwise comparison matrix $\mathbf{A}$, thus obtaining the score vectors $s^{(i)}$. Finally, the score matrix $\mathbf{S}$ is obtained

as $S = [s^{(1)}...s^{(i)}]$. Once the weight vector w and the score matrix $\mathbf{S}$ have been computed, AHP obtains a vector r of global scores by multiplying $\mathbf{S}$ and w(Saaty, 1980).

To conclude, the pairwise comparisons allow finding the relative weight of the criteria with respect to the main goal. It also finds the relative importance of the alternatives with respect to each of the criteria. The comparisons can be easily completed when the accessible data is quantitative, based on a defined scale or ration (Dweiri et al., 2016). Otherwise, if the available data is qualitative or mixed then the comparison follows the importance scale proposed by Saaty (2008), as shown in Table 2.1.

Table 2.1: Importance scale of factors in pairwise comparison. Source: Saaty (2008)

Importance scale	**Importance description**
1	Equal importance of *i* and *j*
3	Weak importance of *i* over *j*
5	Strong importance of *i* over *j*
7	Demonstrated importance of *i* over *j*
9	Absolute importance of *i* over *j*

Note: 2,4,6 and 8 are intermediate values.

When many pairwise comparisons are performed, some inconsistencies may arise. That is why how to measure inconsistency and improve the decision makers judgments is a concern of AHP (Saaty, 2008). The process incorporates an effective technique for checking the consistency of the evaluations made by the decision maker when building each of the pairwise comparison matrices involved in the process, namely $\mathbf{A}$ and $B^{(i)}$. As developed by Saaty (1980), the technique relies on the computation of a suitable Consistency Index (CI) which is obtained, for instance in the case of matrix $\mathbf{A}$, by first computing the scalar x as the average of the elements of the vector whose ith element is the ratio of the ith element of the vector $A \times w$ to the corresponding element of the vector w. Then,

$$CI = \frac{x - m}{m - 1} \tag{2.1}$$

A perfectly consistency implies $CI=0$, but if $CI/RI < 0.1$ the inconsistencies are tolerable and a reliable result may be expected from the AHP (Saaty, 2008). RI is the Random Index, which values for small problems ($m \leq 10$) are shown in Table 2.2.

Table 2.2: Values of the Random Index (RI) for small problems. Source: Saaty (2008)

m	2	3	4	5	6	7	8	9	10
RI	0	0.58	0.90	1.12	1.24	1.32	1.41	1.45	1.51

Overall, researchers such as Dweiri et al. (2016) find AHP an useful tool for checking consistency and reducing bias in a decision-making process. Moreover, the authors also considered it as a robust technique that allows managers to determine preferences of criteria, quantify those

preferences, and then aggregate them across diverse criteria. It is simple and easy to understand and apply.

2.2.2 Supplier Development

Another critical step in procurement is related to supplier development. According to Krause et al. (1998), supplier development is defined as "any set of activities undertaken by a buying firm to identify, measure and improve supplier performance and facilitate the continuous improvement of the overall value of goods and services supplied to the buying company's business unit". The activities the researchers mention can include, for example, supplier audits and training, and performance measurement.

One year later, Krause and Handfield (1999) identify that:

1. Companies need to strategically manage their supplier base for the competitive market;
2. It is needed to invest in the development of suppliers' performance, consider purchasing as a significant source of competitive advantage, and take a strategic viewpoint for suppliers;
3. Buying organizations needs to consider their suppliers as virtual extensions that enables them to improve their own performance;
4. Buyer-supplier relationships determines the opportunity to develop supplier programmes;
5. Buyer and supplier need an appropriate communication and information sharing to supplier development activities.

The importance of supplier development currently relies on the fact that companies depend on their supplier's capabilities as a critical input on developing their products or services in conformity (Shahzad et al., 2016). Gordon (2008) states that measuring supplier performance might significantly reflect lower costs, better-quality goods or services, improved responsiveness to customers, and even technological advantage. Moreover, the author also finds that besides reducing costs it also aims on mitigating risks and driving continuous improvement.

Companies are more and more eager on implementing supplier development strategies not only to improve operational performance but also to develop buyer-supplier relationships. According to Sillanpää et al. (2015), an effective communication, an attitude of partnership, mutual commitment and top management support are among the main success factors influencing supplier development. Moreover, the authors also emphasize the need of supplier development and buyer-supplier relationship to be in a systematic way so that companies can better organize the process and collaborate with suppliers for the improvement of product manufacturing capabilities.

In their research, Shahzad et al. (2016) focus on four major approaches: supplier assessment, competitive pressure, supplier incentives, and direct involvement (Figure 2.4). The assessment of supplier's performance is made through formal evaluation methods, and provide a competitive edge to buyers and a strategic way to set a vision for suppliers (Krause et al., 2000). Providing suppliers with feedback on the evaluation works as a motivational mechanism for the suppliers to improve their own performance (Sillanpää et al., 2015).

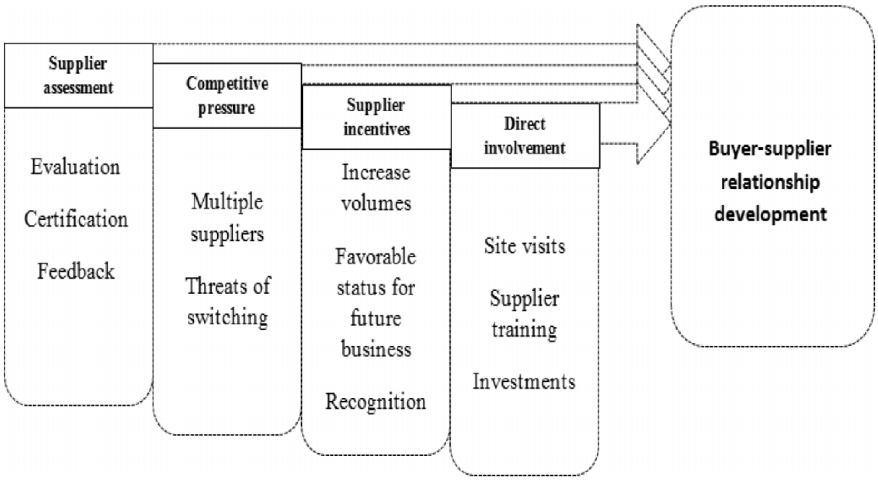


Figure 2.4: Framework of supplier development to buyer-supplier relationship. Source: Shahzad et al. (2016)

Regarding competitive pressure, companies have a set of different suppliers to keep a competitive pressure among them (Sillanpää et al., 2015). This strategy contributes to the analysis of supplier's capability and performance, to provide motivation to other suppliers to improve quality in their operations, and also to build long term business relationships (Krause et al., 2000).

Supplier incentives are another useful supplier development method. Sillanpää et al. (2015) considers this approach as a key motivator for suppliers to improve their performance and in building strong and long-term relationships. For Shahzad et al. (2016), supplier incentives include an increase on purchased volumes, favorable status for future business and recognition for improved performance.

Direct involvement is the last step of the framework proposed by Shahzad et al. (2016) and includes site visits, training and education programs, technical assistance and investments with suppliers. Continuous site visits are important especially to allow suppliers to focus on the required quality by the buyers and enhance the process capability (Sillanpää et al., 2015). During the site visits, the production process is intended to be visually evaluated and developed according to the feedback (Shahzad et al., 2016). Moreover, Shahzad et al. (2016) also enhances the importance of supplier training to improve the relationship trust between buyer and supplier.

2.3 Supply Risk Management

Supply risk management consistently and proactively identifies potential events that might adversely affect the supply chain. Firms can use this information to avoid or reduce their frequency by implementing an effective supply risk framework that identifies and analyzes the relevant risks and provides processes to minimize their impact (The Hackett Group, 2017).

Managing risks in the supply chain is becoming increasingly important for both small and large companies. When entering new markets, firms see themselves in the need of creating new supplier relationships, engage with other third-party entities, and adapt to local laws and culture.

This often leads to a wide range of financial, regulatory, and legal risks (Deloitte, 2017b). For the next two years, The Hackett Group (2018) projects cybersecurity to be the top risk, followed by access to critical talent, intensified competition, disruptive innovation, regulatory risk and industrial espionage.

The use of outsourcing is expected to continue growing. In result, the risk management impact on business performance will increase by affecting costs, service quality, revenue, and even brand (Deloitte, 2017a). For instance, Deloitte (2016) survey found that 85 percent of the respondents had experienced at least one disruption in the past 12 months and that proactive management of supply chain risks represented 50 percent less spending on managing supplier disruption when comparing to those companies that were not proactive.

To create value, companies need to know which risks are worth taking so that they can be managed appropriately. The Hackett Group (2017) suggests nine fundamental steps as part of a supply risk management methodology (Figure 2.5).

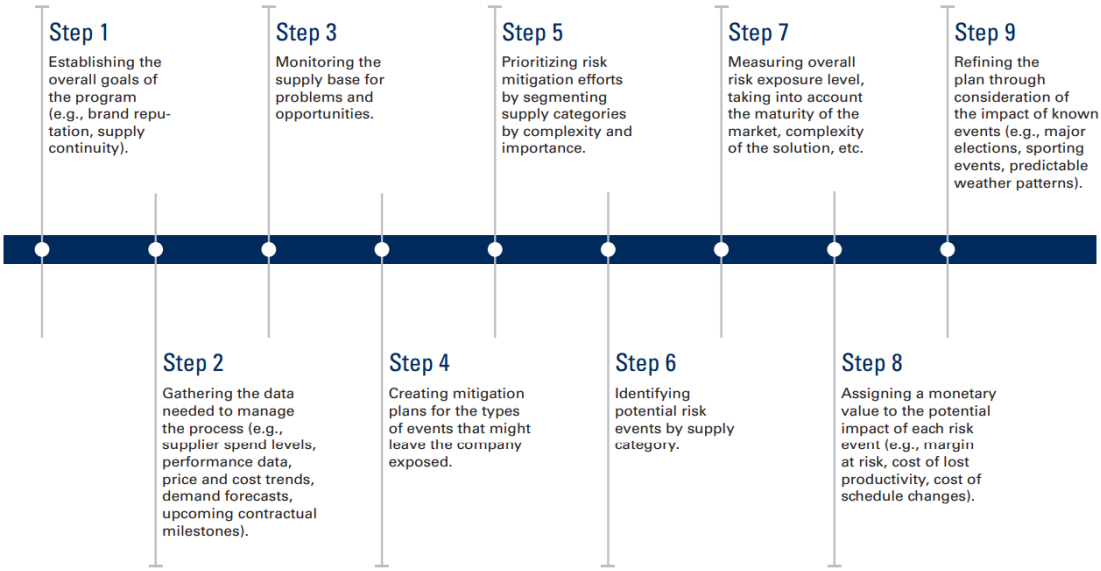


Figure 2.5: Supply risk management program steps. Source: The Hackett Group (2017)

Similarly, Deloitte (2017b) emphasizes the need for managing risks from beginning to end, by first reinforcing the need to consider whether a company's supply network can meet current needs before deciding to include new suppliers. Establishing strategic partnerships with a selected set of suppliers can allow a company to take advantage of a wide variety of benefits such as the potential for scale advantages and priority service. Moreover, it is also crucial to carefully monitor the purchases to ensure that the quality and quantity strictly comply to the requirements set out in the order and so that the company only pays for what it is actually received Deloitte (2017b).

Even if a company carefully follows all the theoretical steps, there is still no certainty that it will be risk-free. Moreover, companies must understand that each activity represents some level of expense against the possibility of a benefit later on, and so mitigating risks that do not ultimately

materialize are unnecessary efforts. Therefore, it may not make financial sense to mitigate every known risk. Nevertheless, the decision must not be simply whether to act, but rather knowing what will work and how much to do (The Hackett Group, 2017).

2.4 Agile Procurement

Flexibility is currently fundamental to the success of an organization on dealing with the volatile modern world. According to Nicoletti (2018), this is only possible in an agile company. Business agility is the "ability of an organization to renew itself, adapt, change quickly, and succeed in a rapidly changing, ambiguous, turbulent environment" (McKinsey&Company, 2015). Agility not only allows organizations to exploit market opportunities but also to respond to competitive risks, and face the countless challenges that accidents may introduce to a supply chain (Nicoletti, 2018).

In 2001, Beck et al. (2001) presented agile as based on twelve principles, which was later on customized in connection with lean and digitize innovation by Nicoletti (2015):

1. Customer and organization satisfaction should be prioritized and pursued by rapid and continuous delivery of value;
2. Welcome changing requirements, even late in the innovation process;
3. Incremental working innovations should be delivered frequently;
4. Working innovations are the primary measure of progress;
5. Agile processes promote sustainability, and the team must be able to maintain a constant pace;
6. Business people and the innovation team should cooperate in a close and daily manner;
7. Face-to-face conversation is the best form of communication;
8. Projects should be built around motivated individuals, that should be trusted and supported;
9. Continuous attention to technical excellence and good design;
10. Simplicity is essential;
11. Teams should be self-organizing;
12. Adaptation to the changing environment is encouraged.

The value proposed by agile procurement is to effectively, efficiently, economically and ethically connect the company's departments to suppliers so that needs can be satisfied. This way, departments can synchronize demand and supply along the chain, meet the whole demand, manage logistics functions, and mitigate risks by tracing the supply flow. To do so, agile procurement requires companies to review their processes, as seen in Figure 2.6, so that potential improvements can be identified. The benefits from this improvement can be measured in the reduction of a

company's money, time, and resources, which consequently can improve its competitiveness and overall profitability. (Nicoletti, 2018).

Feature	Traditional procurement	Agile procurement
Vendors	Many	Few
Interactions	Confrontational	Collaborative
Relationship focus	Transactional	Long term
Primary selection criterion	Price	Performance
Contract duration	Short	Medium to long
Prices in the future	Growing	Declining
Replenishment times	Long	Short
Order quantity	Large lots	Small lots
Quality	Extensive inspections	Quality of the supply
Stocks (supplier and customer)	Large lots	Minimum
Flow of information	Unidirectional	Multidirectional
Flexibility	Low	High
Role in product development	Small	Large (collaborative)
Trust	Limited	Wide

Figure 2.6: The characteristics of agile procurement. Source: Nicoletti (2018)

The future of agile procurement is directly related to some more general developments that are currently taking place. One of the most recent and interesting topics that researchers are studying everywhere is the Industry 4.0 initiative (Nicoletti, 2018). The focus on the next section is the impact of Industry 4.0 on procurement.

2.5 Procurement 4.0

Over the past few centuries, markets have suffered large changes due to the successive industrial revolutions that there have been. In brief, the first industrial revolution (Industry 1.0) resulted in the development of mechanization and the rise of water and steam power. It was followed by Industry 2.0 that led to mass production, assembly lines and the widespread use of electricity. Finally, the emergence of Industry 3.0. which is powered by computer and automation (Shute, 2017).

In consequence, procurement has been following the different trends as presented by Tejido (2015):

- Procurement 1.0: trying to get the right product to the right place, at the right time, and in the correct condition, at the lowest possible price;
- Procurement 2.0: based on category strategy and innovation;
- Procurement 3.0: based on collaboration and partnerships.

The market is currently in the midst of transitioning from Industry 3.0 and Industry 4.0. This recent industrial revolution aims on combining technologies, such as big data analytics, 3D printing and artificially intelligence, to reform companies' operational and administrative processes (Weissbarth et al., 2016). As a response to the concept of Industry 4.0, the market is witnessing the emergence of Procurement 4.0.

Weissbarth et al. (2016) suggest a new strategy and procurement 4.0 framework to help companies to adapt to the radical changes associated with this new industrial revolution as presented in Figure 2.7.

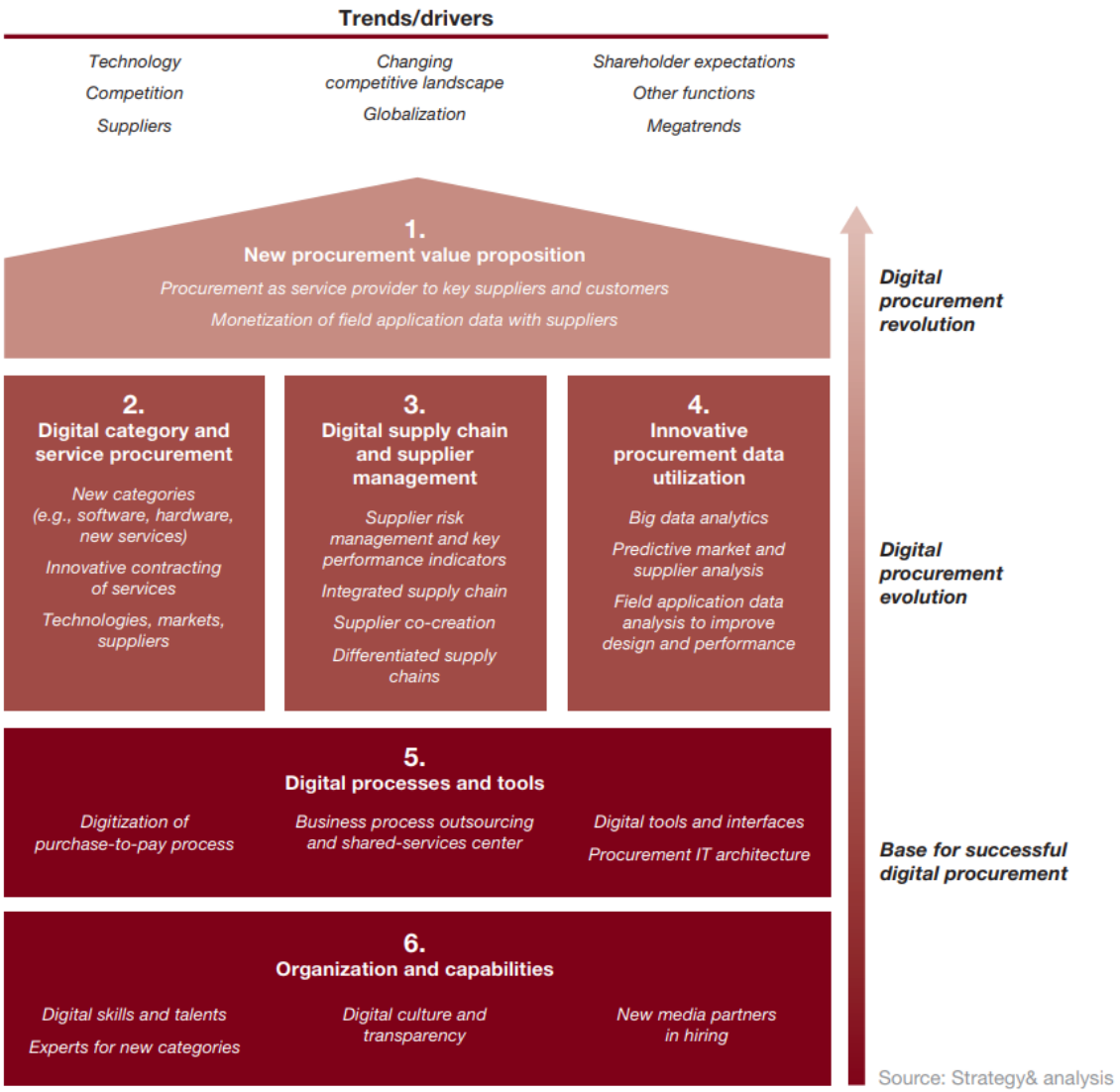


Figure 2.7: Procurement 4.0 framework. Source: Weissbarth et al. (2016)

The framework encompasses six areas:

1. New procurement value proposition: is associated with a redefinition of the value added by procurement. Procurement, as the main owner of the supplier interface, can maintain, and even increase, its singular value proposition by taking advantage of the new opportunities provided by digitalization and big data;

2. Digital category and service procurement: is related to the new business needs that new technologies will lead to. Since capturing, analyzing, and acting on real-time data is at the

heart of Industry 4.0, sensors and actuators are among the new requirements. For procurement, this will essentially mean that certain items will be outsourced much more frequently than before;

3. Digital supply chain and supplier management: refers to data integration. The ability to consolidate all of the data in real time enables a reduction of lead times and inventory costs while improving customer satisfaction and even supplier performance by, for example, predicting risks associated with them;
4. Innovative procurement data utilization: is responsible for ensuring that all of the opportunities offered to the company through the analysis of big data are maximized. Working together with suppliers, data utilization allows stakeholders to benefit from the improvements in supply chain efficiency;
5. Digital processes and tools: will develop collaboration, analytics and engagement by using a set of tools along the entire procurement value chain. It is emphasized the use of digital procurement processes, such as digital requests for quotations, supplier financial analysis, procurement risk analysis, and digital procurement network collaboration;
6. Organization and capabilities: point out the need for reshape the organization and capabilities whereas personnel must be digitally capable so that a company can take full advantages from the opportunities provided by digitalization (Weissbarth et al., 2016).

As companies embrace Procurement 4.0 in its strategy, new value propositions will come into sight and data will be integrated across the value chain to meet new business needs. According to Swali (2017), using analytics to improve decision-making, co-innovating with suppliers, having experienced category specialists, optimizing procure-to-pay processes and achieving enterprise operations transformation through simplification, automation, immersive experience and intelligence are among the main approaches and priorities on building new internal and external value propositions. All this together will enable procurement function to clearly understand the business goals and to drive synergy with suppliers in alignment with business needs (Swali, 2017).

Chapter 3

Problem Overview

The role of procurement in a company goes beyond the purchase of materials and services, playing a strategic role and being present as long as the material is required until it is made available to the internal costumer. The procurement structure is responsible for managing the requirements of all departments and to achieve the company's strategic objectives. This dissertation is highly focused on ADIRA's procurement department and aims to study its operational processes with the objective of increasing their efficiency.

The focus of this chapter is to present and analyze the current situation of ADIRA.

3.1 Introduction

ADIRA's primary final products are press brakes, shears and laser cutting machines. Its largest customers include automotive, aerospace, naval, and metal furniture sectors. Over its long years of experience, the company has provided renown entities such as NASA, Boeing, Salvador Caetano, Metalogalva, Siemens and Motorola. Each line of ADIRA's products includes a vast set of models and optional features that allow the company to adjust the equipment to the needs of each customer. The product development of the company is a responsibility of the Engineering Department, and is based on the customer's required specifications.

Internally, the machines can be classified as standard or special. This distinction depends on the degree of different options previously defined. If a product is in accordance with a previously established list of options then it is considered standard. Otherwise, if the product varies significantly from the possible configurations, then it is treated as special. Moreover, inside the special category, it is included all the laser-related machines.

For the production of these machines, ADIRA counts with more than 27000 different items in its database. Most of them are applied in more than one machine model, leaving a small percentage for specific machines such as exclusive laser components. From all items base, around 70% are buying-items while the rest are produced in-house, meaning that the majority of the items are outsourced. This make-or-buy decision is a responsibility of the Industrial Department, where factors such as capacity and costs are taken into account.

The Industrial Department is also responsible for planning the production based on sales forecast. During this procedure, production orders are introduced and might correspond to machines (final products) or pre-assemblies. Moreover, after each order is launched in the company's Material Requirements Planning (MRP) system, the information on which items are needed with the current stock is crossed. From this information, it is possible to extract which material is necessary to buy and the corresponding scheduling. This is the phase where the Purchasing Department comes into action.

ADIRA is still considered an highly vertical integrated company since they have the control over several areas. They are responsible for developing the product, selling it, producing it (which include fabricating items, painting, welding, machining, and assembling different components), shipping, and providing technical assistance.

3.2 Structure of the Purchasing Function

The Purchasing & Logistics Department is divided in three main areas as shown in Figure 3.1: purchasing, logistics and project. The purchasing area is responsible for all purchases of the company as well as for selecting, negotiating with and evaluating suppliers. The logistics field deals with outbound needs and everything related to warehouse (reception, inventory, etc.). Finally, the project area, a recently new added field, handles potential projects directly connected to purchasing and logistics, that might add value to the company.

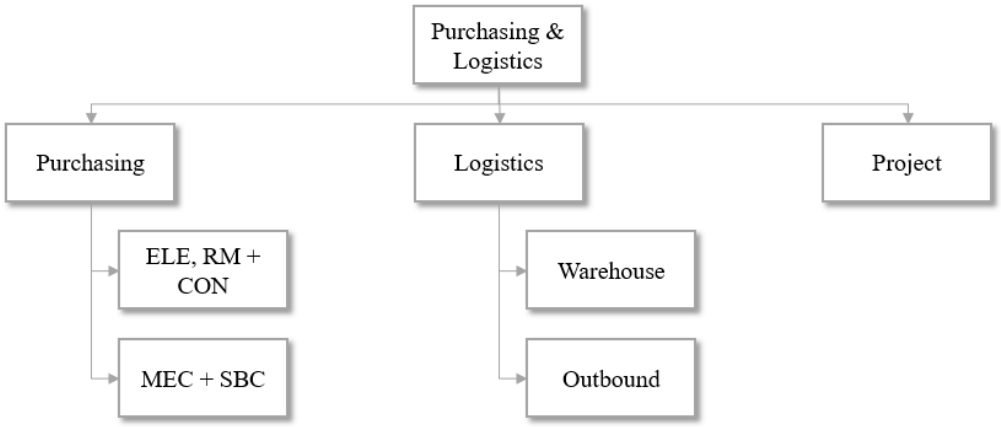


Figure 3.1: Structure of the Purchasing & Logistics Department of ADIRA

The items, and consequently suppliers themselves, are divided in five main categories: mechanical (MEC), electrical (ELE), subcontract (SBC), raw material (RM) and consumable (CON) components. Mechanical, electrical, raw material and consumable suppliers are included in a broader group denominated catalogue suppliers. This group range from multi-brand commercial firms, national agents of international companies (Bosch, for instance), the Portuguese branch of Siemens, and international companies such as Cybelec. For this group, products are generally standardized which allows ADIRA to buy the same component from different suppliers. Even

though this guarantees, at some extent, purchasing independence, it is important to bear in mind that renowned catalogue suppliers such as Siemens play a critical role in ADIRA's supplier dependency mainly due to their high quality standards and determined product specifications. In the case of subcontracts, ADIRA designs and submits the specifications of the items (drawing, materials, treatments, etc.) to the supplier. Therefore, the process of finding potential substitutes is harder when compared to catalogue suppliers since it requires specific processes and equipments to fulfill the needed specifications.

Even though this classification is used in the company for many years, there was still no easy way of corresponding each supplier to the right classification besides asking the company's purchasers. In that way, in collaboration with ADIRA's purchasers, it was developed this association in an Excel sheet that is now accessible in the company's network and will be soon included in the ERP software.

Items can also be classified as supermarket and store components. While the store items are associated with planned and automatic purchase orders, the supermarket items require manual orderings by a Kanban system. With this system, when a container is empty, a purchase order to the supplier of the material contained therein is triggered. This way, orders are according to real consumption instead of expected consumption as it happens in store components. Moreover, there are more than one container for each item so that production is not compromised by the replenishment of empty containers. This system allows to put into practice recent production philosophies that are based on continuous flow and on reducing over-stock situations.

Another aspect to bear in mind is the difference between production orders - orders directly related to the production of ADIRA's products - and service orders - products or services ordered by customers as post-sale services. Understanding their different requirements is crucial and so purchasers must be knowledgeable and careful when making decisions. For example, service orders might expect a shorter lead time when compared to production, as while a component might not be critical right away for producing a machine, it might be urgent for the customer's business. For that reason, the company separates the purchase orders related to production and service in the ERP software, as a way of differentiating its distinct requirements.

3.3 Purchasing Process

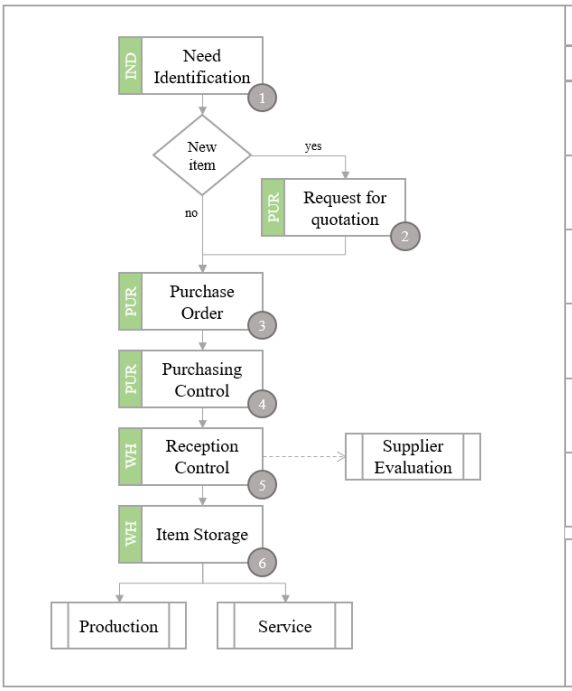
The first step on ADIRA's purchasing process relies on the identification of the purchasing need based on the planned production and the existing stock of each item. Only then, purchasers are informed about all the items that are required to buy and for when they are demanded. ADIRA's purchasing process is schematized in the flowchart presented in Figure 3.2.

Buyers can find two types of items with which they have to deal differently:

- Known-Items: purchasers can automatically proceed with the purchase order in the ERP software, where they will find the information on price and preferred supplier for those items. In the company's ERP software, each buying-item has an affiliation of 100% with a

preferred supplier and 0% with any potential substitutes. This means that when there is a need of buying a known-item, the purchasers have already a favored supplier to buy it from.

- New-Items: buyers have to first send a request for quotation for the potential suppliers and only then continue to the purchase order. In the request for quotation, suppliers are expected to provide information on price, lead time, payment conditions and assurance of quality. After the quotations are submitted, purchasers can evaluate them and reach a final decision on which supplier to buy it from.



Description

Item	Summary	Register
1	Identification and analysis of the purchasing need after production orders are launched	MRP system
2	Request for quotation sent to potential suppliers. Expected information: price and lead time	ERP software
3	Launch the purchase order in the ERP, specifying the purchase requirements (price, quantity, deadline for delivery).	ERP software, E-mail
4	Check how the purchasing order requirements are being fulfilled. Contact suppliers for any necessary changes.	E-mail, telephone
5	Identify item and count the received quantity. Check if the invoice information corresponds to the reality.	Control documents
6	Storage items in the warehouse (First-in-first-out method) in their right warehouse position.	

Caption:
IND – Industrial Department
PUR – Purchasing & Logistics Department (purchasing)
WH – Purchasing & Logistics Department (warehouse)

Figure 3.2: ADIRA's purchasing process: flowchart and description

Then, the purchasing orders are ready to be launched in the ERP and sent by email to the right supplier. This orders specify the price of purchase, description and quantity needed, expected delivery date, payment information, among others.

After the purchase order is accepted by the supplier, its conditions have to be controlled to assure the on-time delivery of components. In addition, changes to the order, for instance on date or quantity, might be needed and so purchasers need to keep in touch with suppliers.

Later on, when the item is received in the warehouse, the employees are responsible for checking if its conditions are in conformance to specifications along with confirming that the invoiced information corresponds to what was shipped. If not, purchasers need to be informed as soon as possible so that the problem can be cleared up shortly.

3.4 Supplier Selection Process

The supplier selection process in ADIRA arises due to three main reasons: i) new-item demand, ii) replacement of a current supplier, iii) or the need to reduce costs. For dealing with these situations, purchasers might choose potential companies from the company's supplier base or search for new suppliers. Both these options rely only on purchasers experience since there is no defined decision support system implemented in the company. Therefore, the comparison between suppliers is usually made under the criteria of price or quality assurance.

After reaching a decision, the supplier might be required to send a sample so that the component can be tested in ADIRA's production site. Finally, purchasers are able to decide whether to associate the selected supplier to the item or go for another one.

Once the final decision is reached, the company can move on to negotiate terms and conditions on the purchasing. The supplier chosen is from then on the preferred supplier to that item, meaning that when the company need the item again it will automatically be associated to that supplier.

3.5 Supplier Evaluation Process

Since a great amount of items are bought from outside ADIRA, it is crucial to have an efficient purchasing process so that production runs smoothly. At the moment, the company can rely on a set of approximately 450 suppliers, with whom relationships are somehow informal. In most cases, they are established for a long time and there are no signed contracts that define procedures for deadlines, payment conditions or even penalties for non-compliance situations. As a consequence, delays in deliveries and non-conforming purchases occur more frequently than desirable. To tackle this problem ADIRA performs an annual evaluation of its suppliers.

The supplier qualification process of ADIRA consists on evaluating the supplier's performance bearing in mind three main criteria: non-on-time delivery (days), price deviation (€) and the number of non-conforming supplies. The evaluation grading system for each criterion is detailed in Figure 3.3.

	A	B+	B-	C	D	E
Grading	100-90	89-70	69-60	59-40	39-20	19-0

	A	B+	B-	C	D	E
upper bound		1	3	6	11	15
lower bound	0	2	5	10	14	
Not-on-time delivery	40,00%	35,00%	27,00%	24,00%	15,00%	0,00%
Price Deviation	20,00%	19,00%	15,00%	11,00%	9,00%	0,00%

	A	B+	B-	C	D	E
upper bound	0	1	3	4	5	6
lower bound		2	4	5	6	
Non-conforming items	40,00%	35,00%	27,00%	24,00%	15,00%	0%

Figure 3.3: Grading system of supplier evaluation

For each criterion there is an upper and lower bound that represent the ranges to obtain a certain weight. For example, for a supplier to obtain a weight of 35% on the non-conforming items criterion, it must only have delivered one or two non-conforming items in the all year.

The weight classification is made per order and per criterion. After each order made to a supplier is classified, the average of weights of each criterion is calculated, obtaining the weight of each criterion for that supplier. Then, final weights of the three criteria are summed, providing the final score of the supplier. From that score it can be attributed a grade from A to E. For instance, if the score of the supplier is 75 points, then it will be graded as a B+ supplier.

Even though the process is connected to the ERP software, making it easy to have its values updated, this model is very limited. It not only has a very reduced number of criteria but it also does not include any qualitative factor. Moreover, after the annually evaluation process, there are no other expected procedures associated with the selection and evaluation of suppliers despite communicating the results to each supplier.

3.6 Data Analysis

It is possible to identify certain key measures that can provide a relevant assessment of the purchasing function. When conducting the first analysis of the purchasing data, On-Time Deliveries (OTD) and Non-Conformities (NCF) were considered as critical.

When analyzing OTD during 2017, it was concluded that a great amount of purchase orders did not arrive on the planned date. Figure 3.4 demonstrates that, in every month, OTD fell short on the company's objective. Additionally, these results will have a clear impact on the supplier evaluation grade, since they represent 80% of the total possible score.

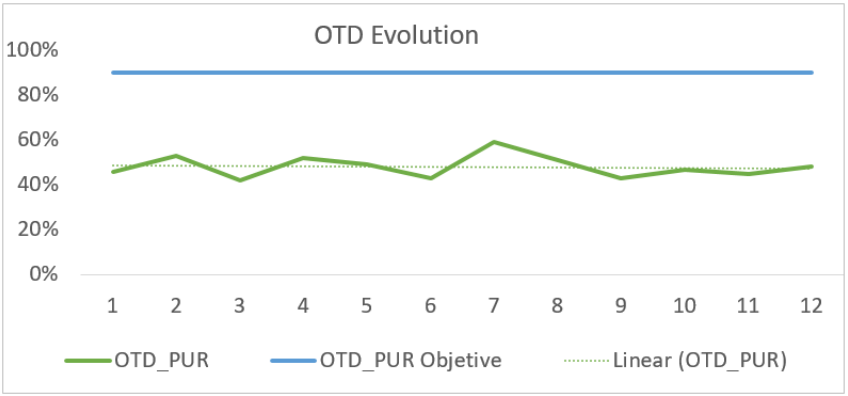


Figure 3.4: On-time deliveries evolution during 2017

The reality of the company includes urgent character purchase orders, which in the ERP system is understood as ordering today for tomorrow. This implies the lead time to be equal to one day and, if the supplier is not able to deliver the product during that day, it will be considered as not on time. In consequence, not only the reliability on analyzing OTD might be compromised but also discourages suppliers from offering good supply conditions to ADIRA.

These urgent orders rely on two main causes:

- Errors on the Bill Of Materials (BOM): inaccurate BOMs might lead to urgent purchase orders since when the problem is detected, the machine is already in production, and a missing component can evolve to a disruption;
- Stock errors: it is still frequent to have inventory errors mainly since recently ADIRA changed its location. Occasionally, when the ERP launches the production orders, some items might have a positive stock associated when in fact there are no products left. When this error is identified, purchasers need to immediately request the missing item.

Nonetheless, on-time deliveries have a significant focus on the Purchasing & Logistics Department as it can lead, among others, to production disruptions. Currently, BOMs are being revised and inventory frequently checked as a way of avoiding urgent orders.

As stated previously, supplier evaluation is a critical process on assuring high levels of ADIRA's production performance. By analyzing Table 3.1, it is clear that SBC suppliers are by far the ones that have the worst performance towards ADIRA.

Table 3.1: Average grade for each type of suppliers in 2017

Type	**Grade**
CON	B+
MEC	B-
ELE	B-
SBC	D
RM	B+

Since SBC suppliers work with ADIRA's drawings and specifications they are required high flexibility and the right technology to meet the purchasing need. However, the majority of those suppliers are locally small and medium-sized enterprises, that might not have quality certification. For instance, in 2017 these suppliers represented 54% of all non-conformities (Table 3.2).

Table 3.2: Volume of purchases and non-conforming supplies for the year of 2017

Supplier Type	**% Total of Suppliers**	**% Total Purchases**	**% Total NCF**
CON	38%	14%	-
MEC	33%	33%	14%
ELE	18%	31%	32%
SBC	6%	17%	54%
RM	5%	5%	-

Even though SBC suppliers only represented 17% of the amount spent on purchases in 2017, it is clear that their bad performance is affecting ADIRA's own performance. They are currently

representing high risks to ADIRA and are being distrusted. For that reason, this dissertation will have a special focus on this type of suppliers.

ABC Analysis

Since ADIRA has a wide variety and quantity of suppliers, it was developed an ABC analysis to classify them based on the annual spend per supplier. This analysis was developed for the purchases of 2017.

First, it was determined the absolute amount spent on purchases for each supplier in 2017. Then, after sorting the supplier in decreasing order of total spend, it was calculated the accumulated annual spend. Finally, suppliers were divided in three classes: A, B and C, based on Pareto's 80-20 rule (Bemelmans, 2012).

From the 468 suppliers analyzed, 76 account for 80% of the total annual spend and are included in the A-class, 96 are B-class, leaving the rest as C-class suppliers. As a way of simplifying the supplier management processes, class C suppliers are considered low-impact suppliers and for that reason are not key targets of the evaluation and development initiatives.

3.7 Opportunities for Improvement

After diagnosing the current situation of ADIRA, certain opportunities for improvement were identified and will be the targets of the methodology presented in the next chapter.

Regarding supplier selection, the current process is only based on personal judgments and technical approval from the Engineering Department, and does not involve any decision-making tool. This, in turn, increases the risk of introducing new suppliers on ADIRA's supplier base which usually is translated in the selection of already known suppliers. Consequently, suppliers get overloaded by different orders which leads to inefficiencies in the supplier performance. For instance, for SBC, the average items allocated to this type of supplier is currently of 245 items per supplier. Another detected problem was related to preferred supplier assignment in the ERP system. This assignment was made over the years by the company's purchasers, which had mainly in mind the price criterion. However, the allocation today might not be as suitable as it was some years ago. First, similar items might be allocated to different suppliers, not taking advantage of economies of scale and negotiating capacity. Second, only 10% of the items have more than one supplier associated. Therefore, the company is highly dependent on some suppliers since the majority of items does not have any potential substitute option.

Frameworking the supplier selection process is extremely necessary. A decision-making tool should be implemented to help the decision makers reach the better-fit decision, and should include not only criteria as price and quality but also other options. Moreover, suppler selection can also work on reallocating suppliers as preferred or substitutes depending on several criteria.

With respect to supplier evaluation, the current process can be simplified in the calculation field and at the same time less limited by increasing the number of criteria employed. On one

hand price deviation, for instance, is not currently a relevant criterion. On the other hand, even though late deliveries and non-conforming items are major issues on the company, they should not be the only criteria on a general supplier evaluation. Instead, this measurements should be performed in a weekly-basis and other criteria included in the evaluation process. In general, the criteria and weights should be target of analysis for understanding which criteria are important for evaluation and how much should they weight on it. Moreover, ranges need to be reapplied to the company's reality.

Currently after each supplier is selected and evaluated there is no other plan of action in regard to its management. With so weak suppliers' performances, the need for supplier development strategies is increasing. Suppliers have to be constantly monitored and its performance measured to assure that they are fulfilling what is expected of them.

Reducing late deliveries and the number of non-conformities are, at this point, the main objectives of the company on the matter of purchasing. Therefore, this dissertation focus on developing the current supplier management to a more complete and dynamic model that can be adapted to the company's reality and to achieve its goals. Moreover, the overall position of the purchasers is currently seen as highly complex. They need to deal with different types of items, suppliers and orders. Managing all these information might be challenging and require constant updates and an agile philosophy.

Proposed Improvements

Table 3.3 summarizes the improvement proposals and their impact in the company. The overall impact of the proposed supplier management methodologies is the improvement of the supplier base performance, with means of bettering the quality of products and reducing late deliveries, and consequently reduce costs.

Table 3.3: Summary of the proposals with impact for the organization

Proposal	**Impact**
Creation of a supplier selection process	-Reduce dependency on purchasers -Reduce overloaded suppliers -Reallocation of preferred suppliers -Increase the number of substitutes for critical items -Improve supplier base performance
Development of the supplier evaluation process	-Improve supplier base performance
Creation of a supplier development process	-Continuous monitoring of the supplier performance -Enhance supplier relationships -Improve supplier base performance

The first proposal consists on creating a supplier selection methodology. Having a structured process for selecting suppliers is a first step on reducing overloaded supplier, increasing the number of substitutes on the supplier base as well as reducing the dependency on current purchasers. Moreover, by selecting supplier in terms of different criteria besides price, helps the company to expect, at some extent, conforming items to specifications and on-time demand accomplishment.

The second proposal is the development of the current supplier evaluation methodology. A different rating-methodology is proposed taking into account qualitative and quantitative criteria. The model is intended to be simple and systematic, and applied to A and B-class suppliers. Each evaluation is followed by a performance report as a way of keeping suppliers informed about their grade and the reasons behind it.

Finally, it is proposed a supplier development framework. It focus on continuous measurement of KPIs and feedback reports to enhance supplier relationships and improve the overall performance of the supplier base.

All the accomplished improvements enhance the global efficiency of the supplier management process and expectedly will, in the mid to long-term, improve the performance of suppliers that is fulfilled with cost effective returns.

Chapter 4

Supplier Management

Linking the identified problems to previously reviewed literature, this chapter will address the research questions in Chapter 1. It begins with defining and developing a supplier selection and evaluation process for ADIRA, followed by supplier development initiatives.

4.1 Criteria Definition

For both supplier selection and evaluation processes, it is required to identify suitable criteria for comparison and evaluation of suppliers. Since the methodology is expected to be flexible as in accordance to an agile company, decision makers need to access different criteria to choose from. Therefore, one of the first steps of this research consisted on listing potential criteria that would fit ADIRA's business environment.

The list of chosen criteria includes 15 different records, which can be consulted in Table 4.1.

Table 4.1: List of criteria on supplier selection and evaluation process

Criteria	**Explanation**
Company experience	Experience of the supplier in the business
Delivery	Ability to delivery products to customer's warehouse
Financial position	Financial position and credit rating
Flexibility	Willingness to adapt to changes
Geographical location	Geographic location of supplier
Lead time	Period since the supplier receives an order until the correspondent item arrives on ADIRA's warehouse
Price	Net price (including discounts)
Production capacity	Capacity to meet ADIRA's demand
Quality	Ability to meet quality specifications
Relationship	Level of relationship with the supplier
Reputation and position	Position in the industry
Service	Post-sale services
Social and Environmental responsibility	Encouragement of a socially and environmentally responsible firm
Technical capability	Capability to meet technicalities, including innovative techniques
Terms and conditions of payment	Condition under which the supplier complete an order

The definition of criteria consisted on a three step process. First, a generic list of criteria was drawn from the literature review that included Dickson (1966) and Weber et al. (1991) work. Then, the list was prioritized according to ADIRA's industry applicability. Finally, the criteria list was run by the company's purchasers and managers, reaching the list presented in Table 4.1.

It is important to realize that since the proposed methodologies comprise qualitative criteria, it is expected a team composed by at least three members from different departments to be a part of the selection and evaluation process. The departments to include should be: the Purchasing & Logistics Department since they are the ones directly involved with suppliers, the Quality Department to guarantee quality as a critical criterion in all steps of the way, and finally the Engineering Department as they are responsible for the specifications of the items.

4.2 Supplier Selection

The suggested supplier selection process was developed using a hybrid AHP and weighting model. The schematic representation of the proposed model is shown in Figure 4.1. This model aims on answering RQ1 presented in Chapter 1, and is partially inspired by the supplier selection process suggested by Monczka et al. (2016) in Figure 2.3 of Chapter 2.

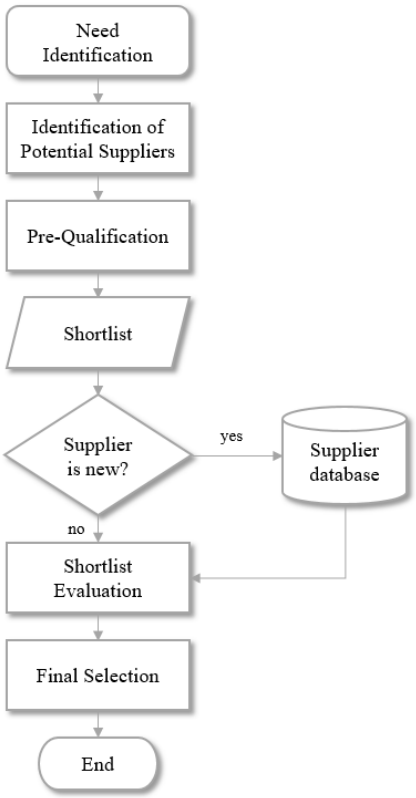


Figure 4.1: Proposed supplier selection process scheme

The "need identification" step consists on recognizing the need for supplier selection and it is where the Engineering Department can provide specifications about the needed items. Then,

it is required an identification of suppliers to establish a pool of potential ones for screening. Afterwards, this pool must be pre-qualified to reach a shortlist in which each supplier is evaluated in comparison to one another. Finally, after the evaluation of the shortlist is completed, the decision makers are able to reach a final selection.

The three main tasks of purchasers on this supplier selection process will be reviewed in more detail in the following sub-topics.

Identification of Potential Suppliers

To reach a suitable pool of potential suppliers for a certain need, decision makers can employ companies already in ADIRA's suppliers database or search for new ones. When the second option occurs, the company can find potential suppliers through a variety of channels: Internet, exhibitions, or recommendations from other stakeholders (for instance, the Engineering Department).

Pre-Qualification

After having a satisfying list of potential suppliers is time for a pre-qualification to short that list up. To do so, companies are evaluated on how reliable they are in terms of financial stability, experience, quality and social and environmental responsibility, as shown in Figure 4.2. These criteria were considered crucial in this phase of the process and, since they can be easily filled without any direct contact with the companies, highly useful. Moreover, in the case of known suppliers, the decision makers have the possibility to add the suppliers' last evaluation grade since their performance as an ADIRA's partner is also a critical factor to bear in mind.

adira
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Legend		
Reliable	✓	1
	!	0,5
Unreliable	✗	0

		25%	15%	45%	15%			
Supplier Name	Contact	Financial situation	Experience	Quality Certification	Social and Environmental Reponsability	Counter	Grade from last evaluation (if applicable)	Comments
Supplier 1		✓	✓	✓	✓	1		
Supplier 2		✓	✓	✓	!	0,925		
Supplier 3		✗	✓	✓	✗	0,6		
Supplier 4		!	!	!	!	0,5		
Supplier 5		✓	✓	✗	!	0,475		
Supplier 6		!	✓	✗	✓	0,425		
Supplier 7		✓	!	✗	!	0,4		
Supplier 8		✓	✓	✗	✗	0,4		
Supplier 9		✗	✗	✗	✗	0		

Figure 4.2: Pre-qualification sheet

After each row is filled, all suppliers in the list have a counter value depending on the answers provided and the weights of each criterion.

Then, it is possible to create a shortlist with the best scored suppliers. This shortlist should include more than three but less than seven names so that the next step is not overly time consuming.

Shortlist Evaluation

In this step, AHP and weighting technique are combined as the methodology to tackle the comparison between suppliers. Here, suppliers are evaluated against qualitative and quantitative criteria separately to reach a combined value. For qualitative criteria the model proposes the use of AHP due to its hard quantification on comparing options. Regarding quantitative criteria, a simple multiplication of a weight for its respective value is considered to be enough.

This multi-criteria, multi-supplier methodology represents the essential aspects of the supplier selection process and the notation used is as follows:

Table 4.2: Notation of supplier selection

Indices	
s	Index of suppliers, s=1,2,...,S
c	Index of quantitative criteria, c=1,2,...,C
k	Index of qualitative criteria, k=1,2,...,K
Parameters	
w_c	Weight of the cth quantitative criterion
w_k	Weight of the kth qualitative criterion
v_{cs}	Value of quantitative criterion cth for the sth supplier
r_s	Result of the AHP analysis for the sth supplier

Equation 4.1 aims a final supplier selection of the sth supplier with minimum E_s.

$$E_s = \sum_{c=1}^{C} (w_c v_{cs}) + \sum_{k=1}^{K} w_k (1 - r_s) \tag{4.1}$$

Each segment of suppliers is expected to have an unique set of criteria for comparison due to their different requirements (Table 4.3).

Table 4.3: Criteria for shortlist evaluation depending on type of supplier

ELE	**MEC**	**SBC**	**CON**	**RM**
Terms of payment	Flexibility	Flexibility	Terms of payment	Terms of payment
Lead time	Lead time	Lead time	Lead time	Lead time
Price	Price	Price	Price	Price
Quality certification	Quality certification	Quality certification	Quality certification	Quality certification
Service	Delivery	Delivery	Location	
		Technical capability		

Besides the criteria proposed and presented in Table 4.3, decision makers have the flexibility to add, change or remove criteria or even amend its weight in the model depending on the requirements for each situation and having as a base the criteria of Table 4.1. Nevertheless, criteria such as lead time, price and quality certification are considered to be the most important ones to ADIRA's reality, and therefore must always be included in the process.

In this phase, purchasers are expected to send requests for quotation and information for each supplier in the shortlist to be able to fill in the fields of the evaluation sheet, as exemplified in

Figure 4.3. Moreover, purchasers can also send the "Assessment Questionnaire" (Appendix C) to suppliers to better judge their capacities, especially for more complex or critical components. Whenever possible the company should also visit suppliers' facilities or at least ask for a sample to confirm their suitability on producing a certain item.

When decision makers have access to all important information, the comparison between suppliers can start.

		Supplier			
Criteria	Weight	Supplier 1	Supplier 2	Supplier 3	Supplier 4
k_1	w_1	(qualitative)	(qualitative)	(qualitative)	(qualitative)
c_1	w_2	v_{21}	v_{22}	v_{23}	v_{24}
c_2	w_3	v_{31}	v_{32}	v_{33}	v_{34}
c_3	w_4	v_{41}	v_{42}	v_{43}	v_{44}
k_2	w_5	(qualitative)	(qualitative)	(qualitative)	(qualitative)

Figure 4.3: Shortlist evaluation sheet

The criteria proposed in Table 4.1 which are subject to the AHP model are: delivery, flexibility, relationship, service, social and environmental responsibility, technical capability, and terms of payment. The remaining criteria are treated as quantitative and expect a weighting model. For the example presented in Figure 4.3 only the criteria k_1 and k_2 will proceed to the AHP model (further explanation in Appendix A).

After the shortlist evaluation sheet is properly filled and AHP is completed, Equation 4.1 is automatically calculated in the shortlist calculation sheet exemplified in Figure 4.4.

		Supplier			
Criteria	Weight	Supplier 1	Supplier 2	Supplier 3	Supplier 4
k_1	w_1	$w_1(1-r_1)$	$w_1(1-r_2)$	$w_1(1-r_3)$	$w_1(1-r_4)$
c_1	w_2	$w_2 \cdot v_{21}$	$w_2 \cdot v_{22}$	$w_2 \cdot v_{23}$	$w_2 \cdot v_{24}$
c_2	w_3	$w_3 \cdot v_{31}$	$w_3 \cdot v_{32}$	$w_3 \cdot v_{33}$	$w_3 \cdot v_{34}$
c_3	w_4	$w_4 \cdot v_{41}$	$w_4 \cdot v_{42}$	$w_4 \cdot v_{43}$	$w_4 \cdot v_{44}$
k_2	w_5	$w_2(1-r_1)$	$w_2(1-r_2)$	$w_2(1-r_3)$	$w_2(1-r_4)$
	E_s	E_1	E_2	E_3	E_4

Figure 4.4: Shortlist calculation sheet

Finally, the best-fit sth supplier is identified by selecting the minimum E_s. At this point, the company is ready to reach an agreement with the selected supplier.

After the decision is reached, the selected supplier will be the preferred one for the item the selection was proceeded for. The rest of the suppliers on the shortlist will be considered as potential substitutes so that ADIRA can keep, at some extent, its supplier's independency. ADIRA

can address substitute suppliers when, for instance, the preferred one is having constant quality problems or out of time deliveries.

4.3 Supplier Evaluation

To monitor supplier performance a score methodology with eight key criteria has been developed: company quality certification, delayed deliveries, flexibility, invoice processing, NCF, product quality certification, relative price and relationship. The choice of these criteria was made in collaboration with purchasers and managers of ADIRA trying to access all current major problems related to suppliers, as expected by RQ2 of this project.

To each supplier a final grade will be given according with the accomplished points over the evaluation process. The grades are: A, B+, B-, C, D and E, being A the best and E the worst grade possible. Each supplier can reach a score of 0 to 100 points, with defined intervals for each grade as presented in Figure 4.5. Each criterion and correspondent score is presented in detail in Appendix B.

min	max	Grade
0	19	A
20	39	B+
40	59	B-
60	69	C
70	89	D
90	100	E

Figure 4.5: Supplier evaluation grading scale

The evaluation of each supplier is performed by ADIRA's purchasers by using structured evaluation sheets such as the one presented in Figure 4.6. It consists on six qualitative criteria that require the input of decision makers, and two quantitative criteria (yellow background) that automatically update through the company's database.

Supplier	Type	Relationship	Relative Price	Delayed Deliveries	Invoice Processing	NCF	Company Quality Certification	Product Quality Certification/Report	Flexibility	x	Grade
Supplier 1	SBC	Good	Low	Very Low	Good	None	Not Certified	Do not send	Average	22,8125	B+
Supplier 2	SBC	Good	Average	Very High	Sufficient	Very High	Not Certified	Do not send	High	73,75	D

Figure 4.6: Supplier group evaluation sheet

To this end, Equation 4.2 can be applied and a grade assigned to each supplier depending on the amount of points achieved. Less points, in this proposed model, mean better grades as shown previously.

Table 4.4: Notation of supplier evaluation

Indices	
s	Index of suppliers, s=1,2,...,S
i	Index of criteria, i=1,2,...,I
Parameters	
w_i	Weight of the ith criterion
x_{is}	Score of ith criterion for the sth supplier

$$X_s = \sum_{i=1}^{I} (w_i x_{is}) \tag{4.2}$$

According to ADIRA's purchasers, a year-time evaluation seems enough for the majority of suppliers. Nevertheless, and regarding the initiatives proposed for mitigating supplier impact and risk presented in the next section, some evaluations can suffer adjustments over the year.

After the evaluation is completed, ADIRA must inform each supplier about the assigned grade as well as the reasons behind it by sending a performance report.

4.4 Supplier Development

Suppliers are an immense space for innovation, continuous improvement and cost reduction (Webb, 2017). By developing its suppliers, it is expected that ADIRA can enhance its planned production and customer responsiveness. The proposed methodology aims on answering RQ3 and focus on two general ideas: after-evaluation development, and weekly-basis development.

Categorizing the supplier base will facilitate the development initiatives. A proper categorization ensures that the company can focus on a set of suppliers while leaving others behind, improving the quality of the supplier base. For the after-evaluation development strategies, a supplier development matrix was created while for the weekly-basis strategies the ABC analysis developed in Chapter 3 was used.

The supplier development matrix aims on segmenting the suppliers on four quadrants, to better understand which plan of action is suitable to each supplier after they have been evaluated. The matrix is determined by two axes: one is the supplier risk which is associated with supplier evaluation (x-axis), and the other axis is the supplier impact (y-axis). Here, the suppliers are divided into four groups: non-critical, leverage, bottleneck and strategic critical (Figure 4.7).

The criteria used to measure supplier impact consist on the volume purchased (€) and the level of dependency of ADIRA in relation to the supplier. Regarding the volume purchased, the demarcation line between high and low is based on an 80-20 rule and can be automatically obtained using the company's database. With respect to supply dependency, it depends on the purchaser judgment and the demarcation line between high and low is drawn by assessing if suppliers do or do not have any accessible competitors.

The scale of the y-axis goes from 1.8 to 10, with the purchased volume representing 70% and dependency the remaining 30% of the total possible attributed points (Table 4.5).

Table 4.5: Score assigned to volume purchased and dependency criteria

	Volume Purchased (€)	**Dependency**
Low	1.8	0
Average	3.5	1.5
High	7	3

Regarding the x-axis of the proposed supplier development matrix, it represents the assigned points on the supplier evaluation process. It has a 0 to 100 scale where the higher the value the riskier the supplier. This scale was developed under the criteria ideas provided in Appendix B, where, for instance, a higher number of non-conformities delivered by suppliers, and consequently higher points, represents higher risks of compromising ADIRA's production.

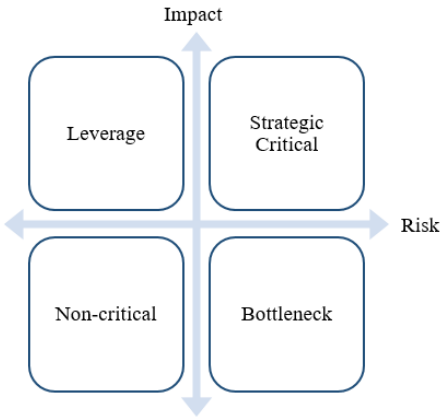

Figure 4.7: Supplier development matrix

As a way of improving supplier's performance and consequently bettering its evaluation, each group of the matrix has a development program assigned:

1. The strategic-critical group focuses on the supplier via on-site visits and improvement activities;
2. The leverage group reinforces and improves cooperation to increase mutual benefits;
3. The bottleneck group will target on assessment questionnaires to hold them responsible for their actions; and
4. The non-critical group maintains the status-quo and pursues a mutual benefit.

Currently, ADIRA has to highly focus on strategic-critical suppliers which are the ones jeopardizing production mainly due to late deliveries and high non-conforming items. Therefore, on-site visits are a first step on implementation. Supplier on-site visits are conducted at the manufacturing facilities and include checks with respect to company, process, quality and finance, similar to the supplier assessment questionnaire (Appendix C). On this matter, it was developed a checklist as illustrated in Figure 4.8.

Nº	Question	Visit Evidence (check for documentation or implementation reports)	What to look for	Opportunities for Improvement
Quality				
1	The supplier is certified? (for instance ISO 9001)		Certification (check validaty date)	

Figure 4.8: Visit checklist template

The "Visit Evidence" field serves to note down evidences about implementation and documentation. Regarding "Opportunities for Improvement", it is the place to make a note of any found opportunity to improve the company's current status. It includes, for instance, redundant, overly complex or not-value adding activities. This proposed checklist works as a simple guide for the visit and should be adapted for each situation since, depending on factors such as company size or development, some of the points presented might not be a reality of the supplier.

After the visit is completed, ADIRA's responsible should prepare an assessment report presenting to the supplier all the opportunities for improvement identified and a suggestion of an action plan. That way, suppliers have the opportunity to improve their processes and business itself, and in consequence, better their performance towards ADIRA and other customers. They can also improve their competitive edge against competitors.

In the next suppliers' evaluation, ADIRA has the responsibility to carefully analyze the visited suppliers to figure out if their performance increased. If not, the company should penalize the supplier and even search for suitable substitutes.

With respect to weekly-basis development, for A-class suppliers it is proposed a weekly feedback report serving as a KPIs announcement. It includes:

- Number of non-conformities and planned resolution (if it is to be returned to the supplier, if ADIRA will deal with the non-conformity internally, etc);
- Information on late deliveries, including percentage of OTD and average late days;
- History performance, on how previous non-conformities were conducted and how OTD is evolving.

Weekly feedback reports are intended to keep suppliers updated in how they are performing towards ADIRA. In parallel to weekly feedback reports, ADIRA must send NCF notices the same day they are detected, to avoid further interruptions related to them. On other note, ADIRA should meet with its largest suppliers two to three times each year, in order to tackle problems but also to find solutions and to make suggestions for improvements.

If suppliers support this kind of initiative and make efforts to develop its performance based on the reports, relationships can enhance and ADIRA can again trust their supplier base.

4.5 Continuous Improvement

The proposed supplier management methodology should not be looked as a static process. Instead, ADIRA and suppliers are encouraged to seek opportunities for continuous improvement throughout their relationship and to comply with agile procurement philosophy. Therefore, this continuous improvement philosophy closes the loop on the proposed supplier management framework as illustrated in Figure 4.9.

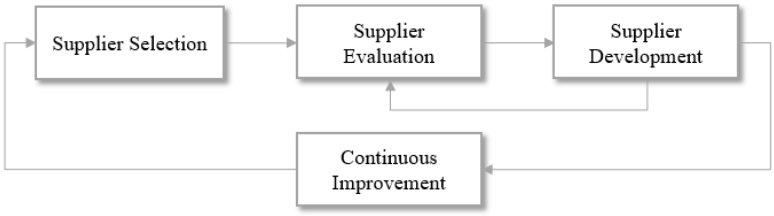

Figure 4.9: Proposed supplier management framework

To be effective, continuous improvement should combine strategic and operational factors. The strategic factor must be focused on the key processes that add value to the company's goals, including ADIRA's satisfaction, and have a long-term orientation. On the other hand, the operational factors must be specific and measurable, such as performance requirements or objectives.

To ensure the continuous improvement cycle, all processes on supplier management should be consistent. For that reason, the methodologies proposed are structured and systematic mainly to remove the variability that individual interpretations proposes. That way, it can assure positive implementation and criticism as well as good communication with all measured suppliers.

4.6 Results and Discussion

Supplier Selection

The developed methodology on supplier selection aims firstly on filling a gap on the current decision-making process as well as turning the process as robust and reliable as possible. Moreover, the fact that the model is at some point flexible in the choice of criteria enables decision makers to be flexible enough regarding each selection case.

In addition, this proposed model can be particularly useful to determine substitutes of problematic suppliers. For instance, 47.5% of the non-conformities that arrived ADIRA's warehouse in 2017 have only one supplier attributed in the ERP which means any potential substitutes are not known. By implementing this methodology, ADIRA can revise its suppliers and better allocate them to the needed items.

Supplier Evaluation

The proposed methodology was validated by the SBC suppliers. As a simulation, the model was applied to the data of 2017, and once again, it was confirmed the need to develop this type

of suppliers since, when applying the model to that year, 46% obtained the grade D which is the second worst grade possible (Figure 4.10).

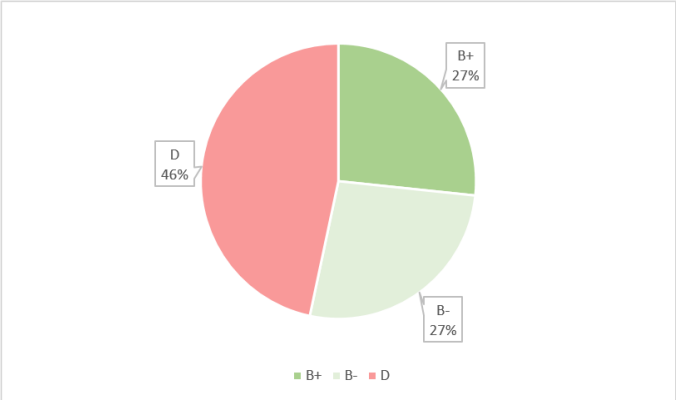

Figure 4.10: Results of the SBC suppliers' evaluation for the year 2017

When comparing the current methodology on supplier evaluation with the proposed one, for the five main SBC suppliers (Table 4.6), results are similar. Nevertheless, two suppliers present different grades and are, with the new method, much more framed in the company's truth.

Table 4.6: Score assigned to volume purchased and dependency criteria

	Old Method	**New Method**
Supplier A	D	D
Supplier B	C	D
Supplier C	D	D
Supplier D	B+	B-
Supplier E	D	D

The proposed model is more robust and accurate than the current one. First, it involves a wider range of criteria. For each criterion more clear instructions are provided so that decision makers are able to fill in the evaluation sheet without any problems. Second, it is not only focused on numbers but also on relationships. Having qualitative criteria on the process enables a focus on ADIRA-supplier relationships. And third, it expects actions after the evaluation is completed.

Nevertheless, this methodology expects more time expended in supplier evaluation than what is currently being done. It is supposed to be a well thought and debated process, with purchasers and other procurement personnel involved. Therefore, this step of the procurement process needs to be part of the annual calendar of the purchasing department, so that time can be saved for this matter.

Supplier Development

When placing the same five SBC suppliers presented in Table 4.6 in the supplier development matrix, four out of five are in the strategic-critical quadrant (Figure 4.11). SBC suppliers

highly need development actions to improve their performances so that their risks to ADIRA can decrease.

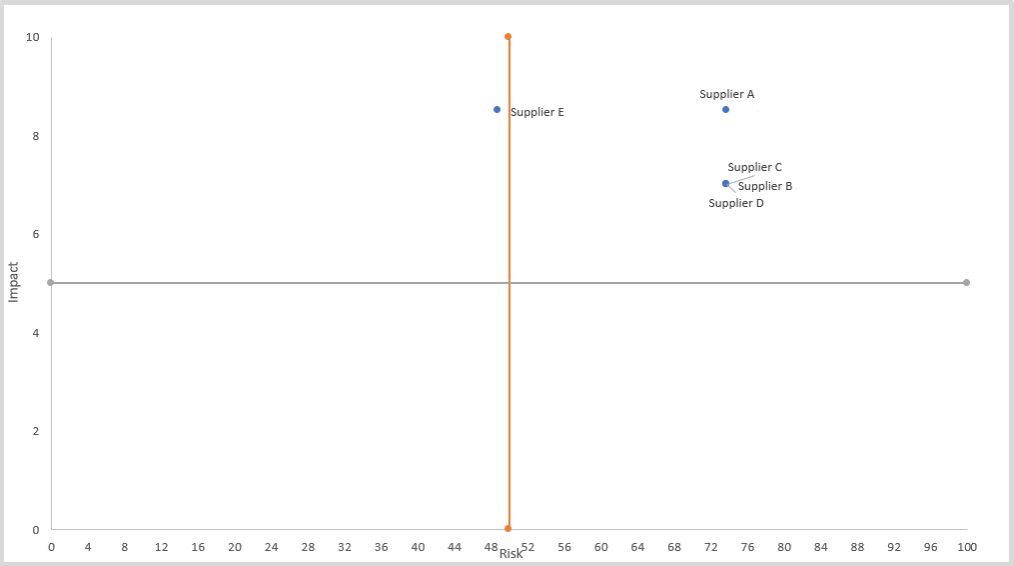

Figure 4.11: Development matrix for SBC suppliers' evaluation for the year 2017

During the time-period of this dissertation, an on-site visit to Supplier A was made. From that visit it was concluded that since they do not have a Quality Department, products are not being inspected at any point of production or before shipping. This might be one of the reasons why this supplier is responsible for a high number of non-conformities. Moreover, it was also detected that some versions of the items' drawings are not being updated and so this supplier was producing items according to old versions and not the updated ones. This would result in a non-conformity since the item is supposed to be delivered in accordance to the specifications of the latest drawings. Versions' drawing information given to suppliers is currently being updated to avoid this kind of problems.

On the matter of weekly-basis development, it becomes important to adopt suitable KPIs directly connected to ADIRA's goals. The suggested KPIs include NCF with a target of 0, and OTD targeting 95% of on-time deliveries per month. This two criteria will be the major ones later on supplier evaluation, as it will be explained in Appendix B.

Chapter 5

Conclusion and Future Research

This dissertation was developed under the challenge proposed by ADIRA in what concerned supplier management. Its goal was to develop a model for the structuring of supplier selection, evaluation and development processes in the company. Improving the company's processes on that matter contributes on obtaining a competitive advantage, since it allows, among others, the reduction of costs and increase its performance.

In order to answer the research questions, a literature review was conducted leading to the proposed methodology. Then, data was gathered either by using ADIRA's database and ERP, or by direct interacting with the company's purchasers. From this, problems on supplier management were identified and opportunities for improvement determined mainly with the analysis of key performance indicators. At this point it was possible to conclude that ADIRA's main issues on the regard of suppliers were the high number of non-conforming items and late deliveries that everyday jeopardized production. When assembling machines, assemblers frequently miss items to proceed the process and many times have to stop what they are doing. Evidently, this results in high costs to ADIRA that, in the worst case scenario, might late their own delivery to customers. Therefore, the established targets for this dissertation were to reduce late deliveries and the number of non-conformities by improving suppliers' management.

In that sense, it was proposed the creation of a systematic supplier selection process, the development of the current supplier evaluation updated to the company's reality, and supplier development strategies to enhance even further supplier relationships.

In regard to supplier selection, a multi-criteria methodology was applied by combining AHP and weighting technique. This fills the lack of a decision-making support tool and reduces the dependency on purchasers over the selection process. Moreover, it also enables decision makers to adapt the model to each situation and type of supplier, translating in accuracy and continuous improvement of the methodology.

Concerning supplier evaluation, the implemented process was developed as a way of updating it as well as include other important criteria to the model. Its base continued to be a rating methodology where each criterion has a weight and a value associated, scoring each supplier on how well they are at meeting ADIRA's expectations. This is generally a yearly-time process and

is followed by a feedback report and a possible development strategy. With the proposed methodology, the company is expected to have more accurate grades on suppliers, to be able to develop their relationships and consequently better both company's performance in a win-win situation.

The last proposal presents a structured framework on supplier development that revealed to be a current gap on the company's supplier management strategy. The new methodology is separated in two phases: the weekly basis reports and the development matrix strategies. Overall, the proposal allows the identification of possible improvement actions and is a basis for a continuous improvement of supplier´s performance. ADIRA expects the supplier to distribute the results to all involved members of its company and to take appropriate actions to improve the performance, either if it corresponds to simple feedback or visit reports.

By applying the proposed evaluation system and development initiatives, ADIRA can achieve a low cost of purchasing, develop products on time, and maintain high quality of products. Moreover, late deliveries and non-conformities are expected to reduce substantially. In general, both ADIRA's and supplier's performance are intended to reach higher levels and consequently an increase on customer satisfaction.

Future Research

Even though some solutions were presented in this dissertation, there is still a long path to go on developing procurement functions.

In the near future the idea of revolutionizing the traditional supply chain and to transform it into a digital network will prevail. As discussed in the literature review of this dissertation, Procurement 4.0 is a mega trend on companies and therefore should be one of the main subjects of research in the future of procurement. In fact, this will certainly soon be a reality of ADIRA since it is currently putting high efforts on developing Industry 4.0 vision over the company.

Developing an online platform or "Supplier Portal" is one of many solutions of Procurement 4.0 that would enhance the proposed methodology. This platform would be a large network to which all stakeholders in the procurement process (ADIRA and suppliers) would have access aiming on business collaboration. Purchasing terms and conditions, partner code of conduct, and supplier requirements manual are among useful documents to be displayed in this platform. With this platform, the company could also combine all supplier management processes in one place which would significantly ease purchasers work. For example, purchase orders could be updated to the platform and an automatic notification sent to the respective suppliers. This would end the sending of each purchase order by email to suppliers.

The main development and advantage of a supplier portal would be enabling the management of all orders in real time as well as foster the exchange of information. The availability of real time information can help the processes to become more transparent and be faster when reacting to errors. It can also optimize safety stock and reduce lead times if, for instance, suppliers would have access to holding inventory up-to-dated information. This availability of real time data might increase the complexity of working in procurement. Purchasers and procurement staff

in general would have to shift from one-on-one relationships to data science and strategic thinking. Moreover, the development of such platform would require a secure system to ensure that data is protected and available at the right moment in the right place in support of the procurement activities.

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Appendix A

Model used for AHP

The proposed model was developed using Visual Basic for Applications in Excel, and it will be explained in this Appendix. The model had as base the literature review made on Chapter 1 as well as the guidance of Albright (2016).

When entering the developed program sheet, the user have first the opportunity to see a brief explanation of the process (see Figures A.1 and A.2) before proceeding to the selection itself.

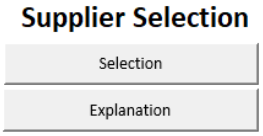

Figure A.1: AHP model interface

Pairwise Comparision

1. First, the model requires to add information on the type and amount of suppliers for selection.
2. Second, it is required to make pairwise comparisions between the criteria, so that each one is assigned its relative importance.
3. Finally, the decision maker has to proceed to the pairwise comparision for each supplier regarding each criteria. This step will specify how each supplier behaves againts the others in a specific criterion.

Level of importance for comparison

Importance	Definition	Explanation
1	Equal importance	The two criteria contribute equally to the objective
3	Moderate importance	Experience and judgement slightly favour one criterion over another
5	Strong importance	Experience and judgement strongly favour one criterion over another
7	Very strong importance	A criterion is favoured very strongly over another
9	Extreme importance	The evidence favouring one criterion over another is of the highest possible order of affirmation
2,4,6,8		Intermediate values

Observation

Method: Analytic Hierarchical Process (AHP)

Since there might exist inconsistencies while proceeding to the pairwise comparision, the method calculates the consistency value of each comparision. If this value is lower than 0.10, then the comparision is consistent. Otherwise, it is necessary to re-evaluate the comparisions.

Figure A.2: Explanation sheet

Only after clicking in the button "Selection", the user is able to proceed to the AHP to determine the r_i used in the equation 4.1.

The first *UserForm* of the program requires the information on the type and amount of suppliers that are going to be compared, such as represented in Figure A.3. With this information, the program is able to automatically identify which criteria is subject of AHP and ask the user to compare them.

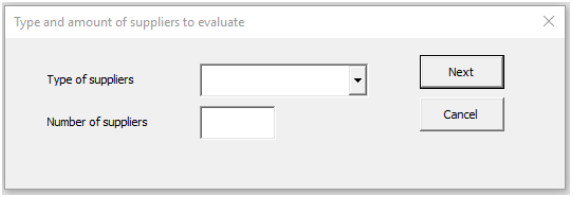

Figure A.3: Selection type and amount of suppliers to evaluate

The example provided in the following figures represent four suppliers ($n = 4$) of the ELE type. As seen in Table 4.3 of Chapter 4, the proposed criteria for ELE suppliers are: terms of payment, lead time, price, quality certification and service. From this, only service and terms of payment are difficult to quantify and for that reason are going to be part of the AHP model ($m = 2$). These criteria have been hierarchically structured in three levels (Figure A.4) in accordance with the AHP framework.

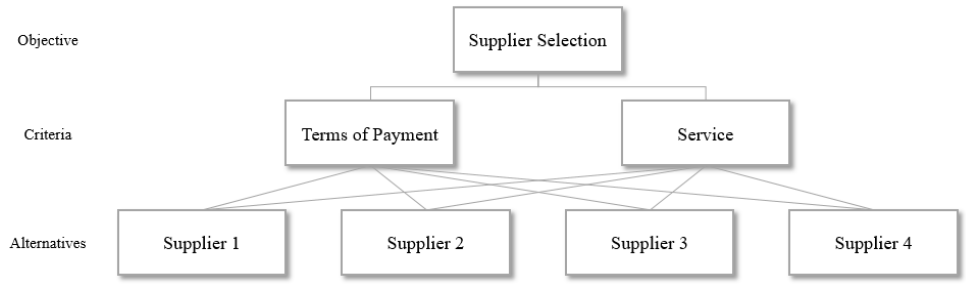

Figure A.4: Schematic representation of the AHP model

The next step is to compare the criteria to assign its relative importance. This step uses Saaty's 1 to 9 scale, presented in Table 2.1 of Chapter 2. The program, per definition, allocates the cursor in value 1 (the criteria are equally important). As seen in Figure A.5, if for example service is a more important criterion when compared to terms of payment, the user should scroll to the right side of the scale in the amount he/she finds reasonable.

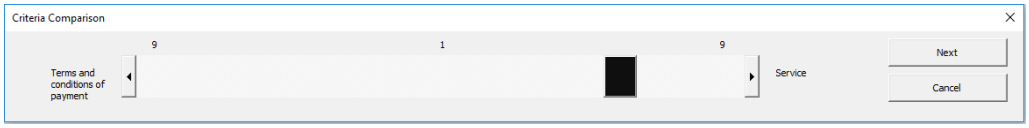

Figure A.5: Comparison between criteria

In mathematical terms, Figure A.5 is represented by Table A.1, , which is related to matrix **A** presented in Chapter 2. All the diagonal elements of the matrix are 1 since the elements are being compared with themselves. In the first row of the matrix, the importance of terms of payment criterion is considered weak over service, being the reciprocal of this value allocated in the lower triangular matrix. This corresponds the weight vector $w = [\, 0.143 \quad 0.857 \,]^T$.

Table A.1: Estimating relative weights of criteria

	Terms of payment	**Service**
Terms of payment	1	1/6
Service	6	1

Then, the user can compare all suppliers for each criteria. For instance, by analyzing Figure A.6, a result such as shown in Figure A.7 would be consistent. The idea of this comparison is very similar to the one made in the previous step and, in this case, corresponds to matrix $B^{(Terms\ of\ payment)}$. An identical *UserForm* for service criterion would appear when the user clicked in "Next" and its values would correspond to $B^{(Service)}$.

		Supplier			
Criteria	**Weight**	Supplier 1	Supplier 2	Supplier 3	Supplier 4
Terms and conditions of payment	5,0%	Payment in advance, with possibility for discounts	Net 30	Net 60	Payment in advance
Lead time (week)	30,0%	1	1	3	2
Price (€ per piece)	15,0%	9	8	4	6
Quality certification	30,0%	Certified	Certified	Not certified	Certified
Service	20,0%	With extra costs	Without costs and flexible	Do not deliver	Without costs

Figure A.6: Shortlist evaluation sheet example

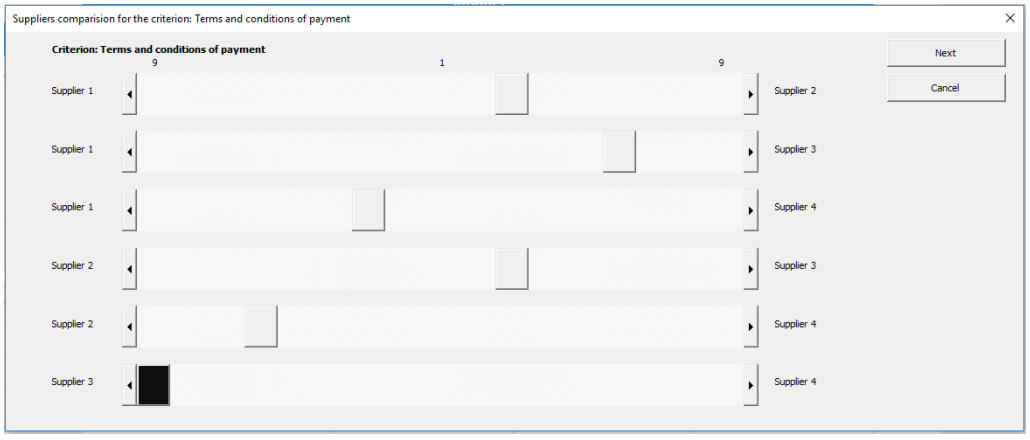

Figure A.7: Comparison between suppliers for each criterion

The correspondent score values are $s^{(Terms\ of\ payment)} = [\,0.108 \quad 0.259 \quad 0.585 \quad 0.048\,]^T$ and $s^{(Service)} = [\,0.108 \quad 0.585 \quad 0.048 \quad 0.259\,]^T$. Hence, the score matrix $\mathbf{S}$ is:

$$\mathbf{S} = \begin{bmatrix} 0.108 & 0.108 \\ 0.259 & 0.585 \\ 0.585 & 0.048 \\ 0.048 & 0.259 \end{bmatrix}$$

and the global score vector is $r = S \times w = [\,0.108 \quad 0.539 \quad 0.125 \quad 0.229\,]^T$. Note that the second option (supplier 2) turns out to be the most preferable in terms of these two criteria. These results can also be found in AHP report presented by the program to the user (Figure A.8).

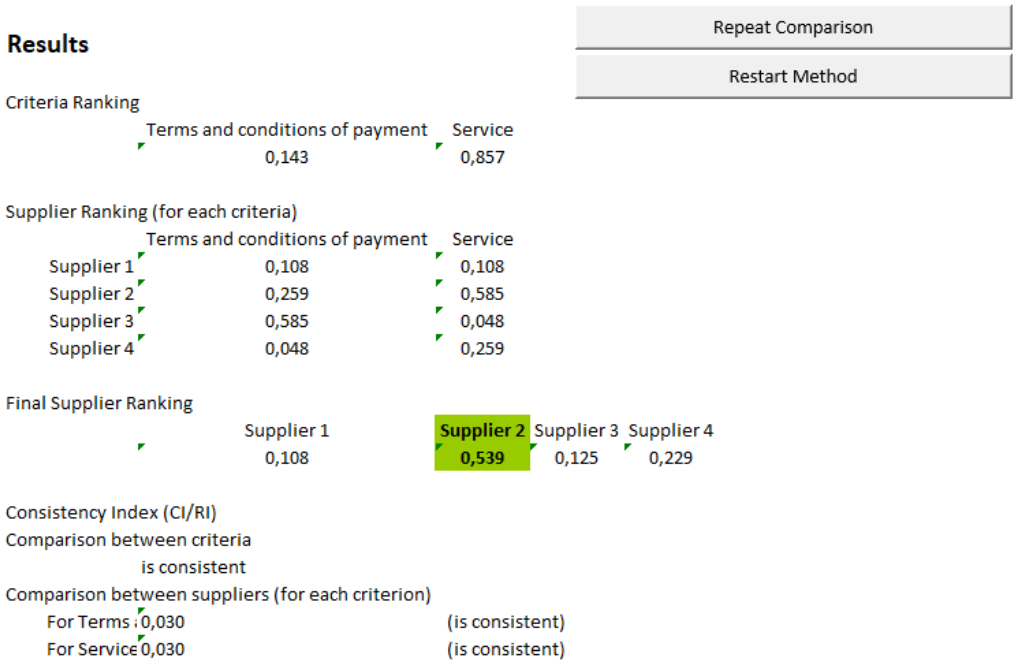

Figure A.8: AHP report

Appendix B

Evaluation Criteria

Company Quality Certification

The criterion measures the supplier's certification to quality management standards, with a weight of 7.5%. Points are awarded as follows:

Table B.1: Score assigned to company quality certification criterion

Company Quality Certification	Score
Certified	7.5
Not certified	0

Delayed Deliveries

Delayed deliveries, together with non-conformities, is a critical reality in ADIRA. As seen, OTD fall short on the company's objective. Therefore, this criterion also has a weight of 25% with the following scores (Table B.2):

Table B.2: Score assigned to delayed deliveries criterion

Delayed Deliveries	Score
Very High	25
High	12.5
Average	6.25
Low	3.125
Very Low	1.563
None	0

For this hypotheses, non means no delayed days, very low is one to five delivered days, low is five to ten days, average is ten to fifty days, high is fifty to twenty days, and finally very high represents more than twenty days of late deliveries.

Flexibility

This criterion is a qualitative measure to state how fast a supplier can adapt to changes. These can include the ability to fill urgent orders, to customize products, or to provide flexible services if needed. It represents a weight of 12.5% and is stated as presented in Table B.3

Table B.3: Score assigned to flexibility criterion

Flexibility	Score
Low	12.5
Average	6.25
High	0

Invoice processing

It is not uncommon to ADIRA's warehouse workers find errors on the invoices sent by suppliers. Whether the quantity invoiced do not correspond to reality or price errors, ADIRA's persists on accurate invoices. This criterion has a weight of 5% with scores presented in Table B.4.

Table B.4: Score assigned to invoice processing criterion

Invoice Processing	Score
Bad	5
Sufficient	2.5
Good	0

Moreover, this criterion also relies on the responsiveness of suppliers to put on the invoice specific information required by ADIRA, as for instance the purchase number or the ADIRA's components code.

Along with the invoice, suppliers should send other important shipment documents with their deliveries. This have to be standardized among all suppliers, by including:

- Product quality certification/report;
- Material age/shelf life information;
- Safety data sheet and accident instruction sheet (when applicable).

Non-conformities

As stated during this dissertation, one of ADIRA's main issues related to suppliers is the high number of non-conformities that everyday arrive to its warehouse. One way of opposing this trend is to constantly monitor this criterion and highly privilege those that meet the demanded specifications. Therefore, in this evaluation model, non-conformities have a weight of 25%, with associated points show in Table B.5.

Table B.5: Score assigned to non-conformities criterion

Non-conformities	Score
Very High	25
High	12.5
Average	6.25
Low	3.125
Very Low	1.563
None	0

This is a quantitative and automatic criterion which means its value is easily withdrawn from the company's records. Regarding the hypotheses of Table B.5, none means zero non-conformities, very low is one non-conformity, low is two non-conformities, average is three non-conformities, high is four non-conformities, and finally very high represents more than 5 non-conformities.

Product Quality Certification/Report

The supplier is fully responsible for the quality of the products delivered and services provided. Therefore, as a way of assuring the compliance of the products to specifications, suppliers need to send a product quality certification/report with each delivery. This is not a current practice and, as a way of making it happen, this criterion enters the model. The scores assigned to product quality certification/report criterion are presented in Table B.6.

Table B.6: Score assigned to product quality certification/report criterion

Product Quality Certification/Report	Score
Send	0
When asked	3.75
Do not send	7.5

Relationship

Another qualitative criterion used in the model is the relationship criterion. It intends to understand what type of relationship ADIRA has with each supplier in terms of communication, cooperation and reliability. The scoring related to this criterion is presented in Table B.7.

Table B.7: Score assigned to relationship criterion

Relationship	Score
Good	0
Normal	2.5
Bad	5

Relative Price

Comparing prices with potential suppliers is a critical step to understand at which level of competition the supplier is. Here the decision maker has three hypothesis: below, average or higher than competition. This criterion counts on a weight of 12.5% and the points attributed to each possible answer are as follows in Table B.8.

Table B.8: Score assigned to relative price criterion

Relative price	Score
Low	0
Average	6.25
High	12.5

Appendix C

Assessment Questionnaire

Based on the analysis of different surveys used by other companies (HP, 2007; Gewerbeaufsicht Niedersachsen, 2010; Orchid, 2016; Continental AG, 2017; PGS, 2017) it was developed a supplier assessment questionnaire.

adira

Supplier Qualification

Name	
Founded in year	
Address	
Zip	
Contact	
Email	
Homepage	

Product/service to supply		Yearly capacity 2017	2018	2019
Product 1				
Product 2				
Product 3				

Comments	

Responsible for filling this document

Name	
Location	
Date	

Figure C.1: Supplier assessment questionnaire

1	**Company**	
1.1	**Strategy**	
	Please describe the company's strategy and its positioning in the market e.g. topics: - strengths; - growing areas; - unique selling point; - potential innovation areas.	
1.2	**Human Resources**	
	Is there a measurement of employees' skills and qualification? (y/n)	
	Is there a focus on employees' motivation and satisfaction? (yes/no)	
	Are employees trained according to their function? (yes/no)	
	If so, the efficiency of those trainings is measured? (yes/no)	
1.3	**Customer**	
	Client satisfaction is measured? (yes/no)	
	complaint rate (external) in per cent of deliveries	5%
	Do you offer a technical support system to your costumers? (yes/no)	
1.4	**Supplier**	
	Do you have a supplier selection and evaluation process implemented? (yes/no)	
	Do you measure the performance of your suppliers over the time? (yes/no)	
1.5	**Sustainability**	
	Is there any plans on reducing enegy consumption and GHGs emissions? (yes/no)	
	Do you aim on waste reduction? (yes/no)	
2	**Quality**	
2.1	**Certification**	
	The company is certified? (yes/no)	
	Company certification:	
	ISO / TS 16949 (yes/no)	
	ISO 9001 (yes/no)	
	ISO 14001 (yes/no)	
	ISSO 18001 (yes/no)	
	If not,	
	Do you plan on getting certifications? (yes/no)	
	If so, when?	
2.2	**Application**	
	Is there a quality management system? (yes/no)	
	Do you have internal and external audits? (yes/no)	
	Do you perform a quality inspection when products arrive to your warehouse? (yes/no)	
	Non-conforming products are well identified? (yes/no)	
	Is there a pre-defined location for non-conforming products? (yes/no)	
	Do you have potential solutions for dealing with non-conformities (internal and external)? (yes/no)	
	Do you perform inspections before expediting products? (yes/no)	
	Your conformity certificate is sent with all your deliveries? (yes/no)	

Figure C.2: Supplier assessment questionnaire (cont.)

3 Process

3.1 Production, processes and equipment

The production procedures are well defined? (yes/no)	
The process is flexible? And if so with low setup time and costs? (yes/no)	
Do you have Lean tools implemented? (yes/no)	
which ones? (e.g. 5S, JIT, Kaizen, Kanban,...)	
Can you send samples of your products, if requested? (yes/no)	
Do you perform production inspections and tests? (yes/no)	

3.2 Planning and capacity

Is there an appropriate planning to production and capacity? (yes/no)	
Do you plan for short and long term? (yes/no)	
Are you capable of assuring supply in long-term? (yes/no)	
Are you capable of dealing with demand fluctuations in the short-term? (yes/no)	

3.3 Maintenance

Do you aim on preventive maintenance? (yes/no)	
Is there defined procedures for preventive and corrective actions? (yes/no)	

3.4 Warehouse and expedition

Is your warehouse adequate? (yes/no)	
Do you have the right equipment for handling with materials? (yes/no)	
FIFO? (yes/no)	
Your stock is adequated to your costumer's needs? (yes/no)	
Your billing is sent corretly? (yes/no)	

3.5 Control and supervision

Is there a statistical process control? (yes/no)	
Do you perform a failure modes and effects analysis approah? (yes/no)	
Is there any plan for reducing potential variations in production? (yes/no)	
Out of control situations are properly documented and treated? (yes/no)	

4 Financial Situation

How do you consider your prices when comparing to competitors? (put x)

Above the average	
Average	
Below in average	

Your financial situation is classifed by any rating agency? (yes/no) ☐ (e.g., Standard & Poors)

If so,

Which one?	
What is your rating?	

Figure C.3: Supplier assessment questionnaire (cont.)

1. Please describe your production process as detailed as possible

2. Please send with this document (the ones applicable)		
- organization structure		(put an x in the ones you will attach)
- copy of certifications		
- quality manual		
- product quality specifications		
- measured KPIs		
- production and warehouse layout		

Figure C.4: Supplier assessment questionnaire (cont.)