SCHOOL OF MANAGEMENT AND TECHNOLOGY
POLYTECHNIC OF PORTO

M **MASTER**
Methods for Business Decision Making

Processes of Outsourcing Optimization and Estimation of Foreign Demand in the Footwear Industry

Raquel Maria da Cunha Francisco

06/**2021**

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"Aqueles que passam por nós, não vão sós, não nos deixam sós.

Deixam um pouco de si e levam um pouco de nós."

(Antoine de Saint - Exupéry)

À minha Avó ...

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Resumo

O aumento das exportações é um dos aspectos mais importantes para a recuperação da crise económica e financeira de um país. No entanto, com um mercado internacional cada vez mais exigente e com o aumento do comércio internacional, para garantirem o seu sucesso as empresas têm de ter uma capacidade competitiva. Portugal tem uma indústria de calçado de alta qualidade. Para além de ser uma indústria tradicional, o calçado em Portugal é fortemente vocacionado para o mercado externo. Neste sentido, a análise da sua competitividade passa por um conjunto de factores tais como, responder a questões como a procura e a capacidade de produção, antecipando assim a tendência do mercado.

Neste estudo, foram utilizados dados de uma empresa que fábrica calçado 100% para exportação. Ao longo dos anos, esta empresa Portuguesa tem tido um acentuado aumento da procura de calçado por parte dos mercados externos. Como forma de aumentar a sua capacidade de produção e dar resposta à procura do mercado, esta empresa recorre frequentemente ao outsourcing. Neste contexto, numa primeira parte, formulou-se um modelo matemático que pretende auxiliar o gestor de produção na atribuição para produção interna ou para produção externa das encomendas às quais tem de satisfazer, de modo a minimizar o custo total da produção. Os resultados apontam para uma redução da percentagem de pares de calçado produzidos recorrendo ao outsourcing. Posteriormente, examinamos quais os fatores que influenciam a procura de calçado, assim como se analisa a sua tendência sazonal. A partir de uma amostra de 42 meses de vendas apresentaram-se duas funções para a procura traduzidas uma em valor das exportações e outra em quantidade de pares exportados. Concluímos que a empresa possui características como a produtividade, o número de trabalhadores e o capital próprio que influênciam a procura de calçado. Para além disso, confirmou-se que as vendas seguem um padrão sazonal ao longo do tempo.

Keywords: Outsourcing, Indústria do Calçado, Otimização, Sazonalidade, Procura

Abstract

The increased of exports is one of the most important aspects of a country's recovery from of economic and financial crisis. However, with an increasingly demanding international market and with the increase of international trade, to ensure their success the companies must have a competitive capacity. Portugal has a high quality footwear industry. In addition to being a traditional industry, the footwear sector in Portugal is strongly oriented towards the foreign market. In this sense, the analysis of its competitiveness involves a set of factors and answering questions such as demand and production capacity, thus anticipating the market trend.

In this study, data from a company that manufactures shoes 100% for export is used. Over the years, this Portuguese company has seen a sharp increase in demand from foreign markets. As a way to increase its production capacity and respond to market demand, this company uses outsourcing. In this context, in the first part of this dissertation a, a mathematical model was formulated that intends to assist the production manager in the allocation the orders to internal or external production with the aim of minimizing the total cost of production. The results point to a reduction in the percentage of pairs produced using outsourcing.

Subsequently, the factors which influence the demand for footwear are examine, and the analysis of its seasonal trend is conducted. From a 42-month sample, two were presented, one in export value and the other in number of exported pairs. We conclude that the company has characteristics, such as, productivity, number of workers and equity, that influence the demand for footwear. Furthermore, it was confirmed that sales follow a seasonal pattern over time.

Keywords: Outsourcing, Footwear Industry, Optimization, Seasonality, Demand

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Acronyms

ACO Ant Colony Algorithm

A-F Assembly - Finishing

AMPL A Mathematical Programming Modelling Language

AP Assignment Problems

APICCAPS Associação Portuguesa dos Industriais de Calçado, Componentes e Artigos de pele e seus Sucedâneos

C-S Cutting - Sewing

FMI International Monetary Fund

GA Genetic Algorithm

GAP Generalized affectation problema

INE National Institute of Statistics

IP Integer Linear Programming

ILP Linear Integer Programming

LP Linear Programming

MIP Mixed Integer Programming

MILP Mixed Integer Linear Programming

NLP Nonlinear Programming

OR Operational Research

PIB Gross Domestic Product

SA Simulated Annealing

Chapter 1

Introduction

The technological development and geographic concentration of most companies producing footwear and its components is on the North and Center regions of Portugal. This location has become part of the sector's strategy, enhancing the development of a regional and sectorial cluster, in order to take advantage of synergies and cost reductions. On the other hand, Portuguese companies invested heavily in modernization and innovation. Therefore, competitively no longer is centered at having the lowest prices but focus on the development of the product and brand quality standards, in an approach aimed at the foreign markets [11].

The Portuguese footwear industry exports more than 95% of its production [3], being one of the sectors that most contributes to the trade balance, so the greater the increase in exports, the greater the contribution to reducing the deficit in the Portuguese trade balance and greater economic growth. On the other hand, companies that invest more on the development of exports present greater productivity [18], create more jobs, become more competitive in the world market and the fore contribute to the sustained development of the country.

The footwear sector has been growing significantly over the years and Portugal has gained worldwide recognition and prestige. International customers recognize that shoes made in Portugal as being of high quality and comfort, increasingly seeking Portugal to purchase products. In this sense, it is interesting to analyze the factors that influence this demand in the company under study. Additionally, to study the determinants of footwear exports, the existence of a seasonal sales trend is also analyzed in this dissertation.

Due to the increase in demand and the lack of labor in the sector, companies do not have the productive capacity to respond to all orders and see outsourcing as a solution. Subcontracting is the purchase of an item or service from another company [12]. When making subcontracting decisions, a company needs to consider many factors, including, in-house production capacity and cost, customers demand, available subcontractors, their production costs and delivery times [27]. Subcontracting is used when the manufacturer does not have in-house capacity and depends on the subcontractor for the entire volume, or part, of the production. When a company subcontracts some of its tasks, it can target its focus to its core competencies. Also subcontracting reduces the investment requirements and therefore the company's financial risk. It furthermore helps the company to improve its response to customer demand. Furthermore, if a company subcontracts an entire operation to a subcontractor, the uncertainty of demand in the supply chain is reduced through the risk polling effect. Thus, outsourcing has become a recurrent practice in this sector. However, it entails an increased cost for the company.In fact, the distribution of order to be produced internally and externally, that on minimizes production costs is not easy process. In the present dissertation the aim is to contribute to this decision process.

1.1 The Case Study

The company under study is recognized worldwide in the footwear manufacturing sector. It currently sells its products to five continents and exports 100% of its production. The company is headquartered in Felgueiras. In this region there is a strong geographic agglomeration of footwear production, which makes the level of competitiveness and competition very high. In this sense, the company, in addition to having a good knowledge of the factors that influence its export value, also needs to be effective and efficient in managing the planning the production of the orders, always aiming to minimize its production costs. Therefore, the present work focuses on two departments: production and export planning.

The main objectives of this dissertation are outlined next:

- Production planning - In order to meet the delivery dates of the orders, the company needs to resort to outsourcing. In this case it needs to plan in view of the lowest possible production cost. For this, a mathematical model will be developed for scheduling the orders to be produced internally and externally, aiming to minimize the total production cost.
- Factors influencing exports - Known factors that determine exports by this company, as well as, analyze the trend of seasonality in sales is also of great importance. Therefore, an econometric model that analyze time series between January 2017 and June 2020, are developed.

1.2 Contributions of This Project

The relevance of the thematic of this dissertation is fundamental in the current context of economic and financial crisis. In fact, knowing the factors that influence exports and minimizing production costs is fundamental in all exporting companies. As for the first objective, in the literature review carried out, no studies were found that specifically address outsourcing in the footwear industry. The present dissertation is intended to fill this gap. In fact, most of the studies found in literature are based on simulated data. The present work uses data from a company in the footwear sector in the Tâmega e Sousa Region.

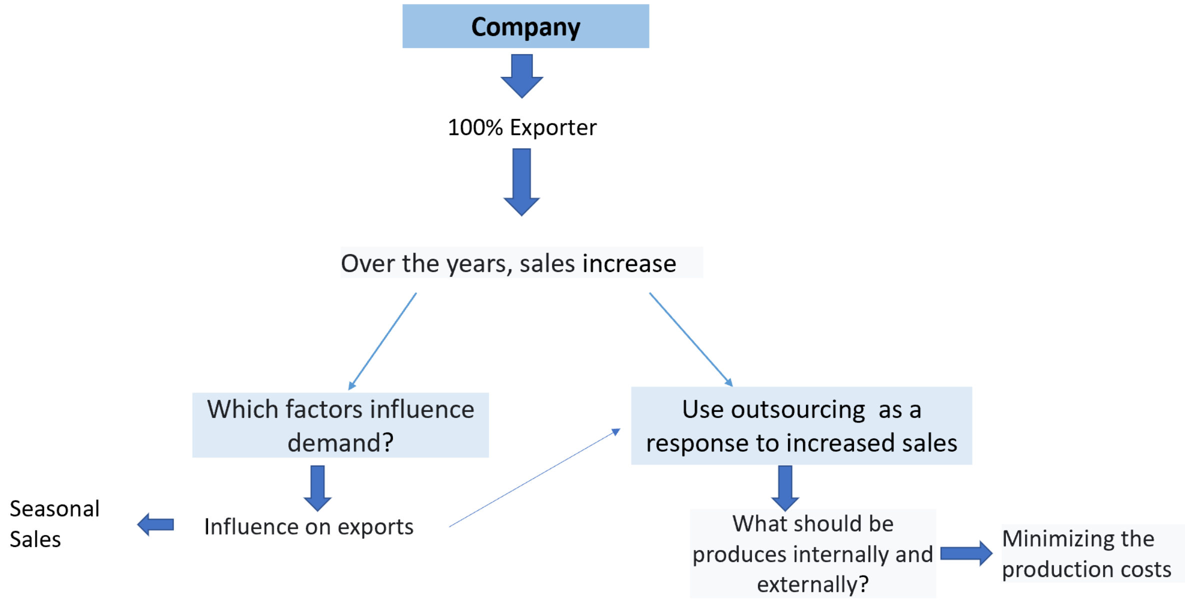


Figure 1.1: Objectives of the present dissertation

Regarding the second objective, there are several studies of the factors that influence exports (see e.g. productivity, number of workers, remunerations). However, data from several companies are used and no articles were found for studying this subject on a single company. This is one of the original aspects of the present dissertation. By consider data from the company under study, all its specificities are taken in to account. Furthermore, the footwear sector is often characterized by production cycles, that is, there is a seasonal trend. However, of the best of our knowledge there is no study this on seasonality of sales in the footwear sector.

1.3 Project Outline

This work is organized into four chapters, as illustrated in Figure 1.2 and outlined next:

Chapter 1: provides a short introduction to the theme of exports in the footwear industry and its importance in the current business environment. Emphasis is given on subcontracting process used in this sector. Furthermore, it presents the objectives of the case study and its innovative contributions.

Chapter 2: consists of the article "Outsourcing Optimization in Shoe Industry: The case of a Portuguese company" whose preliminary version as presented at the Regional Helix 2019 conference. The problem of allocation of the orders for internal and external production is handle. The literature review on outsourcing explains its meaning, and it is generally used in several studies. Furthermore, it portrays the empirical study and a basis for the model that was developed using the as an optimization prole the algebraic modelling language AMPL and solved using the gurobi solver . The model obtained aims to minimize production costs.

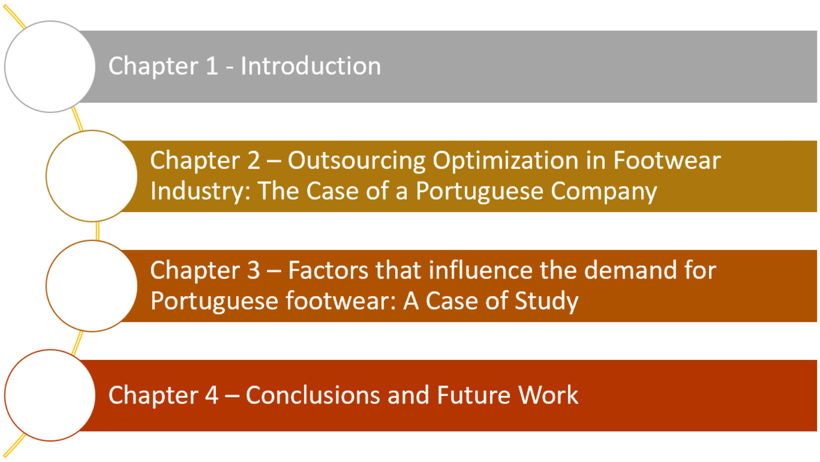


Figure 1.2: Structure of the project

Chapter 3: includes the article "Factors influencing exports and seasonal trends in sales in a footwear manufacturing company" presented at the VII Workshop on Computational Data Analysis and Numerical Methods (WCDANM) in 2020. First importance of exports in the footwear sector is addressed. Literature review is then carried out in order to identify the explanatory variables that should be considered. Subsequently, a characterization of the footwear sector is carried out. The econometric model that was developed used data provided by the company. It takings into account the sample with the determinants of exports and another that, adding the fixed effect, intends to analyze the seasonal trend of the company's sales. The results are analysed and followed by discussion and conclusion.

Chapter 5: presents the general conclusions of the entire project, as well as, suggestions for the future research.

Chapter 2

Outsourcing Optimization in Footwear Industry: The Case of a Portuguese Company

When market's demand exceeds the company's manufacturing capacity, subcontracting is generally considered to be an effective alternative option. Traditionally, the processing of incoming orders is only handled using internal resources. However, in practice subcontracting is often used in various industries to respond to large number of orders occurring in small periods of time. Therefore, several companies consider that each order can be scheduled for internal production or subcontracted (outsourcing) to an external supplier in order to satisfy the customer by fulfilling the delivery dates. This work presents an empirical study, with real data from a Portuguese company in the footwear sector, aim to propose a model for assisting in the decision-making process of production planning. In this chapter, the problem in question and the company are introduced. Additionally, a preliminary analysis of the data is carried out to decide on orders to be produced internally or externally. The aim is to minimize the cost of production, taking into account the conditions that most influence production.

Keywords: Outsourcing, Footwear Industry, Optimization, Binary Linear Programming, Assignment Problem.

2.1 Introduction

In the business context, outsourcing is increasingly used to refer to subcontracting. It occurs when a company transfers or subcontracts a set of activities, processes, services or manpower, to another company [27]. This method became very popular in the 1990s, encouraged by the success of outsourcing at Kodak

[54]. Thus, the use of outsourcing has become a critical strategic decision that can allow organizations to develop and obtain the necessary resources to compete in the current business environment [54].

During the 1960s, outsourcing related to manpower became one of the most important changes made by companies worldwide. According to Blinder [22], three factors drove this change, namely:

- the increase of productivity in the industrial sector, which allowed the production of larger quantity and variety of goods with a lower number of worked hours;
- consumer tastes have changed and started to spend more of their income on services (e.g. meals in restaurants, holidays) and less on goods (e.g. clothing and refrigerant);
- countries import far more production goods for consumption than they did before.

Responding quickly to customers requires flexibility in production. In this sense, when demand exceeds, the production capacity of the company, many companies resort to outsourcing excess production capacity. As a mean to satisfy all their orders, ensuring their timely delivery. The company under study faces periods of a large increase in the orders, which exceeds its internal production capacity. Since the company is not capable to produce all the orders, it resorts to outsourcing for the excess of production required.

Ineffective performance, both in terms of delivery times, overly long processing and defective orders, or in relation to high labor costs, additional costs and emergency orders, can result in customer's dissatisfaction. This is a significant threat to the competitiveness of the company [92]. The production planning system, has as its main objective to ensure that the desired products are produced at the right time, at minimum cost, in the exact quantities, while maintaining the established quality levels [55].

In this sense, this work addresses decision-making issues related to operational planning. Specifically, the main objective is to model the order allocation process to external companies or to internal production in order to minimize the costs associated with outsourcing, as well as, the general costs of the company. The delivery dates, the productive capacity of the companies involved, the cost of production are taken into accounts. In particular, it is intended to contribute to a work tool that assists in the planning of distribution of orders for internal or external (in outsourcing service providers) production.

2.2 Literature Review

2.2.1 Outsourcing

The use of outsourcing in scheduling problems is still taking its first steps. However, there is an increasing tendency the literature to consider this subject [80]. Chen and Li [27] define outsourcing as being a contract with external companies, when the manufacturer does not have internal production capacity. It brings advantages to the company, because by subcontracting it allows the manufacturer to focus on its core competencies. Furthermore subcontracting reduces the company's financial risk and helps the company to improve its response to customer demand [27].

In fact, organizations consider outsourcing essential for its operation, as it helps to extend capacities at lower costs than increasing own capacity [49]. The outsourcing decision includes issues on cost, quality, flexibility, strategic focus and diversification, the potential loss of skills, critical knowledge and the appropriation of the value of the final product. This decision varies between companies to a sector and also differences in the context of each organization [53]. However, care must be taken to ensure that there is a reliable chain of subcontractors capable of responding to peak demand [53]. Ford et al. [36] consider that cost reduction is the main reason that leads to outsourcing.

Subcontracting presents organizations with the opportunity to avoid constraints in their own productive capacity to meet changes in sales volume. In situations where the sales pattern exhibits seasonality or cyclical characteristics, penalties for the lack of internal capacity can be avoided by using outsourcing [53]. Many companies known worldwide have opted for subcontracting, such as Chrysler and Ford, which currently produce less than half the value of all their vehicles internally. Likewise, Boeing began to rely more heavily on outsourcing partners to manufacture its aircraft [40].

According to Belso-Martínez [17] the traditional determinants of competitiveness in the footwear industry were the cost of production and the impact of trade barriers, with the passage of time these determinants have lost some of their relevance in favor of new factors such as technological developments, proximity to the main markets (quick response), requirements for high quality production, access to technology, design and marketing skills, the growing importance of production, outsourcing, availability of raw materials or components. These factors contribute to the potential survival of companies in the footwear industry, allowing them to offer high quality footwear with short leading times. Thus, the concept of *"made in ..."* is challenged.

When the level of demand exceeds the internal production capacity, outsourcing becomes very important for the manufacturer. Outsourcing is a commonly used way to improve production performance [61]. The practice of outsourcing is widespread in many industries due to the many advantages it brings to the company [27] i.e. outsourcing can be used as a secondary source of supply, in addition to in-house production.

2.2.2 Problems Related to Outsourcing

Subcontracting always underlies a classic problem of assigment, *i.e,* matching n jobs to n machines, in order to minimize the total costs, in this spefic case, assigning part of the production to external companies [87, 20].

The planning problems faced by logistics services often involve complex decisions. For *e.g.,* Zapfel and Bogl [94] analyzed a postal company where it is necessary to plan the week for the collection and delivery of orders. Specifically, the transport and personnel involved, as well as, whether it will be necessary to subcontract vehicles and drivers, had to be considered. This problem was formulated as a nonlinear mixed-integer programming model A solution framework, that allows using different metaheuristics, was developed.

While selecting suppliers for subcontracting various services is a very important decision issue, Feng et al. [35] propose a decision model for selecting suppliers to supply different elements of the process / product or service that consists of a long-term collaborative relationship.

Over the past decade, outsourcing has attracted a lot of attention and is embedded in many problem decisions involving production scheduling. The problems of joint decision on outsourcing and scheduling were considered in a single machine, parallel machine, flow shop and shop job. Qi [74] considers scheduling using outsourcing in a single machine environment to mitigate the effects of transportation. It proposes dynamic programming algorithms, modeling the logistics issues as a batch transportation problem with a fixed batching cost. Lee and Sung [59], [60] analyze two machine scheduling problems with the possibility of job outsourcing. They include the problem of minimizing maximum delay and subcontracting costs, and of minimizing total delays and outsourcing costs using heuristic and branch and bound algorithms. It is proved that the problem is NP-hard.

Zhong and Huo [95] studied a scheduling model where jobs can be processed internally on a single machine by resorting to outsourcing. If a job is subcontracted, its processing cost is different from the internal cost and its delivery time is a gradual function of the total processing time of subcontracted jobs. They proved the NP-hardness characteristic of the problem and proposed a pseudo-polynomial algorithm. Hong and Lee [51] analyzed an outsourcing problem with the objective to minimize the cost of outsourcing, considering the maturity dates and capacity limits of the subcontractors. To find the optimal solution, the pseudo-polynomial algorithm was used.

As for the programming of parallel machine with the option of outsourcing, Chen and Li [27] considered a problem where orders can be processed internally or subcontracted to one of several subcontractors available, possibly at a higher cost. The goal is to minimize the total cost while the maximum time for completing the work is limited by an upper limit. The authors propose a heuristic algorithm to solve it. Mokhtari and Abadi [66] consider a single-stage problem where the manufacturer has a parallel machine system and each subcontractor has a single machine. A heuristic method based on the decomposition of the problem is presented using the Lagrangian Relaxation approach to solve the problem. Neto, Filho and da Silva [69] considered an identical parallel machine programming problem in which each job can be subcontracted at a specific cost, while the total outsourcing budget is limited. The problem is solved to minimize the sum of total cost of outsourcing and weighted total delay. For that, an Ant Colony Algorithm (ACO) was developed, whose performance is evaluated by comparing it with the mathematical programming approach. Liu, Lee and Wang [62] addressed a parallel-machine scheduling problem whose objective is to minimize the total resource consumption and the total cost of outsourcing defining an upper bound for the maximum tardiness of all jobs. To solve the problem a branch and bound and a meta-heuristic algorithm which hybridizes genetic algorithm (GA) and simulated annealing (SA) were used.

The outsourcing and scheduling problems were extensively investigated in the flow shop, such as, Qi [75] and [76], Choi and Chung [28], Lee and Choi [28], Tavares Neto and Godinho Filho [68], Mokhtari, Kamal Abadi and Amin-Naseri [66], Chung and Choi [30], Choi and Park [29]. Qi [75, 76] considered a two-phase flow shop with an outsourcing option and have developed some optimization algorithms, including an optimal algorithm and a heuristic algorithm. Choi and Chung [28] and Lee and Choi [28] studied a two-machine or two-phase flow shop schedule with an outsourcing option. They analysed the computational complexity of the problems and presented a polynomial time algorithm. Mokhtari, Kamal Abadi and Amin-Naseri [66] developed a mixed integer programming model for the scheduling problem with an outsourcing option, in which subcontracting is allowed through different subcontractors, and proposed a team process algorithm to minimize the sum of the weighted flow time, in which outsourcing of manufacturing operations is allowed through subcontracts, thus fulfilling the customers due dates. Choi and Park [29] considered a multistage permutation flow scheduling problem in which, each job can be subcontracted as an integer and proved that the problems considered are polynomially solvable.

Among the vast review of existing literature, joint decisions on outsourcing and scheduling are rarely investigated in the job shop. In fact, only the following consider the possibility of outsourcing. Chung et al.[31] were among the first to study job shop subcontracting. The authors assumed that each operation can be subcontracted independently, subject to certain constraints. One of the constraints is that the tasks must be completed before the established delivery date. The objective is to minimize the total cost of outsourcing. A two-stage algorithm was proposed to solve the problem. Guo and Lei [46] studied bi objective job shop scheduling, considering scheduling of jobs in the manufacturer's or subcontractor's stores. The problem consists of three sub-problems: the selection of outsourcing jobs, subcontract scheduling and internal work scheduling. The objectives of the problems are to minimize the total delay and to minimize the costs of outsourcing. A two phased neighbourhood search algorithm is proposed in order to obtain the Pareto optimal solutions. The same authors studied the same problem changing the structure of the objective [61]. One of the objectives, the total cost of outsourcing, is defined as a constraint considering an upper limit and the total delay is minimized as the objective function. A meta-heuristic algorithm called the shuffled frog-leaping algorithm is used to solve the problem.

2.2.3 Production Planning

The permanence of any industry in a competitive market requires a great understanding of the strategic, tactical and operational issues related to markets, products and production. It has become increasingly important to link production planning and control to the strategic level in decision-making. Within the production order, to support competitive priorities, e.g. quality, delivery speed, reliability, price and availability, planning and control systems are vital to provide the correct support [70].

Production planning is one of the most important activities of a company at the operational level. This is why companies need to remain competitive in the markets, as consumers are increasingly demanding. In production planning there are several performance measures, all aimed at the good functioning of the system and customer satisfaction (*e.g.* effective use of resources, delivery of products within the specified deadlines, reduction of production costs [39]).

Maccarthy and Liu [63] claim that the use of classical planning theory in many production environments is minimal. In many factories, production planning is done manually by the production manager or team leaders. In most cases, the existence of a practical tool that can be used in scheduling tasks is not valued. The worst is that, the strategic consequences of poor production scheduling on the company's overall performance are not analyzed. Maccarthy and Liu [63] and Vila and Pascual [77] found that most studies still considered production environments from a theoretical point of view, recognizing that there was still a significant gap between theory and practice.

Olhager and Wikner [70] consider three pillars to understand the conditions of production planning and control:

- Customer - the person or organization that receives the products;
- Product - any product that can be offered to satisfy a customer's need or desire;
- Process - the manufacturing value chain involved in delivering the product to the customer, i.e., the transformation process (with respect to properties, time and location).

The best way to proceed is to divide the production and planning process into three distinct levels: strategic, tactical and operational. In this sense, it is crucial to make the best decisions from the point of view of production planning [88] [14], namely:

- Strategic planning - reduction of production costs, choice of suppliers, location of facilities. It is a long-term strategy, with a time horizon of at least one year;
- Tactical planning - purchases, inventory, transport policy. This type of planning serves as a connection between strategic and operational planning, dealing with production planning and the quantity to be produced in a period of weeks up to six months;
- Operational planning - production decisions, i.e. the exact order in which operations are to be carried out and the size of each production. It serves as a regulator of daily decisions and therefore has a short planning horizon.

Therefore, the production planning system has as its main objective to ensure that the desired products are produced at the right time, at a minimum cost, in exact quantities, maintaining the established quality levels [55]. For all the reasons indicated above, the present work addresses decision-making issues related to operational planning.

2.3 Optimization Models

Since the third industrial revolution, organizations have undergone major changes (namely the increasing complexity, the division of labor, the segmentation of responsibilities) resulting in impressive results. In fact the world has witnessed extraordinary growth in both the size and complexity of organizations [47].

Although there are good points in specializing problems, as complexity and specialization increase, it becomes more and more difficult to allocate the resources available for the various activities in the most efficient way. These type of problems, combined with the need to find the best solution, created the necessary conditions for the appearance of Operational Research (OR) [48].

OR may have its origin in Classical Antiquity, however, only after World War II, the pioneer Leonid Kantorovitch (Nobel Prize in Economics in 1975) began its development. More specifically, its origin is attributed to military services at the beginning of World War II, with the need to allocate scarce resources to the various military operations and activities within each operation effectively [82].

Logistical problems have arisen with the necessity to move, accommodate and maintain large armies, requiring more efficient management of scarce resources and operations of the armed forces [48]. In fact, the contribution of the many scientists who contributed to solving these tactical and strategic problems, and given the OR post-war success, motivated its application outside the military environment. Since then, OR was used in several areas, such as, commercial, governmental, industrial. Its rapid expansion took into account two determinant factors [48]:

- Advancement of OR techniques led to the appearance in 1947 of the simplex method. This is a problem solving process of Linear Programming (LP), supported by various computational techniques for its resolution, which was developed by George Dantzig, and reached its peak of development in 1950;
- Solving OR problems become increasingly difficult and the need to develop digital computers with the capability to solve mathematical problems in a much faster way, arise. This led to the era of the "computational revolution". After this impulse, personal computers appeared with easy access to OR software, thus boosting its progress. Today, millions of people have access to computers and good solvers to solve much more complex problems.

Management is based on making decisions that usually involve using accurate models to solve problems. For Hillier and Lieberman [48] the resolution of an OR problem is carried out in 4 steps (see also Figure 2.1):

1. Observation and definition of the problem and data collection - Three fundamental aspects need to be taken into account: accurate description of the objectives of the study, an exact identification of the decision alternatives that exist and recognition of the limitations and requirements of the system.

2. Formulation of the mathematical model as a representation of the real case to be solved - It is necessary to find the mathematical model that best suits the problem. The most used mathematical models are linear programming;

3. Model validation - This step consists in verifying that the solution found meets the requirements of the problem;

4. Implementation of the solution - Once the model has been validated, the solution must be implemented.

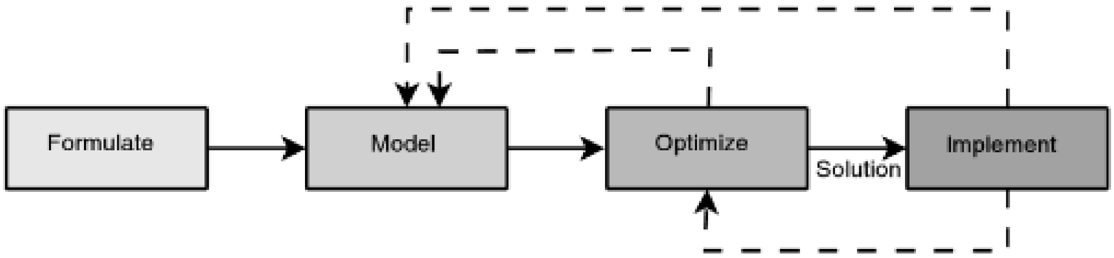


Figure 2.1: Decision process - Source:[86]

The quantitative aspects of OR analysis, together with Applied are substantiated, with methods for constructing quantitative representations, i.e. mathematical and statistical models, of real situations, as well as, computing optimal solutions of such methods and interpreting the results. OR is used in the management of organizations and its use has had positive and intelligible conclusions that assist the decision-making process. OR permits to solve conflicts of interest and tries to find the optimal solutions, i.e. the best solution [48].

LP is used to obtain the optimal solution of a linear objective function, subject to linear equality and inequality constraints [82].

LP is increasingly used in business management, in various ares such as, production planning, marketing, finance, logistics, or in human resources [50]. Therefore, LP is a valuable aid to the effective resolution of problems that contribute to meeting the companies objectives.

LP is extremely important, as computer scientist Laszlo Lovasz said in 1980: "If one would take statistics about which mathematical problem is using up most of the computer time in the world, then (not including database handling problems like sorting and searching) the answer would probably be linear programming.That same year, Eugene Lawler of Berkeley offered the following summary: It [linear programming] is used to allocate resources, plan production, schedule workers, plan investment portfolios and formulate marketing (and military) strategies. The versatility and economic impact of linear programming in today's industrial world is truly awesome." [9].

The basic concept of optimization is to find the best possible solution for a given model. An optimization problem aims to optimize (maximize or minimize) a given mathematical function, subject to a set of constraints. The mathematical function that is optimized is known as the objective function, usually depending on several variables [82].

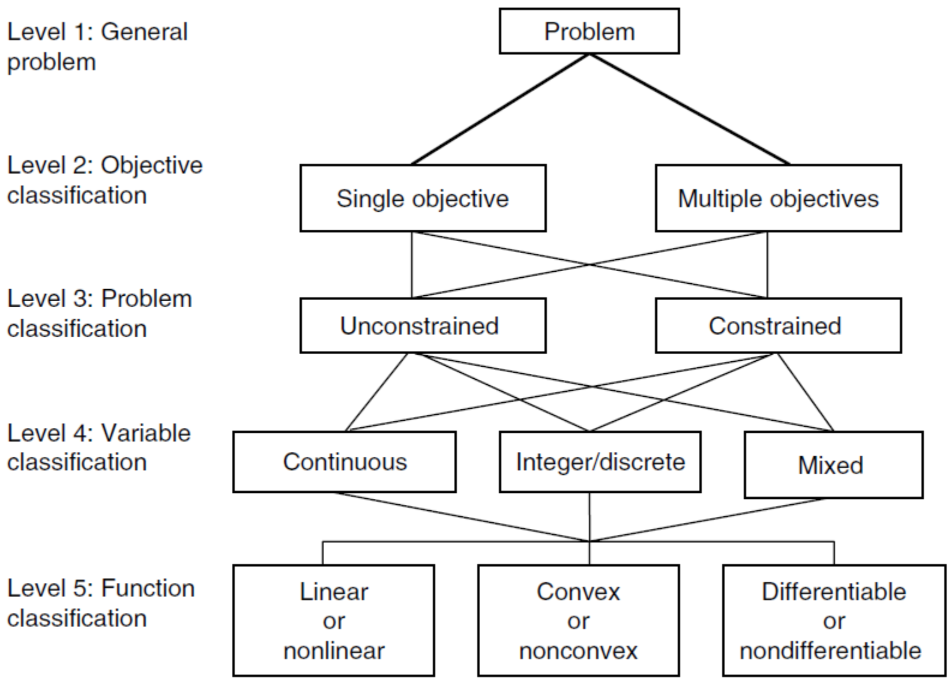


Figure 2.2: Classification of optimization problems - Source:[82]

Several classifications of optimization problems exist. Sarker and Newton [82] present the following classification that take into account several levels Figure 2.2, namely:

- Level 1: Objective classification - single objective or more than one objective.
- Level 2: Problem classification - distinguishes between unconstrained, when there are no constraints, and constrained, otherwise.
- Level 3: Variables classification - optimization problems can be continuous, integer, binary or mixed. In the case of continuous problems the variables are a subset of real numbers; integer problems have integer variables, binary problems have variables with only two possible values: zero or one; mixed problems involve both continuous and integer (or binary) variables. The methods for solving each of problems are quite divergent.
- Level 4: Function classification: if all model functions are linear if one or more functions nonlinear then the is nonlinear.

Sometimes the multiple objectives of an optimization problem contradict each other. When the objectives do not contradict each other, problems with multiple-objectives can be converted to single-objective problems. Real life problems frequently present constraints (equality and inequality) and/or variable limits.

The general form of an LP problem, with n decision variables and m constraints, can be given as:

$$\min \quad c\,x \tag{2.1}$$

s.t.

$$Ax \leq\geq b \tag{2.2}$$

$$x \geq 0 \tag{2.3}$$

where $*$ may be $\leq$, $=$ or/and $\geq$, $x = (x_1, x_2, ..., x_n)^\top$ is the vector of continuous decision variables, $c = (c_1, c_2, ..., c_n)$ is the vector of the objective coefficients, $b = (b_1, b_2, ..., b_m)^\top$ is the vector of the independent terms of the constraints and $A = (a_{ij})_{i=1,...,m;j=1,...,n}$ is the matrix of coefficients of the functions constraints. Expression (2.1) represents the objective function, (2.2) represents inequality or equally constraints, while (2.3) represents the non-negativity constraints.

LP is one of the most satisfactory models for solving optimization problems. In fact, for continuous linear optimization problems, accurate algorithms, such as, simplex methods or interior point methods, exist. Note that, by far, the simplex method is the most used method. The efficiency of the algorithms is due to the fact that the admissible region of the problem is a convex set and the objective function is a convex function. So any optimal local solution is a global optimal [86].

In Nonlinear programming problems (NLP), the objective function and/or the constraints are nonlinear [19]. A continuous problem of nonlinear optimization consists of the minimization (or maximization) of a continuous domain. Continuous nonlinear models are much more difficult to solve than linear ones. Therefore there are many techniques for linearizing a nonlinear problem [44]. Generally, linearization techniques, introduce extra variables and constraints into the model and, in some cases, some degree of approximation [43]. Meta-heuristics are good candidates for solving problems with high dimensionality, multimodality. In optimization theory, continuous optimization algorithms are more developed than discrete optimization. However, there are many real-life applications that are optimized with integer variables, so continuous models are largely unsuitable for these problems. In fact, in many practical optimization problems, resources are indivisible (machines, people, etc.). Optimization models with integer variables are called Integer Programming (IP) [93].

When decision variables are integer and continuous, the models are designated MIP (Mixed Integer Programming). Therefore, MIP models generalize LP and IP models. The resolution of MIP problems has improved dramatically in recent years, with the application of advanced optimization techniques. For small problems with integer variables, enumerative algorithms, such as, branch and bound, can be used. The size is not the only indicator of the complexity of the problem. In fact, the structure of the problems is also determinant for its complexity [86].

A more general class of IP problems are combinatorial optimization problems. This class of problems is characterized by decision variables and a finite search space. However, objective function and constraints can take any form [72].

2.3.1 Assignment Problems

An organization's poor performance results in poor customer service (prolonged processing and delivery of incorrect shipments) and high costs (labor, additional costs and emergency shipments), both of which pose a significant threat to the competitiveness of the entire chain [92].

The outsourcing problem can be seen, from the point of view of optimization, as an Assignment Problem (AP). These problems arise in several areas of economics, mathematics, management, among others and first appeared in 1952 in an article by Votaw [90]. Later, in 1955, the Hungarian method was proposed by Kuhn [56] to solve AP.

The classic AP involves combining the elements of two sets individually, in order to minimize the sum of their associated weights. The dimensions of AP refers to the number of sets of elements to be matched. When there are only two sets, as is the case for most of the variations, the elements of these sets are referred as "tasks" and "agents". Thus, for example, "tasks" may be jobs to be done and "agents", the people or machines that can do them [73].

There are a number of variants of this classic problem, which include problems with different or multiple objectives, problems that involve matching one to many or many to one, and problems that involve matching the elements of three or more sets. Over the past 50 years, there have been several publications on variants of the classic AP. For example, including budget constraints, or recognition of individuals' qualifications for tasks, or time constraints [73].

Caron et al. [24] and Volgenant [89] have considered AP with side-constraints, in which the constraints concern with:

- designate agents only for tasks for which they are qualified;
- recognize seniority classes of agents, who require preference to assign tasks to agents in the upper classes;
- recognize authority classes for tasks, which require tasks with higher priorities to take precedence over the rest.

As previously described, the problem is to find an individual correspondence between n tasks and m agents, in order to minimize the total cost of assignments. In the original version, the PA involves assigning each task to a different agent and each agent is assigned at most one task. However, there are models that involve assigning multiple agents to a task and still others that assign multiple tasks to the same agent [73].

Several mathematical models of AP have been developed, such as:

Classic Model - no more than one task is assigned to an agent. The problem is finding an individual correspondence between n tasks and n agents, in order to minimize the total cost of assignments.

The mathematical model is given as [73]:

$$\min \sum_{i=1}^{n} \sum_{j=1}^{n} c_{ij} x_{ij} \tag{2.4}$$

subject to:

$$\sum_{i=1}^{n} x_{ij} = 1 \qquad j = 1, ..., n, \tag{2.5}$$

$$\sum_{j=1}^{n} x_{ij} = 1 \qquad i = 1, ..., n, \tag{2.6}$$

$$x_{ij} \in \{0, 1\} \tag{2.7}$$

The expression (2.4) represents the objective function, the expressions (2.5), (2.6) are the constraints and the expression (2.7) is the definition of the variables of decision, where $x_{ij} = 1$, if agent i is assigned to the task j and $x_{ij} = 0$ otherwise. While c_{ij} represents the cost of assigning agent i to task j. The (2.5) constraints ensure that each j task is assigned only one i agent and (2.6) constraints ensure that each i agent is assigned to only one task. The mathematical structure of the problem makes the constraint that x_{ij} is binary. In fact, it may be relax to $0 \leq x_{ij} \leq 1$.

Model with multiple tasks per agent - it consists of a type of that allows or requires assignment to the same agent more than one task. The version of the PA that allows an agent to be assigned to multiple tasks is called the Generalized Assignment Problem (GAP). This model assumes, as in the classic AP, that each task will be assigned to one agent, but allows the possibility that an agent may be assigned to more than one task, taking into account his ability to perform the tasks. Therefore, the GAP is an example of a AP that recognizes agent capacity limits and that a task can only use part of an agent's capacity, instead of all. The formulation of a GAP, where n is the number of tasks and m is the number of agents [73]:

$$\min \sum_{i=1}^{m} \sum_{j=1}^{n} c_{ij} x_{ij} \tag{2.8}$$

subject to:

$$\sum_{i=1}^{m} x_{ij} = 1 \qquad j = 1, ..., n, \tag{2.9}$$

$$\sum_{j=1}^{n} a_{ij} x_{ij} \leq b_i \qquad i = 1, ..., m, \tag{2.10}$$

$$x_{ij} \in \{0, 1\} \tag{2.11}$$

Expression (2.8) represents the objective function of a GAP and the expressions (2.9), (2.10) and (2.11) are the constraints to which the GAP is subject, where, $x_{ij} = 1$, if agent i is assigned to task j and $x_{ij} = 0$ otherwise; c_{ij} represents the cost of allocating the agent i to task j, a_{ij} represents the capacity used by agent i if it is assigned to task j, and b_i is the available capacity of agent i. Constraints (2.9) ensure that all tasks are assigned to only one agent and constraints (2.10) ensure that the set of tasks assigned to an agent does not exceed its capacity. Note that, although there are m constraints on (2.10), one for each agent, only one resource is considered, i.e.. the agent's ability to do these tasks.

2.4 Characterization of the footwear industry

The Portuguese footwear industry is one of the most competitive in the world, exporting its products to the five continents [7]. This cluster is composed predominantly of small and medium-sized companies, also including component companies in this area, which combines know-how with technologies and qualified labor, thus leading the industry to high added value markets [5]. The Portuguese footwear industry is concentrated in two areas: Felgueiras and São João da Madeira. In these centers there is a complex network of formal relationships, but above all informal relationships, namely subcontracting [6]. The shortage of qualified labor has become a serious problem in this sector[2]. In fact, this is a region with many companies in the sector and with a high demand, leading to its frequent use of outsourcing.

According to data released at the APICCAPS juncture [2], there was a slowdown in activity in 2018, this was due to the lack of labor combined with insufficient orders from abroad as well as weather conditions.

According to APICCAPS [5] portuguese footwear has a future if the export levels achieved so far are maintained. In 2018, this cluster exported 84 million pairs of shoes to 163 countries, covering the 5 continents, employing 47 thousand workers. Portugal exports 95 % of its total production and the largest share of production refers to women's shoes [8]. Portugal is in second place in the ranking of the highest selling price of footwear [6].

The strategic plan for 2020, launched by the sector association, APICCAPS, has the following vision: "To be the international reference the footwear industry, for its sophistication and creativity, strengthening Portuguese exports based on a national, sustainable and highly competitive production, founded on knowledge and innovation" [6, pp. 234].

The objectives of APICCAPS (see Figure 2.3) in Portuguese are:

1. to attract to the cluster young people with qualifications appropriate to the requirements of modern production processes and qualify current colaboratores;

2. Innovate in terms of materials, components, processes and products;

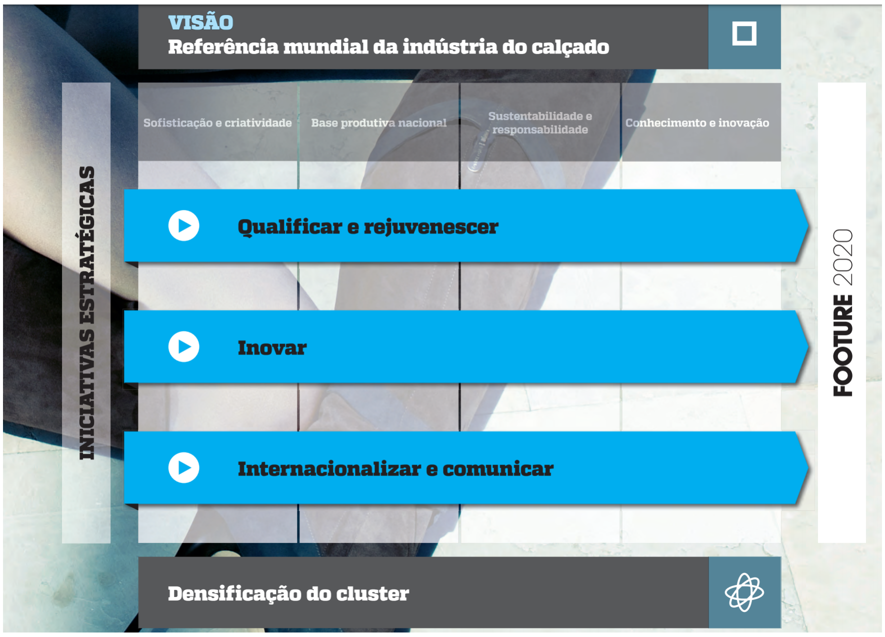


Figure 2.3: Goals for 2020 - Source:[6]

3. Sustainable and responsible development;
4. International reputation of the companies;
5. Internationalization of the value chain.

2.5 Empirical Study

2.5.1 The company and its objective

The footwear industry is characterized by peaks in production related to the seasons, namely Spring-Summer and Autumn-Winter collections. These peaks result from the excess of orders and a consequent deficit in productive capacity. The scarcity of qualified labor [2], leads this sector to frequently resort to outsourcing, to satisfy the execution of all received orders, while trying to ensure control of fixed costs. The incorporation of outsourcing in production planning can pose a problem for companies that need to decide which orders will be produced internally and which will be produced externally, in order to minimize the cost of production and to meet short deadlines of delivery[80].

Resourcing to outsourcing is in many situations more advantageous for companies since internal produced will increase personnel costs. In fact, there are legal barriers that are difficult to overcome, such as making redundancies at the time of breaking orders. Another limitation in the footwear sector is the fact that there is no qualified labor available on the market to increase internal production capacity.

The company under study is located in the Felgueiras Region. Its main activity is the manufacture and sale of footwear. It produces more than half a million pairs of shoes per year. To satisfy all the orders a daily production of 2500 pairs is required. Since the company does not have this installed capacity, it is obliged to resort to outsourcing. The focus of this work is on the production planning of orders to be produced internally and externally, minimizing both outsourcing and production costs.

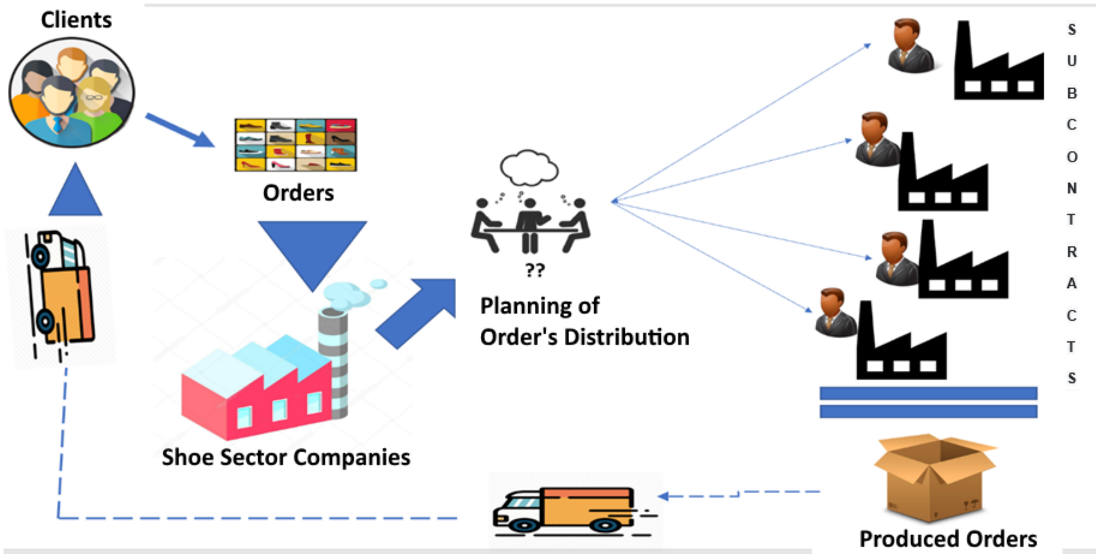


Figure 2.4: Order planning process

In shoe production there are two major sequential production phases: cut-sewing and assembly-finishing. The company under study uses subcontracting services for cutting-sewing and assembly-finishing throughout the year. The combination of tight delivery times with the productive capacity of the company and the service providers, causes an excess of work for the company's planning. The selection of the subcontractor have to take into account the production price of each subcontractor, since the same item may have a different prices depending on the entity that produces it. Currently, these cost differences are not always taken into account. Additionally, the distribution of the orders will have to comply with the production capacities of each subcontractor. Also, each order must be produced entirely in the same factory, as a way of simplifying the ordering process for raw materials and subsequent distribution to the factories.

The company's production process is divided into two phases:

- Cutting - Sewing (C-S): in which, each part that constitutes the footwear, is cut and sewn;
- Assembly - Finishing (A-F): in which all the components are interconnected giving shape to the footwear with its final appearance, followed by the finishing process, *i.e.*, shining, brushing.

Each of these two phases can be, for each order, placed on the company's premises or on the subcontractors. Figure 2.4 shows the entire planning process currently carried out by the company.

In the footwear industry there are several production phases that are sequential, as shown in Figure 2.5, after cutting-sewing and assembly-finishing, the footwear are packed and dispatched to the customer.

Figure 2.5: Productive process - Source:[4]

2.5.2 Database

The company under study is recognized worldwide for the quality of its products and the ability to deliver orders on time. Currently, the company's products are present on five continents. The production manager is responsible for the order production and distribution process. Its mission is to ensure that all orders are produced on time so that the delivery date is satisfied with the required quality and at minimum costs. Both internal and outsourcing costs must be taken in to account on the decision-making process. Currently, the manager at the company is only concerned with meeting delivery deadlines and does not manage costs.

To carry out the empirical study, the company provided a database, with information concerning the orders for the year 2020. More specifically:

- Orders received in 2019 with delivery date in 2020. In fact, it may happen that some orders received in 2019 have to be produced in 2020;
- All orders received and delivered in 2020;
- Orders received in 2020 with delivery date in 2021. In fact some orders received in 2020 will only be produced in 2021.

Table 2.1 describes the information contained in the database. The database contains 5250 orders, in a total of 470641 pairs divided by 97 customers from 33 countries, covering the five continents.

In Figure 2.6 we verify that 70.19% of the produced pairs are for European countries, 16.04% are for American market while Asia and Oceania have more or less the same number of pairs ordered representing 6.93% and 6.83%, respectively.

In Figure 2.7 it is possible to observe that the countries with the highest expression are Germany (17.60%, corresponding to 82847 pairs), USA (14.83%, 69785 pairs), Denmark (10.07%, 47392 pairs) and Australia (6.83%, 32156 pairs). These four countries represent 49.33% of the total portfolio, while the remaining countries order smaller quantities.

Table 2.1: Description of the variables in the database

Variable	Description
Order_nr	Order Identification
Date_Reception	Reception Date of each order
Mon_Recep	Reception Month
Week_Recep	Reception Week
Year_Recep	Reception Year
Date_Del	Delivery Date of each order
Mon_Del	Delivery Month
Week_Del	Delivery Week
Year_Del	Delivery Year
Time	Available Time to produce the order
Qtd_Order	Quantity of each order
Ref_Fact	Reference of the Article
Cut_Seam	Price of cut-sewing manufacturing, per pair
Asse_Finis	Price of assembly - finishing manufacturing, per pair
Company_Cut_Seam	Company that manufactured cut-sewing to order
Company_Asse_Finis	Company that manufactured assembly - finishing to order
Client	Client Identification

[1]Source: Own elaboration

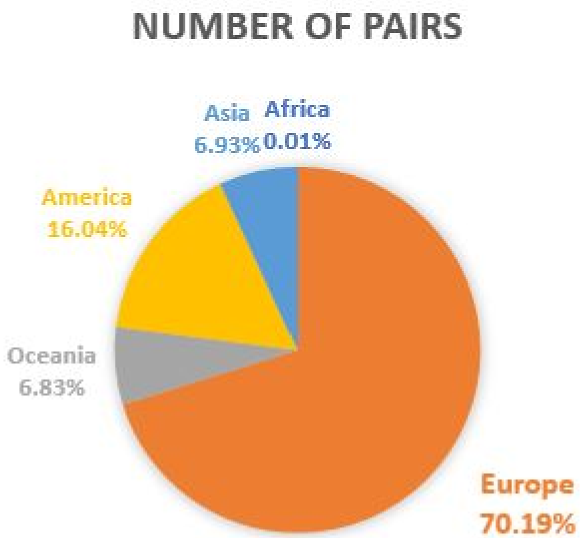


Figure 2.6: Distribution of the number of pairs of shoes per continent

The database contains information on 97 customers. However, six customers stand out from the others by the large volume of pairs they buy, which represents 51.91% (corresponding to 244291) of the total number of pairs. The other 91 customers represent a percentage below 50%. In fact, there are many customers who order several items in small quantities.

Figure 2.7: Number of pairs of shoes, per country

As shown in Table 2.2, the minimum number of pairs ordered is three and the average is 89. This reality changes production planning considerably. In fact, small quantities increase the number of different articles that need to be produced, this decreases the daily capacity, of the company. In fact, there is a total of 550 different articles.

Table 2.2: Descriptive analisys relative to 550 different articles

	Time (days)	Number of pairs per order	C-S Cost (€)	A-F Cost (€)
Minimum	7	3	1.00	2.00
1st quartile	36	14	3.80	3.25
Median	59	36	4.05	3.25
Mean	65.1	89.65	4.42	3.16
3rd quartile	87	96	5.20	3.25
Maximum	193	4000	7.85	3.50

Source: Own elaboration

In a more detailed analysis of the quantities to be produced (Table 4.2 in Appendix), it is evident the problem of insufficient production capacity during all the year. The need of subcontracting external companies occurs practically every month. The costs of subcontracting differ from factory to factory, and from article to article. A base cost for each article is considered and a percentage factor is introduced for each factory. Further details on these factors will be given in Section 2.5.3. Next, the analysis for the base price of each article is performed.

Table 2.2, refers to the cost of C-S, which ranges from 1.00€ do 7.85€, with an average of 4.42€ per pair. Furthermore, 50% of the articles present prices equal or less than 4.05€ and 25% above 5.20€. Whereas, A-F presents more uniform prices, with a minimum of 2.00€ , a maximum of 3.50€ , with an average of 3.16€, per pair. Thus, the prices of C-S present more variability and are higher than the A-F prices.

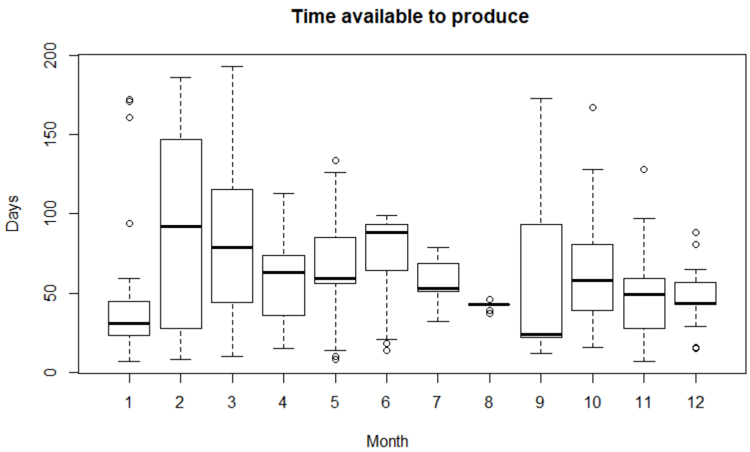


Figure 2.8: Time available to produce the orders for each month of 2020

Subcontractors represent a difficult challenge for production management, since they have different weekly production capacity. Although, most orders are received with some advance to the delivery date (65 days in average), this does not always happen (see Figure 2.8). The variability in the time available to produce the orders requires an efficient and timely planning, as otherwise, delivery dates may not be met.

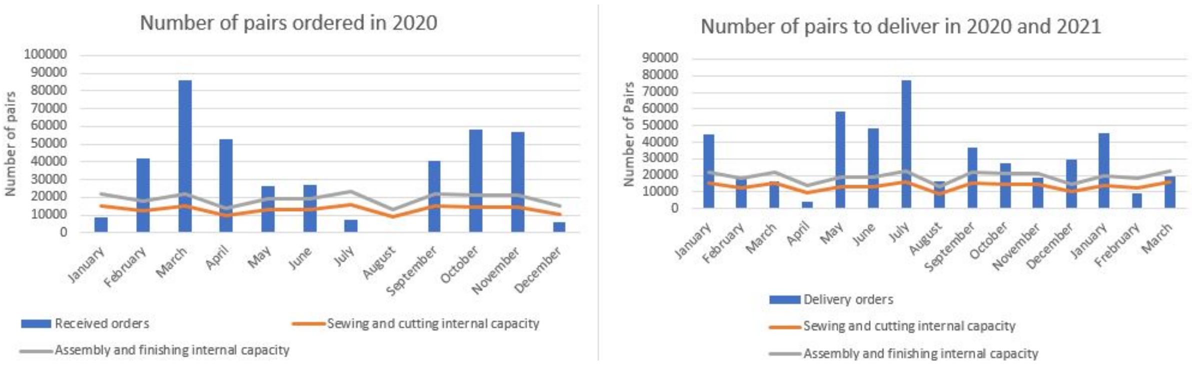


Figure 2.9: Number of pairs taking into account the dates of reception and delivery of the orders.

Figure 2.9 contains two graphs: the one on the left, presents the number of pairs ordered from January to December 2020, the other, presents the number of pairs to dispatch each month, from January 2020 to March 2021. For the two stages in production, from Figure 2.9 and Figure 4.2, in Appendix, it can be conclude that for:

- C-S: The company has a daily internal production capacity of 700 pairs. Therefore, it only has capacity to produce all the orders received in four months (January, July, August and December).

However, analyzing by the delivery date, the company only has the necessary internal capacity in the months of April and February, i.e. two from the 15 that are considered.

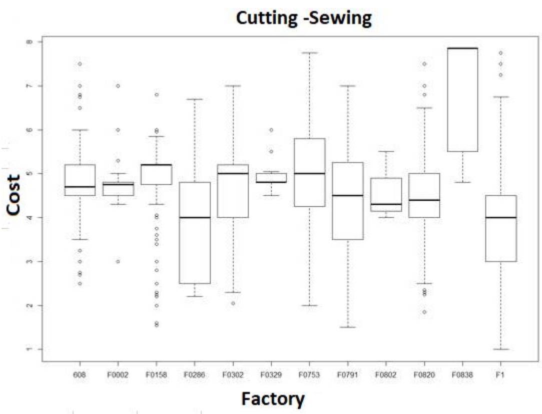
- A-F: The company has a daily internal production capacity of 1000 pairs. Therefore, it only has the capacity to produce all the orders received in four months (January, July, August and December). When analyzing it by the delivery date, the company can only respond with its internal production capacity for five months (March, April, November, February and March).

Table 2.3: Estimate of the quantities to produce internally and externally.

	Cutting - Sewing	Assembly - Finishing
Number of pairs	470,641	470,641
Number of working Days	290	290
Production capacity	203,000	290,000
Number of pairs to be subcontracted	267,641	180,641
Outsourcing	56.87%	38.38%

[1]Source: Own elaboration

Table 2.3 presents a summary of the estimated quantities to be produced internally and externally, according to available capacities. It shows that the company needs to resort to outsourcing for C-S in 56.87% and for A-F in 38.38% of the total number of pairs to produce. For C-S, the estimated value (923) corresponds practically to the value actually subcontracted by the company (927). While, for A-F, the estimate was of 623 and only 596 were actually subcontracted by the company.



Assembly -Finish Cost	
Minimum	2.00
1st quartile	3.25
Median	3.25
Mean	3.16
3rd quartile	3.25
Maximum	3.50

Source: Own elaboration

Figure 2.10: Outsourcing costs, per pair, for each subcontracted factory

As the main objective of the company, when resorting to outsourcing, is to minimize the cost of production and each company has a different cost of production (see Figure 2.10), a carefull planning of the orders allocated to the available factories needs to be performed.

2.5.3 Model Formulation

For formulating the problem of planning the production process of the company, the phases of Cutting-Sewing and Assembly-Finishing, are modeled as binary programming problems, that are solved sequentially. The formulation of each of these problems is presented next.

The parameters of each binary programming model are:

- $i \in \{1, \ldots, m\}$ designates the m available factories;
- $j \in \{1, \ldots, n\}$ designates the n orders;
- c_j is the base cost of producing each pair on order j;
- n_j is the number of pairs in order j;
- a_i is the percentage factor cost of factory i;
- p_i is the production capacity of factory i.

For a better understanding of the parameters c_j, n_j and a_i, let us consider the following example. A given order j requires the production of 100 pairs of a certain article. Suppose that the base cost of this article, which is equal for all the factories, is 3.00€. Furthermore, consider that there are three factories available to produce the order, and factories 1, 2 and 3 have percentage factors of 0%, -5% and 5%, respectively. Thus, the cost of assigning order j to:

- Factory 1 is $100 \times 3.00 \times (1 + 0) = 300.00$ €;
- Factory 2 is $100 \times 3.00 \times (1 + (-0.05)) = 100 \times 3.00 \times 0.95 = 100 \times 2.85 = 285.00$ €;
- Factory 3 is $100 \times 3.00 \times (1 + 0.05) = 100 \times 3.00 \times 1.05 = 100 \times 3.15 = 315.00$ €.

Therefore, for each factory i there are different costs of producing order j, which given are:

$$n_j \times c_j \times (1 + a_i).$$

Since materials, such as leather, have specific patterns, the orders cannot be divided trough different factories, the following decision variables are used:

$$x_{ij} = \begin{cases} 1 & \text{if order } j \text{ is produced at factory } i \\ 0 & \text{otherwise} \end{cases}$$

The binary programming problem solved in each phase is formulated as:

$$\min \quad \sum_{i=1}^{m}\sum_{j=1}^{n} n_j\, c_j\,(1+a_i)\, x_{ij} \tag{2.12}$$

$$\text{s.t.} \quad \sum_{i=1}^{m} x_{ij} = 1, \quad \forall j \in \{1,\ldots,n\} \tag{2.13}$$

$$\sum_{j=1}^{n} n_j x_{ij} \leq p_i, \quad \forall i \in \{1,\ldots,m\} \tag{2.14}$$

$$x_{ij} \in \{0,1\}, i = 1,\ldots, \; j = 1,\ldots,m \tag{2.15}$$

Expression (2.12) is the objective function of the assignment problem and aims to minimize the production costs. Constraints (2.13) ensure that all orders are produced. While (2.14) ensure that the set of orders assigned to each factory do not exceed its maximum production capacity.

As stated before, the company's production process is divided into two phases:

- Cutting-Sewing: which has a production capacity of 1920 pairs per day, divided by 9 factories;
- Assembly-Finishing: which has a production capacity of 1750 pairs per day, divided by two factories.

Daily, the company has to produce m orders in n factories. Since the internal production capacity, both for C-S and A-F, is not enough to guarantee that all orders are finalized with no delays to the clients, the production manager needs to decide on which orders must be produced by subcontractors.

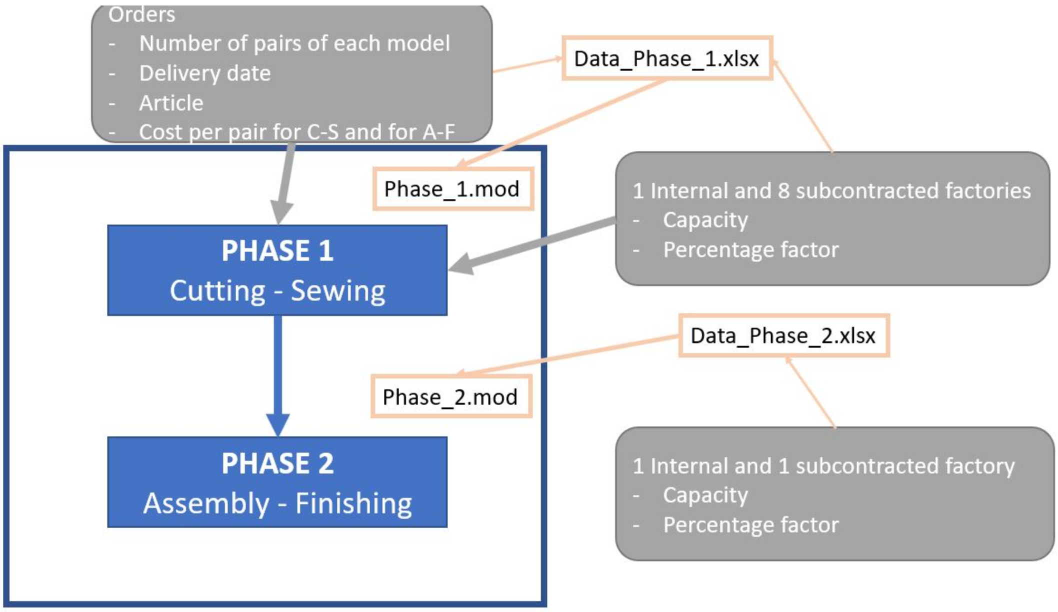


Figure 2.11: The developed approach

Figure 2.11 shows the approach that was developed in the present work for the optimization of the production process of the company, in terms of assigning the orders for internal or external production. The blue boxes represent each of the production phases. While the gray boxes represent the information provided by the company that is used as inputs for the binary programming models. This information is divided into two groups: **(1)** data on orders, which includes, for each order, the number of pairs, delivery date, the article and the cost per pair for C-S and A-F; **(2)** data on internal and external production capacity and characteristics. According to Figure 2.11, to produce the orders, the company has a daily maximum production capacity for C-S, that include its internal capacity and the capacity of eight subcontractors. For A-F, the available capacity consists on its internal capacity and the capacity of one subcontractor.

The production costs vary from order to order, and from factory to factory. In fact, each order that is received has an identification number, and contains the article identification, the number of pairs and the delivery date. Note that, each order corresponds to an unique article. Therefore, there may be several orders from the same client, which are treated as individual orders. For each order, a base cost for C-S and A-F are attributed. This information, together with the capacity of each factory and a percentage factor that differentiates the costs on each factory, is aggregated in an excel file (`Data_Phase_1.xlsx`, for Phase 1 and `Data_Phase_2.xlsx`, for Phase 2).

2.6 Results

The results obtained were divided into two sections. In the first part, the results obtained were formulated month by month for the production of the Autumn- Winter collection. The information obtained suggests which orders to produce at each factory during that month. The section 2.6.2 presents the results of the formulation executed in more detail for the month of July, as it is the month with the highest number of sales. The analysis consists of comparing the planning by order with the planning by item and whether this planning should be done monthly or biweekly.

2.6.1 Results month by month

To solve the optimization problem of each of the two phases, AMPL modeling language and the Gurobi solver, with AMPL interface, were used [37]. The AMPL algebric modeling language was chosen because of its simplicity and versatility and since it allows interface with various open source and commercial optimization software. The Gurobi solver is an optimization software that numerically solves LP and MILP. The data necessary for each phase is read from excel files to AMPL[1]. The excel file created for each phase contains the number of pairs per order n_j and the respective production cost, c_j, as well as, the available factories its capabilities, p_i, and the percentage factor a_i, as outlined in Figure 2.11.

As already mentioned, there are two seasons: Spring-Summer and Autumn-Winter. The Autumn-Winter collection is more expressive for the company. Therefore the results will be obtained for instances regarding this collection for orders from March to September, (54.69% of the database). The selection of

[1]This is a recent improvement in AMPL that simplifies the modeling

Table 2.4: Results for C-S

	March-April	May	June	July	August	September
Using the developed approach						
Number of pairs	20,700	58,536	48,341	76,982	16,355	36,497
Outsourcing, in pairs	13,001	37,186	30,491	48,284	10,055	22,847
Unused capacity	420	24	619	1,738	925	943
Number of days needed to produce	11	30.5	25.5	41	9	19.5
Production cost	87,604.60	266,725.10	223,741.68	371,579.71	74,531.40	180,036.85
Outsourcing cost	47,149.60	140,525.20	125,521.33	199,759.01	41,271.60	101,870.35
Quantity of orders to produce	189	647	532	853	205	494
% Internal	37.19%	36.47%	36.93%	37.28%	38.52%	37.40%
% Outsourcing	62.81%	63.53%	63.07%	62.72%	61.48%	62.60%
The Company process						
Internal production, in pairs	9,590	21,572	16,084	21,903	4,157	13,554
Outsourcing, in pairs	11,110	36,964	32,257	55,079	12,198	22,943
% Internal	46.33%	36.85%	33.27%	28.45%	25.42%	37.14%
% Outsourcing	53.67%	63.15%	66.73%	71.55%	74.58%	62.86%

[1]Source: Own elaboration

the orders to consider are still not completely automatic. In fact, for deciding on how many days are necessary to produce the orders and the moment that production should start in to meet the deadlines stills requires manual selection. An instance consisting of orders from March to September, with a total of 257,411 pairs distributed by 2920 orders, was considered. The results obtained are presented in Table 2.4 and Table 2.5.

Table 2.5: Results for A-F

	March-April	May	June	July	August	September
Using the developed approch						
Number of pairs	20,700	58,536	48,341	76,982	16,355	36,497
Outsourcing, in pairs	8,701	25,036	20,349	32,988	6,857	15,500
Unused capacity	300	89	659	18	270	253
Number of days needed to produce	12	33.5	28	44	9.5	21
Production cost	6,3530.50	182,772.29	152,450.01	243,318.00	51,474.83	114,795.00
Outsourcing cost	24,517.25	73,503.99	61,053.21	99,614.45	20,606.33	46,398.15
Quantity of orders to produced	189	647	532	853	205	494
% Internal	57.97%	57.23%	57.91%	57.15%	58.07%	57.53%
% Outsourcing	42.03%	42.77%	42.09%	42.85%	41.93%	42.47%
The company process						
Internal production, in pairs	11,103	37,108	24,812	38,237	4,157	13,554
Outsourcing, in pairs	9,597	21,428	23,529	38,745	12,198	22,943
% Internal	53.64%	63.39%	51.33%	49.67%	25.42%	37.14%
% Outsourcing	46.36%	36.61%	48.67%	50.33%	74.58%	62.86%

[1]Source: Own elaboration

Regarding C-S (Table 2.4), to produce 257,411 pairs divided by 2920 orders, using all the available factories, approximately 137 working days are required. Therefore, the production should start on February 17th and continue until September 16th. The production costs of C-S totals 1,204,219.34€, where 656,097.09€ are related to the outsource production cost. The solution obtained for this instance suggests that outsourcing of C-S should be used for 161,864 pairs, corresponding to a percentage that varies between 61.48% and 63.59%. These results express great expressiveness of outsourcing at this stage of production. On the contrary, the company should produce 95,547 pairs internally, corresponding to percentages varying between 36.47% and 38.52%.

The percentage of outsourcing for C-S is above 60% while in A-F it drops to 42% (Table 2.5). In the A-F section, more days are needed to produce, since the available factories capacity for produce A-F is less than that of C-S. The production cost of A-F totals 808,340.60€, where 325,693.40€ are related to outsource production cost. The solution obtained for A-F suggests that outsourcing should be used for 109,431 pairs , corresponding to a percentage that varies between 41.93% and 42.85%.

In summary, for the period under analysis, the company resorts to outsourcing on average 62.88% for C-S and 42.51% for A-F (Figure 2.12).

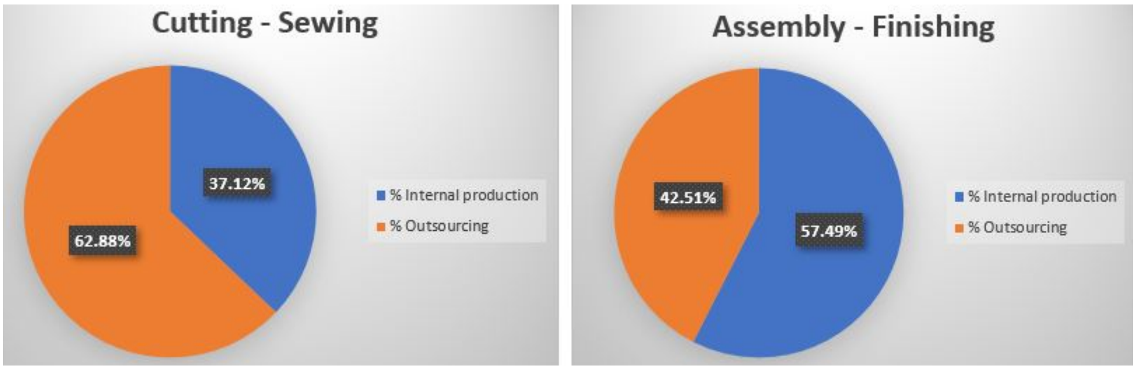


Figure 2.12: Internal production and outsourcing

Comparing the results obtained using the developed models and the traditional method used by the company, for the same period (see Tables 2.4 and 2.5) it can be concluded that, using the proposed approach:

- outsourcing would decrease in 8,687 pairs in C-S producing more internally;
- on average, the company would reduce outsourcing by 3.37% in C-S , since the average outsourcing would drop from 66.26 % to 62.88 %;
- in the A-F phase, there would also be a decrease of 19,009 in the number of pairs to produce resorting to outsourcing;
- in the A-F phase, the percentage of pairs produced by external factories varies between 53.67% to 74.58%, with an average of 49.90%;
- With the proposed approach, outsourcing would decrease by 7.38% on A-F.

Figure 2.12 shows that, on average, the company resorts to outsourcing in 63 % in the 1st phase (C-S) and in 43% for A-F. The unused capacity of the factories allows to answer last minute orders. The percentage of outsourcing used by the company or its current procedure is not very different from the one obtained with the developed model. The monthly comparison between the outsourcing planning using the developed approach and what the company actually subcontracted can be observed in Figure 2.13.

The results obtained in phase C-S and A-F, month by month, reveal that outsourcing is inferior compared to the current method used by the company (see Figure 2.13).

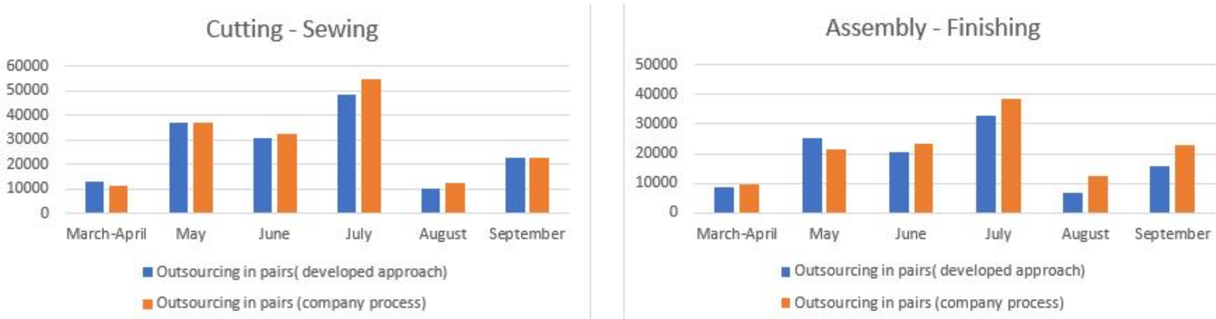


Figure 2.13: Production internally and outsourcing per month

The company can perform a monthly, biweekly or weekly planning. The month of July is the one with the highest number of pairs to deliver (76,982 pairs, in total). Therefore a more detailed analysis of this month is present next.

2.6.2 Results for July

A plan was elaborated for the month of July, monthly (July 1st to 31st) and biweekly (July 1st to 16th and July 17th to 31st) planning. The results obtained are presented in Table 2.6 and Table 2.7. To produce the 76,982 pairs, corresponding to 853 orders, a total of 41 days of C-F and 44 days of A-F are necessary.

In order to comply with the established delivery dates, therefore, the production should start on May 25th and continue until July 29th.

The majority of the orders are received at the begining of the preparation for the next season production. In fact, the Spring-Summer orders are received in September/October while Autumn - Winter are received in February/March. As the objective of this work is to define which orders to produce on each factory so that the total cost of production is minimized, it becomes necessary to analyze the best planning strategy. For using the proposed approach (see Figure 2.14), two strategies can be used, namely:

- by order: the article on each order is not considered;
- by article: the orders of the same article are grouped and each article is produced at a minimum number of factories.

Table 2.6: Results for the month July

	Cutting-Sewing					
	Orders			Article		
	July	1st to 16th	17th to 31st	July	1st to 16th	17th to 31st
Using the developed approach						
Number of pairs	76,982	46,901	30,081	76,982	46,901	30,081
Days needed to produce	41	25	16	41	25	16
Production cost	371,579.71	226,194.39	145,432.40	371,761.01	225,401.35	145,010.19
Quantity orders produced	853	466	387	171	122	99
% Outsourcing	62.72%	62.69%	62.77%	62.72%	62.7%	62.77%
% Internal	37.28%	37.31%	37.23%	37.28%	37.30%	37.23%
Outsourcing, in pairs	48,284	29,401	18,881	48,282	29,407	18,881
The company process						
Internal production, in pairs	21,903	15,718	6,185	21,903	15,718	6,185
Outsourcing, in pairs	55,079	31,183	23,896	55,079	31,183	23,896
% Outsourcing	71.55%	66.49%	79.43%	71.55%	66.49%	79.43%

[1]Source: Own elaboration

According to the company, the first strategies bring advantages. In fact, the larger the variety of articles each worker has to produce, the less productive is the worker. Higher productivity is achieved when the article is not constantly changed.

From Table 2.7, it is possible to see that the difference beetween monthly and biweekly planning is small both in terms of production cost and percentage of outsourced production.

Table 2.7: Results for the month July

	Assembly-Finishing					
	Orders			Article		
	July	1st to 16th	17th to 31st	July	1st to 16th	17th to 31st
Using the developed approach						
Number of pairs	76,982	46,901	30081	76,982	46,901	30,081
Days needed to produce	44	27	17,5	44	27	17,5
Production cost	243,317.80	148,147.90	95,095.83	243,215.60	148,112.00	95,095.82
Quantity orders produced	853	466	387	171	122	99
% Outsourcing	42.85%	42.45%	41.96%	42.84%	42.43%	41.84%
% Internal	57.15%	57.55%	58.04%	57.16%	57.57%	58.16%
Outsourcing, in pairs	32,988	19,908	12621	32,982	19,908	12,587
The company process						
Internal production, in pairs	38,237	23,545	14,692	38,237	23,545	14,692
Outsourcing, in pairs	38,745	23,356	15,389	38,745	23,356	15,389
% Outsourcing	50.33%	49.80%	51.16%	50.33%	49.80%	51.16%

[1]Source: Own elaboration

The percentage of internal production of C-S (37%, on average) is much lower than the percentage of A-F (58%, on average). Thus the company should resort to outsourcing in the C-S phase more then in the A-F phase (see Figure 2.15). Using the "by orders" strategy, the percentage of production resorting to external factories is 37.28%, equal using the "by article" strategy.

In the situations exposed and the results obtained, the company can choose to plan monthly or biweekly.

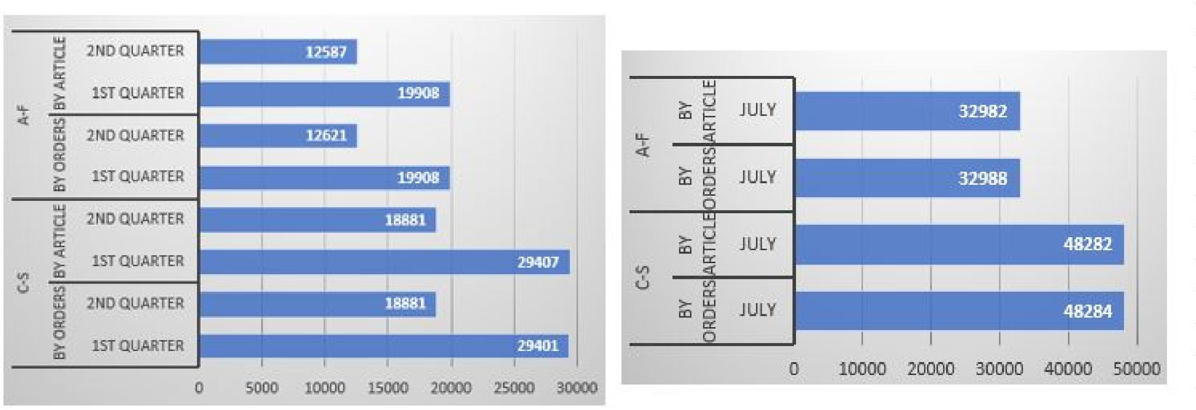


Figure 2.14: Outsourcing quantities for July

In phase C-S the percentage of outsourced is equal (37.28%) whether biweekly or monthly. However, the A-F phase the percentage of outsourcing is higher by 0.59% in monthly planning. As there are no big differences, it is more advantageous for the company to plan biweekly for logistical reasons and less risk of failures.

In relation to planning by article or by order, there are no relevant differences either, since the percentage of outsourcing in the C-S phase is equal (62.72%) either by order or by article. In A-F phase there are also no differences as the percentage of outsourcing by order is 42.85% and by article 42.84%.

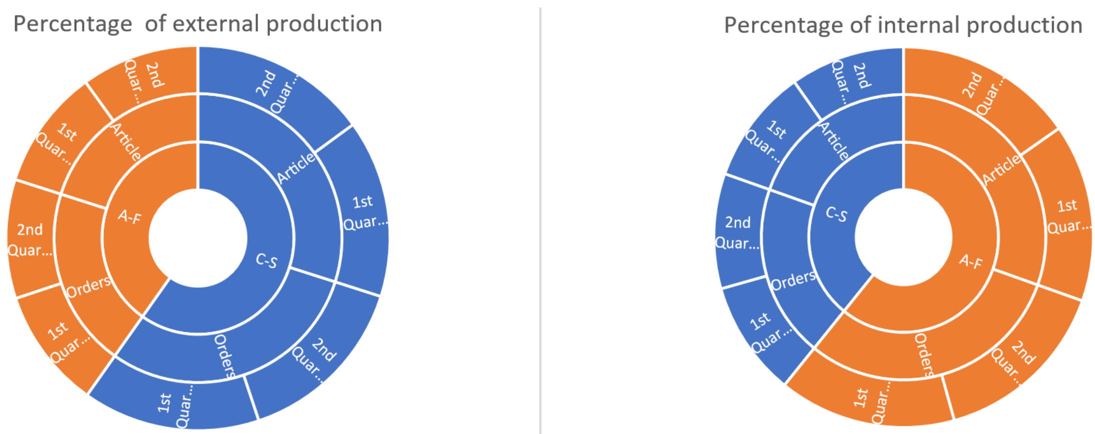


Figure 2.15: External vs Internal production

Thus, it is always up to the company, depending on the cases, to choose what suits it best, taking into account that the grouping by article and biweekly brings immense productive advantages for the company and subcontractors.

2.7 Conclusions

The Portuguese footwear industry is one of the most prestigious nationally and internationally. It is a competitive market that responds to customer needs. Due to the dynamics and high quality of Portuguese products, they have achieved notoriety in the international market when compared with the Italian. The footwear sector faces a low-cost mass production paradigm for large international companies. Reindustrialization has again become a political, economic and productive priority, and the footwear industry in Portugal benefits from the fact that it has a cutting-edge industry, capable of responding quickly and to small orders. Furthermore, it has a unique capacity for developing new products and has an enormous capacity to adapt to new processes.

The market is changing, and the downward trend in the number of pairs per order was accentuated with the COVID-19 pandemic. Customers do not want to risk accumulating stocks in their warehouses. As so they expect the supplier to have a quick and efficient response capacity for replacement of article with high demand.

Production planning of footwear companies often depends on outsourcing services. In fact, this is a widely common procedure for many industries this sector. The company must select from a set of service providers with the objective of maximizing production and minimizing costs. To contribute to this, the objective of the present work was to develop a tool to assist the production planning. It is expected that it will contribute to improve the decision of resorting to outsourcing.

The results obtained show that there is an economic advantage in using mathematical modeling for planning the production of orders. In fact, for the instances tested, the company would reduce the 3.37% of outsourcing in C-S and 7.38% in A-F when compared to its current procedure. From the analysis of short-term vs. long-term planning, the results show that, for the instances tested, the difference between biweekly and monthly planning is small. Therefore, taking into this account, the company must analyze the suggestions of each planning strategy and choose the one that better fits its present situation.

Chapter 3

Factors that influence the demand for Portuguese footwear: A case of study

The turnover in exports is fundamental for the sustainability of an internationalized company, despite the associated sunk costs. The footwear industry is no exception, since it exports 95% of its production. Note that, this industry is one of the industries with the greatest positive contribution to the trade balance.

This study aims, firstly, to analyze the factors that influence the footwear demand, and additionally, evaluate the seasonal trend in sales. For this purpose, a database with information from a footwear exporting company is used. A time series with monthly data was collected, for the period between January 2017 and June 2020, therefore the sample contains 42 observations.

To explain the determinants of exports, two demand functions are used. The two functions differ only in the dependent variable: number of pairs of shoes sold and sales volume.

Results show that the variables productivity, number of works, own capital of the company and the lagged variable of sales have statistical significance, therefore they have an impact on the company's exports. Spending on workers seems to have no influence on exports. Additionally, results indicate the possible seasonality in footwear exports.

Key words: Footwear Exports, Demand Function, Seasonality, OLS.

3.1 Introduction

In a growing global world and with the increase in international trade, it is important to increase the competitive capacity of economies and companies in order to guarantee their success in an increasingly demanding foreign market.

The Portuguese footwear industry is one of the most competitive in the world, exporting its products to five continents [7]. This cluster is predominantly composed of small and medium-sized companies and includes, not only companies that produce the final product (footwear), but also companies that produce footwear components. Combining the know-how with technologies and skilled labor, drives the industry to high value-added markets [5]. The footwear industry comprises the manufacture of footwear using various materials, which belongs to the CAE - Portuguese Classification of Economic Activities - 152. In this sector of activity, in 2018, there were 2123 companies employing 46642 workers and with a volume of sales and services of 2413848 thousand euros [10].

Portugal is the sixth largest exporter in the world and has gained a prominent place, both nationally and internationally. This fact is mainly due to the dynamics and high quality of Portuguese products that have achieved notoriety in the international market compared to the Italian ones [5].

This study aims to analyze the determinants of demand for Portuguese footwear and evaluate a possible seasonal trend of the footwear industry. In this sense, data relating to a company headquartered in *Felgueiras* and which exports 100% of its production is used. The defined time interval is 42 months, from January 2017 to June 2020. The topic of this study is relevant, because monthly data is used and allows to evaluate the seasonality of footwear exports, which is an innovation in literature.

This chapter proceeds in the following way. In section 3.2, a literature review on the determinants of exports is carried out, in section 3.3, brief caracterization of the footwear sector is made and section 3.4 comprehends the methodology and data, followed by empirical results. The chapter ends with a section of concluding remarks.

3.2 Literature Review

The concept of Internationalization appears in the mid 1920s [64], but this process accelerated after the second world war, when the phenomenon of globalization began to take its first steps [42]. Initially, most companies choose to gain and establish a strong position in the domestic market before deciding to enter on the international market. Bernard et al. [18] argue that good companies become exporters, since they have the desirable characteristics to enter on the international market. The same authors [18] indicate that growth and survival probability are higher in exporting firms. Note that, to enter international markets, companies incur in sunk costs and that are very important in the internationalization process [45].

3.2.1 Factors that influence Exports

Literature cites two reasons why exports can lead to an increase in company productivity. First, exporting companies can receive technical assistance from overseas buyers. Second, exporting companies must innovate quickly to remain viable in competitive international markets [21].

Productivity plays an important role in companies and intensifies exports [79]. More productive companies are better able to explore export markets, several studies ([15] [33], [34], [45]) show just that. However, there are large fixed costs to enter the export market, costs that only the most profitable and productive companies can afford [79].

Productivity also influences sunk export costs. Therefore, exports can be considered a result of productivity increases, not a cause [21]. The study of Bernard and Jensen[18] states that there is a direct and positive relationship between productivity and exports. In the same sense Fryges and Wagner [38] defend the productivity factor as a determinant of exports and a positive relationship between exporting companies and productivity. However, there are also studies, such as, Castellani [25] that do not find evidence of a direct relationship between productivity and exports.

One of the most cited determining factors in studies is the size of the company, which generally positively affects exports. The more workers a company has, the more likely it is to be an exporter. According to Baldauf and Cravens [16] the larger the company, the greater the performance in the export activity. Larger numbers of workers usually exist in larger companies, therefore with larger levels of production, resources and capacity, which could lead to increased exports. In this context, several studies such as those of Wakelin [91] and Girma, Greenaway and Kneller [41] demonstrate that this factor positively affects company exports. This association between company size and internationalization should not be considered an export barrier. Sterlacchini [85] points out that there is a limit above which the number of workers does not increase the propensity to export, and that this limit can be reached even by small companies. In this sense, the relationship between company size and export performance is not always positive.

Also, employee compensation is a relevant determinant of exports. Bombardini et al. [23] compared industry wages in various countries and concluded that the increase in the productivity of an industry leads to an increase in wages. Therefore, Wakelin [91] states that workers' salaries are higher in exporting companies due to the increase in productivity and the economies of scale that allow obtaining wage premiums.

In that regard Girma, Greenaway and Kneller [41] argue that high salaries are a positive factor due to higher wages in exporting companies as well as the presence of more qualified personnel. However, there are several studies such as Srinivasan and Archana [85] who argue that there is a negative impact of remuneration on exports, as higher remuneration causes an increase in production costs and thus decrease the company's production and competitiveness.

Further more, the net result of a company reflects the economic and financial performance in a given period of time. In this context, this is a very important variable in exports. In accounting terms, net result means the profit or loss of a company. The greater the profit, the greater the possibility of self-financing, which can be decisive for the growth of sales in the foreign market due to its capacity to increase production and, consequently, increase in exports. Srinivasan and Archanan [84] argue that there is a positive impact on exports when they are profitable. Because the greater the profit, the easier companies face external competitiveness. Generally, an entity's equity is composed of share capital, reserves, retained earnings and net income. A company with positive equity has a greater ability to finance itself, showing that the company is financially healthy.

Companies with greater equity capital are more likely to export [32] and [78], therefore, it represents a positive impact on exports, as it demonstrates security and financial viability.

Bernard and Jenson [18] claim that a company with a healthy financial structure helps to cover the fixed and additional costs that cannot be avoided when a company is an exporter. Financial shortages can become an impediment to exports, as they may not obtain the financial means to cover the costs required to enter the foreign market [65]. This ratio positively affects exports, as the greater their autonomy, the greater their stability and the better their ability to export.

Innovation is extremely important for exports, as the world is increasingly technologically developed and the consumer increasingly demanding. The way to measure a company's innovation is by its expenditure on research and development spending. Innovation is essential in exports. In fact, according to Lachenmairer and Woessmann [57], companies that innovate more have higher export shares. In this context, research and development has a positive impact on exports. Thus, company's ability to generate exports is positively related to its ability to innovate [26].

According to data from the Northern Regional Coordination and Development Commission, this region was the engine of productivity growth in the country during the period of economic recovery. During this period, the growth of the Northern region was well above the national average. From this point of view, the companies in the Northern region will have a greater capacity to export than companies located in the rest of the country.

The age of company can affect its propensity to export and the percentage of sales [52]. Additionally, Baldauf et. al. [16] report a negative relationship between company's age and export sales.

Moreover, the value of time-lagged exports is believed to have an influence on current exports. More specifically, the experience of past exports is a very powerful indicator of the behavior of current exports. In fact, it has been found that companies that export in an earlier period are three times more likely to export in the future than those that previously did not export [41].

3.2.2 Seasonality

The seasonality of exports is not a subject frequently discussed in literature, as the data available in most cases are annual and, for the study of seasonality, monthly or daily data are necessary. Seasonality shows variations over time, and substantial growth may occur in certain periods. In classic time series analysis models, it is assumed that the total variation of data can be decomposed into four basic components: trend, seasonality, cycle and volatility [58].

Seasonality corresponds to an oscillatory movement, which occurs regularly in sub-periods of a fixed period of time (usually one year) that is, it refers to systematic movements up and down, around an average value, repeating it self in a given fixed period of time. Seasonal effects can be due to several factors, such as climate change, preferences and specific dates during the year.

3.3 Characterization of the Footwear Sector

According to data from *Banco de Portugal* [1] the Portuguese footwear industry represents 5% of companies, 3% of turnover and 7% of the number of people employed in manufacturing industries. The footwear cluster is strongly focused on international markets. According to the APICCAPS Statistical Monograph of 2018 [8], the footwear industry is the one that contributes the most to the Portuguese external accounts and in a systematic way.

The Portuguese footwear industry is concentrated in two municipalities: *Felgueiras* and *São João da Madeira*. In these industrial poles, there is a complex network of formal relationships, but mostly informal relationships, namely subcontracting [6].

According to APICCAPS information [5] Portuguese footwear has a future, if the achieved export levels can be maintained. In 2019, this cluster exported 76 million pairs of footwear to 163 countries, covering the 5 continents and employing 47 thousand workers. Portugal exports 95% of its total production, being in second place with the highest price in the world, with only Italy ahead [6]. The largest share of production refers to women's shoes [8].

From 2010 to 2019, worldwide footwear production has increased by 21.2%, at an average annual growth rate of 2.2%. In 2019 the industry slowed down, failing only 0.6% compared to the previous year, but it was enough to set a new production record of 24.3 billion pairs.

The shoe industry is highly concentrated in Asia, where nearly 9 out of 10 pairs of shoes are manufactured. Africa, Europe and North America maintain stable shares of 2% to 3% of the world total [83].

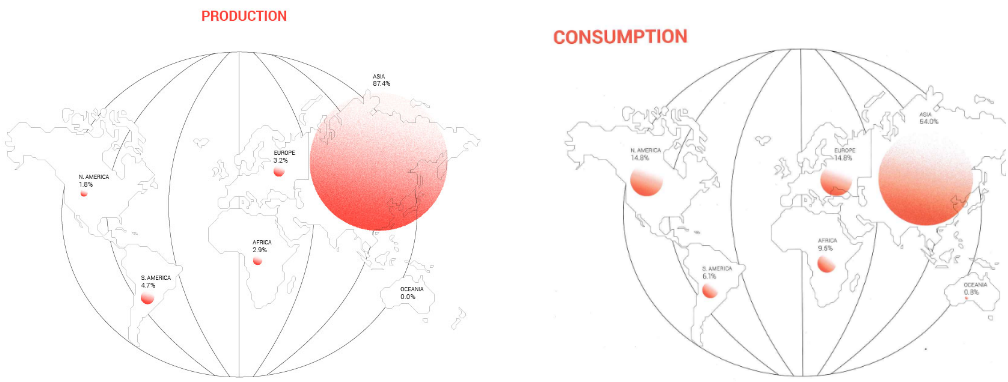
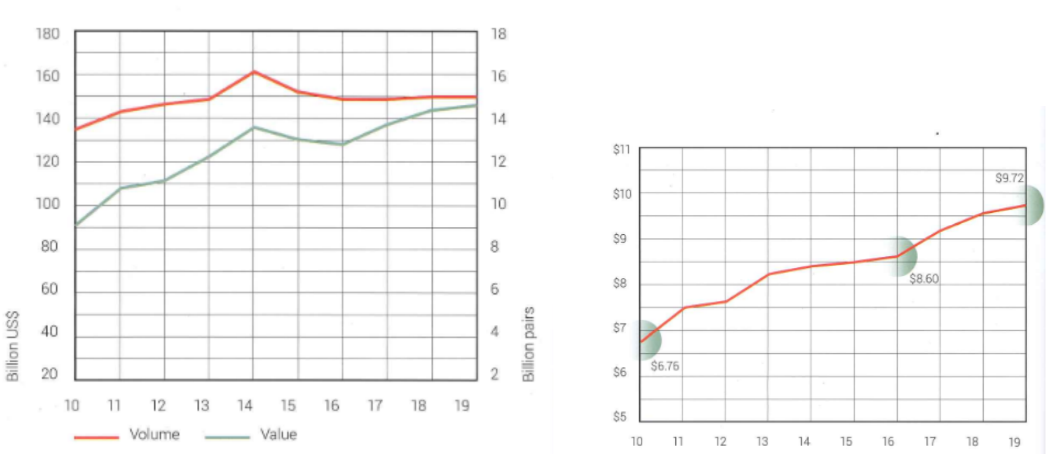


Figure 3.1: Distribution of footwear production and consumption by continent (quantity) in 2019 (Source: [83])

In terms of Continents, footwear consumption is more evenly distributed than production, as shown in Figure 3.1. However, the consumption *per capita* of shoes varies between 1.6 pairs in Africa and 5.6 pairs in North America [83].

The value of global footwear exports keeps increasing in 2019, reaching a new record of 146 billion dollars, 2% more than 2018 (Figure 3.2). Note that, since 2010 the accumulated growth was 59% [83].



(a) World Footwear Exports 2010-2019 (b) Worldwide unit price 2010-2019

Figure 3.2: Footwear exports worldwide between 2010 and 2019 (Source: [83])

The different trends in value and quantity exports reflect changes in the average export price. This shows an almost linear growth trend over the decade, setting a record 9.72 dollars in 2019 [83] (Figure 3.2). Intra-European trade flows (30%) are the main building block, representing almost a third of the world's

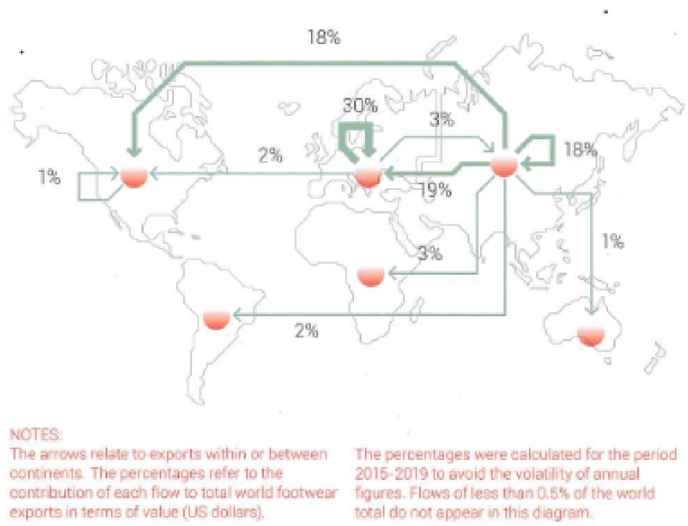


Figure 3.3: Geographic patterns of the footwear trade between 2015 and 2019 (Source: [83])

total. There are three other pillars with equal importance (18%, 19% to 18%): intra-Asian trade, trade from Asia to Europe and to North America. Together, they represent 86% of all footwear trade (Figure 3.3).

Portugal is also included in the list of the 20 biggest producers and is highly export-oriented (100.1%).

Italy stands out among the main producers with the highest average export price (57.11 dollars). Just behind, Portugal is the second in the list of producers with the highest average export price per pair (26.26 dollars). China presents a price of 4.72 dollars and India 8.82 dollars [83].

Consumption is largely determined by the population and wealth of each country. The most populous country on the planet, China, is the largest consumer of shoes, accounting for 18.7% of global consumption. America's imports exceed its consumption, because the country re-exports part of what it imports [83].

FOOTWEAR INDUSTRY

	VALUE		QUANTITY		PRICE
	Million USD	World Rank	Million Pairs	World Rank	USD
EXPORTS	2 002	15	76	19	$26.26
IMPORTS	766	29	65	46	$11.82
PRODUCTION			76	20	
CONSUMPTION			65	53	

Figure 3.4: Analysis of the Portuguese footwear industry in 2019 (Source: [83])

Portuguese footwear industry ended the year 2019 with a 5.66% drop in exports, which stood at 2002 million dollars and 76 million pairs, with an average price of 26.26 dollars. However, Portugal also imports 65 million pairs, with an average price of 11.82 dollars. Regarding the production, Portugal exports 76 million pairs, being in the twentieth place in the ranking of the biggest footwear producers, exporting 100.1% and and imports for consumption (65 million pairs) 3.4. This downward trajectory remained in 2020, due to the Covid-19 pandemic.

The year 2020 is marked by the beginning of the Covid-19 pandemic and continues to affect the short and medium term prospects for the Portuguese and international economy [13]. Because of that, 2020 was an extremely difficult year for Portuguese footwear companies. In 2020, Portugal exported 61 million pairs of shoes, with a value of 1494 million euros (-16.3% compared to 2019). In the same period, European exports dropped 18.6%. Note that, relatively to Portugal, the fall in exports was less accentuated in extra-community countries. In the last decade, this is one of the great achievements of the sector, as the weight of extra-community sales has practically doubled.

3.4 Methodology and Data

The company under study is located in the region of *Felgueiras* and its main activity is the production and sale of shoes, producing more than half a million pairs of shoes annually. To carry out all orders, a daily production of around 2,500 pairs is required.To fulfill this demand, at certain periods of the year, it is necessary to resort to outsourcing. All of the company's production is exported, directly or indirectly, a little all over the world.

The footwear industry is characterized by peaks in production related to the seasons with the existence of two collections: Spring-Summer (production from October to February) and Autumn-Winter (production from March to September). These peaks lead to a surplus of orders in certain periods and, in other, orders deficit this leads to a lack of uniform production. Thus, providing the existence of a deficit in production capacity there are not enough orders for the installed production capacity.

The main objectives of this study are to determine the company's demand function, that is, which factors influence the company's footwear exports and to analyze the seasonal trend of sales. As the company is a 100% exporter, it is fundamental to determine which factors influence its exports.

3.4.1 Methodology

In the literature, the main empirical strategy to assess the factors that that influence a company's exports is the estimation of a demand function. The demand for footwear can be measured through turnover or through quantity demanded. Thus, in this study, two models are estimated in which the dependent variable is measured in these two ways. Explanatory variables in determining the determinants of exports were based on the theoretical contributions presented in the literature review (Section 3.2). Therefore, the models to be estimated have the following form:

$$EXP_t = \beta_0 + \beta_1 Exp_{t-12} + \beta_2 NTr_t + \beta_3 Rem_t + \beta_4 CP_t + \beta_5 Prod_t + u_t \tag{3.1}$$

$$QEXP_t = \beta_0 + \beta_1 QExp_{t-12} + \beta_2 NTr_t + \beta_3 Rem_t + \beta_4 CP_t + \beta_5 Prod_t + u_t \tag{3.2}$$

where t represents time, in months ($t = 1, 2, ..., 42$); EXP_t is the value of exports, in euros, and is the dependent variable of the model (3.1); $QEXP_t$ is the number pairs of shoes exported and is the dependent variable in the model (3.2); u_t is a random error term that captures other unobservable determinants of footwear demand, and it is assumed to be uncorrelated with the explanatory variables; Exp_{t-1} and $QExp_{t-1}$ are the lagged variables included in the first and second model, respectively. They are included in the equation to reflect the cumulative nature of the orders process. Additionally:

- $Prod_t$ represents the productivity in month t. According to literature, the greater the productivity, the greater the production capacity and, consequently, greater the quantity exported. So the theoretically expected sign is positive.

H1: *Productivity has a positive impact on exports.*

- NTr_t denotes the number of workers in month t. The theoretically expected sign is positive, as an increase in these variable leads to an increase in production and as the company is 100% exporter, this fact will result in an increase in exports.

  H2: *The number of workers has a positive impact on exported quantity.*

- Rem_t represents worker expenses, in euros, in month t; The theoretically expected sign is negative. The higher the level of workers' remuneration, the more expensive the labor becomes, and consequently, the price less competitive. In other words, the increase in this variable causes an increase in the unit production price of footwear and, assuming that this good has substitute products, it could result in a decrease in sales/exports.

  H3: *Remuneration has a negative impact on Exports*

- CP_t is the company's Own Capital, in euros, in month t. The theoretically expected sign is positive. Equity can be seen in two different ways, on the one hand it is considered as possible form of financing the company's investment and operating activities and, on the other hand, it represents the company's assets at a given time. Taking into account the two definitions, this variable represents "the company's financial health", i.e greater security and greater capacity to invest in exploring export markets.

  H4: *Equity has a positive impact on Exports*

Time series can be defined as observations of a variable arranged sequentially in time. Time series are analyzed from the main movements such as: trend, volatility cycle and seasonality [58].

As such, in order to control for the time specific effects, capturing the unobserved time-invariant factors of time that may influence footwear demand, the dummy variable, $Dtempo_t$, is added. The base category is January. This term also allows to control for seasonal patterns throughout the year, constant over time. These models can be expressed by:

$$EXP_t = \beta_0 + \beta_1 Exp_{t-12} + \beta_2 NTr_t + \beta_3 Rem_t + \beta_4 CP_t + \beta_5 Prod_t + \beta_6 Dtempo_t + u_t \tag{3.3}$$

$$QEXP_t = \beta_0 + \beta_1 QExp_{t-12} + \beta_2 NTr_t + \beta_3 Rem_t + \beta_4 CP_t + \beta_5 Prod_t + \beta_6 Dtempo_t + u_t \tag{3.4}$$

The seasonal pattern can be also explained using the sine and cosine functions, once they have a cyclical behavior, i.e. the behavior is always repeated periodically. In this sense, the sine and cosine functions were added to the model to explain the existence of the seasonal trend/pattern or cycles. Thus, models augmented with the sine and cosine terms, can be defined as:

$$EXP_t = \beta_0 + \beta_1 Exp_{t-12} + \beta_2 NTr_t + \beta_3 Rem_t + \beta_4 CP_t + \beta_5 Prod_t + \beta_6 sin(2\pi * Dtempo/12) + \\ + \beta_7 cos(2\pi * Dtempo/12) + u_t \quad (3.5)$$

$$QEXP_t = \beta_0 + \beta_1 QExp_{t-12} + \beta_2 NTr_t + \beta_3 Rem_t + \beta_4 CP_t + \beta_5 Prod_t + \beta_6 sin(2\pi * Dtempo/12) + \\ + \beta_7 cos(2\pi * Dtempo/12) + u_t \quad (3.6)$$

where $sin(2\pi * Dtempo/12)$ and $cos(2\pi * Dtempo/12)$ represents the possible seasonal pattern, i.e. the coefficients of these variables β_6 or β_7, respectively, provide evidence on the existence of a seasonal trend.

One of the objectives of the econometric method is to estimate the regression coefficients using an appropriate statistical method, always taking into account the presence of the random disturbance term [71]. Equations are estimated using the Ordinary Least Squares (OLS) method. This method minimizes the sum of the squares of the residuals.

In econometric analysis, the choice of method has to do with the optimal properties of the estimators: centricity, efficiency (OLS is the minimum variance estimator, not having another one with smaller variance than this) and consistency. For such and to validate the estimation results using the OLS method, it is necessary to verify the validity of its assumptions. To validate the normality of errors, the Shapiro-Wilk test[1] is used. Also, the Durbin-Watson test[2] for auto-correlation of errors and the Breusch-Pagan test, [3] were used. A correlation matrix is performed to verify the existence of multicollinearity between the explanatory variables.

All the statistical analysis presented was conducted using the R software, Version 1.1.463.

3.4.2 Data

The data used in this essay was provided by the company and there is information at the company level, such as:

- **Productivity (Prod)** - is the ratio between the Gross Added Value (VAB) and the number of workers (NTr). By definition, VAB is the difference between the gross value of production and the value of intermediate consumption.

[1] The Shapiro-Wilk test allows to test to the normality of the errors, under the null hypothesis that the errors follow a normal distribution

[2] The test used was the Durbin-Watson and is used to detect the presence of auto-correlation and dependence in the residuals of a regression. The null hypothesis of the test is that auto-correlation between errors is equal to zero.

[3] The Breusch-Pagan test allows to test for the homoscedasticity and the null hypothesis is that the error variances are equal, i.e. the errors are homoscedastic.

- **Number of workers (NTr)** - is the number of employees in the company's in month t, representing its size.
- **Remunerations (Rem)** - is the total expenses spent on worker, in euros.
- **Own Capital(CP)** - is the company's equity, in euros.

Furthermore, the database contains information about monthly sales volume (in euros) and the monthly number of pairs of shoes sold.

The sample used in this analysis comprises 42 observations, corresponding to the period of January 2017 to June 2020. Descriptive statistics are present in Table 3.1.

Table 3.1: Descriptive statistics

Variables	Obs.	Average	Std. Dev.	Min	Max
Sales, in €	42	1,127,417	662,836.60	31,796	2,323,519
Number of pairs of shoes	42	44,202	23,388.59	2,226	85,107
Productivity	42	2,355.40	1,190.67	261.90	5,841.90
Number of workers	42	116.7	2.29	111	120
Remunerations, in €	42	159,294	22,934.87	129,662	215,322
Own Capital, in €	42	6,138,745	619,354.70	4,985,120	7,190,213

[1]Source: Own Elaboration

Between January 2017 and June 2020, the value of exports registered substancial changes, since this variable assumes a minimum value of 31,796 euros and a maximum value of 2,323,519 euros. The average monthly sales volume is 1,127,417 euros. The number of workers in the company is, on average, 117

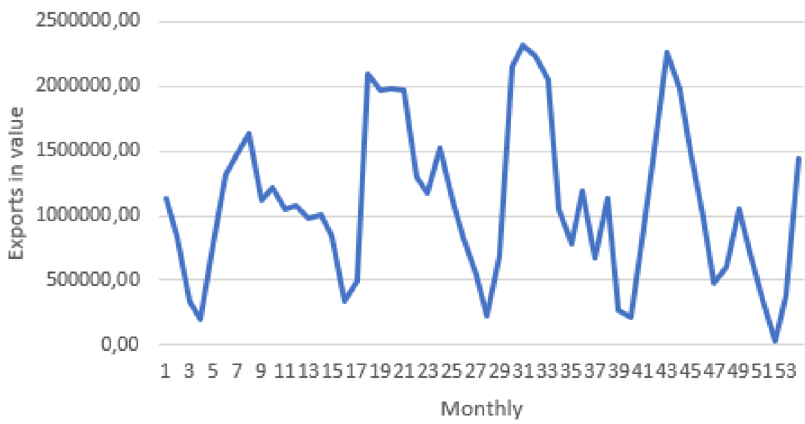


Figure 3.5: Sales from January 2016 to June 2020

workers, and varies slightly over the period under study, with a minimum of 111 and a maximum of 120 workers. These workers have a cost to the company 159,294 euros, on average. Productivity ranges between 261.9 and 5,841.9 and the average productivity of the company is 2,355.40.

Figure 3.5 shows sales exported between January 2016 and June 2020. It is observed that sales are not uniform over time, as mentioned. Additionally, a possible trend of seasonality in exports can be observed.

As expected, the number of pairs is not uniform over the months, following the same pattern as sales exported, varying between 2,226 pairs and 85,107, with an average of 44,202.

Figure 3.6: Number of pairs of shoes exported from January 2016 to June 2020

Figure 3.6 represents the number of pairs of shoes exported, per month, from January 2016 to June 2020. It can be observed that, there is a pattern that repeats itself every year. In this sense, also seems to exist a seasonal pattern that repeats itself in each cycle.

3.5 Empirical Results and Discussion

This section presents the results achieved with the estimation of models 3.1 to 3.6 in order to identify the determinants of the company's demand for footwear, as well as, the seasonal trend.

In a first stage, demand equation with explanatory variables that characterize the company, considering the two different dependent variables (sales amount,in euros and the number of pairs of shoes exported) is estimated by the OLS method. The estimated functions are defined in equations 3.1 and 3.2.

In order to validate the results, the necessary tests for this purpose were carried out. First, for the purpose of testing the validity of the errors normality, the Shapiro-Wilk test was applied and the null hypothesis that the errors follow a normal distribution was not rejected, to a significance level of 5%. Also to test the validity of homoscedasticity, the Breusch-Pagan test was applied and the null hypothesis was not rejected, allowing to validate that the errors are homoscedastic, at a 5% significance level. Finally, the Durbin-Watson test was performed. This test allows to analyze the absence of correlation and independence of the errors, and the null hypothesis was not rejected at a 5% level, thus there is no auto-correlation of the residuals, thus the errors are independent. The results of these tests are shown in Table 3.3.

In order to verify the existence of multicollinearity[4] between the explanatory variables, the correlation

[4]Multicollinearity exists when the correlation coefficients are greater than 0.85 [67]

matrix was performed. The results are presented in Table 3.2.

Table 3.2: Correlation matrix

Variables	**Prod**	**NTr**	**Rem**	**CP**
Productivity	1.0000			
Nr workers	0.1721	1.0000		
Remuneration	0.4322	0.3523	1.0000	
Own Capital	0.1155	0.4527	0.4127	1.0000

[1]Source: Own Elaboration

By analyzing the correlation matrix, the absence of multicollinearity can be assumed, i.e. explanatory variables are linearly independent. Once assumptions were validated, it can state that OLS is the best minimum variance estimator for β.

With the purpose to verify the existence of a seasonal trend in the company's sales, two alternatives specifications are experimented. On the one hand, the fixed effect of time is included (equations 3.3 and 3.4) and, on the other, the trigonometric functions, sine and cosine, have been added (equations 3.5 and 3.6). The results of these regressions are reported in Table 3.3.

The value of the R^2 of the models ranges between 78% and 93% which means that the fit quality of the models is very good. The *p-value* of the F-statistic test is very close to zero, so these models are globally statistically significant at the 1% level.

As expected, results show that regardless the dependent variable used, the sign of the variables, remain the same. So, results show that productivity has a positive and significant effect on exports in all models. As explained in the literature review, there is a direct and positive relationship between these two variables, so the higher the productivity, the greater the production capacity and, consequently, the greater the increase in exports. Srinivasan et al. [84] and Girma et al.[41] state that productivity has a positive influence on exports.

Equity has a negative impact on the dependent variable and is statistically significant at 5%. The findings in different models show that the result is not robust. Furthermore, this negative influence of own capital on sales exported/number of pairs sold is at odds with the literature review. Srinivasan et al. [84] state that equity has a positive influence on exports, revealing financial stability of the company. Thus, the H4 is not validated.

Lagged variables are statistically significant in models 1 and 3, suggesting that exports from previous years have a positive influence in current sales. These results reflect the cumulative nature of the orders process. It can mean that customers are satisfied with the company's performance, making them loyal and earning their trust.

The results show that the variable remuneration does not influence the demand for footwear, not validating the hypothesis H3 formulated above. This is in line with the study carried out by Girma et al.[41] and

Table 3.3: OLS regressions results

	Model 3.1	Model 3.3	Model 3.5	Model 3.2	Model 3.4	Model 3.6
VARIABLES	**Dependent variable: Value exports, in euros**			**Dependent variable: number of pairs**		
Intercept	-4656000	-3482000	-3804000	-149100	-85970	-122300
	(0.0689)'	(0.1198)	(0.1293)	(0.1587)	(0.3477)	(0.2559)
Productivity	214	118.2	202.30	7.556	3.897	7.278
	(0.0001)***	(0.0339)*	(0.0004)***	(0.0009)***	(0.0867)'	(0.0026)**
Nr workers	51760	44690	50730	1704	1250	1721
	(0.0282)*	(0.0524) '	(0.0290)*	(0.0826)'	(0.1816)	(0.0838) '
Remuneration	-1.674	2.682	-2.348	-701.3	0.2611	-0.1057
	(0.4823)	(0.6634)	(0.3252)	(0.4836)	(0.3072)	(0.3019)
Own Capital	-0.2099	-0.2151	-0.2887	-0.006809	-0.00909	-0.01002
	(0.0202)*	(0.0154)*	(0.0033)**	(0.0652)'	(0.0125)*	(0.0150)*
Lag Sales	0.7002	-0.02777	0.6155			
	(2.6e-07)***	(0.8761)	(0.0000)***			
Lag Quantity				0.6532	-0.1994	0.6038
				(0.0000)***	(0.2998)	(0.0000)***
February		-39630			3275	
		(0.8088)			(0.6332)	
March		-569300			-23490	
		(0.0038)**			(0.0039)**	
April		-801900			-39540	
		(0.0005)***			(0.0001)***	
May		-409500			-19940	
		(0.0200)*			(0.0083)**	
June		611000			27600	
		(0.0154)*			(0.0068)**	
July		821600			30580	
		(0.0048)**			(0.0074)**	
August		653400			12750	
		(0.0800)'			(0.3978)	
September		734700			21950	
		(0.0028)**			(0.0176)*	
October		108900			1631	
		(0.5677)			(0.8359)	
November		-88930			-5859	
		(0.6169)			(0.4324)	
December		-56540			-13480	
		(0.8860)			(0.4168)	
Cosine			71530			2982
			(0.4246)			(0.3340)
Sine			91400			-5864
			(0.0457)*			(0.1290)
Observations	42	42	42	42	42	42
R^2	0.8440	0.9313	0.8656	0.7764	0.9047	0.7979
Adjusted R^2	0.8224	0.8873	0.838	0.7453	0.8437	0.7563
F teste	38.96	21.18	31.29	25	14.83	19.18
p-value	$<1.493e-13$	1.151e-10	4.951e-13	$<8.679e-11$	5.704e-09	4205e-10
Shapiro-Wilk	0.9877	0.9797	0.9856	0.9805	0.9777	0.9591
p-value	0.9262	0.6513	0.8674	0.6815	0.5729	0.1371
Durbin-watson	2.0373	2.1511	2.1937	2.1420	2.0825	2.2521
p-value	0.798	0.944	0.988	0.9	0.954	0.902
Breusch-Pagan	0.2461	1.4304	0.0352	0.0787	2.1386	0.0021
p-value	0.6198	0.2317	0.8512	0.7790	0.1436	0.9635

Source:Own Elaboration

Note: Standard errors in parentheses. Significance levels: *** p<0.001, ** p<0.01, * p<0.05, ' p<0.1 .

Srinivasan et al. , [84], for which the remuneration variable was not significant either. Additionally, the number of workers has a positive and statistically significant (at 5% level) impact on the value exports, but it has no influence when the dependent variable is the number of pairs of shoes exported.

Regarding the estimated models, it can be conclude that productivity, the number of workers and lagged variables in time are statistically significant and their increase has a positive impact on the value of exports, validating hypotheses H1 and H2 being in line with the studies carried out by Girma et al.,[41], srinivasan et al.[84] and Bernard et al. [18].

However, the variable equity had a negative coefficient, in contrast to the presented in the literature review, so hypothesis H4, instead of implying a positive impact, presented a negative opposite to the study presented by Srinivasan et al. [84].

The fixed effect of time is added to model 2 (Table 3.3), and results indicate that there are seven months (from March to September) that are statistically significant. Note that, these months refer to the production of the Autumn-Winter collection. In other words, these months have an impact on the demand for footwear: a negative influence from March to May and a positive influence from June to September. From the analysis of the estimated model, it can be conclude the possibility of the existence of a seasonal trend.

To test the robustness of the seasonality of exports, model 3 was estimated. The statistical significance obtained in sine function shows that there is a seasonal pattern that repeats itself over time, thus confirming the seasonal trend.

3.6 Conclusions

The main objective of this study was to identify and characterize the main determinants for exports of a Portuguese company in the footwear sector. This objective was achieved using an econometric study using a 42-month time series of a footwear company. The identification of the main variables that make up the econometric model emerged based on a literature review and other empirical studies that address the issue of exports.

The study analyzes the demand function that can be measure through the quantity and value of exports. The explanatory variables considered were productivity, number of workers, remunerations, equity, lagged variable of sales and lagged variable of quantity. From these, econometric models were formulated.

From the analysis of the results of the estimation, it is concluded that productivity, number of workers and lagged-sales, have a positive influence on the demand for footwear. However, equity is statistically significant, consenting a negative impact on exports.

Adding the fixed effect of time, results indicate that there is a seasonal trend in the value of exports and the econometric functions added later, confirm the robustness of the existence of this pattern.

Chapter 4

Conclusions and Future Work

Exporting is the most common form of international expansion, and exports play a key role in stimulating a country's economic growth and overall productivity [81]. Promoting exports is a high priority for most governments, assuming it is good for productivity and growth. Until recently, however, there were few studies linking exports to companies' performance.

Outsourcing is commonly used by the manufacturer to respond to increased production in specific periods [61]. Outsourcing brings many advantages for most companies [27]. In fact, outsourcing can be used as a secondary source of supply in addition to in-house production.

In the first part of this dissertation, a mathematical model was formulated to assist the production manager in planning the distribution of orders to be produced internally and externally aiming at minimizing with the aim of minimizing the cost of production. The AMPL algebraic modeling language and the Gurobi solver with AMPL interface were used to obtain results from several instances extracted from the data provided by the company. The results obtained allowed to carry out the distribution of orders for internal and external production, either for C-S or A-F, in an automatic way. It can be observed that, for the tested instances, there was a reduction in the percentage of pairs produced using outsourcing one or both of the production phases.

In a second part, the factors that influence exports were analyzed using a database provided by the company with 42 observations from January 2017 to June 2020. In order to explain the demand for footwear, two econometric models were presented. The results confirm the consistency and explanatory relevance of the variables productivity, number of workers, equity, sales and lagged quantity. However, the variable remuneration was not significant in this study. This suggests that, in addition to trade barriers at the country level, company characteristics, such as its size and productivity, as well as its financial structure, are relevant for participation in trade. The seasonal trend was also confirmed.

In future, it is expected to perform further tests with the developed optimization model and to implement this tool in the company. Furthermore, in order to improve the demand functions, more tests with a higher number of observations must be performed. The incorporation of the estimate of the demand to the production planning model is also a future objective.

References

[1] Análise setorial da indústria do calçado banco de portugal. https://www.bportugal.pt/comunicado/nota-de-informacao-estatistica-estudo-da-central-de-balancos-10-analise/-setorial-da. Accessed: 2020-06-08.

[2] Boletim de Conjuntura APICCAPS. https://www.apiccaps.pt/library/media_uploads/conjuntura-95.pdf. Accessed: 2019-12-28.

[3] Calçado em Números APICCAPS. https://www.apiccaps.pt/news/calcado-em-numeros/3276.html. Accessed: 2021-5-24.

[4] Depositphotos depositphotos. https://pt.depositphotos.com/. Accessed: 2020-11-28.

[5] Facts & Numbers APICCAPS. file:///C:/Users/admin/Downloads/facts--numbers-2019.pdf. Accessed: 2019-12-28.

[6] Footure 2020 - Plano estratégico Cluster do Calçado apiccaps. apiccaps.pt/library/media_uploads/APICCAPS20166289123310p.pdf. Accessed: 2019-12-28.

[7] Histórias de sucesso - Indústria do Calçado INESCTEC. https://www.inesctec.pt/pt/historias-de-sucesso/industria-calcado#o-inicio. Accessed: 2019-12-28.

[8] Monografia Estatística APICCAPS. https://www.apiccaps.pt/getfilev2/?t=monografia-estatistica-2018&f=/monografia-estatistica-apiccaps-2018.pdf&idf=NDEOMg==. Accessed: 2020-06-08.

[9] Professor George Dantzig: Linear Programming Founder Turns 80 sol. https://web.stanford.edu/group/SOL/dantzig.html. Accessed: 2020-01-08.

[10] Quadros setor banco de portugal. https://www.bportugal.pt/QS/qsweb/Dashboards. Accessed: 2020-07-01.

[11] Retrato do Setor do Calçado em Portugal Gabinete de Estratégia e Estudos. https://www.gee.gov.pt. Accessed: 2021-5-24.

[12] Subcontracting Policy in the Airframe Industry. Division of Research Graduate School of Business Administrat.

[13] APICCAPS. Análise trimestral de conjuntura - 2º trimestre 2020. APICCAPS, 2020.

[14] Marcos Arenales, Reinaldo Morabito, Vinicius Armentano, and Horacio Yanasse. Pesquisa operacional: para cursos de engenharia. Elsevier Brasil, 2015.

[15] Bee Yan Aw, Sukkyun Chung, and Mark J Roberts. Productivity and turnover in the export market: micro-level evidence from the republic of korea and taiwan (china). The World Bank Economic Review, 14(1):65–90, 2000.

[16] Artur Baldauf, David W Cravens, and Udo Wagner. Examining determinants of export performance in small open economies. Journal of World Business, 35(1):61–79, 2000.

[17] José Antonio Belso-Martínez. Differences in survival strategies among footwear industrial districts: the role of international outsourcing. European Planning Studies, 16(9):1229–1248, 2008.

[18] Andrew B Bernard and J Bradford Jensen. Exceptional exporter performance: cause, effect, or both? Journal of International Economics, 47(1):1–25, 1999.

[19] Dimitri P Bertsekas. Network optimization: continuous and discrete models. Athena Scientific Belmont, 1998.

[20] J Bijsterbosch and A Volgenant. Solving the rectangular assignment problem and applications. Annals of Operations Research, 181(1):443–462, 2010.

[21] Garrick Blalock and Paul J Gertler. Learning from exporting revisited in a less developed setting. Journal of Development Economics, 75(2):397–416, 2004.

[22] Alan S Blinder. Offshoring: the next industrial revolution? Foreign Affairs, pages 113–128, 2006.

[23] Matilde Bombardini, Christopher J Kurz, and Peter M Morrow. Ricardian trade and the impact of domestic competition on export performance. Canadian Journal of Economics/Revue Canadienne d'économique, 45(2):585–612, 2012.

[24] Gaetan Caron, Pierri Hansen, and Brigitte Jaumard. The assignment problem with seniority and job priority constraints. Operations Research, 47:449–453.

[25] Davide Castellani. Export behavior and productivity growth: Evidence from italian manufacturing firms. Weltwirtschaftliches Archiv, 138(4):605–628, 2002.

[26] Alka Chadha. Product cycles, innovation, and exports: A study of indian pharmaceuticals. World Development, 37(9):1478–1483, 2009.

[27] Zhi Long Chen and Chung Lun Li. Scheduling with subcontracting options. IIE Transactions, 40(12):1171–1184, 2008.

[28] Byung-Cheon Choi and Jibok Chung. Two-machine flow shop scheduling problem with an outsourcing option. European Journal of Operational Research, 213(1):66–72, 2011.

[29] Byung-Cheon Choi and Myoung-Ju Park. Outsourcing decisions in m-machine permutation flow shop scheduling problems with machine-dependent processing times. Asia-Pacific Journal of Operational Research, 31(04):1450028, 2014.

[30] Dae-Young Chung and Byung-Cheon Choi. Outsourcing and scheduling for two-machine ordered flow shop scheduling problems. European Journal of Operational Research, 226(1):46–52, 2013.

[31] Daeyoung Chung, Kichang Lee, Kitae Shin, and Jinwoo Park. A new approach to job shop scheduling problems with due date constraints considering operation subcontracts. International Journal of Production Economics, 98(2):238–250, 2005.

[32] Sofronis K Clerides, Saul Lach, and James R Tybout. Is learning by exporting important? micro-dynamic evidence from colombia, mexico, and morocco. The Quarterly Journal of Economics, 113(3):903–947, 1998.

[33] Matthew A Cole, Robert JR Elliott, and Supreeya Virakul. Firm heterogeneity, origin of ownership and export participation. World Economy, 33(2):264–291, 2010.

[34] Miguel A Delgado, Jose C Farinas, and Sonia Ruano. Firm productivity and export markets: a non-parametric approach. Journal of International Economics, 57(2):397–422, 2002.

[35] Bo Feng, Zhi-Ping Fan, and Yanzhi Li. A decision method for supplier selection in multi-service outsourcing. International Journal of Production Economics, 132(2):240–250, 2011.

[36] David Ford, Barry Cotton, David Farmer, Andrew Gross, and Ian Wilkinson. Make-or-buy decisions and their implications. Industrial Marketing Management, 22(3):207–214, 1993.

[37] Robert Fourer, David M Gay, and Brian W Kernighan. A modeling language for mathematical programming. Management Science, 36(5):519–554, 1990.

[38] Helmut Fryges and Joachim Wagner. Exports and productivity growth: First evidence from a continuous treatment approach. Review of World Economics, 144(4):695–722, 2008.

[39] Helio Yochihiro Fuchigami and Socorro Rangel. A survey of case studies in production scheduling: Analysis and perspectives. Journal of Computational Science, 25:425–436, 2018.

[40] K Matthew Gilley and Abdul Rasheed. Making more by doing less: an analysis of outsourcing and its effects on firm performance. Journal of Management, 26(4):763–790, 2000.

[41] Sourafel Girma, David Greenaway, and Richard Kneller. Does Exporting Lead to Better Performance?: A Microeconometric Analysis of Matched Firms. Leverhulme Centre for research on globalisation and economic policy, 2002.

[42] P Gjellerup. SME support services in the face of globalisation. concerted action seminar, opening address. In Conference Proceedings, Danish Agency for Trade and Industry, Copenhagen, pages 16–28, 2000.

[43] Fred Glover. Improved linear integer programming formulations of nonlinear integer problems. Management Science, 22(4):455–460, 1975.

[44] Fred Glover. An improved mip formulation for products of discrete and continuous variables. Journal of Information and Optimization Sciences, 5(1):69–71, 1984.

[45] David Greenaway and Richard Kneller. Exporting and productivity in the united kingdom. Oxford Review of Economic Policy, 20(3):358–371, 2004.

[46] Xiuping Guo and Deming Lei. Bi-objective job shop scheduling with outsourcing options. International Journal of Production Research, 52(13):3832–3841, 2014.

[47] Frederick S Hillier. Introduction to operations research. Tata McGraw-Hill Education, 2012.

[48] Frederick S Hillier and Gerald J Lieberman. Introdução à pesquisa operacional. McGraw Hill Brasil, 2013.

[49] Rudy Hirschheim and Mary Lacity. The myths and realities of information technology insourcing. Communications of the ACM, 43(2):99–107, 2000.

[50] Clyde Holsapple, Anita Lee-Post, and Ram Pakath. A unified foundation for business analytics. Decision Support Systems, 64:130–141, 2014.

[51] Jung Man Hong and Jong Hyup Lee. Outsourcing decisions in single machine scheduling problem with multiple external facilities. Journal of Marine Science and Technology, 24(3):603–609, 2016.

[52] Mauricio Jenkins. Sourcing patterns of firms in export processing zones (epzs): An empirical analysis of firm-level determinants. Journal of Business Research, 59(3):331–334, 2006.

[53] David Jennings. Strategic sourcing: benefits, problems and a contextual model. Management Decision, 40(1):26–34, 2002.

[54] Cengiz Kahraman, Ahmet Beskese, and Ihsan Kaya. Selection among erp outsourcing alternatives using a fuzzy multi-criteria decision making methodology. International Journal of Production Research, 48(2):547–566, 2010.

[55] André A Keller. Mathematical Optimization Terminology: A Comprehensive Glossary of Terms. Academic Press, 2017.

[56] Harold W Kuhn. The hungarian method for the assignment problem. Naval Research Logistics Quarterly, 2(1-2):83–97, 1955.

[57] Stefan Lachenmaier and Ludger Wößmann. Does innovation cause exports? evidence from exogenous innovation impulses and obstacles using german micro data. Oxford Economic Papers, 58(2):317–350, 2006.

[58] JJ Lazzarotto, JC Fioravanço, et al. Trends and seasonality in brazilian table grape exports and imports. Informações Econômicas-Instituto de Economia Agrícola, 43(1):43–58, 2013.

[59] Ik Sun Lee and Chang Sup Sung. Minimizing due date related measures for a single machine scheduling problem with outsourcing allowed. European Journal of Operational Research, 186(3):931–952, 2008.

[60] Ik Sun Lee and Chang Sup Sung. Single machine scheduling with outsourcing allowed. International Journal of Production Economics, 111(2):623–634, 2008.

[61] Xiuping Lei, Deming e Guo. A shuffled frog-leaping algorithm for job shop scheduling with outsourcing options. 54(16):4793–4804, 2016.

[62] Zhaohui Liu, Wen-Chiung Lee, and Jen-Ya Wang. Resource consumption minimization with a constraint of maximum tardiness on parallel machines. Computers & Industrial Engineering, 97:191–201, 2016.

[63] Bart L Maccarthy and Jiyin Liu. Addressing the gap in scheduling research: a review of optimization and heuristic methods in production scheduling. The International Journal of Production Research, 31(1):59–79, 1993.

[64] Harry Matlay, Mitja Ruzzier, Robert D Hisrich, and Bostjan Antoncic. SME internationalization research: past, present, and future. Journal of Small Business and Enterprise Development, 2006.

[65] Carole Maurel et al. Financial approach to export performance in french wine smes. In 4th International Conference of the Academy of Wine Business Research, 2008.

[66] Hadi Mokhtari, Isa Nakhai Kamal Abadi, and M Reza Amin-Naseri. Production scheduling with outsourcing scenarios: a mixed integer programming and efficient solution procedure. International Journal of Production Research, 50(19):5372–5395, 2012.

[67] Mauro Naghettini and Éber José de Andrade Pinto. Hidrologia estatística. CPRM, 2007.

[68] RF Tavares Neto and Moacir Godinho Filho. An ant colony optimization approach to a permutational flowshop scheduling problem with outsourcing allowed. Computers & Operations Research, 38(9):1286–1293, 2011.

[69] Roberto Fernandes Tavares Neto, Moacir Godinho Filho, and Fabio Molina Da Silva. An ant colony optimization approach for the parallel machine scheduling problem with outsourcing allowed. Journal of Intelligent Manufacturing, 26(3):527–538, 2015.

[70] Jan Olhager and Joakim Wikner. Production planning and control tools. Production Planning & Control, 11(3):210–222, 2000.

[71] M Mendes Oliveira, Luis Delfim Santos, and Natércia Fortuna. Econometria. Escolar Editora, pages 259–333, 2011.

[72] Christos H Papadimitrou and Kenneth Steiglitz. Combinatorial optimization: algorithms and complexity. 1982.

[73] David W Pentico. Assignment problems: A golden anniversary survey. European Journal of Operational Research, 176(2):774–793, 2007.

[74] Xiangtong Qi. Coordinated logistics scheduling for in-house production and outsourcing. IEEE Transactions on Automation Science and Engineering, 5(1):188–192, 2008.

[75] Xiangtong Qi. Two-stage production scheduling with an option of outsourcing from a remote supplier. Journal of Systems Science and Systems Engineering, 18(1):1–15, 2009.

[76] Xiangtong Qi. Outsourcing and production scheduling for a two-stage flow shop. International Journal of Production Economics, 129(1):43–50, 2011.

[77] Imma Ribas Vila and Ramon Companys Pascual. A hybrid flow shop model for an ice cream production scheduling problem. Journal of Industrial Engineering and Management, 2(1):60–89, 2009.

[78] Mark J Roberts and James R Tybout. The decision to export in colombia: An empirical model of entry with sunk costs. The American Economic Review, pages 545–564, 1997.

[79] Andrés Rodríguez-Pose, Vassilis Tselios, Deborah Winkler, and Thomas Farole. Geography and the determinants of firm exports in indonesia. World Development, 44:225–240, 2013.

[80] Hamid Safarzadeh and Farhad Kianfar. Job shop scheduling with the option of jobs outsourcing. International Journal of Production Research, pages 1–18, 2019.

[81] Robert M Salomon and J Myles Shaver. Learning by exporting: new insights from examining firm innovation. Journal of Economics & Management Strategy, 14(2):431–460, 2005.

[82] Ruhul Amin Sarker and Charles S Newton. Optimization modelling: a practical approach. CRC Press, 2007.

[83] World Footwear Portuguese Shoes. World Footwear Yearbook 2020. CEGEA, 2020.

[84] TN Srinivasan and Vani Archana. Determinants of export decision of firms. Economic and Political Weekly, pages 49–58, 2011.

[85] Alessandro Sterlacchini. The determinants of export performance: A firm-level study of italian manufacturing. Review of World Economics, 137(3):450–472, 2001.

[86] El Ghazali Talbi. Metaheuristics: from design to implementation, volume 74. John Wiley & Sons, 2009.

[87] Russ J Vander Wiel and Nikolaos V Sahinidis. The assignment problem with external interactions. Networks: An International Journal, 30(3):171–185, 1997.

[88] Carlo Vercellis. Business intelligence: data mining and optimization for decision making. Wiley Online Library, 2009.

[89] A. Volgenant. A note on the assignment problem with seniority and job priority constraints. European Journal of Operational Research, 154:330–335.

[90] DF Votaw. The personnel assignment problem. Symposium on linear Inequalities and Programming, 1952.

[91] Katharine Wakelin. Innovation and export behaviour at the firm level. Research Policy, 26(7-8):829–841, 1998.

[92] Gerhard Wascher. Order picking: a survey of planning problems and methods. In Springer, editor, Supply Chain Management and Reverse Logistics, pages 323–347.

[93] Laurence A Wolsey and George L Nemhauser. Integer and combinatorial optimization. John Wiley & Sons, 2014.

[94] Günther Zäpfel and Michael Bögl. Multi-period vehicle routing and crew scheduling with outsourcing options. International Journal of Production Economics, 113(2):980–996, 2008.

[95] Weiya Zhong and Zhiming Huo. Single machine scheduling problems with subcontracting options. Journal of Combinatorial Optimization, 26(3):489–498, 2013.

Appendix

Table 4.1: Results analyses per factories A-F

			Description	F1 e F0500	F0326	Total
A-F	Orders	1 - 31 July	Available capacity	44000	33000	77000
			Capacity used	43994	32988	76982
			% of capacity used in each company	99.99%	99.96%	
			% of pairs produced in Factory i	57.15%	42.85%	100.00%
		1-16 July	Available capacity	27000	20250	47250
			Capacity used	26993	19908	46901
			% of capacity used in each company	99.97%	98.31%	
			% of pairs produced in Factory i	57.55%	42.45%	100.00%
		17-31 July	Available capacity	17500	13125	30625
			Capacity used	17460	12621	30081
			% of capacity used in each company	99.77%	96.16%	
			% of pairs produced in Factory i	58.04%	41.96%	100.00%
	Article	1 - 31 July	Available capacity	44000	33000	77000
			Capacity used	44000	32982	76982
			% of capacity used in each company	100.00%	99.95%	
			% of pairs produced in Factory i	57.16%	42.84%	100.00%
		1-16 July	Available capacity	27000	20250	47250
			Capacity used	27000	19901	46901
			% of capacity used in each company	100.00%	98.28%	
			% of pairs produced in Factory i	57.57%	42.43%	100.00%
		17-31 July	Available capacity	17500	13125	30625
			Capacity used	17494	12587	30081
			% of capacity used in each factory	99.97%	95.90%	
			% of pairs produced in factory i	58.16%	41.84%	100.00%

Table 4.2: Order analysis

	2019	2020	2020	2020	2020	2020	2020	2020
	2019	January	February	March	April	May	June	July
Quantity received	58627	8480	41765	85732	53099	26395	27149	7615
Quantity to be produced daily		385.45	2320.28	3896.91	3792.79	1389.21	1428.89	331.09
Monthly production capacity C-S		15400	12600	15400	9800	13300	13300	16100
Monthly production capacity A-F		22000	18000	22000	14000	19000	19000	13000
Quantity per month to deliver		44681	19242	16618	4082	58536	48341	76982
Quantity to be produced daily of delivery		2030.95	1069	755.36	291.57	3080.84	2544.26	3347.04
Working days		22	18	22	14	19	19	23
Number of orders	522	304	176	13	647	532	853	205
Number of orders per day	23.7	16.9	8	0.9	34.1	28	37.1	15.8

	2020	2020	2020	2020	2020	2021	2021	2021	
	August	September	October	November	December	January	February	March	Total
Quantity received	3786	40289	58552	56691	5881				470641
Quantity to be produced daily	28.92	1831.32	2788.19	2699.57	391.40				
Monthly production capacity C-S	14700	14700	10500	14000	12600	16100			
Monthly production capacity A-F	22000	21000	9100	15400	21000	150000	20000	18000	23000
Quantity per month to deliver	16355	36497	27553	18413	29172	45800	9219	19150	470641
Quantity to be produced daily of delivery	1258.08	1658.95	1312.05	876.81	1944.80	2290	512.17	832.61	
Working days	13	22	21	21	15	20	18	23	290
Number of orders	494	261	183	376	487	173	24	5250	
Number of orders per day	12.4	8.7	25.1	24.4	9.6	1			

daily production capacity C-S = 700 pairs/day

daily production capacity A-F = 1000 pairs/day

[3]Source: Own elaboration

Table 4.3: Results analyses per factories C-S

			Description	608	F0002	F0158	F0286	F0302	F0791	F0753	F0820	F1_E_F2	Total
C-S	**Orders**	1 - 31 July	Available capacity	10250	6150	6970	8200	8200	2050	6150	2050	28700	78720
			Capacity used	10250	6149	6970	8200	6465	2050	6150	2050	28698	76982
			% of capacity used in each company	100.00%	99.98%	100.00%	100.00%	78.84%	100.00%	100.00%	100.00%	99.99%	
			% of pairs produced in Factory i	13.31%	7.99%	9.05%	10.65%	8.40%	2.66%	7.99%	2.66%	37.28%	100.00%
		1-16 July	Available capacity	6250	3750	4250	5000	5000	1250	3750	1250	17500	48000
			Capacity used	6242	3750	4250	4997	3912	1250	3750	1250	17500	46901
			% of capacity used in each company	99.87%	100.00%	100.00%	99.94%	78.24%	100.00%	100.00%	100.00%	100.00%	
			% of pairs produced in Factory i	13.31%	8.00%	9.06%	10.65%	8.34%	2.67%	8.00%	2.67%	37.31%	100.00%
		17-31 July	Available capacity	4000	2400	2720	3200	3200	800	2400	800	11200	30720
			Capacity used	4000	2400	2714	3196	2575	800	2400	796	11200	30081
			% of capacity used in each company	100.00%	100.00%	99.78%	99.88%	80.47%	100.00%	100.00%	99.50%	100.00%	
			% of pairs produced in Factory i	13.30%	7.98%	9.02%	10.62%	8.56%	2.66%	7.98%	2.65%	37.23%	100.00%
	Article	1 - 31 July	Available capacity	10250	6150	6970	8200	8200	2050	6150	2050	28700	78720
			Capacity used	10239	6144	6958	8193	6507	2047	6144	2050	28700	76982
			% of capacity used in each company	99.89%	99.90%	99.83%	99.91%	79.35%	99.85%	99.90%	100.00%	100.00%	
			% of pairs produced in Factory i	13.30%	7.98%	9.04%	10.64%	8.45%	2.66%	7.98%	2.66%	37.28%	100.00%
		1-16 July	Available capacity	6250	3750	4250	5000	5000	1250	3750	1250	17500	48000
			Capacity used	6245	3747	4250	4999	3924	1249	3746	1247	17494	46901
			% of capacity used in each company	99.92%	99.92%	100.00%	99.98%	78.48%	99.92%	99.89%	99.76%	99.97%	
			% of pairs produced in Factory i	13.32%	7.99%	9.06%	10.66%	8.37%	2.66%	7.99%	2.66%	37.30%	100.00%
		17-31 July	Available capacity	4000	2400	2720	3200	3200	800	2400	800	11200	30720
			Capacity used	3981	2397	2717	3186	2604	800	2400	796	11200	**30081**
			% of capacity used in each company	100%	100%	100%	100%	81%	100%	100%	100%	100%	
			% of pairs produced in Factory i	13.23%	7.97%	9.03%	10.59%	8.66%	2.66%	7.98%	2.65%	37.23%	100.00%