ISCTE Business School
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Proposing an alternative allocation algorithm for smartphones – the case of Forall Phones

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Acknowledgments

The completion of the Master’s in Services and Technology Management marks the beginning of a new stage. In ISCTE-IUL students are provided the opportunity to learn and to grow, which I believe I did, and ISCTE-IUL has prepared me as person to face the challenges that life throws at me. This final work is to me the reflection of the knowledge and growth acquired as a student in ISCTE-IUL, but the realization of this demanding project would not be possible without the help of some people, to whom I must thank deeply.

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“Viver não é necessário; o que é necessário é criar.”

Fernando Pessoa

Resumo

O mercado dos recondicionados tem crescido a um ritmo considerável nos últimos anos. O desenvolvimento deste mercado deve-se ao esforço de vários países em mudar para um consumo circular de recursos que é o que define uma economia circular (Mugge, Jockin, & Bocken, 2017). Isto é possível ao reduzir-se o lixo criado e ao reaproveitar materiais que iriam parar ao lixo, voltando a usá-los como recursos (European Comission, 2019).

Esta mudança tem sido aceite pelas organizações e pelos seus clientes que começam a ver o mercado dos recondicionados como uma grande oportunidade. As empresas vêem a oportunidade de escoar stocks de produtos usados e de recuperar parte do seu valor (Weelden, Bakker, & Mugge, 2016). Os clientes vêem a oportunidade de comprarem produtos completamente funcionais a uma fração do preço original.

O desenvolvimento e crescimento do mercado dos recondicionados tem sido bastante notório no segmento dos *smartphones*, incluindo em Portugal, onde a Forall Phones tem sobressaído. Foi na área logística que este projecto foi realizado (uma área fulcral para a performance da empresa), sendo o objectivo melhorar a alocação de *smartphones* aos canais de venda.

Após o mapeamento dos processos foram identificadas algumas oportunidades de melhoria. De seguida o *feedback* relativamente à abordagem (criada para dar resposta às oportunidades de melhoria) foi aplicado e esta foi implementada em Excel. A abordagem foi depois comparada com outras abordagens, sugerindo-se depois recomendações para melhorar ainda mais o seu desempenho.

Palavras chave: problema de alocação de recursos, otimização, heurística, smartphones recondicionados, programação por metas, problema de otimização dinâmico multi-objetivo

Abstract

The refurbished market has grown at a considerable pace in recent years. The development of this market is due to the efforts of several countries to move to circular resource consumption that defines a circular economy (Mugge, Jockin, & Bocken, 2017). This is possible by reducing the waste created and reusing materials that would end up in the waste that are used again as resources (European Commission, 2019).

This change has been accepted by organizations and their customers who are beginning to see the refurbished market as a great opportunity. Companies see the opportunity to dispose of used product stocks and recover some of their value (Weelden, Bakker, & Mugge, 2016). Customers see the opportunity to buy fully functional products at a fraction of the original price.

The development and growth of the refurbished market has been quite noticeable in the smartphone segment, including in Portugal, where Forall Phones has been excelling. It was in the logistics area, in the allocation of smartphones to sales channels, that this project was carried out (a key area for the company's performance), with the aim of improving the allocation of smartphones to sales channels.

After mapping the processes, some opportunities for improvement were identified. Then feedback on the approach (designed to respond to opportunities for improvement) was applied and implemented in Excel. The approach was then compared with other approaches being afterwards suggested some recommendations to further improve its performance.

Key words: resource allocation problem, optimization, heuristics, refurbished smartphones, goal programming, dynamic multi-objective optimization problem

Executive Summary

The development and growth of the refurbished market has been quite noticeable in the smartphone segment, including in Portugal, where Forall Phones has been excelling. One of the keys to success of any company is to be able to allocate the right amount of a product at the right time, to the right location in a proper condition to the right customer.

This project tries to give an answer to the previous statement especially to the questions of the right amount, of the right product and of the right location. The project was to design a stock allocation approach and to implement it in a user-friendly tool, aiming to answer the research question: "How to improve the process of allocation of equipments to sales channels?". Since for a proper stock allocation it is necessary to look at several variables to make an informed decision, the developed approach transforms the data from the several sales channels into variables that can be applied to logistics models in the literature, and the approach then uses those models to take the decision whether to allocate a smartphone, and if a positive response is given to the previous question, to what sales channel.

For that, in the first stage of the project, Forall Phones's stock allocation process was mapped for the two approaches developed by Forall Phones that were used during the length of this project, by making use of direct observation and of semi-structured interviews to the actors that intervene in the process. Afterwards some improvement opportunities were identified, for both approaches, being identified that the approaches resorted to very general data and that there was a very standardized way of allocating smartphones and of defining the maximum stocks with no justifications in the literature. It was also identified that some data was not being used, although not necessary for the context in which Forall Phones was using both approaches, and that the approach used for the current allocation process could be manipulated by sales managers. For the problems identified possible solutions in the literature were presented.

Having in mind the identified possible solutions in the literature, a heuristic approach was constructed that used that literature, and that tried to tackle some of the issues that Forall Phones wanted that the approach considered. The feedback received in semi-structured interviews and in focus group presentations was integrated in the approach, that was then implemented in a user-friendly tool, Excel, where it was also used the Excel VBA for needed data manipulation. During the implementation it was checked to see if the data was being manipulated in the way that was defined in the approach, and to get a

reasonable computation time it was exploited the use of some implicit Excel's functionalities.

In the last step, with the goal to assess the performance of the proposed heuristic method, the three approaches were evaluated under the scope of stock coverage, that was one of the implicit objectives in our approach and is a good indicator of the quality of a resource allocation approach. The results obtained indicate that the heuristic approach outperformed the initial and the current Forall Phones approaches, selling all smartphones 27% and 46% faster respectively.

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1. Introduction

This chapter presents a contextualization of the theme, the industry in which the company is operating and some of the challenges that will be addressed in this Master project in subchapter 1.1., followed by the general objective (subchapter 1.2.) and specific objectives (subchapter 1.3.). In subchapter 1.4. the research question is presented. In subchapter 1.5. is exposed the methodology used in this project. After that, the scope of the project is presented (subchapter 1.6.), and to end, in subchaper 1.7., the structure of the thesis is presented.

1.1. Contextualization

From the 1,6 billion tons in EU that ended up in landfills or incinerated in 2010, it is estimated that 600 million tons could be reused or recycled (European Comission, 2019). The European Union (EU) wants to improve its waste management, and to recover more of the resources that end up daily in landfills or incinerated (European Comission, 2019). This can be done by increasing the rates (by waste hierarchy priority) of waste prevention, waste reuse, waste recycling and waste recovery. According to the European Comission (2019) "Turning waste into a resource is one key to a circular economy.". Quoting Mugge *et al.* (2017; p. 284) "Circular Economy aspires to transform linear consumption into a circular system by minimising waste and keeping the value of materials". This shift towards a more sustainable consumption model offers important opportunities to regain value from used products (Ellen MacArthur Foundation, 2012).

From the several methods that contribute to a Circular Economy, refurbishment is an approach that enables high original value retention (Weelden, Bakker, & Mugge, 2016).

Refurbishing is an environmentally friendly strategy. "Through refurbishing, it is possible to save significant (critical) raw materials and energy, and to avoid emissions (e.g., CO2)" Mugge *et al.* (2017; p. 285).

The refurbishment industry is a growing business, where we start to see an increasing number of players entering the market, not only because of the big opportunities that it offers, but also due to lower taxes in general, fruit of EU's legislation, and being that big retail players see this has an opportunity to regain value from equipments that they would consider otherwise with no value.

Forall Phones is a company that is in the smartphones refurbishment industry with retail stores in Portugal and Spain, but also sells to several other countries throughout their website. The company distinguishes from other players in the smartphones refurbishment industry in Portugal by having several stores spread across the country (the other players normally just have an online presence and/ or a single physical store where they sell this type of equipments.) and this in part explains Forall Phones success.

Along stores openings and business growth, there has been an increasing concern with individual stores performances, mainly because of the stock that was stopped in some stores being that in other stores that stock was not available including in the online channel due to stockouts. For that reason, Forall Phones began to criticize the method they used for resource allocation across stores. The method that was being used was to look individually to a smartphone that needed to be allocated, to search for the existing stock of that specific smartphone type in each sales channel, and then to allocate that smartphone to the sales channel that had the lowest stock of that specific smartphone type, or, in the case of a tie, to allocate it to the sales channel with the highest sales objective for the month, between those with the lowest stock. This form of allocation had some problems because it took a considerable amount of the logistics operator time, it did not count with the rithm of sales in each store, which led to an increasing amount of stock that was stopped, that would eventually be reallocated, and this allocation also resulted in lost sales. A new method is thus considered a key issue for Forall Phones since a good resource allocation is a key success factor to any company that wants to remain competitive and thrive in a certain market (Chen & Cochran, 2005).

This project comes up in that setting, to analyse the current resource allocation method of smartphones in Forall Phones and evaluate how to improve in terms of efficiency and effectiveness that resource allocation. It is expected that this new allocation mechanism allows Forall Phones not only to save costs by reducing the time required for the logistics operator in this task, but also to increase sales, by reducing to a minimum the stock that is stopped in certain stores if all other aspects remain static (*ceteris paribus*).

1.2. Overall Objective

The purpose of this thesis is the development of a new resource allocation algorithm for the equipments produced in Forall Phones's headquarters. This new algorithm should determine how many equipments of each type should be received in each sales channel.

1.3. Specific Objectives

The specific objectives serve to contextualize the problems the company is facing and help to support the overall objective, helping to achieve it. The specific objectives of this project are as follows:

- Presenting Forall Phones together with the sector in which it operates;
- Mapping the macro processes of the company, and in particular the smartphones allocation process;
- Identifying opportunities for improvement and important factors to be considered in the allocation process;
- Constructing and validating the new resource allocation approach taking into account the identified improvement factors and opportunities;
- Implementing the resource allocation approach in a user-friendly tool;
- Evaluating the proposed resource allocation algorithm, comparing the results with the current allocation process;
- Present final recommendations;

1.4. Research Question

The research question to which this project intends to respond is: "How to improve the resource allocation process of smartphones at Forall Phones?"

1.5. Methodology

The current Master Thesis is a project, involving the proposal, implementation and evaluation of a Resource Allocation algorithm in Forall Phones. It is a project based on a Case Study, since, according to Yin (2003):

- It answers the questions 'why' and / or 'how';
- The researcher has little (or no) influence on the activity of the operation;

- The focus of the study is on a contemporary phenomenon.

In order to reach the proposed objective, the present Project presents the following investigation steps:

- Process Mapping
- Identification of Improvement Opportunities
- Construction of a Resource Allocation algorithm, based on improvement opportunities identified before
- Implementation of the resource allocation algorithm in a user-friendly tool
- Evaluation of the tool and further adjustments

1.6. Scope

The project was chosen among others top priority projects that Forall Phones wanted to implement and following the advice of the Head of Supply Chain that identified the Resource Allocation as a project with a tremendous potential for improvement in terms of efectiveness and efficiency. The Resource Allocation Approach is projected to be used by the Logistics department when alocating smartphones to sales channels (both online and to physical stores in Portugal).

1.7. Overall Structure

This project is organized in 6 chapters as follows:

Chapter 1: Introduction of the Project, giving a context to the problem, the goals to achieve, the definition of the research question, the methodology that is going to be used, the scope and the structure.

Chapter 2: Literature review that presents methodologies and tools in detail, that have potential to be used to solve the problem, and the advantages and disadvantages regarding the several methods, that allow the researcher to choose the best suit for the project.

Chapter 3: Methodology where first it is going to be justified the type of research methodology and then explained in which phase the chosen methods are going to be used.

Chapter 4: Final heuristic proposal, where the approach developed to the case of Forall Phones, the theorical background behind it, the way that the approach operates and its classification under the literature are going to be presented.

Chapter 5: Case study with a description of the industry where the company is inserted, the company itself and the mapping of the initial processes inherent to the smartphones allocation, as well as identification of opportunities for improvement. First sketches of the approach and its improvement and validation, bearing in mind the improvement proposals, and Forall Phones requirements and preferences. Implementation and evaluation of the algorithm with further optimizations.

Chapter 6: Presentation of conclusions and limitations of the Resource Allocation approach.

2. Literature Review

In this section are presented studies that are relevant to the matter at hand, that will help to sustain this project, and to reach the objectives set by both parties. Key words used (individually or in combination) for building this literature review are resource allocation, hybrid retailing, refurbished phones, channel priority strategy, replenishment inventory control systems and supply uncertainty.

2.1. Resource Allocation approaches

This chapter is focused on the review of Resource Allocation approaches proposed in the literature since the aim of this project is to build a resource allocation approach for smartphones. Research allocation can be pursued through the use of different approaches. According to (Heidenberger & Stummer, 1999) there are several major techniques when addressing project selection and resource allocation, with the more appropriate for resource allocation in new businesses being Simulation, Game Theory and Optimization, that encompasses mathematical programming techniques and heuristics (Rothlauf, 2011). A simulation model is a theoretical representation of a reality. A model tries to mimic real world processes to understand the impacts that a process has in the real world (Simul8 Corporation, 2019). By changing the parameters associated with the model, one can test new or existing processes or, through a series of simulations, to assess a model sturdiness when responding to specific situations with a relatively low cost (Simul8 Corporation, 2019). Although possible, simulation will not be used because of the high number of possible scenarios, and the difficulty to evaluate the results. Simulation is not really concerned with the input/ output of a model, that in this case can not be manipulated according to this project needs, and therefore it can not be ensured that all the requirements are fulfilled when allocating smartphones in the simulation. That can only be confirmed after each simulation run, and a decision maker was needed to choose the solution that was more fitting, or, in a more extreme case, to work on a solution to make it appropriate. This method would be really time consuming, making it an unappealing approach.

Game theory analyzes the strategic decisions made by interacting players. Game theory uses the assumption of *homo economicus* – a self-interested, rational maximizer (Behavioral Economics, 2019). Applying to this case, if a certain store gets more smartphones, it has more opportunities to sell and in the end of the month to reach their individual objectives. According to (Hausken, 2002), for game theory to be applied three requirements are needed:

- There have to be at least two players;
- At least one of the players must have the opportunity of choosing between at least two strategies;
- The utility to each player depends on the combination of strategies chosen by all players;

Stores can ask for a certain smartphone, if there is an iminent sale, but since the allocation of products is a central decision, the points of sale normally do not choose, and it is of the headquarters interest that all of them should receive inventory. The many sales channels exist to help achieve a common goal set by Forall Phones, and not to compete against each other, and for that reason game theory can not be applied.

Optimization focusses on finding an optimal or near-optimal solution to a problem with low computational effort. The first step is to build a model that captures the key elements of the problem. An optimization model can have one or several objective(s) to be optimized, that represent the measure(s) of performance in the system, the parameters, that are used to describe objects statically, the variables, that may change during the optimization process, and the constraints that set the relationships among the variables and determine the allowable values for the variables (Neos Guide, 2019). Since it is possible to include the resource allocation requirements in the optimization model, in a way that all the solutions comply with the conditions, it can be concluded that Optimization is the most suitable approach for this case.

2.2. Optimization for resource allocation

In today's global market, manufacturers who fail to efficiently allocate and utilize their resources will eventually lose their competitiveness (Chen & Cochran, 2005). Efficient resource allocation allows optimizing companies objectives, a successful promotion of business performance and achieving goals (Huang, Lu, & Duan, 2011), (Chen & Liaw, 2001) and (Metaxiotis, Psarras, & Ergazakis, 2003).

And that is where optimization enters, as a method that can be used to support an efficient smartphone allocation to the several points of sale and help achieve goals.

Optimization can be found in a great number of areas such as engineering, management science and industrial processes (Anjos & Zhang, 2006). After searching the existing literature, some studies were found that used optimization for retail shelf space allocation (Yang, 2001), (Ozcan & Esnaf, 2011), (Lim, Rodrigues, & Zhang, 2004), (Corstjens & Doyle, 1981), organs transplantation (Freeman, et al., 2002), inventory management (Axsäter, 2003), (Li, 2013), (Ramakrishn, Sharafali, & Lim, 2015), (Bhatnagar & Syam, 2013), (Chen & Dong, 2018), (Joines, Gupta, Gokce, King, & Kay, 2002), project management (Hegazy, 1999), resources scheduling and operations planning (Belien, 2006), (Sujono & Lashkari, 2007), (Marques, de Sousa, Rönnqvist, & Jafe, 2014), job-shop scheduling (Sadeh & Fox, 1990), electricity retail market (Ghazvini, et al., 2015), and to (of course) solve classical optimization problems (Doerner, Gronalt, Hartl, Kiechle, & Reimann, 2008), (Laporte, 1992), (Dias, Captivo, & Clímaco, 2007), (Chaharsooghi & Kermani, 2008). Despite the abundance of research, to our knowledge there are no studies focused on optimization for smartphone allocation, and not even in smartphone allocation approaches. Therefore, research for optimization in resource allocation within the retail industry was pursued, by exploring some of the examples mentioned above to try to justify the use of optimization in our case. In retail shelf space allocation, three studies used heuristics to solve a single objective shelf allocation problem, being that in two of them (Lim, Rodrigues, & Zhang, 2004), (Ozcan & Esnaf, 2011), a higher level heuristic (metaheuristics) was adapted and fused with another method in order to solve a problem, while in the other (Yang, 2001), an algorithm used to solve the knapsack problem (one of the classical optimization problems) was slightly modified, and then fused with another methods. In the study of (Lim, Rodrigues, & Zhang, 2004), the hybrid method got better results comparing with heuristics/ metaheuristics procedures, being that in the three studies, the adapted/ hybrid methods achieved near-optimal solutions.

Looking to organs transplantation, more precisely to the liver (Freeman, et al., 2002), an evidence-based model was built, that according with a scale (related to a severity score, that had a high accuracy in predicting) and other factors, would give a patient more or less priority for transplantation. Although not explicitely mentioned in the study, the model uses a heuristic to determine which patient should receive a liver when one becomes available, according with the mortality risk level (linked to the score), the age, the location and time waiting (TW). This new allocation system was then implemented nationwide, and initial results (six months after implementation) showed an improvement when comparing with the previous allocation policy.

In inventory management (Ramakrishn, Sharafali, & Lim, 2015), a problem faced by an online retailer of pet food was analysed. The decision had to do with (when a warehouse faced a stockout) whether to request a product transhipment from another warehouse (a decision that depended on the inventory level of the warehouse and the time until the next stock review), and then fulfill the order, or to place an emergency order to the central warehouse, that had a bigger cost. The objective was to minimize the total operating cost of the system. Several heuristic procedures were combined, and results showed that optimality could be achieved by this hybrid method.

Within resources scheduling and operations planning, several problems in a hospital setting were analysed. The study (Belien, 2006) started addressing the several single objective problems by using exact algorithms. When an exact algorithm would turn out to be too time consuming, the algorithm was changed into a heuristic procedure (or merged with one) to cope with the desired maximum running time. In the staff scheduling problem it was used an activity-based approach instead of an approach based on the staff, but still respecting each staff set of skills. This approach resulted in a better staff efficiency when comparing with traditional approaches, since the staff was used more time. In the operation room problem, some models were created for building surgery schedules (some attention was given to resource usage as a function of the surgery schedule) with leveled bed occupancy, considering several factors in order to put on the model some uncertainty that is also felt in the real world. The objective of the models was to minimize the expected total bed shortage, which meant that the hospital could give response to a bigger share of its demand. After both problems had been solved individually, the staff and the operating room scheduling tasks were integrated, and considerable opportunities for staff saving were presented in the case study, showing the great potential that exact algorithms combined with heuristics had. Even thought the possible cost reduction in real life might be much smaller (due to the smaller flexibility with which surgery schedules can be modified), the methods used in this study allow the managers to see the waste due to the workforce surplus per shift, and to eliminate that surplus accordingly, making it possible to reduce the staff costs and related resource types, although the possible slight decrease in the quality of care.

In electricity retail (Ghazvini, et al., 2015), the case of four light-asset retailers was analysed. The retailers with few physical assets appeared due to the energy market liberalization, the removal of entry barriers for new entrants and the increased facilitation of switching between different retailers. The light-asset retailers in this study resell the energy purchased in the market to customers at competitive prices, but also have distributed generation units (DG) and energy storage systems (ESS) at the distribution network. On top of that, they use their demand response (DR) programs, with a few days in advance, to offer the consumers with smart meters incentives in certain time frames. The incentives of the DR program are offered to customers groups only for those hours that they are expected to consume more than the baseline load. The objectives for the model are to maximize the short-term profit and to reduce total peak demand at the points where the retailers are serving the end-users. Retailers pay to distribution companies for a service proportional to their peak demand, and the grid operator also charges more for the retailers' high demands, since in peak hours, electricity is produced in more inefficient power plants that contribute highly to emissions, therefore it is important to reduce those peaks. To solve this model the non-dominated sorting genetic algorithm II (NSGA-II) was used to designe the financial incentives that would maximize the profit and minimize the total peak demand. The NSGA-II was first compared with another method and got better solutions. The algorithm was then used to show the Pareto front of using each asset (DG or ESS) individually, of only the DR program, and from the combination of strategies. The best results were obtained by using the combination of strategies, and the hourly incentives for each customer group that maximized the payoff were presented, showing that the NSGA-II can be successfully implemented in the electricity retail market for strategy optimization, leading to increased payoffs.

In this section several issues related to the use of optimization techniques to support resource allocation decisions will be addressed. Based on the revision of the studies above, it will be explored the selection of objectives most widely used for resource allocation purposes (2.2.1.), and afterwards, the type of solution approaches that are available in the literature will also be presented (2.2.2.).

2.2.1. Single or Multi-Objective

Optimization concerns with finding the best solution for a problem from among the set of all feasible solutions. An optimization problem can be single objective, when it envolves a single objective function, and the best solution for a model can be found, or it can be a multi-objective, when there are several conflicting objectives to be considered simultaneously (Branke, Roman, Miettinen, & Deb, 2008). When several objectives are being optimized, "there is no single optimal solution, but a set of alternatives with different trade-offs, called Pareto optimal solutions, or non-dominated solutions" Branke *et al.* (2008). In those cases, when addressing a multiobjective problem, a decision-maker (DM) may be asked to take part in the solution process. In *a priori* methods, the preference information and aspirations are first coupled in the model, and then the solution process tries to find a Pareto optimal solution satisfying them as well as possible (Branke, Roman, Miettinen, & Deb, 2008). The setback for this method is that the DM does not necessarily know the possibilities and limitations of the problem beforehand. For that reason, it may exist a better Pareto optimal solution (in the DM point of view). In *a posteriori* methods, a set of Pareto optimal solutions is first generated and then the DM is supposed to select the most preferred one among them (Branke, Roman, Miettinen, & Deb, 2008). The trouble with this method is that if there are more than two objectives in the problem, it may be difficult for the DM to analyze the large amount of information (Branke, Roman, Miettinen, & Deb, 2008), overall it takes a lot of time to generate a set of Pareto optimal solutions, and if there are time limitations, the real Pareto optimal set may not reached. Input from the DM can also be received during the optimization routine, by using an iterative solution algorithm (which can be called a solution pattern), and, between each iteration, the DM specifies information according to his preference in the form that the algorithm in question can utilize (Branke, Roman, Miettinen, & Deb, 2008). This information is used to direct the solution process to the DM's local preferences and only a part of the Pareto optimal solutions has to be generated and evaluated (Branke, Roman, Miettinen, & Deb, 2008). By using interactive methods, the DM learns about the interdependencies in a problem and one's own preferences (Branke, Roman, Miettinen, & Deb, 2008; Silver, 2004). The drawback is that although not being so computationally expensive, the process can take a lot of the DM's time, as the DM is asked to express his preferences several times during the solution process.

To our knowledge, there are some studies in the literature for resource allocation of equipments, but they are mainly in shelf space allocation. From the three shelf space allocation problems, (Yang, 2001) and (Ozcan & Esnaf, 2011) solved a single objective function, while (Lim, Rodrigues, & Zhang, 2004) transformed a multi-objective function into a single objective function, by incorporating the demand function and the gross cost into the objective function. There is a study (Sujono & Lashkari, 2007), outside the retail scope that is worth to mention, in which a bi-objective model was formulated for operation allocation and material handling system selection. The objectives (minimize total costs and maximize part-equipment compability) were first analysed individually by transforming the other objective in a constraint, and the results obtained for the single objective functions and for some other numerical instances were verified by using two multi-objective solution methods (Goal Programming and Weight-Sum). The multi-objective solution methods achieved results similar to those of the single objective functions.

Despite the nature of the equipments allocation problem in Forall Phones, where multiple concerns must be addressed, the focus of the project will be in both single and multi-objective approaches, to also be in accordance with the literature.

2.2.2. Exact Methods or Heuristics

Optimization problems can be solved by two different type of methods: exact methods, that guarantee finding an optimal solution, and heuristics that can not guarantee finding an optimal solution (Rothlauf, 2011). Although having the ability to find an optimal solution, the run-time to calculate exact methods (for hard combinatorial optimization problems) increases exponentially with the instance size, and often only small or moderately-sized instances can be practically solved (Puchinger & Raidl, 2005). Heuristic algorithms, on the other hand, produce good-quality solutions because they are problem-specific, and they exploit properties of the problem in reasonable computation times and good enough for practical purposes (Rothlauf, 2011).

Since the allocation of smartphones needs to be done on a daily basis and the management wants to have information to support the decision in a quick way the attention will be geared towards heuristic methods.

In the following subchapters, the basic types of heuristic solution methods will be analysed (2.2.2.1.), and then higher-level heuristics will be discussed (2.2.2.2).

2.2.2.1. Basic types of Heuristic methods

In this subchapter it is going to be briefly discussed the heuristc concept and the several heuristic methods available. According to Silver (2004; p. 2) "The term heuristic means a method which, on the basis of experience or judgement, seems likely to yield a reasonable solution to a problem but which cannot be guaranteed to produce the mathematically optimal solution.". According to (Silver, 2004) the choice of which heuristic (or metaheuristic) to use depends on several factors such as:

- whether the decision area is strategic, tactical or operational;
- the frequency with which the decision is made;
- The time available to run a method and come up with a decision;
- the analytical qualifications of the decision maker(s) involved;
- the size of the problem (including the number of decision variables);
- the absence or presence of significant stochastic elements.

Before passing to the different heuristic solution methods, it is important to refer that they are not mutually exclusive and are normally combined with other(s) in the resolution of a single problem. At least one example will be provided for each method.

Randomly Generated Solutions

The concept for this approach is to generate random feasible solutions to the problem, test each and choose the best (Silver, 2004). (Joines, Gupta, Gokce, King, & Kay, 2002) used this approach to generate the initial solutions population (constrained by bounds) to be used in their genetic algorithm.

Problem Decomposition / Partitioning

In this method a complex problem is divided into several simpler subproblems and each is solved separately (Silver, 2004). This division can be due to hierarchy of decisions, by major resources or by chronological time of decisions (Silver, 2004).

According to (Silver, 2004), once the subproblems are defined there are three options:

1. Solve the subproblems independently and somehow join the independent solutions into a feasible solution of the overall problem;
2. Solve the subproblems sequentially using the results of the first as input to the second and so on, until a solution is found. (He, Zheng, & Peeta, 2015) used this approach for a large-scale transportation network evacuation;
3. Solve the subproblems iteratively, not just in a sequential way, in order to get the best marginal benefit in each step.

Inductive Methods

This method involves the generalization from smaller (or simpler) versions of the same problem or a closely related from a mathematical perspective, where it is embraced the concept of analogy (Silver, 2004). (Yang, 2001) used this approach, by understanding the analogy between the knapsack problem and the shelf space allocation problem, when considering just one shelf. An algorithm for the knapsack problem was for that reason adapted to solve the shelf space allocation problem.

Methods that Reduce the Solution Space

This method aims to reduce drastically the solutions that are even considered while trying not to seriously affect the quality of the solution obtained. This can be done by tightening existing constraints or by introducing extra constraints, being this an outcome from the analysis of the regression relationships, that gives values of the decision variables as functions of key parameters of the problem, or from the features observed in all, or a majority, of the optimal solutions (Silver, 2004). (Liang, Chen, & Xu, 2015) followed this by assuming that the conditions observed in some optimal solutions, would hold for any future cases to be investigated, being the solution partially specified.

Approximation Methods

Approximation methods are specifically concerned with manipulating the mathematical model in some way (or using a solution from a related simpler model). As stated by (Silver, 2004), to manipulate the model one has four options:

1. Aggregate variables: Through replacing several variables by a single aggregate variable, by replacing a multistage process by a similar single stage process, by scaling the units of each decision variable, or by transforming a two-dimensional combinatorial problem into a related single dimensional problem;
2. Modify the objective function: Through approximating a non-linear function by a piecewise linear one, as was done in (Godfrey & Powell, 2002), or by simply assuming a simpler objective function. Results must then be evaluated by using the most accurate representation of the true objective function (Silver, 2004);
3. Approximate probability distributions or stochastic processes: By assuming that random variables are constants at their mean values, or by using an analytically convenient distribution, that reproduces the behaviour of the variable under consideration (Silver, 2004). This is widely done for the distribution of demand during the replenishment lead time in inventory control models (Silver, 2004);
4. Change nature of constraints including relaxation methods – By approximating a non-linear constraint by a linear one, by choosing to completely ignore some constraints as done in (Axsäter, 2003), by replacing several constraints by a single, linear combination of them, or by relaxing the problem as done in (Jacko, 2016), being that the solution of the relaxed problem gives information about the solution of the original problem, and for a minimization problem, gives a lower bound on the objective function value of the optimal solution (Silver, 2004).

Constructive Methods

Constructive methods use the data of the problem to construct a solution, step by step. Usually, no solution is obtained until the procedure is complete. A special constructive approach that was used by (Yang, 2001) is the so-called greedy method, where, at each step, the next element of the solution is chosen to give the best marginal benefit, being the greedy method very similar to a sequential myopic perspective.

Local Improvement (Neighbourhood Search) Methods

The basic concept of local improvement methods is quite simple. One starts with a feasible solution to the problem, often the result of a constructive method. Feasible solutions in the neighbourhood of the current solution are evaluated. If one of these is better than the current solution, it becomes the new solution. This continues until no improvement can be found and the current solution, at that stage, is a local optimum. (Lim, Rodrigues, & Zhang, 2004) used this method in their 5-phase Squeaky-Wheel Optimization. One can also exhaustively evaluate all points in the neighbourhood (all points within a certain Euclidean distance of the current solution) and choose the one giving the largest improvement. The distance is normally specified/ randomly generated within certain parameters of the heuristic search.

To escape from a local optimum, where this method can get trapped at, it is needed a broader search by significantly increasing the size of the neighbourhoord of the current solution, but it may lead to a drastic escalation of the computational time as the size increases. Other option is to restart the search from a number of points, randomly chosen from the search space.

2.2.2.2. Metaheuristics

Following the definition provided by (IST, 2009), a metaheuristic is "a general solution method that provides a general structure and strategy guidelines for developing a heuristic method". Metaheuristics arrived to give an answer to some of the limitations that heuristic methods had. The heuristic solution methods are problem-specific, tend to converge to a local optimum and generate only a very limited number of different solutions (Yaghini, 2009). Metaheuristics can replace heuristic methods and are problem independent methods particularly concerned with not getting trapped at a local optimum and/or drastically reducing the search space (Silver, 2004).

Metaheuristics are general frameworks that use heuristic guidelines and can be applied to all kinds of discrete problems and adapt to continuous problems. By adjusting a few parameters, it is possible to make them adapted to a specific problem. Metaheuristics have the following characteristics, according to (Dréo, Pétrowski, Siarry, & Taillard, 2006):

- They are, at least to some extent, stochastic, which counters the combinatorial explosion of the possibilities;
- Generally of discrete origin, they have the advantage to be direct, i.e. they do not resort to often problematic calculations of the gradients of the objective function;

- They are inspired by analogies with physics (simulated annealing, simulated diffusion…), with biology (evolutionary algorithms, tabu search…), or with ethology (ant colonies, particle swarms…);
- Difficulty of adjustement of the parameters of the method and the large computation time.

The last point is the one that brings more problems. It is important that the approach that we end up developing to be able to run until the end, with no limitations, in a narrow amount of time. There is also the question that the parameters are difficult to adjust, and that (if static) the effectiveness of the parameters may change during the search (PPT Seminar). Those are the reasons why the focus of the project will be on developing a heuristic method, however, due to metaheuristics ability of getting great results in several problems, some metaheuristics features will be analyzed, and, if deemed necessary, will be added to the approach.

2.3. Conclusions

The intention of this project is to create an approach that can serve as the basis for a resource allocation tool that can be used as an aid to make decisions on which store a certain smartphone should go to.

The literature review of this project begins with the aim to assess what are the subjects that could be incorporated on the approach that is going to be the basis for the resource allocation tool. After some review the approach that best suited the purpose of this project was Optimization, and when exploring the literature that applied Optimization in the retail industry, several examples appeared that used approximation methods to solve optimization-based resource allocation problems (Heuristics and Metaheuristics). Both methods were reviewed, being that Heuristics were chosen mainly due to the need to have reduced computational time. Looking to the use and the results of heuristics in the literature, it is possible to say that this methodology has potential for the development of a resource allocation approach for the smartphones industry.

3. Methodology

In this chapter it is going to be presented the methodology of the project. We will start by presenting the basic methodology, which is based on a case study, followed by the description of the research steps to be followed in order to reach the defined objectives. This project will be divided into six main steps.

3.1. Investigation Methodology

This project is based on a case study. A case study is based on the in-depth investigation of a real phenomenon within the context in which it fits. According to (Yin, 2003), this project is based on a case study because:

- The research question answers to the question “how”;
- The researcher has little or no influence over the processes being studied;
- The research focuses on contemporary events, since the refurbishment industry is a market that only now is being explored by companies, being the data in our case obtained via direct observation and by interviews to people involved;
- The research data has many more variables of interest (from multiple sources), that need to converge, and this data benefits from the prior development of theoretical propositions;

The present project is a case of descriptive and exploratory study. It is descriptive as the project describes Forall Phones’s smartphones resource allocation practices, and some peculiarities and traits are, by means of specific features found in the refurbishment industry, interrelated to companies operating in the same market. It can also be considered exploratory, since we have a research question that can be applied to other case studies, where improvements and consequent evaluation are proposed, in a sector that was barely studied (Yin, 2003).

There are several types of case studies, such as an individual, a group, an organization, an event, a problem, or an anomaly (Yin, 2003). The unit under analysis here is the problem, *i.e.* Forall Phones’s smartphones resource allocation processes, and how the approach/ algorithm may help Forall Phones achieve a better resource allocation.

As for the design of the case study, this project is a single case (just one case study), as this study focuses exclusively on Forall Phones smartphones resource allocation processes.

3.2. Investigation Steps

This chapter presents the several research steps followed for the preparation of the project. Each of the five research steps will be described in detail below.

3.2.1. Processes mapping

In this phase, flowcharts are going to be used to map the As-Is processes and subprocesses in Forall Phones. We are going to give more attention to the smartphone resource allocation process, and collect important variables that constitute the process itself, *i.e.* what variables are the basis for Forall Phones smartphone resource allocation, the time it takes to do such allocation, and other data that is going to be collected through direct observation of the operation and through semi-structured interviews with some of Forall Phones's Heads of department and other employees directly involved in the operation, and also by seeing some documentation. The program that is going to be used for the design of the As-Is processes is the Bizagi Modeler, using the Business Process Management and Notation language.

3.2.2. Identification of improvement opportunities

After the processes mapping, we will try to justify each step of the current smartphones resource allocation (mainly those in which we see improvement opportunities), by seeing if each step can be justified by the literature, or if it is justifiable (or not) in the basis of experience. We will also identify some errors in the current process that may be affecting the smartphones resource allocation that can be immediately corrected to improve the current smartphones resource allocation. Some waste will also be identified, although not being the main focus of our project. This will be done by using semi-structured interviews and through direct observation.

3.2.3. Heuristic construction and feedback

Based on the improvement opportunities and in some smartphones resource allocation procedures that are not justified by the literature, we will develop a heuristic approach that gives an answer to both problems, and answers some questions that were unaddressed in the scarce smartphones resource allocation, as Forall Phones can not buy exactly what they want and need, whether it is a specific equipment or the quantity needed of a certain equipment. It is going to be given the feedback, the validations and the preferences that are going to be collected both in the semi-structured interviews and in the focus group presentations that will lead to that final heuristic approach. It is also here that we will contextualize the approach based on Optimization literature.

3.2.4. Implementation of the approach in a user-friendly tool

The heuristic approach is going to be implemented in Excel and in Excel's Visual Basic Editor due to the need of having a user-friendly interface where the users can put the necessary information, so that the Visual Basic for Applications can manipulate the data according with the heuristic approach and give the proper result. The data required to be able to use the approach will be listed. This will involve the deepening of the learning of Excel and Excel VBA. Some adjustments required to accommodate some functions and put the Excel tool to run in acceptable times are also going to be made, and reports that extract the necessary data from the system for the heuristic to use are also going to be created. The treatment of data is going to be done through direct observation and measurements to see if the tool replicates the behaviour of the heuristic approach.

3.2.5. Heuristic assessment

The heuristic developed is going to be very difficult to assess due to several reasons. The main objective that Forall Phones wanted to achieve was (by a correct allocation of the smartphones) to maximize the number of smartphones sold. The problem with this method of measurement is that if any of the methods is going to be implemented, the other can not be assessed for the same time period and therefore it is very difficult to draw conclusions. For a better understanding of the correctness of the method used to compare the approaches, it is going to be explained why the issue of allocating smartphones to sales channels is a resource allocation problem, and some justifications will also be given on how our approach tries to give a response to the resource allocation problem. After that, to assess both smartphones resource allocations it is going to be used the stock coverage that counts with time. The stock coverage may be deemed appropriate for our case based on the definition of a resource allocation problem, and the results from this method will be observed and measured.

After obtaining the results, some recommendations will be presented relatively to some of the weaknesses (or appropriatness) of the methods used in this approach to Forall Phones problems and needs. Some considerations on the methods used by this approach, and how to obtain better the results will also be given.

Part of the explanations on how it is possible to prove that our approach is appropriate for this case have already been stated, but it is also important to show how this approach sustains itself. For that reason, the theoretical background used to build the heuristic approach will be shown in the next chapter, in order to preserve the flow of the case study.

4. Heuristic Proposal

In this chapter, based on the choices made in the literature review, it is going to be presented the theoretical background behind the proposed approach, and the approach itself, but first we are going to step back. It is important to refer that this approach modification would influence the smartphones resource allocation process. The field that deals with the application of scientific methods to processes in areas such as management and administration of organized military, commercial processes, industrial processes and to the solution of managerial and administrative problems is Operations Research. “The subject matter of operations research consists of decisions that control the operations of systems. Hence, it is concerned with how managerial decisions are and should be made” Ackoff, Holstein, Eilon & Tanenbum (2018). It is possible to apply those words to Forall Phones case. The managerial decision of how the allocation of smartphones should be done was passed to the employees directly involved in the smartphones allocation, and therefore the approach (decision) controls the operation. In Operations Research it is made an extensive use of older disciplines such as logic, mathematics, and statistics, as well as more recent scientific developments. For that reason, application of disciplines such as the ones related with logistics and supply chain seem appropriate for our case, as we are dealing with an issue in the logistics area of the company.

In the following subchapters it is going to be reviewed the theoretical background used in our approach (subchapter 4.1.), and in subchapter 4.2., it is going to be presented the approach and how it operates.

4.1. Theoretical Background

One of the questions that must be answered first to guide our research is what does Forall Phones want to achieve in the logistics area with the smartphones resource allocation. One thing that seems obvious, is that they want to sell the maximum number of smartphones, and that, if they let someone work on the smartphones resource allocation, is because they believe it is possible to do better in that aspect. Other thing that seems obvious is that, even though Forall Phones may see in a certain moment that there is a need of a (or several) smartphone(s) in a certain (or several) sales channel(s), the reordering and the replenishment are much likely done once a day or more far-between, in the appropriate period, mainly due to organizational, geographical and monetary reasons.

This is the point that will be picked to start our research, the replenishment policy. A replenishment policy is defined when it answers two questions: the review period for reordering and an order quantity (Sehgal, 2008). Although having an influence on inventory levels, the review period is not going to be a focus in our research, as it is a result from the reasons stated above but may also be a result from other factors such as contractual obligations and of the presence (or not) from sophisticated IT systems. As it is easy to change the review period if our assumption of the replenishment frequency is wrong, it is going to be assumed what was stated before, that the replenishment is done once a day. This assumption leads us to follow the periodic review path. As said by Sehgal (2008) "Under periodic review, the inventory levels are reviewed at a set frequency.", and that frequency is of one day. Since the sales channels are replenished once a day, the reordering (order placement after the review) can also be done just once a day. In this case, the stock levels are reviewed at a certain time, and if they are below the pre-determined level, then an order for replenishment is placed, otherwise it is ignored until the next review cycle (Sehgal, 2008).

There is also the question of quantity. There are two options here: to place a fixed pre-defined quantity order for that item-location, when the stock level drops below a certain point, or to use a target inventory level approach where the quantity is determined as the difference between the on-hand stock on the review day, and the pre-determined target inventory level (Sehgal, 2008). Although it was possible to go with either option, the choice was made to use the target inventory level alternative due to several reasons. Forall Phones operates in the refurbishment industry, that is characterized by having problems to secure the supply of products in volume and variety both upstream and downstream (Whalen, Milios, & Nussholz, 2018), (Jayanta, Guptaa, Gargb, & Khan, 2014), and so it is not possible to ensure the replenishment of a fixed quantity order. Sometimes what happens is that a supplier has a specific phone at hand, but the time to diagnose the exact failure and repair is uncertain, or it may not even be repairable due to costs (Sabbaghi, Cade, Behdad, & Bisantz, 2017), or due to the inability to do the correct diagnosis. To calculate the target inventory level, it is going to be used the historical demand data and the periodic review. It is also going to be used the safety stock, as it can accommodate changes in the demand and in the supply of products. Here however, it is only going to be used the demand, as suppliers face constant shortages, it is not possible to guarantee a product, and as Forall Phones works in a push logic. To calculate the safety stock, it is needed the historical demand data, the periodic review, as well as a service level that is going to be specified afterwards. As the approach is to be used by the headquarters, and the smartphones for allocation depend on the smartphones produced in the headquarters, the reorder level is equal to the target inventory level. For a possible allocation it is just checked if the allowable stock is below or equal the target inventory level (that includes the safety stock). If the stock is above, there is no chance to allocate a smartphone to a given location. Next are the equations to calculate the safety stock and the target inventory level for the periodic review system:

$$Safety\ Stock\ (SS) = Z \times \sqrt[2]{(LT + RP) \times \sigma^2}$$

$$\text{Target inventory level (TI)} = \bar{d}\ (LT + RP) + SS$$

Variables	**Description**
Z	Service Level – A user-based input
LT	Lead Time – In this case, in this considered instantaneous
RP	Review Period – The review period for Forall Phones is of one day
σ	Standard Deviation – Used in the normal distribution to assess data dispersity
$\bar{d}$	Daily Average Sale – A uniform distribution of the sales among a period

Table 1- Equations variables

In Forall Phones case it is assumed that the lead time is instantaneous, and it is not used the supplier lead time variability in the formula.

The possible allocation of a smartphone to a sales channels instead of the others is going to be assessed by the stock coverage. Stock coverage enables to know how long a store is able to continue selling items or groups of items given a sales history and inventory (LS Retail, 2019), being for that reason an excellent indicator.

After presenting the majority of the theoretical background, it is time to present the approach. The approach is going to be presented by way of an algorithm, a step by step method, i.e., a sequence of instructions for solving a problem (Techopedia, 2019).

4.2. Heuristic Approach

The developed heuristic approach is presented in Figure 1:

<u>Nomenclature:</u>

CS – Current Stock	(D) – Device
HMS – Half Maximum Stock	(M) – Memory
MS – Maximum Stock	(Co) – Colour
SC – Stock Coverage	(C) – Category
SS – Safety Stock	

Stock for Half Demand:	**Minimum Stock:**	**Stock for Full Demand:**
CS (D) ≤ HMS (D) + SS	CS (D)+(M)+(Co) < 1	CS (D) ≤ MS (D) + SS
SC (D)		SC (D)
CS (D)+(M) ≤ HMS (D)+(M) + SS		CS (D)+(M) ≤ MS (D)+(M) + SS
SC (D)+(M)		SC (D)+(M)
CS (D)+(M)+(Co) ≤ HMS (D)+(M)+(Co) + SS		CS (D)+(M)+(Co) ≤ MS (D)+(M)+(Co) + SS
SC (D)+(M)+(Co)		SC (D)+(M)+(Co)
CS (D)+(M)+(Co)+(C) ≤ HMS (D)+(M)+(Co)+(C) + SS		CS (D)+(M)+(Co)+(C) ≤ MS (D)+(M)+(Co)+(C) + SS
SC (D)+(M)+(Co)+(C)		SC (D)+(M)+(Co)+(C)

Figure 1- Developed heuristic approach

The heuristic approach was divided into three main steps: the stock for half demand, the minimum stock, and the stock for full demand, being that the minimum stock feeds itself from the unallocated smartphones from the stock for half demand, and the stock for full demand feeds itself from the unallocated phones from the minimum stock. It is now time to explain how the approach works. Just before starting, lets take as an example an iPhone 7, 32 gigabytes, rose gold, grade C (physical grade), that Forall Phones sell at their stores. If only the device is being addressed, its just an iPhone 7. If its also being addressed its memory, its an iPhone 7 with 32 gigabytes, and so on, until we include the 4 characteristics of a Stock Keeping Unit (SKU). The input for the stock is obviously the smartphones that need to be allocated, but how does it work? First it is checked the type of smartphones that need to be allocated. Then, for each smartphone type, for each location, the demand historical data is worked in order to obtain the daily average sale for each smartphone type in each location. Then, the type of smartphone-location combination is sorted by the decreasing value of the daily average sale, employing therefore a greedy approach, since the smartphones with the biggest value are the ones that are sold more rapidly, and should be handled first. This daily average sales enters the first step of the approach, and the first condition, that is a comparation between the current stock of the smartphones with a certain device type and half of the maximum demand allowed for that type of smartphones, is checked. Each smartphone-location combination is evaluated individually. If the current stock of the smartphones with a certain device, in a certain location is superior to half of the maximum demand for smartphones with a certain device, in that same location, the combination smartphone-location is not allocated and will pass to the second step of the approach. If the current stock of the smartphones with a certain device, in a certain location is inferior or equal to half of the maximum demand for smartphones with a certain device, in that same location, it passes to the second condition to be checked. If the current stock of the smartphones with a certain device and memory, in a certain location is inferior or equal to half of the maximum demand for smartphones with a certain device and memory in that same location, it passes to the third condition. However, if the current stock of the smartphones with a certain device and memory, in a certain location is superior to half of the maximum demand for smartphones with a certain device and memory in that same location, the combination does not get immediately unallocated. Instead, the type of smartphone-location combination is assessed by using the device stock coverage, to see if it makes sense to allocate that smartphone to that store. If the device stock coverage for that location is inferior or equal to the other locations, it gets allocated. In the other cases, the type of smartphone-location combination is not allocated and will serve as input for the second step of the approach.

To not extend the explanation on how the approach works too much, figure 2 shows all the different outcomes of the approach.

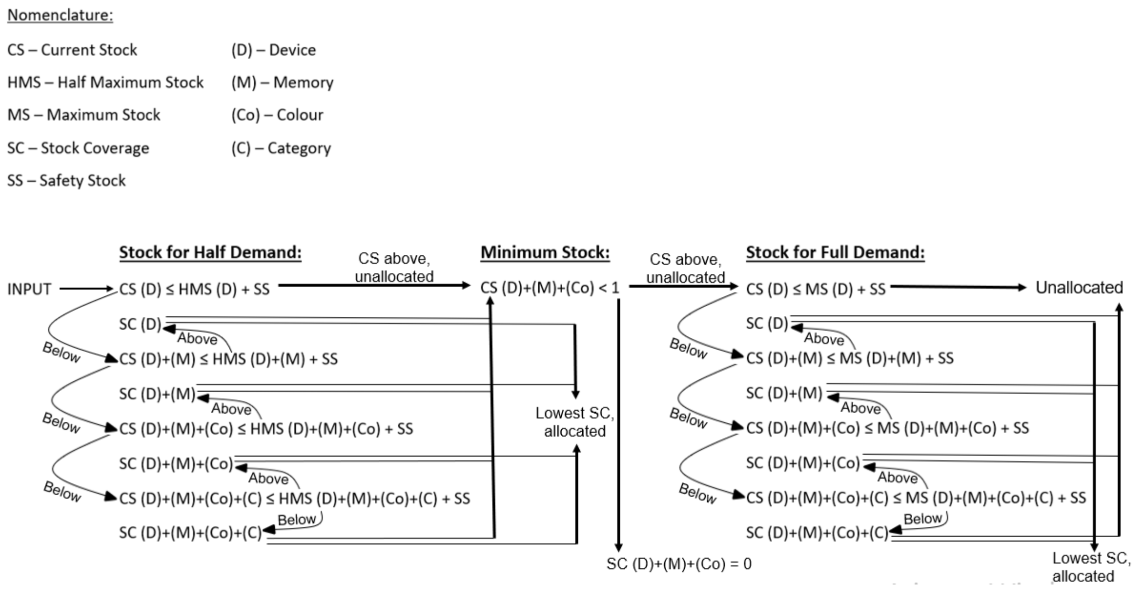


Figure 2- Scheme of all the possible outcomes of the heuristic approach

As it is possible to see in figure 2, the way of functioning of the first step (Half Demand) is equal to that of the third step of the approach (Full Demand). The second step is to see if the current stock of the smartphones with a certain device, memory and color in a certain location is inferior to one unit (this step was validated with Forall Phones). If it is inferior to one unit, the smartphone is allocated to that location, and if it is not, the type of smartphone-location combination is not allocated and passes to the third step of the approach.

This approach adresses at least three of the objectives that Forall Phones wants to accomplish when allocating the smartphones to the sales channels:

- Define the target stock and minimize the deviation to the target stock – This is possible due to the application of a replenishment policy, and the use of the periodic review system and of the target inventory level approach. By adding the daily average sales considering just one common characteristic and then the one by one cumulative combinations, until all the characteristics that define a smartphone are considered, was a way of defining and limit the target stock in each location, modelling the complex relationships between them. This limit/ definition (validated by Forall Phones) works like a strainer, the smartphones are first allocated considering all of their attributes, until the top level, when it is only considered a single characteristic. It makes use of Goal Programming, an alternative that often is more effective in capturing the nature of real world problems (Parsaei & Sullivan, 1993), as it tries to minimize the distance to the target, and of the rank ordering approach, as it only considers the allocation of a smartphone in a certain location at a certain level if the first condition is met, that the location has not exceeded the maximum number of smartphones for that level (Georgia Institute of Technology, 2002). In a common situation, where there is a steady supply, and a production capability to meet the market demand, it was possible to just consider each type of smartphone individual demand at each location. As this is not Forall Phones case, there was a need to limit the number of smartphones that can be allocated to a location, but maintaining the possibility of selling a substitute product, an alternative when an item is out of stock (IBM, 2017). The possible allocation of a substitute product is justified because it will "occupy" in a certain way, part of the average daily sales of one or several out of stock smartphones.

- Equitative distribution by seeking to minimize the disruption between sales channels, i.e., reducing the stock coverage gap between the sales channels. In the heuristic, there is an attempt to have equal stock coverages, and that same stock coverage is based on "merit". The sales channel ability to sell more smartphones in a narrower period of time allows a sales channel to fit a bigger number of smartphones under the same stock coverage.
- Maximize the number of smartphones sold – Although not explicitly having an objective function, an effort is made to maximize the number of smartphones sold, either by employing a greedy method (decreasing order of daily average sales), but also by applying an iterative method, a sub-method of problem decomposition/ partioning (as stated in the literature review). When an allocation occurs, the sales channels dynamics changes (normally), and the sales channel with the lowest stock coverage changes (normally). When this happens, the remaining smartphones are reordered, and the approach tries to allocate the remaining type of smartphone-location combination by the decreasing daily average sales.

One of the subproblems addressed by this heuristic was changed from a non-linear function to a piecewise linear (approximation method), where the historical demand data can assume any not-negative real number, as in reality a sell (or not) of a smartphone can only be represented by the natural numbers set (including zero). This also determines that the original problem is a combinatorial problem (at least NP-hard) that has discrete variables (Yaghini, 2009). The transformation resulted on a mixed problem, as we still respect the fact that is only possible to allocate a single smartphone as a whole, and that, when it is used the historical demand data, the result is always rounded up, turning the number into an integer. The model that the heuristic tries to solve is also a deterministic constrained problem, as the variables are bounded, and the parameters are assumed to be known accurately (although they may change when the data changes) (Neos Guide, 2019).

This hybrid method is a junction between a heuristic constructive method and a goal programming model, making use of other heuristic solution methods such as the approximation method, and the problem decompostition/ partitioning.

A great part of how this heuristic approach operates, and of the methods used in the model were presented in this chapter. It is now time to pass to the case study.

5. Case Study

In this chapter, it is going to be reviewed the smartphones refurbishment industry in Portugal, being that Forall Phones is also going to be introduced (the company to which this project is applicable). Then the processes mapping and the improvement opportunities are going to be addressed. Based on that the heuristic approach will be developed, and then the smartphone allocation methods will be compared regarding their ability to balance stock coverage between the stores.

5.1. Company Summary

In the present chapter, it is presented Forall Phones and its sector of activity.

5.1.1. Smartphones refurbishment industry in Portugal

This project depicts a company that is inserted in the smartphones refurbishment industry. Refurbishing is the process of restoring used products to a functional and satisfactory state regarding their original specification (Rathore, Kota, & Chakrabarti, 2011). Refurbishment can be applied to regain value from used products and is an economically and environmentally viable strategy to extend a product life, and to stimulate a shift towards a more sustainable consumption model (Weelden, Bakker, & Mugge, 2016). This strategy was first employed by small companies, but big retail companies quickly followed, as they saw in refurbishment a way to regain value of products that they would otherwise consider of no value, but that in reality could be quickly (and not so expensively) returned to a satisfactory condition, and resold.

The global refurbished smartphones market growth slowed to only 1% in 2018 (Counterpoint, 2019), when just a year before the global market for refurbished smartphones grew 13% (Counterpoint, 2018). This small growth was mainly due to the trade tensions in two important markets (USA and China), as new smartphone sales declined 11% on those countries, it was registered lower upgrade cycles in 2018, which affected the flow of devices into the secondary market, and devices in both countries were held up in customs for much longer than normal (Counterpoint, 2019). However, the market is expected to keep growing, as just before the trade tensions, an IDC report forecasted that the market would grow 10% year-on-year until 2022 (Galaxy eSolutions, 2018).

Although no data is available regarding the smartphone refurbishment industry in Portugal, it is assumed that the growth of this industry is similar to that of Europe, where there was a 7% growth in the number of refurbished devices sold, as it is possible to see in figure 3.

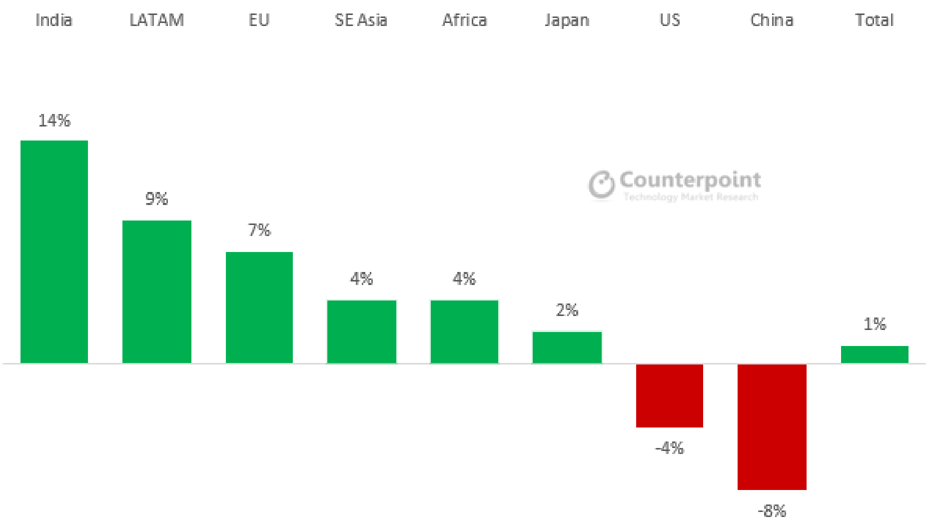


Figure 3 - Regional Refurbished Devices Growth Rates

Source: Counterpoint (2019)

Based on this premise, Forall Phones is a company that wants to keep growing and ciment its position in the smartphone refurbishment industry in Portugal and wants to expand its business and open stores in other countries (beside Portugal and Spain), as stated by its founder and CEO, José Costa Rodrigues.

5.1.2 Forall Phones analysis

History

Forall Phones is a portuguese company created by José Costa Rodrigues in the end of 2015 from the desire to have an Apple smartphone, an iPhone 4S, when he was 16 years old. Due to the high cost of the phone, José's parents refused to give him one. So, in order to be able to purchase the iPhone 4S, José sold his portable playstation and some junk that he had at home and with that amount he was able to purchase a used iPhone 4S through the OLX marketplace. Later he resold that same smartphone with a profit, and that is how José saw the business opportunity of buying and resseling used smartphones. He started to buy smartphones from friends and family, and he created a Facebook page, where he shared the description and pictures from his products, and a network of ambassadors, a group of influential friends from his high school that received a commission when they sold a smartphone. With this method, he was able to sell 70,000€ worth of products in just three months. It was around that time that he registered the brand Forall Phones and hired Forall Phones first employee.

Forall Phones then moved from Ourém to Lisbon, and in their first year they made 350,000€, essencially through word-of-mouth, and the website was created later in that year.

As of today, Forall Phones counts with 89 full-time employees, 76 in Portugal, 12 in Spain, and 1 in China, 10 physical stores, 7 in Portugal (Alvalade (Lisbon), Porto, Coimbra, Leiria, Setúbal, Baixa-Chiado (Lisbon) and Oeiras), and 3 in Spain (Madrid, Barcelona and Salamanca), sells for 16 countries in Europe through several marketplaces, and has reached 4.2 million dollars in sales in 2018. Forall Phones became known due to its sustainability mission of reducing the e-waste that ends up on landfills and also due to its business proposition of selling premium smartphones at affordable prices, becoming in Portugal an overnight success.

Products and services

The products that Forall Phones sells have changed from what was the original scope. In the beginning, Forall Phones started by selling smartphones from both Samsung and Apple, but as their employees's competencies were mainly in iPhones, their sales were more relevant for Apple products, and as in terms of SKUs and of costs it was easier to manage just iPhones, the company took the decision of just selling iPhones. Almost all of their smartphones come from suppliers, that collect thousands of smartphones from retailers/operators and resell them, and after Forall Phones inspects and refurbishes them, they sell those phones at up to 50% off from the original price. As business grew, Forall Phones started selling smartphones accessories to their final customers, and the range of products increased, passing from simply selling iPhones, to also sell chargers, protection capes, tempered glass, powerbanks, earphones, smartphone holders for cars, and so on, where Forall Phones is able to get better margins.

In terms of services, Forall Phones started by offering repairing services for almost any smartphone and with business growth, they let each technician at each store choose what they wanted to repair, according with their skills. They also expanded the number of services, by starting to include services like installement payments, warranty extension and smartphone ensurance in order to reassure clients that a refurbished smartphone is as good and can last as long as a new smartphone.

Competitors

The refurbished smartphone market is slightly recent in Portugal, being characterized for companies in the electronical retail industry, such as Worten, Fnac, Radio Popular and Phone House, and by small companies that focus more on second-hand smartphones, but have mostly an online presence, as they do not have a specialized location where they sell their smartphones. Forall Phones has opened several physical sales channels in order to match the Portuguese customer profile, that has to see a product to buy it and is still uneasy when buying things over the internet. As Forall Phones grows the competition with other big brands becomes more intense. Forall Phones main competitors are at the moment iServices and Phone House. Phone House Portugal is a telecommunications retailer with more than 70 multi-operator stores across Portugal, and more than 500 stores in Spain, where Forall Phones just entered, aiming to offer the best telecommunications and multimedia solutions, covering all brands and operators. They focus on the smartphone market and operator services, having entered in the refurbished smartphones market, selling mainly iPhones and Samsung Galaxy smartphones. The brand iServices is the market leader in Portugal in smartphone repair services having a team of mostly certified Apple technicians. It has a partnership with Apple, having certified technician centers in Portugal, and are one of the representatives of the brand in repair services in Portugal. Aside from the repair service that includes other brands, they also sell refurbished iPhones in their 14 stores across Portugal.

Talking of the global market, the refurbished smartphones market has seen an even greater dominance of top players (such as Apple and Samsung), than the new smartphones market. In the refurbished smartphones market, the two brands combined own almost three-fourths of the market with Apple leading by a significant margin (Counterpoint, 2018). This is not only due to customers preferences, when buying a refurbished phone from an original equipment manufacturer (OEM), but also due to the huge advantages these OEM have over other companies. As the refurbishment industry grows it becomes more and more important for non-OEM companies to come up with strategies to counter the difficulties of the refurbished smartphones market, and to get their own competitive advantages.

Taking Apple as an example, there are several competitive advantages that they have over other companies trying to repair their smartphones. For instance, Apple has a repair manual with instructions on how to proceed when certain malfunctions occur, being able to fix a greater number of smartphones than other companies. This manual is based on the knowledge they acquired when building and repairing their smartphones and it is only shared with a few partners. Another example is Apple's diagnosis tool, that does a variety of tests to evaluate the state of several components and allows tests to be performed more cheaply. Apple only provides this tool to their partners that work under their rules, being a help in detect the malfunctions of the smartphones that come under warranty. Other example is that Apple has software inside their chargers (and smartphones), and companies selling refurbished iPhones (or just chargers) normally have to buy original Apple chargers. If other companies do not buy original chargers, or if the companies fail to pay for their charger licenses, Apple changes the charging method and the chargers from other companies stop working and/ or start damaging Apple's iPhones.

It is therefore vital to come up with strategies to counter the difficulties of the market, so that non-OEM companies can counter the disadvantages that it has to Apple and its partners.

Customers

Forall Phones is a company that sells refurbished smartphones to consumers B2C (Business to Consumer). These consumers normally hear about Forall Phones through the word-of-mouth or through online ads, being the digital marketing one of the strong points of the company. The company does a really good job online, being active in social media and has great reviews on the Trustpilot, mainly due to the great after sales service that they provide, making the service as personal as possible. The digital aspect of the business is a extent of the physical side, and the other way around is also true, as the consumers that go to the stores, already know what they want and recognize the brand, and in the other hand, customers that do not find something at the store can buy a product online, being that they recognize Forall Phones as a trusted brand with physical locations.

5.1.3. Forall Phones headquarters

The headquarters is the heart of Forall Phones operations. It is in the headquarters that several value-adding activities are performed, and it is there that essential business-related operations are done, being also responsible for the success of Forall Phones operations. Forall Phones is divided into 5 main departments:

- Operations department – This department is responsible for the normal operation of the business. This department is divided into three main areas: Logistics area, responsible for the reception and conference of products that come from the suppliers, the expeditition of products to sales channels and to final customers and of the after-sales service; Technical area, responsible for the inspection and refurbishment of smartphones; Operational area, liable for purchasing, design of new operations, products assortment and operational reports;
- Marketing department – This department is responsible for the communication strategy, promotional campaigns, advertising, managing the brand presence on the internet, products assortment, among other activities;
- IT department – This department is responsible for the website maintenance, the development of applications, data extraction for reports, technological support, data protection, among other activities;
- HR department – This department is liable for job interviews, hiring, handling personnel data, labor obligations, personnel well-being, among other activities;
- Financial department – This department is liable for budgeting other areas, payments, expenses allowances, organization of documents, taxes payment, contability, among other activities;

The focus of the project will be in the logistic area, inside the operation department, as before the beginning of the internship, it was decided together with Ms. Maria Bexiga, Head of Supply Chain, that this was an area of big interest for Forall Phones.

5.2. Investigation steps applied to Forall Phones

In this subchapter are going to be presented all investigation steps applied to Forall Phones: Processes mapping (5.2.1.), Improvement opportunities identification (5.2.2.), Heuristic construction and feedback (5.2.3.), Implementation of the approach in a user-friendly tool (5.2.4.) and Heuristic assessment (5.2.5.).

5.2.1. Processes Mapping

The processes from the reception of the smartphones in Forall Phones's headquarters until they leave the headquarters to go to the stores, and all the different possibilities in each process were mapped so that current and future employees could have a better understanding of Forall Phones general operation regarding their smartphones. For this project, the process that matters the most and will be shown is the Logistics process of the smartphones resource allocation, that was surveyed through direct observation and by doing semi-structured interviews.

The purchased smartphones are received by a logistics operator, and then they enter the technical area, where they are tested to see if they have anomalies in their functions (being the possible defective parts narrowed down due to the strong correlation between component-function), repaired (if there is a defective function), tested again (to see if everything was okay), updated and formatted (to clean any information that might exist in the device), and then cleaned, where the smartphone grade is given, and the smartphones are put into boxes. The smartphones resource allocation process starts there (Figure 4), with the logistics operator collecting the boxes with smartphones from the technical area. From there, the logistics operator takes the smartphones to its desk, where they are sorted based on the 4 characteristics of their SKU: Device, Memory, Color and Grade (or Category).

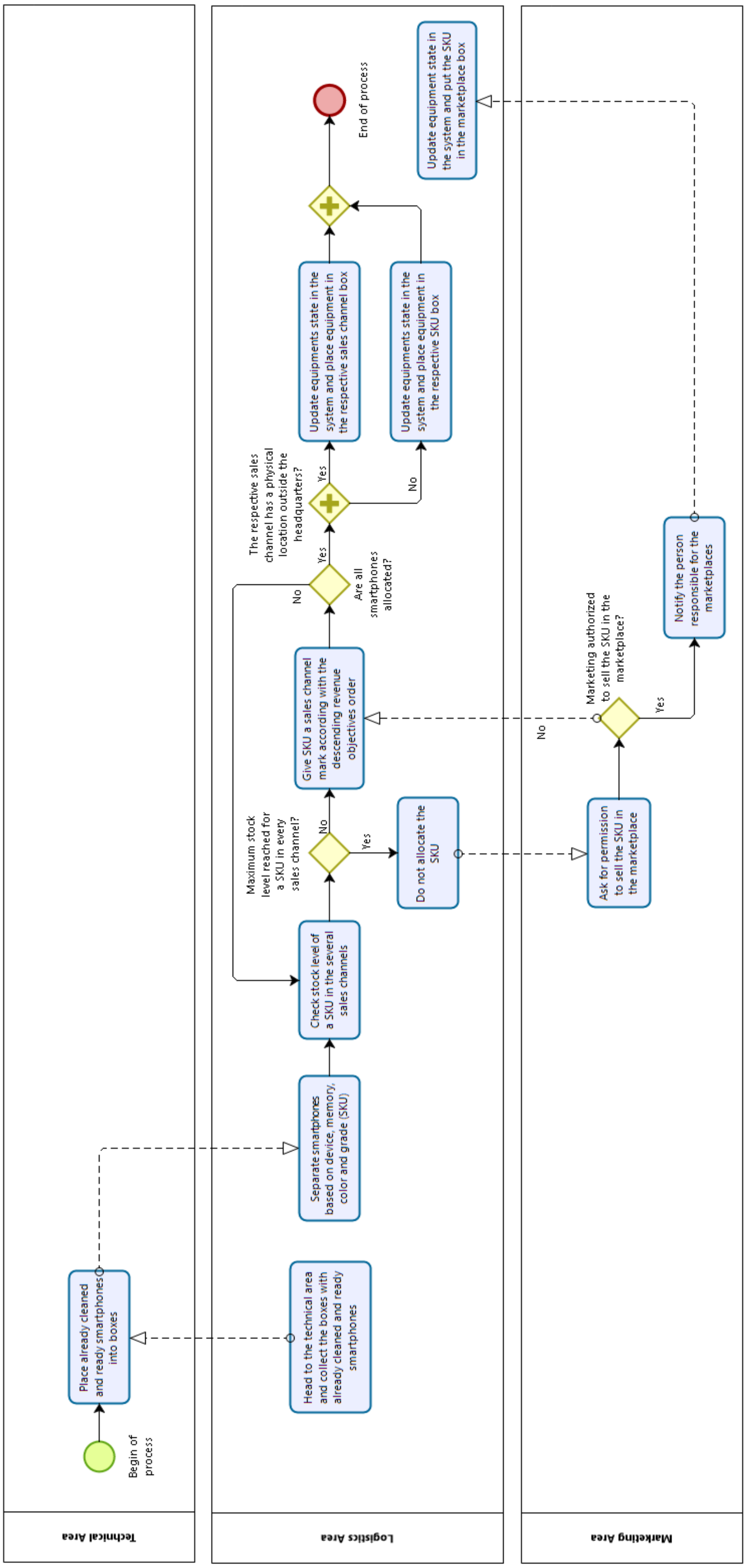


Figure 4 - Stock Allocation Process

After the separation, the SKUs stocks are seen in the system for each sales channel (Figure 5), and the smartphones are allocated one by one to a zone representing each sales channel according with the decreasing revenue objective (DRO).

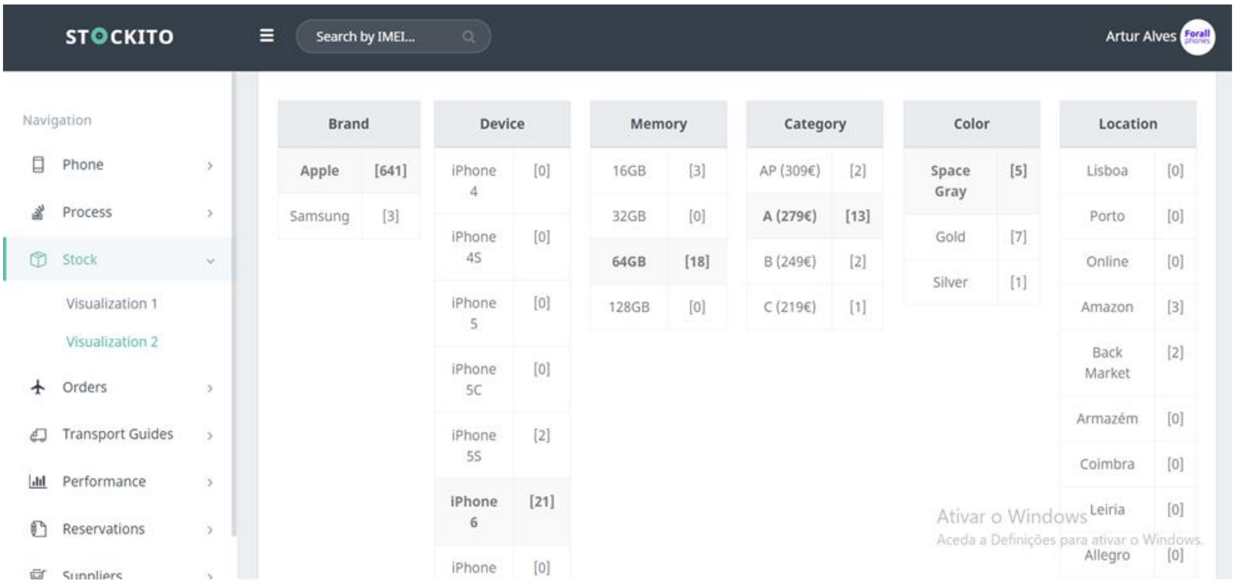


Figure 5 - Stock level in each sales channel (Stockito)

To better explain how the allocation is done, lets assume the case where there is not a single SKU unit in any of the sales channels. In that case, the first unit is allocated to the sales channel with the highest revenue objective (first in the DRO), the second unit to the second sales channel in the DRO, and so on, until all the sales channels have one unit of a particular SKU. If there are more smartphones from that SKU to be allocated, it restarts all over again, and the unit is allocated to the first sales channel according with the DRO, until it is reached the limit of 3 units of a certain SKU in all sales channels. In those cases, and if there are still smartphones from that SKU to be allocated, permission is requested to the marketing department to sell those extra units in the marketplaces (Amazon, Back Market, C-Discount, OLX, …). Normally such permission is given, and they only refuse to sell those phones in the marketplaces if they are planning a promotional campaign for that smartphone in the future, or if they have another use for that smartphone.

After the box(es) from the technical area is (are) empty, and all smartphones have a pre-specified location, the state of the smartphones are updated on the system, so that the system displays the current state, whether if the smartphones are going to the sales channels (being therefore in Transport), if the smartphones are going to be sold online in

Forall Phones website (being On Sale), or if they will go to the marketplaces (being on Stock, although some exceptions could occur, and having the location of the marketplace associated). This smartphone resource allocation process can occur one or several times a day, depending also of the amount of work the logistics technicians have. The smartphones are identified on the system by their unique number (IMEI). This was the first approach while the previous IT system (Stockito) was in place. With this system and approach, the logistics operator took less than one minute to allocate a smartphone, according to Forall Phones.

There is also a second approach, that was developed by the Chief Operating Officer together with other directors, after some feedback reunions regarding this heuristic approach, that started being used when the current IT system (Opsify) was already put into place. The process itself is equal to the first process until the actual smartphone resource allocation phase, where a new approach is applied. However, before passing to the new smartphones resource allocation process, it is important to discuss some important terms that are used in this new approach. One of the things that was thought for this approach was to use new indicators when talking of a SKU performance in each sales channel. For performance measurement, it was created the “sale-time” and the “shelf-time” indicators. These indicators serve to see the time that a (or several) smartphone(s) are in a sales channel and how fast (or slow) are they selling. It is possible to obtain the “sale-time” by seeing the day that a smartphone was sold and subtracting it by the day that specific smartphone state changed to On Sale. For the “shelf-time”, it is almost the same, but it is the current day minus the day that specific smartphone state changed to On Sale. For this new approach it was also done something else, it was used the group SKU (GSKU). In the GSKU it is aggregated the grades, and two group colors. In Forall Phones there are four types of grades conform the state of a smartphone. For prestine smartphones it is grade A+, for very good smartphones, with minimal marks it is grade A, for good smartphone with light wear it is grade B, and for smartphones with some wear and marks it is grade C. The grades were aggregated because Forall Phones buys batches of grade C smartphones (that normally has, according with Forall Phones standards, equal numbers of smartphones from grades A, B and C), but does not know what grades each smartphone will have, only afterwards. Even though it was possible to buy batches of grade B, and of grade A smartphones, the margins of Forall Phones would be seriously affected, and grade C batches are seen as offering the best value for money. The two color groups created were the neutral colors, formed by the silver, space gray, black and jet black iphones, and the bright colors formed by all the other possible iphone colors. For this new approach it is only used the “sale-time” of the feature device. The new process is shown in figure 6.

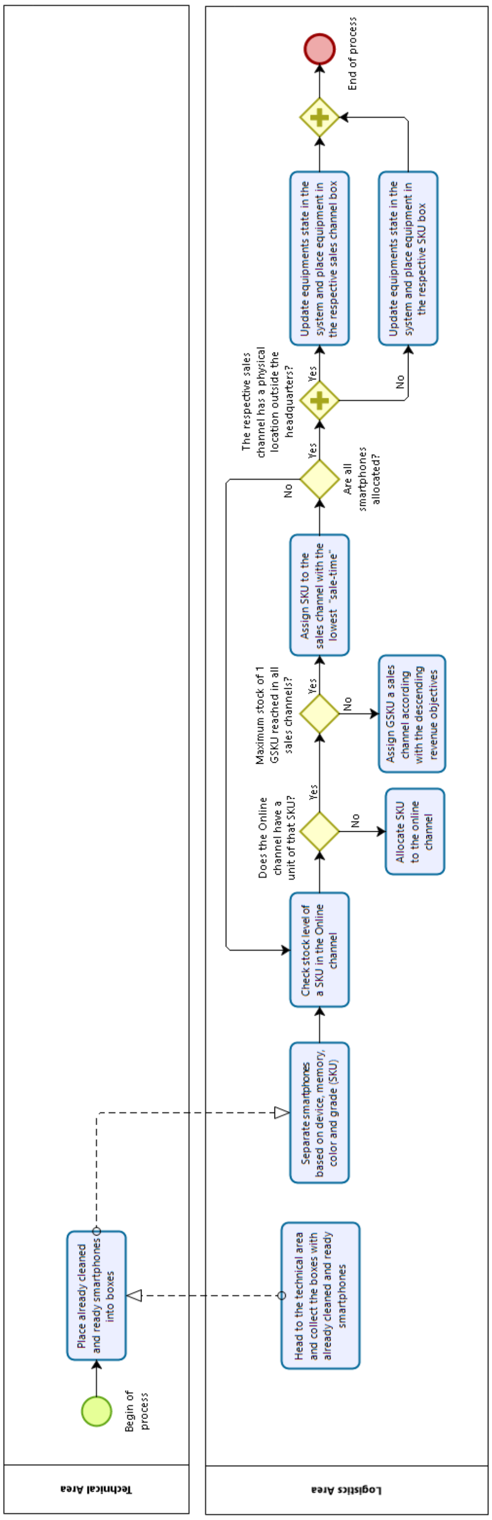


Figure 6- Current Stock Allocation Process

As it can be seen in this new process, the decision of trying not to sell smartphones in the marketplace was also took, since that in this new process, marketplaces related processes disappeared, and the marketing department is not asked if a smartphone should be sold in the marketplaces.

Through clustering the features, Forall Phones narrowed down the allocation choices, being that by this grouping there are about 65 different GSKUs in total (even though each sales channel can have more). The allocation of a single smartphone by using this method was of roughly 4 minutes according to Forall Phones.

5.2.2. Identification of improvement opportunities

After the detailed analisys of the previous processes, it is now time to identify the improvement opportunities for both processes, but our focus will be clearly on the first process as it was the original process in which this project focused on. The identified improvement opportunities are organized in two types: improvement opportunities for initial process and improvement opportunities for current process, being the identified improvement opportunities discussed below.

5.2.2.1. Improvement opportunities for initial process

The identified improvement opportunies for the initial process are presented in table 2, being described in more detail afterwards. The first column concerns the areas or topics in which improvement opportunities were identified, and the problems that such areas/ topics have in the first process is presented in column two. In column three, it is seen if the area/ topic approach is based on the literature or not. If it is not even covered, this column for a certain line will be filled with "-". In column four, it is going to be presented a possible solution that is present in the literature. It is important to see if a topic or area appears in the literature, as in the literature the methods are proven to be correct, and at least very good when certain requirements or conditions are met.

Improvement opportunity	Problem	Justifiable by literature?	Possible solution by the literature
Maximum stock level	Standard maximum stock of 3 units	No	Target inventory level with SKU historical demand data
Decreasing Revenue Objective	Too general allocation method	No	SKU historical demand data
Transport	Not covered	-	Transport data and periodic review
Time to replenish	Not covered	-	Periodic review
Proportionality	Proportionality not used, based on DRO order	No	Stock coverage with SKU historical demand data ratio

Table 2 - Improvement opportunities for initial process

The standard maximum stock of 3 units for all SKUs is not justifiable by the literature. Even though that the sales of a SKU for the physical sales channels never surpassed the sale of three units in a day (for the period between the 2nd of February and the 26th of June) when the current smartphone resource allocation process was already in place, and there were some sales channels with some SKUs level above the three units, it does not mean that this is a good way of defining the maximum stock level. In the same period considered before, the Online sales channel surpassed that limit of three units several times, in several different days (although it may have been during promotional campaigns), and that is not to talk of the stock that is in the sales channels and was not sold, that must also be considered. When analysing the SKUs, it is possible to see that for a single SKU, the historical demand data for that SKU is really different in each sales channel, and in a certain sales channel it can pass several weeks without a SKU being sold, and in other it is sold every other day. This is to say that the maximum stock of a SKU has to consider this data to have a proper maximum stock, and since there is a lot of supply uncertainty, it is not possible to assure that Forall Phones can buy that type of smartphones when needed, which means that misallocated smartphones can have a huge repercussion in the performance of Forall Phones. It is therefore proposed the target inventory level method that makes use of the SKU historical demand data, which can be really benefitial to Forall Phones.

For the decreasing revenue objective (DRO) for a month, although based on the sales that a certain sales channel has accomplished, it is a very general allocation method. Inside the sales and the stock that a certain sales channel has had in the previous month, there are smartphones that sell much faster, other much slower, and even those that were not even sold. Although globally alright, as it is first considered the sales channel that has achieved the highest number of sales, and so on, it is possible to do a much better allocation if the historical demand data is explored at the SKU level, being it justified by several methods (such as the replenishment policy) that make use of this variable. The smartphones in transport and the replenishment time were not considered in the initial allocation, as the smartphones leave Forall Phones headquarters at around 5 p.m. and are in the physical sales channels (in Portugal) in the following morning but could be considered. As the initial approach was only valid for the sales channels in Portugal, it is okay not to consider such topic, but as Forall Phones internationalizes, and the smartphones take longer to reach its destination, it is important to account with these factor, even if it is just to open to the possibility of considering other replenishment periods for some sales channels in Portugal.

The proportionality is not used in the initial smartphones resource allocation process, as the allocation is based on the DRO order, being allocated one unit at a time to each sales channel, until the maximum of three units. The problem with this was explained before, there are units that sell faster, and others slower, and there are even units that were on a sales channel for weeks and have not been sold (period between the 2nd of February and the 26th of June). It is important to count with the speed at which the sales occur, if a type of SKU is sold three times faster in a sales channel than the same SKU in other channel, the allocation approach should reflect it.

Some errors that could happen in the process were also identified. It was seen that the logistics operator when doing the allocation keeps the stock tab open in the computer, but does not refresh the tab. When doing just one smartphone resource allocation round a day it is okay not to refresh the tab, but when several rounds happen throughout the day, some mistakes may happen, and the situation was reported and corrected straight away. As for the waste, it was identified that the smartphones could be put straight away in the location boxes, instead of using location' post its, but that was partially due to the little available space in the logistics operator desk.

5.2.2.2. Improvement opportunities for current process

The improvement opportunities for the current process are shown in table 3. The justifications are not going to be detailed as this process is not the focus of our analysis.

Improvement opportunities	Problem	Justifiable by literature?	Possible solution by the literature
Transport	Not covered	-	Transport data and periodic review
Time to replenish	Not covered	-	Periodic review
Proportionality	Proportionality not used, based on "sale-time"	No	Stock coverage with SKU historical demand data ratio
No maximum stock to lowest "sale-time" sales channel	Build-up of SKU/ GSKU units	No	Target inventory level with SKU/ GSKU historical demand data
"Sale-time"	Can be influenced by a bad allocation	Yes, but…	SKU historical demand data
Maximum 1 SKU/ GSKU in sales channels	Limitation of allocation	No	Target inventory level with SKU historical demand data
Influentiable/ Randomness	Influentiable by sales managers	No	Not influentiable by sales managers

Table 3 - Improvement opportunities for current process

The three first points of this table were already explained. The no maximum stock of a SKU for the sales channel that has the lowest "sales-time" is something that leads to a

SKU/ GSKU build-up if the Online sales channel has those same SKUs. As for the sale-time, it can be influenced by a bad allocation. Imagine the following case: A single SKU is allocated to a sales channel (that had no units of a SKU, and was never sold in that sales channel), and that unit is sold in 4 days. In that case, the “sale-time” of the unit is of 4 days, and the daily average sale is of 0.25 units per day. Now consider the allocation of 10 smartphones from that SKU (with the same conditions), being that one unit is sold every day and the first is sold in day 0. For this situation, the daily average sale is of 1 unit per day, but the “sale-time” of those 10 units is of 4.5 days. In this situation, the worst case would have the preference as it has the best “sale-time”, even though the second option, the sales channel that sold the 10 units in 9 days was the best option.

The maximum of 1 GSKU for each location is a limitation that has no real motive to exist. Although it may be reasonable to prioritize the Online sales channel, has it is reachable to virtually anyone in Portugal, due to the fact that Forall Phones has built a good brand, that is starting to be recognized by the Portuguese people nationwide, and has excellent reviews from customers, the maximum of 1 GSKU for sales channel almost forces a client to buy Online, even if the client is not confortable with it, or to buy a phone at a store, with probably a color or grade that was not the customer preference. It is possible to also request a smartphone to a sales channel (if a customer knows how to do so), but in a certain way, it almost takes out the possibility to occur an impulsive sale.

The randomness or the possibility to influence this allocation is another factor. If a sales manager or a salesperson learns about the smartphones resource allocation approach, and wants to influence such approach, they can do so by trying to only sell the smartphones that were recently allocated to the sales channel, in order to reduce the “sale-time” so that their sales channel receives more smartphones, or to return some smartphones on purpose, in order to receive the same smartphones, or others, with a new On Sale date.

It is also important to mention two things, applicable to both processes, that influence the number of errors and the overall predictability of which sales channel should a type of smartphone, that are the number and range of the produced SKUs, that change everyday, and was possible to notice by direct observation, and the logistics operator own allocation when a approach based allocation seemed wrong, that was confessed by the logistics operator during the semi-structured interview and were observed in the smartphones resource allocation process. To counter this, and get feasible results, the approaches will be replicated as they are stated.

5.2.3. Heuristic Construction and Feedback

In this subchapter the first proposed heuristic approach is going to be presented, and Forall Phones requirements, preferences, and validations will be given, culminating in the heuristic approach presented in chapter 4. It is important to remember that this heuristic approach was initially developed for the initial process. The scheme for the first proposed heuristic approach is shown in figure 7.

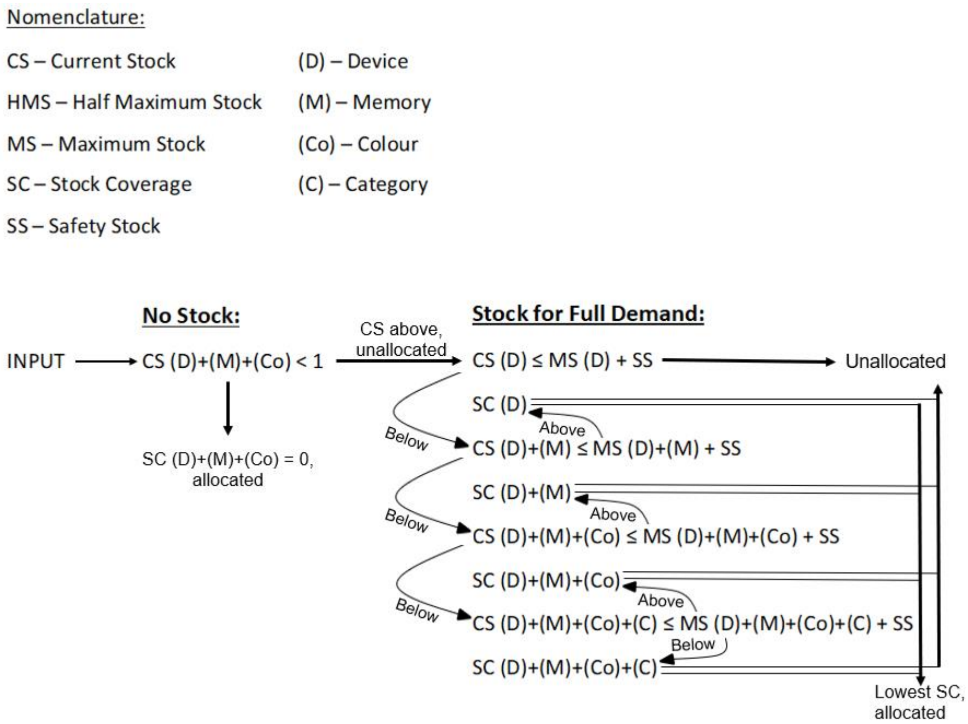


Figure 7 - Scheme of the first proposed heuristic approach

This was the first proposal presented to Forall phones that aimed to respond to some of their concerns. As it is possible to see, the first heuristic approach already resembles a bit the final heuristic proposal. The input to this approach (and to the final approach as well) is the decreasing daily average sales, and the first thing that is done is to desconsider the grade in the smartphone type, and to only consider the device, the memory and the color. If in a sales channel there is stock of a SKU that has those three characteristics (up to four can exist, as it can have any grade), the smartphone is not allocated, and it is passed for the next smartphone in the decreasing daily average sale order. If there is no stock of a smartphone that as those three particular characteristics, the type of smartphone being analysed is allocated. This was so that any sales channel could have at least one smartphone with the considered characteristics. The grade was disconsidered due to two main reasons, being one the purchasing of type C batches of smartphones to the supplier, that is not only seen as the best value for money, but also because the purchase of other batches reduces Forall Phones margins drastically and for some smartphones it is even economically unbearable, and the other is that although grade C batches are bought, the actual grades according to Forall Phones are different, and can be smartphones of grade A, B and C, but it is only possible to be sure after they enter Forall Phones headquarters.

After the smartphones pass through the No stock step, the unallocated smartphones go to the second step, the Full Demand step. In this step it is compared the current stock of smartphones with the desired number of smartphones, by only considering the device feature and it is seen if the current stock is below, equal or even above the target stock. If it is above, the smartphone is not allocated, if it is equal or below, it passes to the evaluation of the second condition, where the current stock of smartphones with the device and memory features is analysed with the desired stock level of those two features combined. If it is equal or below it passes to the third condition, and if it is above, it is assessed the stock coverage considering the device feature only as shown in the scheme of figure 7. The heuristic approach works as a strainer and the first target condition allows a possible allocation of a bigger number of smartphones than the second, and so on until we are looking at the SKU level, and the heuristic is a allocation scheme from the bottom to the top, as the first smartphones (for an empty sales channel) are allocated at a SKU level, and then, as the level goes up, less and less features are considered, but the approach always making sure that a certain allocation makes sense according with the stock coverage.

The approach variables, the target inventory level, the historical demand data, the transportation data and the periodic review system and the standard deviation were all immediately accepted by Forall Phones as those variables were recurrently used in the logistics literature. In the standard deviation it is used the central limit theorem, where each variable is the sum of a number of independent variables, that is approximately normally distributed with mean equal to the sum of the independent means and variance equal to the sum of the independent variances (Belien, 2006). The division by feature(s) level, the minimum service level for each feature(s) level and the use of the stock coverage to assess the feature(s) level were also deemed as appropriate and accepted by

Forall Phones. It is used a service level (Z) of 1 for the SKU level, of 2 to the device plus memory plus color level and so on, up until 4 at the device level, something that Forall Phones also accepted. These validations occurred both during semi-structured interviews and through feedback after the presentation of this approach to a focus group. One of the things discussed during the presentation with the focus group was the necessity and preference that the approach developed was able to assure for a particular sales channel at least half of the historical demand, before the No Stock step. All feedback was included, being that for the new added step, some alterations were done regarding the stock coverage, so that there was not a stock coverage comparation between sales channels, but rather the assessment if the stock that was allocated to a sales channel was enough to cover for half of the historical demand data. In this method, the allocation of a smartphone normally makes sense for several sales channels, has for each sales channel it is seen if a condition is fulfilled, and in the stock coverage method the allocation of a smartphone only makes sense (normally) to a single sales channel, as the smartphone is allocated to the one with the lowest stock coverage.

One other thing that was validated with Forall Phones was to use 1,01 to smartphones that had no days in a sales channel and were sold too fast, and a real small number was added (0,001) to smartphones that had never been in a sales channel to distinguish them from others that had been, but were taken out as they were not even sold.

The final heuristic proposal that was showed to Forall Phones is defined in chapter 4.

There is also a little trick that prevents that the assessment of a type of smartphone-location combination continues indefinitely, that is to analyse under the same level if the current stock reaches a number equal to the target inventory level, being that when it happens, other type of smartphone-location combinations are tested.

This approach is a hybrid method as it is a junction between a heuristic constructive method, that constructs a solution step by step, and a goal programming model, since target levels are defined. This approach also makes use of other heuristic solution methods such as the approximation method, by using the daily average sales (an approximation), since it is only possible to sell an integer number of smartphones, and the problem decompostition/ partitioning by having divided a problem into several subproblems and by solving them iteratively in order to get the best marginal benefit.

5.2.4. Implementation of the approach in a user-friendly tool

The heuristic mentioned in chapter 4 started being implemented in Excel. For the stock coverage part two calculation methods exist. In order to calculate the stock coverage of the original method it is used the stock data and the the daily average sales. For the stock coverage of the fulfilment condition method it is used the stock data, the daily average sales and the replenishment lead time.

As the smartphones resource allocation task is done at least once a day, from Mondays to Thursdays and the shipped smartphones are in the physical sales channels in the next business day prior to that shipping, the replenishment lead time is assumed to be instantaneous for all physical sales channels and just the periodic review is counted (although it may be changed afterwards). The periodic review to the Online sales channel was established as the minimum between the physical sales channels (validated with Forall Phones), because even though in theory the Online sales channel could have a periodic review and lead time close to 0, it is assumed that the logistics operators are not constantly checking for the ready and cleaned smartphones in the technical area as they have many more tasks to do, and because that when it is decided to do such task, all sales channels and all the information should be considered, in order to do the best possible allocation, being this option of defining the Online lead time the wisest decision. For the formula it will only be considered the periodic review as Forall Phones works in a push system logic, of moving what they produced to the sales channels.

As for the desired service level, it is a user-based input. The service level is a parameter in the periodic review system used to define a safety stock, that mitigates the risk of stockouts and that can together with the target inventory level to cover the demand variations with a desired probability until the next replenishment.

The other parameters must be calculated based on the data. The necessary data to obtain the daily average sales is the type of smartphones sold, the quantities, the day at which they were sold, and the type of smartphones and the days they were On Sale and in which sales channel (end of each day) to be possible to attribute a daily average sales to a smartphone type in a certain sales channel. The standard deviation will also be calculated based on those variables. For the stock the necessary data is the On Sale smartphone types and quantities in a certain location in the present day. For that reason, it was asked to the IT department to do a report that extracted that information of the system, and they were able to provide a browser (My S3 browser), that at every hour extracted that information from the system. The information was divided into 4 reports, as shown in figure 8, being that three of those reports were regularly used, the not_sold, the on_sale and the solds.

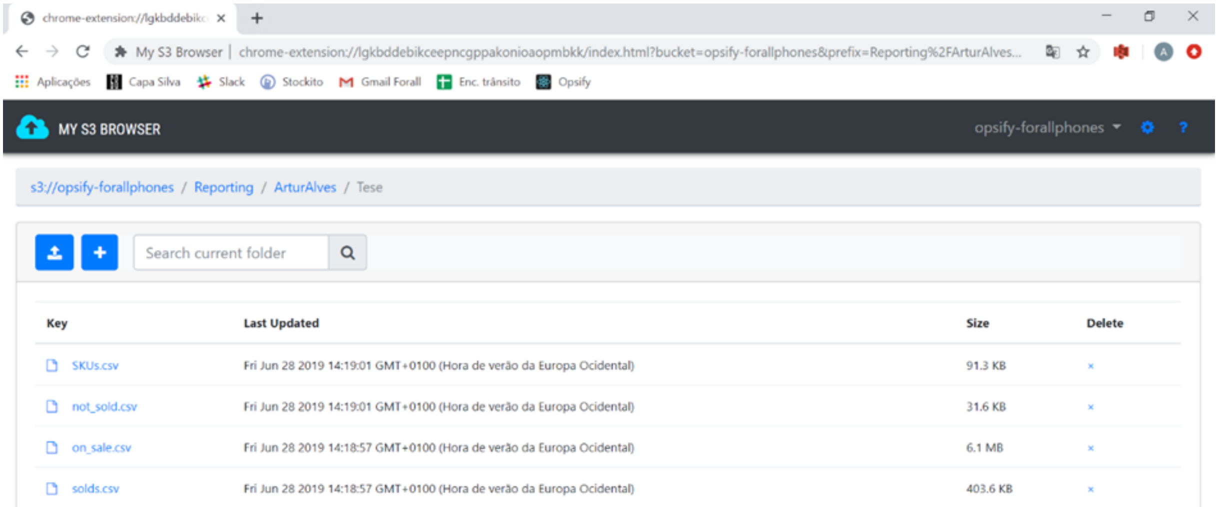


Figure 8 - Reports S3 Browser

The on_sale contains for the smartphones that have, or have had the On Sale state the date, the location, the product ID (or smartphone type), the quantity and the concatenation of the product ID with the location, in order to join the type of smartphones-location combination and be able to do the right calculations. The Solds contains for the smartphones that were or that have been sold, but returned for a reason, the date, the location, the product ID, the quantity and the concatenation of the product ID with the location. The not_sold contains the smartphones that were never sold but can be allocated. For this report, the information required was the type of smartphone and the IMEI, each smartphone unique number. The IMEIs of the smartphones were introduced in Excel by scanning each smartphone bag. The fourth report, and that was only used once was to relate the product ID with the respective characteristics, for the feature(s) levels.

It is very simple to use the tool. First the logistics operator goes to the My S3 Browser and copies the information of the 3 reports and pastes that information in the respective sheets in Excel. Then it is asked for the logistic user to split that information to columns for the three reports, as shown in figure 9, and finally to scan the IMEIs of the to be allocated smartphones and to press the “Iniciar Alocação” button (figure 10).

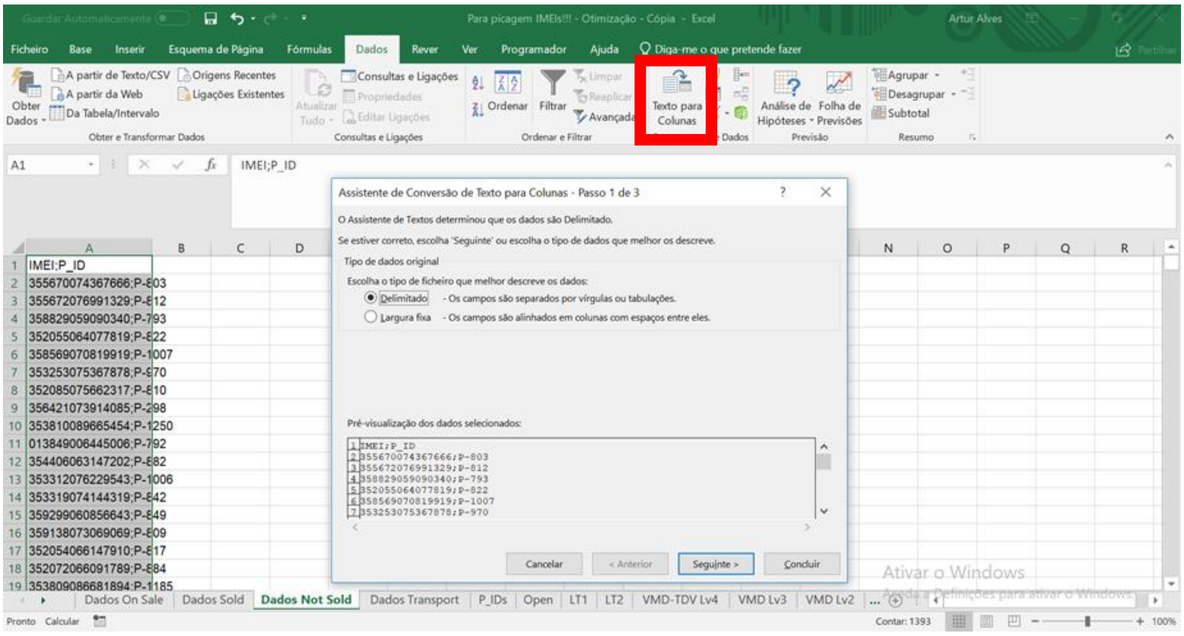


Figure 9 - Data split from data original retrieved from the S3 Browser

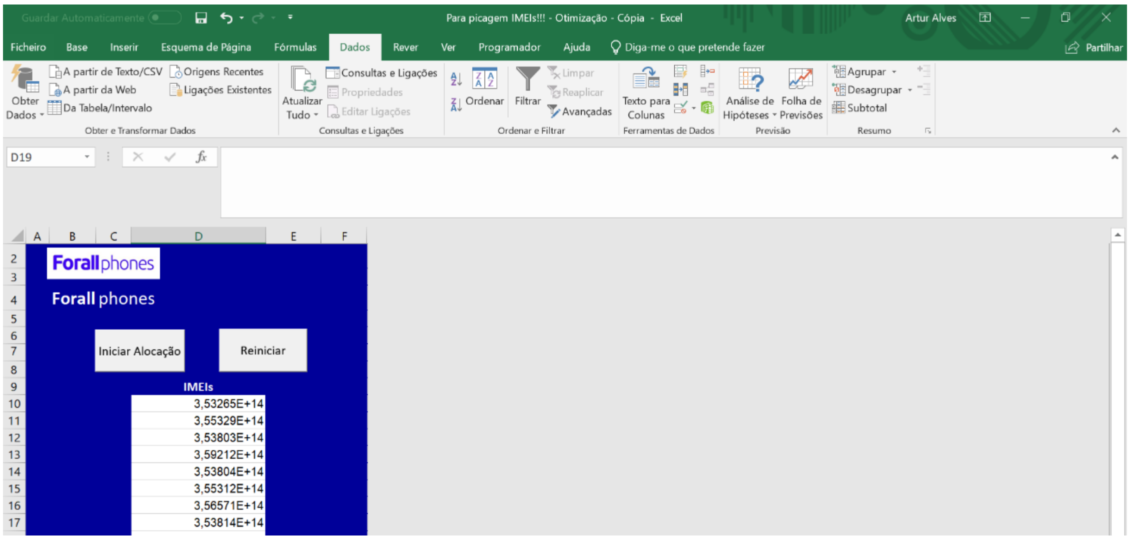


Figure 10 - Scan area for the ready and cleaned smartphones

The transportation report was not created due to two reasons. The first was already explained, the smartphones are shipped at 5 p.m. and reach a sales channel in the following business day, in the morning, and the lead time is considered to be instantaneous. The other reason is that there were some misplaced smartphones in the Transport state (that had to be) when IT was asked to do these reports, and due to the possible insertion of errors in the heuristic approach it was chosen not to consider the smartphones in transport.

The approach and its calculations were built into an Excel sheet (figure 11) that served itself from other calculation sheets, being that the calculation sheets served themselves from the sheets that contained the data that was extracted from Forall Phones database.

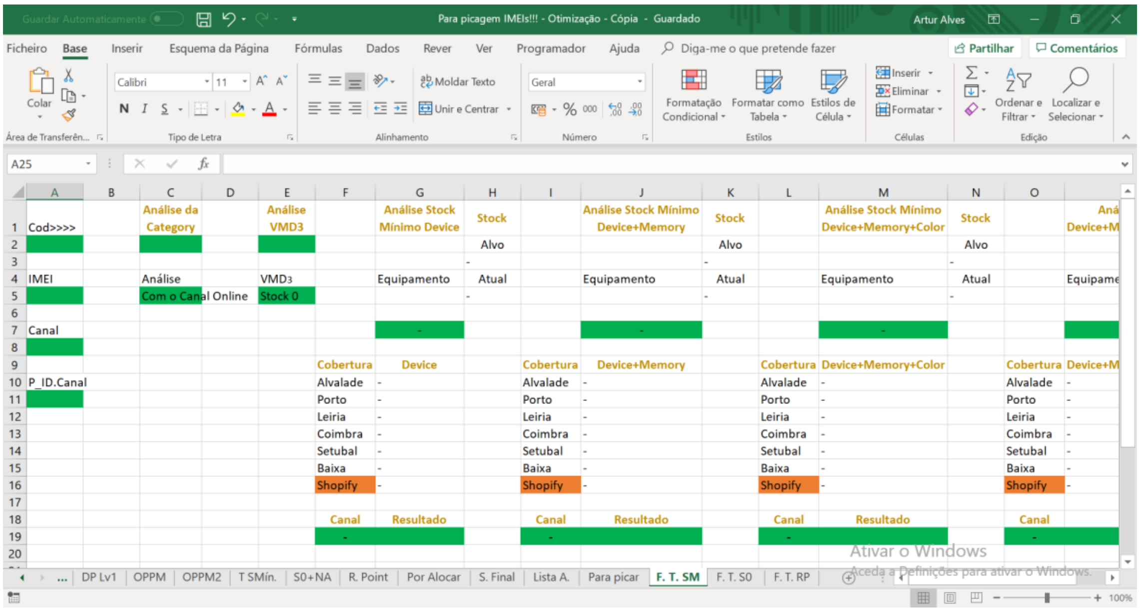


Figure 11 - Approach and respective calculations in Excel

In order to make the Excel Tool dynamic it was written some code in Excel Visual Basic Editor, so that the tool could do the number of iterations needed, perform the tests and allocate a smartphone if it complied with all requirements, eliminate the combinations of a type of smartphone-location if that smartphone was already allocated, to make calculations when the data was inserted into sheets and other aspects. Some measures were also taken to speed up the tool, such as to order the data and use Excel's tree search, to look for the information that was needed when the tool was running.

After using such techniques, the tool setup decreased to 2 minutes, one for initiating and the other at the end of the approach, and the allocation of each smartphone took on average 3 seconds, being counted in that time the failed allocations that could occur.

5.2.5. Heuristic Assessment

The heuristic approach was implemented in Excel as a way of evaluating the approach in a quick manner and to do some final tunings if necessary. To do such evaluation two things need to be done first: to explain why Forall Phones problem is a resource allocation problem, and to explain how our approach tries to give a solution to it, and only then try to evaluate if with our approach it is possible to achieve better results than with other approaches. "Allocation problems involve the distribution of resources among competing alternatives in order to minimize total costs or maximize total return." Ackoff *et al.* (2018). This is exactly the situation in Forall Phones, the smartphones (resources) distribution is done among "competing" sales channels (alternatives). If there are more resources than jobs, the solution should indicate the resources that are not used, and if there are more jobs than resources, the solution should indicate what jobs are not to be done (Ackoff, Holstein, Eilon, & Tanenbum, 2018). Both things can happen in the smartphones resource allocation. In our approach we will adopt a resource perspective and look at the smartphone to see if the smartphone was allocated or not to a sales channel.

The allocations that are made in one period may affect those in subsequent periods, and time must be considered in the solution as the problem is dynamic (Ackoff, Holstein, Eilon, & Tanenbum, 2018). Unfortunately, this dynamic can not be replicated, as the Excel tool is not prepared to perform such tasks, as it was not possible to obtain from Forall Phones the data worked in a straightforward way, and also due to time limitations.

To try to prove the correctness of our method, it will be used the stock coverage, that counts with time as mentioned in the literature. The reason that lead us to believe that it may be a suitable indicator for our analysis can be driven from a hyphothetical situation where there are 2 approches allocating the same number of smartphones to several sales channels. If each sales channel has its own historical data, the approach that is able to allocate the smartphones and produce the lowest stock coverage sum is the approach that is better suited at allocating smartphones to a sales channel where they are sold more frequently, but this is not normally the best situation as it does not account with time. The approach that tries to balance the several stock coverages across all different sales channels is the one that considers time in its analysis, being that when the two are together, it is when it is possible to maximize the number of smartphones sold in a period of time, being that the objective behind the design of our approach, an approach that was able to identify the sales channel where a smartphone had a higher average daily sales, and to allocate it if it made sense in a stock coverage perspective, *i.e.*, to allocate the smartphone to the sales channel with the lowest stock coverage.

To calculate the daily average sales, it is going to be used the arithmetic mean that is going to be modelled into a modified binomial. The reason behind this is that it is being dealt with a small sample data, and it is needed a distribuition that deals well with skewed data and that captures the reality of the situation. It is going to be assumed that the probability of success can be calculated, as the mean for the binomial distribution is considered to be the arithmetic mean and in a binomial there are only two possible outcomes, being one the failure to sell a smartphone (represented by zero), and the other being the success in selling “a smartphone”, that is modelled to be the ratio (mean) between the quantity of smartphones sold and the count of the days in which those smartphones were sold, being that each smartphone type has its own success number that is always superior or equal to one.

The data modelled in this way is still relevant for the problem, and the binomial was chosen because there are no outliers, being one of the advantages of using this distribution. The four conditions to be able to use this distribution are met since according to (Stat Trek, 2019):

1. The experiment consists of n repeated trials, that are the days in which (for a sales channel) a smartphone was available for sell;
2. Each trial can result in just two outcomes. In order to do that, it was done a slight transformation, and for a smartphone type (if it exists in a sales channel) there is the possibility of it not being sold and of being sold with a number that is equal to the ratio between the number of smartphones sold and the count of days in which they were sold;
3. The trials are independent, the days in which a smartphone was available for sell and the respective result in a certain day (if it was sold or not) do not affect the results in other days, when the same smartphone type is available in the same sales channel;
4. The probability of success in every trial is the same. Although not being completely true, due to promotional campaigns and some seasonality, the effect in our analysis will not be considered, because there is the possibility to remove those periods from the analysis, and also because the period analysed in our approach there was a relative balance differently from seasonality periods;

Before passing to the test, it is crucial to understand what the stock coverage is, and how it correlates and affects our approach. Stock Coverage is a type of measure that enables a person to know how long a store is able to continue selling items or groups of items given a sales history and inventory (LS Retail, 2019). The result of the stock coverage is a time variable that is also one of the dimensions expressed in the daily average sales (calculated by using the sales history), and as the daily average sales are used to obtain the maximum stock, the variable time is also expressed in it. That time variable in the maximum stock however, is limited by the sum of the lead time with the review period. For that reason, and in order to be able to use the heuristic approach, one has to raise the sum of the lead time with the review period so that the daily average sales times the sum of the lead time with the review period is at least at the same level of the inventory at the sales channels, but it is advisable to count also with the number of smartphones to be allocated.

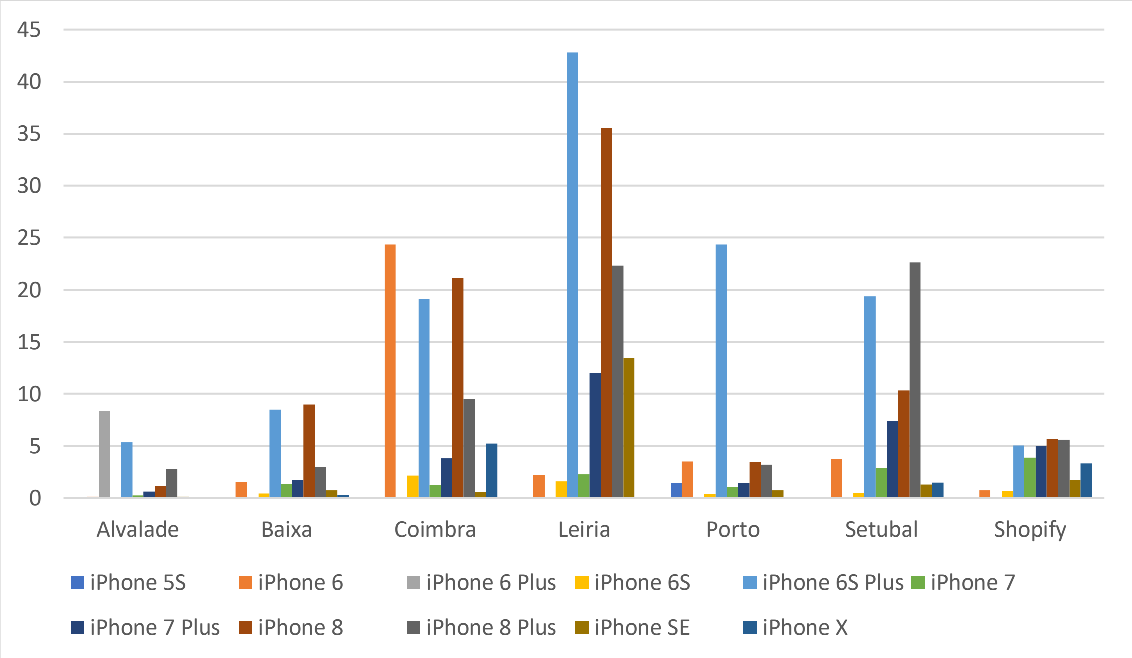
The test will consist of using the three approaches to allocate the same random type and number of smartphones to several sales channel and to assess the disparities they produced themselves, and to compare the methods against one another.

The data that is going to serve as the basis is the one from the 2nd of February to the 25th of June, including the stock that was available at each sales channel, and for a true measurement, the assumption of the value for a smartphone that was never sold (0,001) was taken out. The chosen sum of the lead time with the review period was of 4.1 for this case. The potential daily average sales (counts with all the SKU data) was of 329.363, which multiplied by 4.1 gives 1350.388, a little more than the double of 673, the stock that was available in all sales channels. This was done to try that the approach worked between the second and the third level, being that in the first and second level, the method used was the condition fulfilment and in the third and fourth level it was the stock coverage. The heuristic approach tried to allocate 100 smartphones, being that only 65 complied with the rules of the heuristic approach. For that reason, for the other methods, 65 smartphones will be allocated. The 65 types of smartphones are listed below:

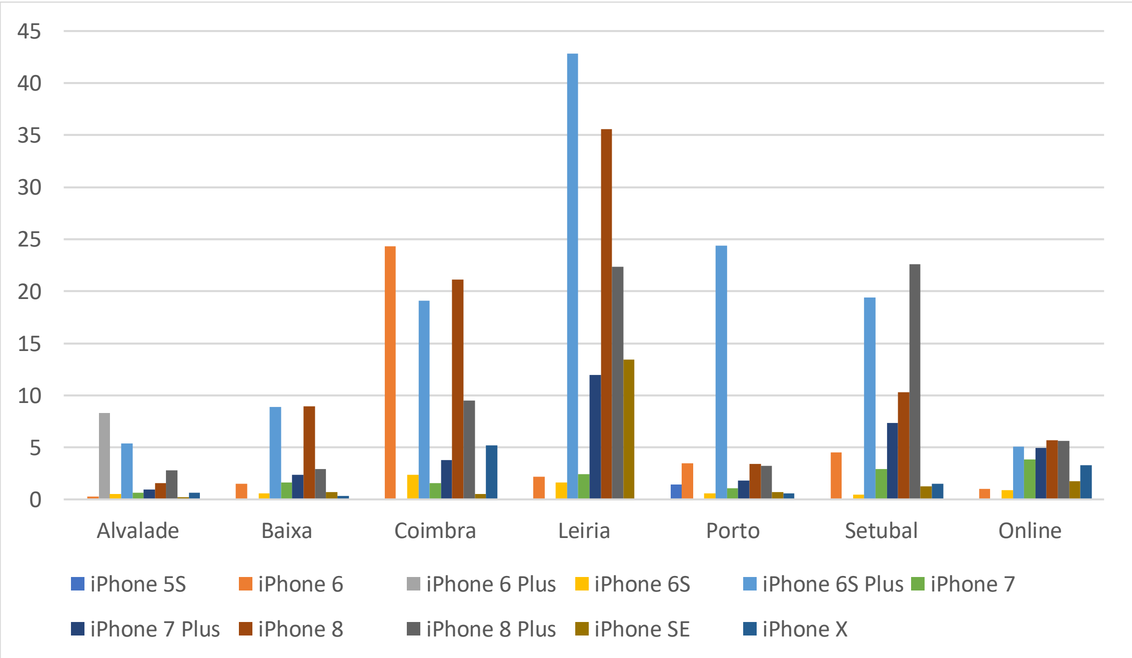
iPhone 7 Rose Gold 128GB A	iPhone 7 Black 128GB C	iPhone 7 Rose Gold 32GB B	iPhone 7 Plus Rose Gold 128GB A+
iPhone 7 Rose Gold 128GB A	iPhone 7 Rose Gold 128GB B	iPhone 6S Gold 64GB C	iPhone 7 Plus Rose Gold 32GB A
iPhone 7 Gold 128GB A	iPhone 7 Jet Black 128GB C	iPhone 7 Plus Silver 128GB B	iPhone 7 Plus Jet Black 128GB B
iPhone 7 Silver 256GB B	iPhone 6S Space Gray 64GB C	iPhone 6S Rose Gold 16GB B	iPhone 7 Plus Rose Gold 32GB B
iPhone 6S Space Gray 32GB A	iPhone 6S Silver 64GB B	iPhone 7 Gold 128GB C	iPhone 7 Plus Rose Gold 256GB C
iPhone 7 Jet Black 128GB B	iPhone 7 Plus Gold 128GB C	iPhone X Silver 256GB C	iPhone 6S Plus Rose Gold 16GB C
iPhone 7 Plus Silver 256GB B	iPhone 7 Plus Black 32GB A+	iPhone 6S Silver 16GB B	iPhone 6S Space Gray 128GB B
iPhone X Silver 256GB B	iPhone 6 Space Gray 64GB A	iPhone 6S Gold 32GB B	iPhone X Space Gray 256GB B
iPhone 7 Silver 128GB A	iPhone 7 Plus Gold 128GB B	iPhone 7 Plus Black 32GB B	iPhone 6S Space Gray 16GB B
iPhone 7 Black 32GB B	iPhone 6S Silver 32GB C	iPhone 7 Plus Gold 32GB B	iPhone 6S Space Gray 32GB B
iPhone 7 Gold 128GB B	iPhone 6S Gold 16GB C	iPhone 6 Space Gray 16GB B	iPhone X Space Gray 64GB B
iPhone 6 Space Gray 16GB C	iPhone 6S Rose Gold 64GB B	iPhone X Silver 64GB B	iPhone 7 Jet Black 128GB A
iPhone 7 Black 128GB B	iPhone 7 Plus Black 128GB A	iPhone 8 Gold 64GB A	iPhone 7 Rose Gold 32GB C
iPhone 7 Black 32GB C	iPhone 7 Rose Gold 32GB A	iPhone SE Silver 64GB A	iPhone 6S Silver 16GB C
iPhone 7 Black 32GB A	iPhone 7 Plus Black 128GB B	iPhone 6 Space Gray 64GB C	
iPhone 7 Red 128GB B	iPhone 6S Gold 128GB C	iPhone 7 Plus Silver 32GB A	
iPhone 6 Gold 16GB C	iPhone 6S Gold 32GB C	iPhone 7 Silver 32GB B	

Figure 12 – Types of smartphones for allocation

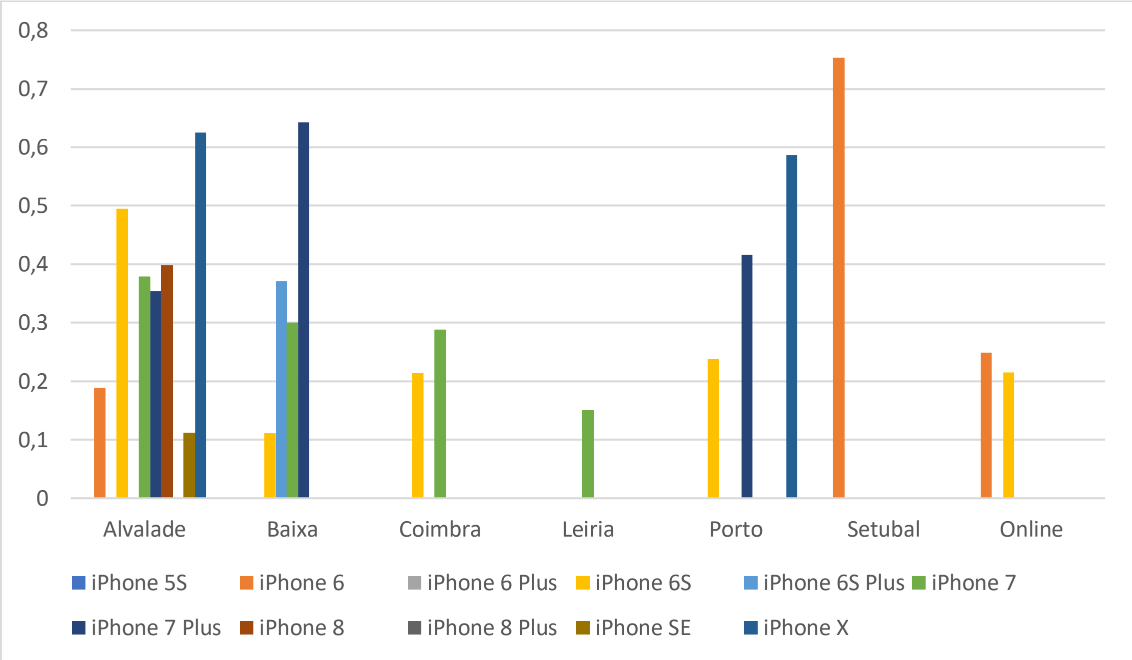
The stock coverage graphs for each of the approaches and for the stocks that existed in the sales channels on the 25th of June at the end of the day, prior to the allocations are going to be shown below. Then a table will be shown to compare the three methods against each other, to assess the number of smartphones each method could potentially have sold according to their potential daily average sales and respective stock coverage.



Graph 1 - Original Stock Coverage

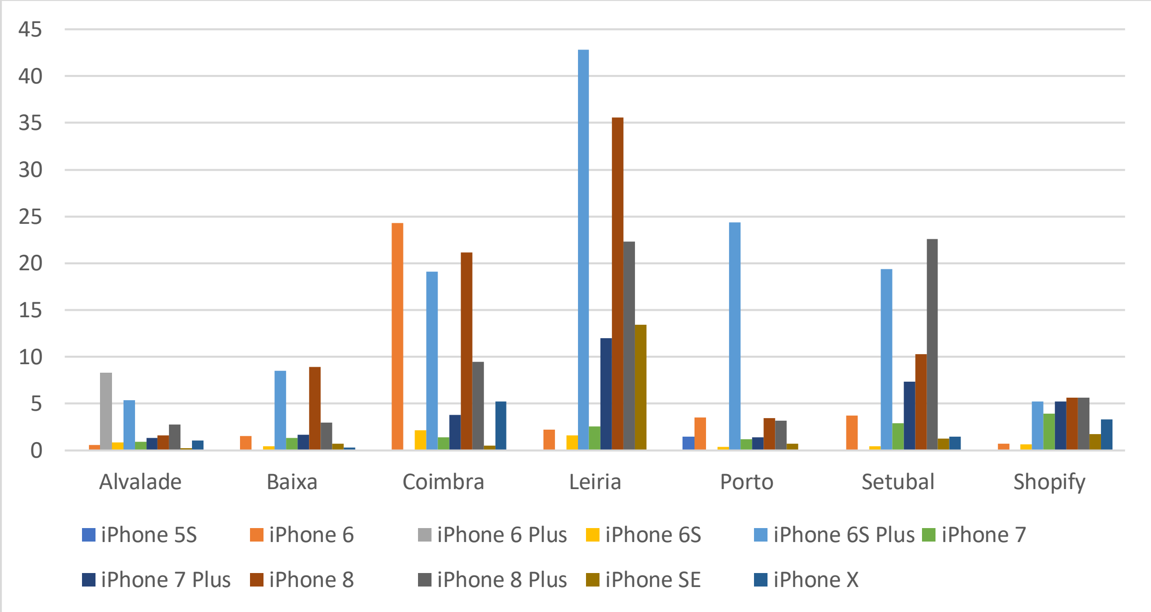


Graph 2 - Heuristic Approach

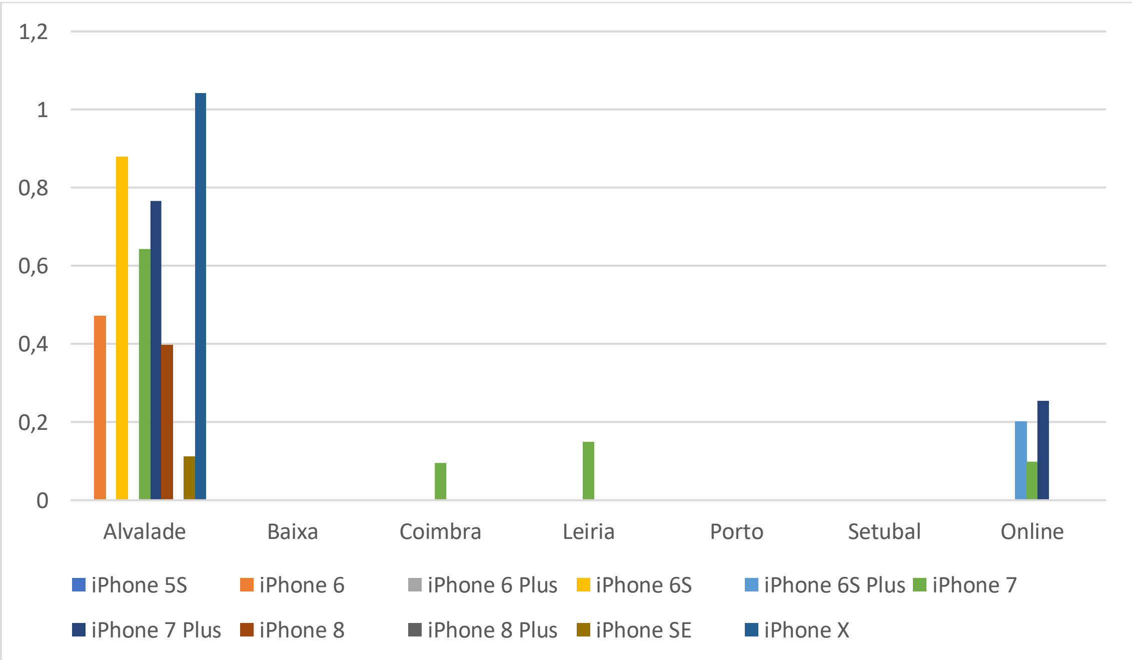


Graph 3 - Heuristic ApproachStock Coverage

As it is possible to see in graph 3, the heuristic approach allocated the smartphones to sales channels according with the stock coverages. The only exceptions seem to be the light blue bar of Baixa and the orange bar from Setubal, where before the allocation, both had stock coverage enough to cover the 4.1 days. However, this allocation could be possible in the three bottom levels of the heuristic approach. These two allocations were likely possible due to the excessive stock of a certain type of smartphones, that raised the stock coverage in those locations, but not enough in number that would block those allocations. The heuristic managed to get great results, being that the highest stock coverage addition was to Setubal with 0.752 days, being that according with this indicator, that all the smartphones would have been sold after those 0.752 days, if the device-type daily average sales profile was followed. The approach also did a great job in sending smartphones to all sales with just a little increase in stock coverage. Now it is time to compare the original stock with that of the Initial Approach.

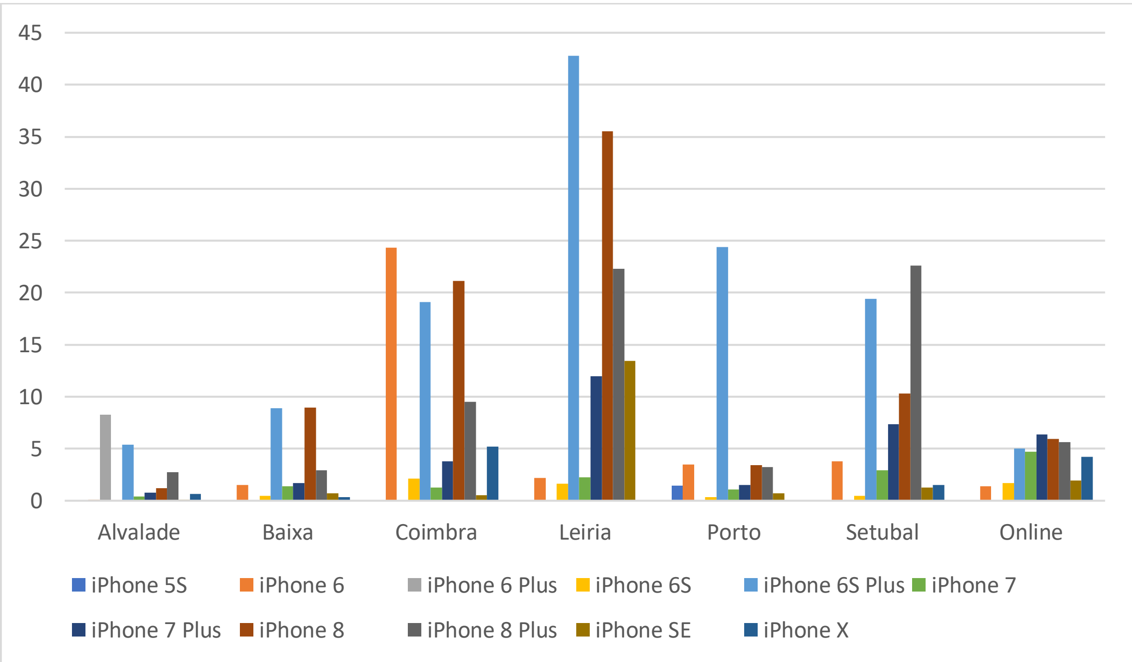


Graph 4 - Initial Approach Forall Phones

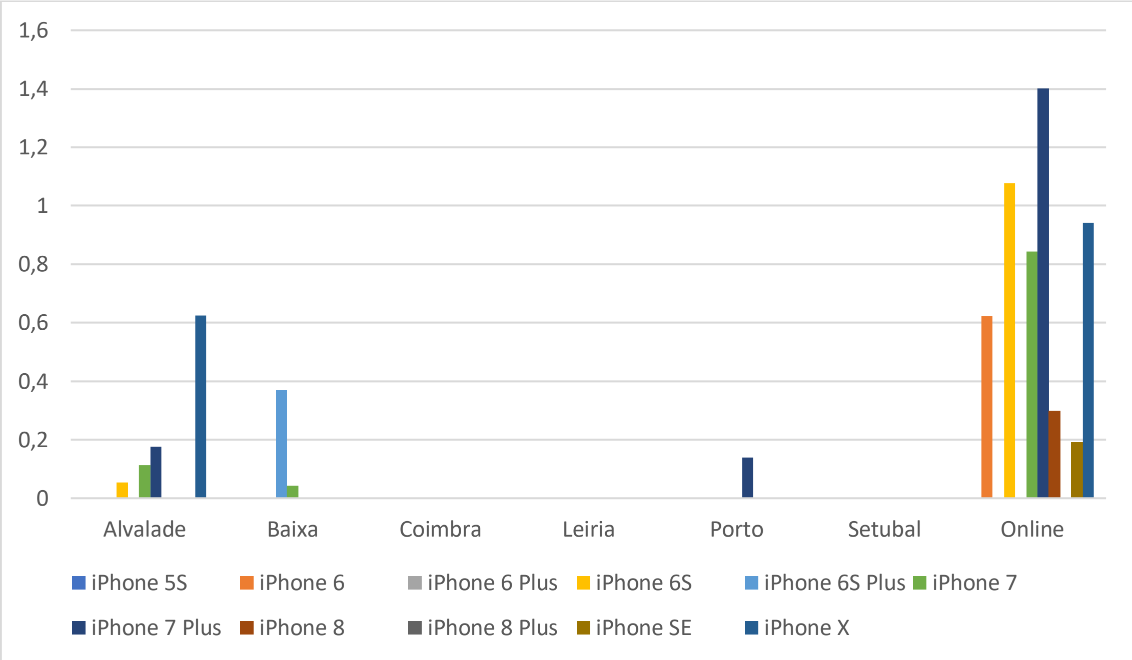


Graph 5 - Forall Phones Initial Approach Stock Coverage

As it is possible to see, the initial approach of Forall Phones also managed to get good results. The first sale of a group of smartphones is actually faster than that of the heuristic approach, but there is a need to look globally. After that fast sell, the heuristic approach is the one that presents a better allocation system in the overall, as it has the lowest variability among different stock coverages from different types of smartphones, and it is the one that sells faster in the overall. It is possible to say so, because the stock coverage is a measure of time, that counts for every sales channel, and therefore the sale of all groups of smartphones occurs after 0.752 days, against 1.04 days in the initial approach. This goes without saying that what is being considered here is not really each SKU daily average sales, but the potential daily average sales of a group of smartphones, that although treated more or less similarly here, as if all smartphones inside a group get sold at the same time, it is different from reality, where different SKUs from the same group can have huge differences between them. Contrary to the initial approach, the heuristic approach has several levels, one of which considers the analysis of a SKU by itself, and therefore it is much more likely that a more correct and reliable allocation is done by the heuristic approach. It is now time to show the graphs for the current approach.



Graph 6 - Current Approach Forall Phones



Graph 7 - Forall Phones Current Approach Stock Coverage

As it is possible to see, this approach was the one that performed the worst in terms of allocation. The stock coverage reached 1.4 days, being that this is the maximum between the three approaches, and it is the approach that has the biggest difference between the highest and lower points in the stock coverage). It is now time to compare the number of smartphones sold during the time coverage extent. To this analysis, it is only considered the integer part of the daily average sales, without roundings.

Time (Days)	Heuristic Approach	Initial Approach	Current Approach
0.1	9	8	8
0.2	28	19	18
0.3	45	29	26
0.4	55	37	32
0.5	60	46	38
0.6	62	51	43
0.7	64	57	49
0.8	65	61	54
0.9	-	64	57
1.0	-	64	59
1.1	-	65	62
1.2	-	-	63
1.3	-	-	64
1.4	-	-	64
1.5	-	-	65
Total sold:	65	65	65

Table 4 – Number of smartphones sold throughout time for the three approaches

Considering the above table, the heuristic approach outperforms the other two methods when time is being considered. Although not having the fastest smartphone sold, right at 0.1 days, it already has more smartphones sold than in the other two methods. Here it is being done a device-type only approach, that encompasses all the individual daily average sales of the several smartphones, but in reality, the results would be worse in general. To have results similar to those of the potential daily average sales, Forall Phones would have to have in stock all the smartphones in all the sales channels that Forall Phones had in the period between the 2^{nd} of February and the 25^{th} of June in a single day, if no promotial campaigns and no substitute relations between smartphones are considered. The reason why it is being done the type of device is due to time limitations, due to the need to get perceivable results, and also due to the attempt of trying to represent the same type of smartphones as being substitutes for each other. Considering the results, the method that performed the best was the heuristic approach, that had a more balanced stock coverage for the generality of the type-of-devices, being the one that had the lowest maximum stock coverage and for which it would be more likely to recoup the money faster, according to the comparison between methods.

5.2.5.1. Limitations and recommendations

In this section some limitations of the heuristic approach are presented, and also some recommendations, to tackle those same limitations and to inhace the overall performance of the smartphone allocation process. Even though in this initial test, the heuristic approach showed a good performance, more tests need to be done to assess the superiority of the heuristic approach in comparison with the other approches. The consideration of all different SKUs under a device-type is not completely appropriate and it must also be assessed if whether the modified binomial distribution can be used to describe the variability of having (or not) a sale, as it serves to calculate the standard deviation. It is advised to this last point, to also try to assess if the poisson distribution could be a good substitute.

Although capable of doing a good resource allocation, it is possible to do better in the smartphones resource allocation to the sales channels. A limitation that the heuristic approach has is that it is really constricting when it comes to the allocation of smartphones, being that only 65 out of the 100 smartphones that the heuristic tried to allocate were effectively allocated. This can be a result of rigidly establishing the number of a type of smartphones that can go to a sales channel, without looking to the benefit of allocating a smartphone to a sales channel. This is a common problem in goal programming, where all condition must be met before an allocation occurs. It is therefore advisable to use this approach in combination with other methods, in order to possibly get more smartphones to the sales channels. Other possibility, but more in the medium/ long term is to come up with a complementary method that can be used in this approach, and that brings more flexibility to the allocation, like for example by using stock coverage in a more clever way, that can be done by for instance not effectively allocating the faster-selling smartphones to the respectives sales channels in a first phase, but later,when trying to balance the stock coverage, because as the fast-selling smartphones get allocated, the smartphones that do not get sold as fast, and that contribute to higher stock coverages can jeopardize the possibility of assuring an even stock coverage among all sales channels. It is also important to remove unusual peaks of demand from the data, that can occur at days of promotional campaigns and of seasonality, such as the Christmas or Black Friday, as they only add more to the uncertainty, being this more for the future.

As for the data, it can not be considered totally reliable, as there are small sample datas and it is difficult to extend and generalize that those patterns of demand will be followed, as they are not extensive enough whether in terms of encompassing SKUs, whether in terms of days that Forall Phones has held a great number of the SKUs. It is advised that Forall Phones gathers more data in the course of their operation, and to try to buy some SKUs that they never had, and SKUs that were sold quickly.

For new sales channels openings, it is recommended to do a manual allocation at first, or to just use the first two steps of the approach, as only half of the demand or the presence of a smartphone with a certain device, memory and color is considered. As the days go by (for example 3 months), and Forall Phones feels more confident that a sales channel has more reliable data, it can then be used the third step of the approach.

A weakness of the approach is the possibility to let an allocation occur, even when it is not totally need, *i.e.*, the possibility to allocate a certain type of smartphone in other level, when the current stock is more than enough to cover the full demand of that SKU by itself. One recommendation is to limit the possible allocation of any smartphone to just the full demand.

Despite this heuristic approach not being fully tested, it has showed good results, and with the aim to respond to the research question "How to improve the resource allocation process of smartphones at Forall Phones?", it is advised that Forall Phones uses this approach, as it was built considering existing literature and as it has managed to get better results in initial tests.

6. Chapter conclusions and future work

This project was developed in Forall Phones, being the proposed general objective to improve the smartphones resource allocation process, specially the approach used in the smartphones resource allocation. To find possible ways to improve the smartphones resource allocation, it was searched in the literature for resource allocation problems, as it is the class of problems to which our project belongs. As there was not literature in resource allocation for the smartphones industry, other studies were sought, being that it were found some studies in retail shelf space allocation, in health, in logistics, in electricity retail and in manufacturing. Being the central theme to come up with an approach that can be used by the logistics operator, the starting point is smartphones allocation approaches. For resource allocation approaches, the literature is not really extent, but the main methodologies used are optimization, simulation and also game theory. After analysing the main methodologies extensively and due to the nature of the smartphones resource allocation problem, it was concluded that optimization was the methodology most suited for this context, and that there were multiple objectives to be considered.

It was seen afterwards that this type of problems, fall under the category of operations research. As operations research deals with the application of scientific methods in managerial processes, and as in operations research it is made use of disciplines like mathematics, statistics, it was chosen to make use of logistics and statistics to build our approach.

In a first stage, the smartphone resource allocation processes were mapped for the two approaches, after several semi-structured interviews and direct observation. After that, some improvement opportunities were identified, concerning questions that were not considered in Forall Phones and the methods used by the approaches were verified to see if they had theoretical background supporting them. Having that in mind, and all the internal information that was collected, it was choosen to use a periodic replenishment policy to define the maximum stock levels, based on the daily average sales that the data gave us of each type of SKU in each location, and stock coverage. In here the maximum stock levels were also the reorder level, as the headquarters decided to which sales channel should a smartphone go to, and the objective was to reach the target. The approach used a greedy method to the daily average sales, that served as input to the allocation system. After the presentation of the approach, some points were validated and the feedback received was incorporated in the approach, that was then implemented in Excel and in Excel VBE. The approach was then tested against the two approaches of Forall Phones, being that in the initial stock coverage test the heuristic approach performed better where, assuming the calculated daily average sales for the type of devices, the allocation of the heuristic approach allowed to sell smartphones faster than in the initial approach (27%) and than in the current approach (46%). It can be concluded that the use of the greedy approach together with the stock coverage produces good solutions for the allocation of the smartphones to several sales channels.

For future work it is recommended to keep testing this approach with other used at Forall Phones, to try to test other versions of the approach, as for example, the use of stock coverage only for all levels, and even to test it against metaheuristics, which can obtain good result for nearly every problem. The comparation between the features of heuristics and metaheuristics reveals that a great advantage that metaheuristics have over heuristics is their use of memory, and the constant comparison of several solutions (Blum & Roli, 2003). This could have helped in the resolution of the problem, but as the problem was not static, there are much more possible combinations and to use the memory feature would not greatly benefit Forall Phones problem, specially due to the time tradeoff.

Other recommendation for the future is to do a more throughout analysis of the levels of the approach and try to find a possible substitute in the literature to replace those levels, as the levels role in the heuristic approach were mainly to distinguish the characteristics between SKU, see what were the characteristics that Forall Phones could assure when buying to the suppliers and to module the relationships between substitute SKUs inside a device-type group. It is therefore advised to see other methods in the literature other than those of the heuristic approach, that have the capability of accounting with the possibility of substitute products, and that can define them, even outside the device-type group. If other substitutes in the literature are not found, one can inspire on the work of (Sujono & Lashkari, 2007), by using several criteria to obtain the degree to which a smartphone can be considered as a substitute of another(s), and based on that (and in previous allocations) to maximize that substitute compatibility sum.

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