Faculdade de Engenharia da Universidade do Porto

Start-ups - Integrating product, market and supply chain decisions to build-up a market entry strategy

Start-ups – Integração de decisões de produto, mercado e cadeia de abastecimento para a definição de uma estratégia de entrada no mercado

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Resumo

Start-ups são empresas tecnológicas recém-criadas para introduzir novos produtos e serviços no mercado. Elas são uma parte importante do sistema económico mundial, liderando a introdução de muitas inovações no mercado e contribuindo para a geração de emprego. Enquanto procuram o seu modelo de negócios, as start-ups vão adaptando-se constantemente a novos mercados e necessidades dos clientes, procurando acompanhar e refletir as mudanças que encontram nas características do seu produto e nas operações internas.

A importância da adaptação do produto às necessidades do mercado tem sido vastamente enfatizada na literatura de empreendedorismo, e ao mesmo tempo, o consenso existente relativo à gestão de operações reconhece também o importante papel do desenho do produto no desenho da cadeia de abastecimento da empresa. A integração de decisões sobre produto, mercado e cadeia de abastecimento apresenta-se assim como uma área destacada de investigação, como potencial facilitador da criação de uma estratégia de entrada no mercado adequada, em especial no caso de start-ups.

O presente estudo contribui para essa área de investigação através da aplicação de um "framework" de decisões de produto, mercado e cadeia de abastecimento como base para a definição da estratégia das start-ups. Inicialmente foi realizado um estudo de caso para poder perceber como as start-ups podem usar o "framework" proposto para desenvolver as suas estratégias de entrada no mercado. Posteriormente, esses resultados foram usados para planear as operações de uma start-up na área biomédica (usando uma abordagem de pesquisa-ação), desenvolvendo estratégias para a criação de uma rede global de parceiros em áreas diversas, versando desde o processo de industrialização, o plano e locais de produção, a lista de parceiros da cadeia de abastecimento e também os requisitos de certificação.

Os resultados da estratégia escolhida foram comparados com os concorrentes da start-up existentes no mercado global, usando uma ampla análise de benchmarking da concorrência em todo mundo de forma a poder avaliar a qualidade da solução desenvolvida com relação aos custos de produção interna previstos.

No final, conclusões sobre estratégias de operação de start-ups foram colocadas em prática usando um modelo de simulação existente, no contexto de uma competição global de estratégia e operações.

Abstract

Start-ups are new ventures created to introduce new products and services to the market. They are an essential part of the world economic system since start-ups lead the introduction of many innovations into the market and contribute to job generation. While searching for their business model, start-ups continuously adapt to new markets and customer needs, which leads to changes in product features and internal operations. The importance of product adaptation to market needs has been emphasized in entrepreneurship literature. On the other hand, operations management literature recognizes the vital role of product design in shaping a firm's supply chain. Therefore, studying the integration of product, market and supply chain decisions to build-up a market entry strategy in start-ups seems to be a prominent area of research.

The present study contributes to this area of research by studying the use of a framework of product, market and supply chain decisions for start-ups strategy definition. Initially, a multiple case study was carried out to develop insights on how start-ups may use the proposed framework to develop their market entry capabilities. These findings were later used to plan the operations of a biomedical start-up (using an action research approach), namely in developing strategies for a global sourcing partners network, for the industrialization process, the production plan and locations, the list of supply chain partners and also for the certification requirements.

The results of the chosen strategy were latter compared with existing start-up competitor's, using an extensive benchmarking analysis of the worldwide competition to access the quality of the developed solution with regards to the forecasted internal production costs.

In the end, findings regarding start-up operations were put into practice using an existing simulation model, in the context of a global strategy and operations competition.

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To all, my sincere gratitude.

And may the best be yet to come.

Luis Valente

All the world’s a stage,
And all the men and women merely players;
They have their exits and their entrances,
And one man in his time plays many parts.

William Shakespeare

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Abbreviations

List of abbreviations (ordered by alphabetic order)

3DCE	Three-dimensional concurrent engineering
ABS	Acrylonitrile butadiene styrene
BOM	Bill-of-materials
CAD	Computer-Aided Design
CTO	Chief Technology Officer
EMAF	Feira Internacional de Máquinas, Equipamentos e Serviços
GMKC	Global Marketing Competition
IP	Intellectual Property
NPD	New product development
PBCM	Process-Based Cost Modeling
PCB	Printed Circuits Board
P-M-SC	Product-Market-Supply Chain Framework
R&D	Research and Development
RFQ	Request for Quotation
SC	Supply Chain
SLA	Stereolithography
TPM	Technology- Product- Market Framework
USA	United States of America

Chapter 1

Introduction

This thesis is a dissertation for the Master's in Electrical and Computer Engineering, Automation Major, lectured at the Faculty of Engineering of the University of Porto, Portugal.

This first chapter will present an overview of the work, namely regarding the context and motivation to carry out this project, its objectives, the methodology used, the work plan, and considerations about the structure of this document.

1.1 - Context and Motivation

One of the fundamental characteristics of the modern world is the rapid pace at which consumer trends change and evolve. This creates a challenge for companies that seek to take advantage of this change to gain a competitive advantage over their competitors, frequently by introducing new products to the market (Christopher, 2006).

To be the first to meet customer needs does matter immensely! Pioneer companies perform better than followers and usually achieve higher sales, market share and profit (Mittal et al., 2004). While the effect on initial market share starts to reduce over time, other competitive advantages can still be observed on the long-term, as profit margins for pioneers are higher even after a considerable period of time (Robinson and Fornell 1985; Urban et al. 1986).

Companies are aware of that importance, and taking the utility patents granted yearly as an indicator, it seems that they are indeed taking innovation seriously. As seen in Figure 1, the number of granted utility patents in the USA has almost doubled in the last ten years and has been on a steadily rising trend in the past 50 years (Crouch et al., 2019). While not all patents represent innovation and not all innovation is patented, to keep up with the change companies are indeed dedicating a more significant portion of their budgets to research and development (R&D) (OECD, 2018), which can lead to more patents being requested as means of using intellectual property (IP) to protecting their investment.

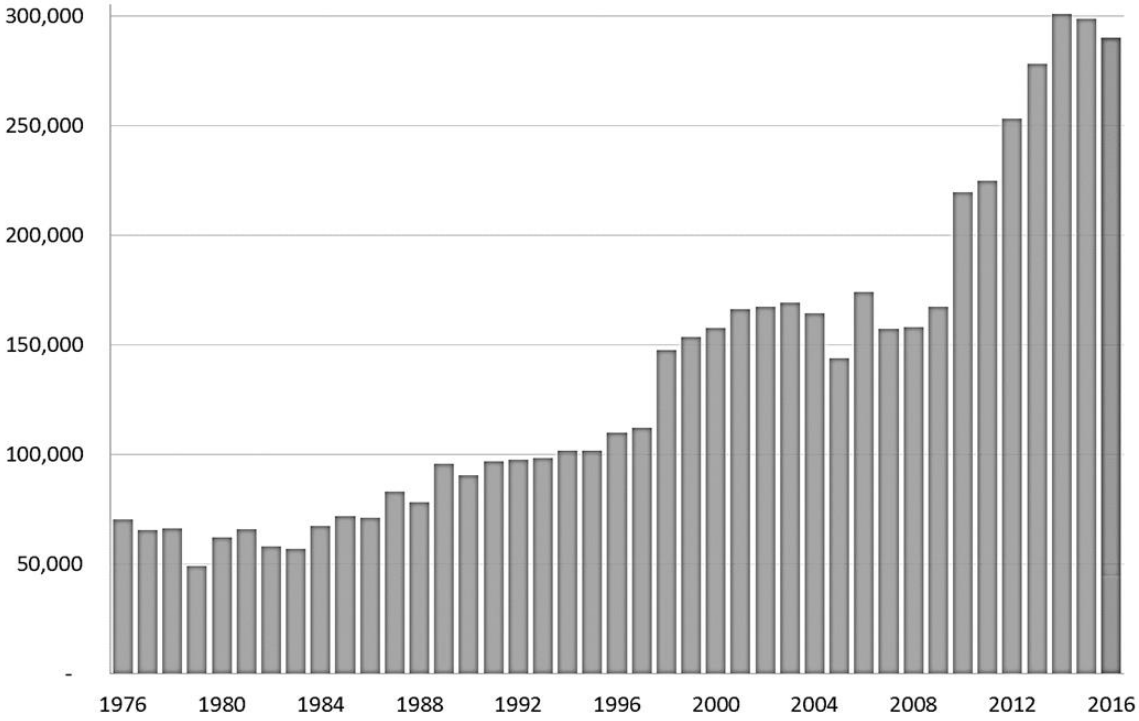

Figure 1 - Utility patents granted in the USA
(Crouch et al., 2019)

However, not all companies are equally innovative. While important for all companies, some businesses are entirely born out of a desire to solve a problem with an innovative solution. To those companies, new ventures created to introduce new products and services to the market, we usually call start-ups. They are an essential part of the world economic system since start-ups lead to the introduction of many innovations into the market and contribute to job generation. As a matter of fact, their fast growth makes them increasingly more important to our economy. Today, new jobs are created at a faster rate by start-ups than by established companies (see Figure 2), making them fundamental for any country that aims to achieve a stable and vibrant job market (Mandel, 2017).

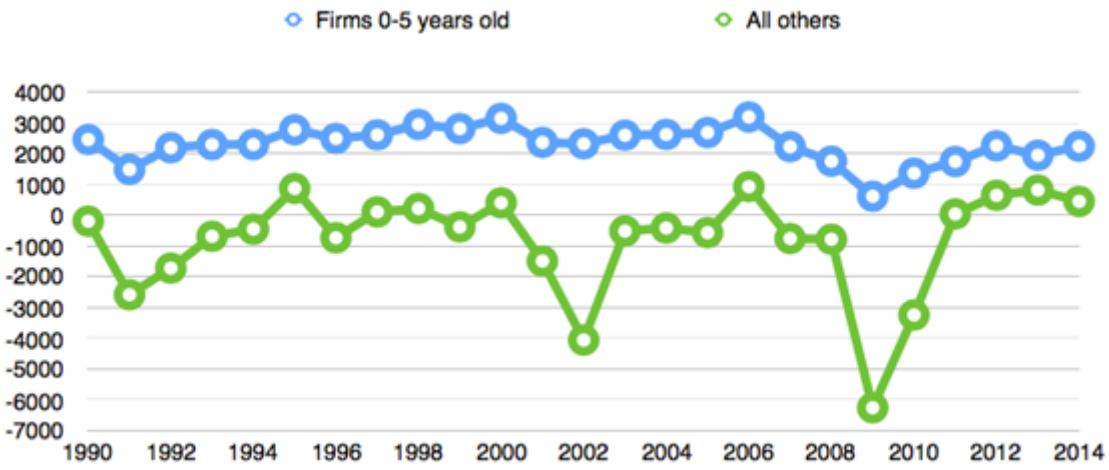

Figure 2 - Contribution of young firms to job growth in the USA (net job creation, thousands of jobs) (Mandel, 2017)

Unfortunately, as much as the general public loves start-ups and their products are sometimes rapidly introduced into our everyday lives, they are also incredibly fragile. About 80% of start-ups already financed fail (Ghosh, 2012), which means that they face enormous challenges to succeed: they must get it right the first time, or they might not be a second time.

For these reasons, we are faced with a challenge: start-ups often fail, but the ones that make it are sometimes totally revolutionary to our everyday lives. So, a pertinent question arises: how can we help them? And to answer that question, first we need to understand their challenges.

While searching for their business model, start-ups continuously adapt to new markets and customer needs, which leads to changes in product features and internal operations. The importance of product adaptation to market needs has been emphasized in entrepreneurship literature. On the other hand, operations management literature recognizes the vital role of product design in shaping a firm's supply chain. Therefore, studying the integration of product, market and supply chain decisions to build-up a market entry strategy in start-ups seems to be a prominent area of research.

The present thesis contributes to this area of research by proposing and studying the usefulness and impact of using a framework of product, market and supply chain decisions for start-ups strategy design.

1.2 - Objectives

This study aims to contribute to the area of research at the intersection of entrepreneurship and operations management by studying the use of a framework of product, market and supply chain decisions in the start-up's strategy definition.

The proposed goals for this thesis were:

1) Study and identify different frameworks that could help start-ups develop market entry strategies
2) Carry out a multiple case study analysis to develop valuable insights into the topic
3) Use the findings to plan the operations of a start-up
    a) Develop strategies for the design of a global partners network, namely
        i) Establish a network of production and industrialization partners
        ii) Research the best production plans and locations
        iii) Access the company's certifications needs
        iv) Elaborate a Process-Based Cost Modeling (PBCM) on the resulting production strategy
    b) Evaluate and compare the resulting estimated internal production costs with existing start-ups competitors
    c) Create a benchmarked analysis of the company global potential competitors
4) Use the findings to plan the operations of a simulated start-up

1.3 - Thesis Methodology and Work Plan

This thesis began with a review of the literature/state of the art regarding the tools available to improve the process of defining a company strategy, culminating with the choice and proposition of an adequate framework for this case. A formal definition of a start-up was also defined to set a boundary between start-ups and established companies, presenting later on the various start-up phases.

Next, a case study research methodology was put in place, through the analysis of several hours of recorded interviews with Portuguese technological start-ups. In the end, a with-in case and cross-case analysis were formed, enabling the extraction of main insights regarding start-ups strategy definition.

Those findings were put in place on a real-life start-up using an action-research methodology, planning the actions and then putting them in place while also designing a production network and establishing a global partners network for the start-up. In the end, the same findings were used in a simulation modeling methodology, through the participation in a global operations and supply chain competition.

A more detailed version of the full work plan can be found in Figure 3.

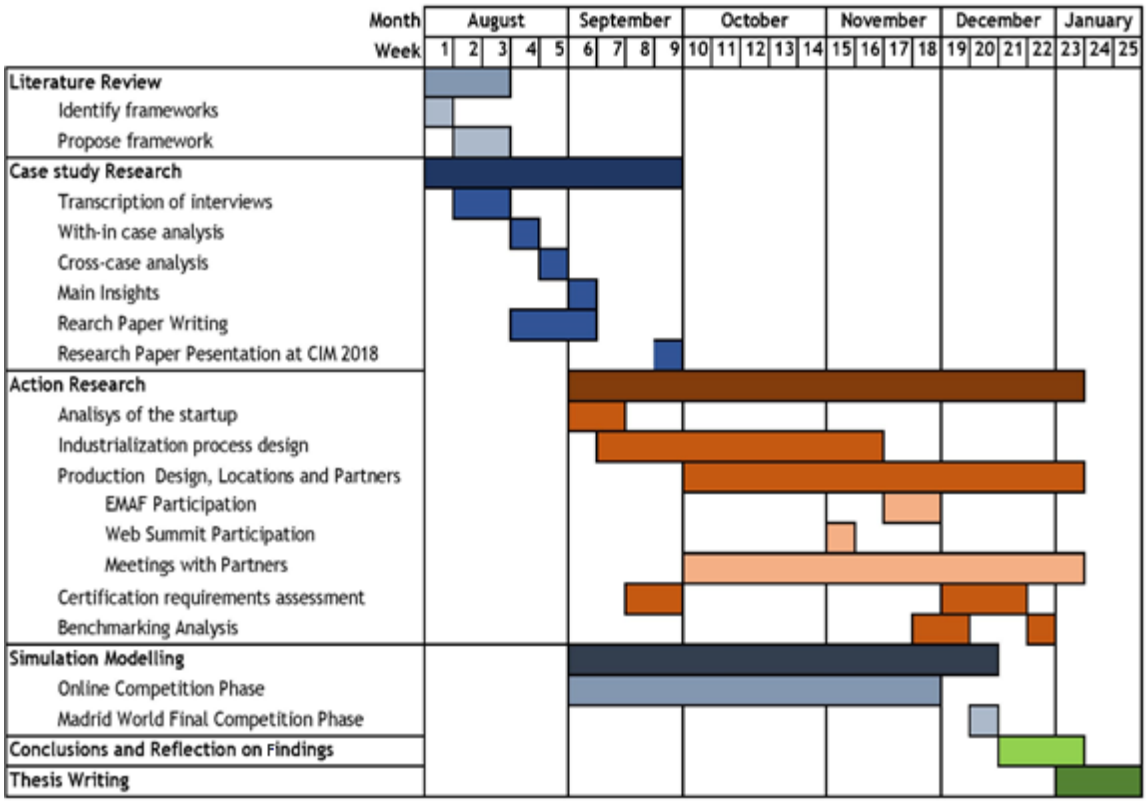

Figure 3 – Thesis work plan detailed through 25 weeks

1.4 - Document Structure

Apart from the present Chapter 1 where an introduction to the work is presented, the rest of the document is structured in six additional chapters, leading to a total of seven chapters.

In Chapter 2, the state of the art/literature review is presented, namely versing about the definitions of a start-up, tools, and frameworks to improve companies and ending with considerations regarding the chosen framework (and said supply chain, market, and product themes). Chapter 3 presents the research method, by specifying the types of methods, units of analysis, data collection, and data analysis methods used.

Chapter 4 presents the results of the case research with some specific with-in and cross-case analysis. In the end, major insights about the findings are included. This chapter is based on the conference paper Valente, L.F., Barros, A.C., Maia, C., Cunha, J.P. (2018), "Start-ups: Integrating product, market and supply chain decisions to build-up market entry capabilities", 22nd Cambridge International Manufacturing Symposium, 27–28 September 2018, Cambridge, UK. https://doi.org/10.17863/CAM.31721

In Chapter 5, the action research case is presented, with the presentation of the start-up, objectives, challenges, and the results of the designed strategy and Process-Based Cost Modelling. Afterward, Chapter 6 puts forward a simulation model and explains the context of the simulation / real world competition, the objectives of the challenge, the main variables and how they correlate with this study. In the end, the main results are presented.

Finally, Chapter 7 concludes this work and discusses the main global results, reflections on the fulfillment of the objectives and also considerations about future work.

1.5 - Main Contributions & Achievements

Throughout this study several tools, documents and achievements were created and acomplished, some of which, for their relevance and pertinence, can stand-alone as outputs of this thesis in addition to this present document.

Regarding the case study research, a conference paper was created, accepted and presented at the 22nd Cambridge International Manufacturing Symposium, which took place on the 27–28 of September 2018, in Cambridge, United Kingdom.

Regarding the action research, several tools, analysis, and documents were created, many of which are currently being used by the start-up. Some examples of main outputs are an automatic production cost calculator, a production strategy layout or a partner's network, all of which will be useful for the start-up’s aspiractions. A conference article based on the academic findings of the action research is currently underway (an abstact was already submitted for approval at EurOMA, and is currently waiting approval).

On the Simulation Modeling, a 1st Place was achieved in a global operations and supply chain competition, out of more than 5.000 competitors from 89 countries, enabled by the application of the findings and insights gathered throughout this work.

Chapter 2

Literature Review

As it is widely known, defining the business strategy can sometimes be the "make-or-break" of a company. To solve that gap, over the years some studies have been made to better access how to help companies define their business strategies, and in order to develop tools to help operational managers steer the company in the right path.

However, due to their own rapid and volatile nature, start-ups are sometimes unable to use existing tools, creating a void of knowledge that may lead to bad strategy-making decisions.

In this section, existing frameworks for early strategy design will be analyzed, and an appropriate framework will be presented as the basis of the following work.

As a start-up differs from an established company, research about the challenges and phases of a start-up will also be presented, detailing the steps and obstacles that a start-up must overcome to succeed.

2.1 - Start-ups – Definition and Description

There has been some confusion over the years reading what exactly is a start-up. To this day, controversy exists regarding what companies count as start-ups, and exactly when (if ever) does a company stops being called a start-up to become an established company (Viswanathan, 2018)

While no official worldwide definition exists for what exactly makes a start-up, it appears to have been reached a consensus around the definition coined by Steve Blank, who stated that a start-up is a temporary organization in search of a scalable, repeatable, profitable business model (Blank et al., 2012). The type of organization can be financed by a variety of

instruments: venture capital, crowdfunding or just the founder's capital are some of the options usually chosen to kickstart the process.

It is believed that the term became popular in the world scene during the "dot.com" era, where many tech companies in the USA where founded, reaching a rapid growth in both customer base and evaluation, with most of them ceasing functions just after a few years (Ofek et al., 2003).

If a start-up does not cease to exist by bankruptcy, it is widely believed that it can also lose the title of start-up if it becomes a publicly traded in an IPO or becomes a non-independent entity via a merger or acquisition (Baporikar, 2015).

Some authors choose to define start-ups with regards to its goals and the environment it operates, especially with regards to innovation and uncertainty, seeing the start-up as a human institution designed to create a new product or service under conditions of extreme uncertainty (Ries, 2011).

Regarding the challenges and objectives that start-ups face, the literature often highlights the themes of innovation, uncertainty, fast growth and scalability as essential points that must be met in order for a company to be called a start-up.

However, a start-up is made of many more characteristics, some of with can be encountered in Table 1.

Table 1 - Recurrent themes in start-ups
(Giardino et al., 2014)

Theme	Description
Lack of resources	Economical, human, and physical resources are extremely limited.
Highly reactive	Start-ups can quickly react to changes in the underlying market, technologies, and product (compared to more established companies)
Innovation	Given the highly competitive ecosystem, start-ups need to focus and explore highly innovative segments of the market.
Uncertainty	Start-ups deal with a highly uncertain ecosystem under different perspectives: market, product features, competition, people and finance.
Rapidly evolving	Successful start-ups aim to grow and scale rapidly.
Time-pressure	The environment often forces start-ups to release fast and to work under constant pressure (terms sheets, demo days, investors' requests).
Third-party dependency	Due to lack of resources, to build their product, start-ups heavily rely on external solutions.

Small team	Start-ups start with a small number of individuals.
One product	Company's activities gravitate around one product/service only.
Low-experienced team	A good part of the development team is formed by people with less than five years of experience and often recently graduated students.
New company	The company has been recently created.
Full organization	Start-ups are usually founders-centric, and everyone in the company has significant responsibilities, with no need for high-management.
Highly risky	The failure rate of start-ups is exceptionally high.
Not self-sustained	Especially in the early stage, start-ups need external funding to sustain their activities (Venture Capitalist, Angel Investments, Personal Funds, among others).
Little working experience	The basis of organizational culture is not present initially.

By looking at the above themes, one question may arise: if the lack of resources is a recurrent theme in start-ups then internet giants like Uber and Airbnb should no longer be considered start-ups because of their vast wealth and resources: even though in reality, they are usually referred by the public as such.

In fact, the differentiator that turns a start-up into an established company seems to be more correlated with growth than with resources (Graham, 2012).

For the purpose of this work, and having in regard the type of start-ups that we are going to analyze in this document (mainly characterized by growth and tech-related topics), the considered definition will be the one coined by the U.S. Small Business Association. Said definition states that in the world of business, the word "start-up" goes beyond a company just getting off the ground, being also associated with a business that is typically technology-oriented and has high growth potential (Janáková, 2015).

2.2 - Start-ups Challenges and Phases

As we stated before, start-ups are quite fragile and face enormous challenges in order to succeed, being susceptible to failure in many points of the way.

Their innovative nature and exponential growth make them face more significant challenges than other companies, and sometimes the code of rules and good practices that applies to other companies does not apply to start-ups. A good analogy would be trying to safely drive a car at 200 km/h trying to use advices from the book one studies in order to get a driving

permit. It will not only be impossible to follow, as even trying to follow said rules might lead to a more significant risk of having an accident.

In order to thrive start-ups must find and follow their set of rules, specially made for them and their business. To address this knowledge gap, many communities, hubs, and incubators of start-ups were created in the recent year, refiling on mutual help and mentoring as a means of avoiding failure. One Portuguese example of these type of community is the "Founders Founders", a Porto based incubator aiming to provide a good space and culture for start-ups to grow on, with the following set of rules (taken from the official website):

- Grow by learning, from founders with diverse business experiences and life stories, helping you grow safer, faster and stronger.
- Learn by Sharing, challenges, solutions and your network, giving and taking, empowering you and the community with knowledge.
- Share by Living, with a like-minded community at your company's doorstep, when you need it, when it's time. All the time.

All around the world these communities try to increase the change of survival for start-ups by letting their founders know of the main obstacles in each stage of the start-up. However, what exactly are the most common risks and phases for a start-up, and which milestones must it reach to surpass them?

The literature presents a model with four phases for the life of a start-up: discover, commit, organize and grow (Joglekar et al., 2013), as seen in Figure 4.

The discover phase is the initial step when the founder must recognize that opportunity, the problem in the market that requires an innovative solution.

The commitment phase is when the founder starts to allocate resources (human, financial and others) in order to feed the new venture that was just formed.

The organizing phase is a requirements assessment step where the future and present necessities are listed, verified and organized in order to reach the goals fixed, and enabling the opportunity to grow the new venture into a successful business able to release a viable product.

The growth phase is the final step of this process, a final part when the proof of concept of the product was successful, and now a new challenge arises from them: it must grow in order to survive.

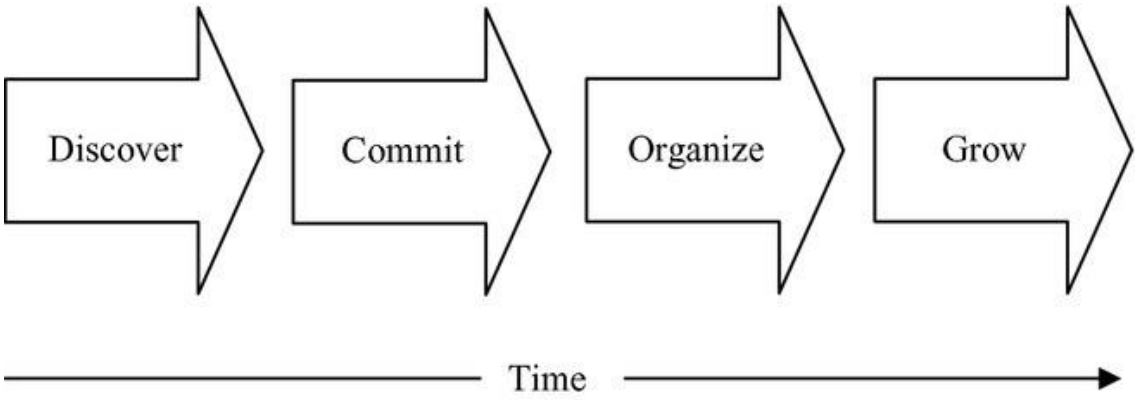

Figure 4 – Stages of a startup life
(Joglekar et al., 2013)

However, even considering that from stage 1 to stage 4 of the company there is a constant risk of failure, the probability of said risk is not constant. Indeed, literature has identified two moments when a company is much more likely to fail (and when in fact the vast majority of them do fail).

Those moments, generally divided into two single stages, represent obstacles in every the daily life of every start-up and are referred to in the literature as "Valleys of death" (Figure 5).

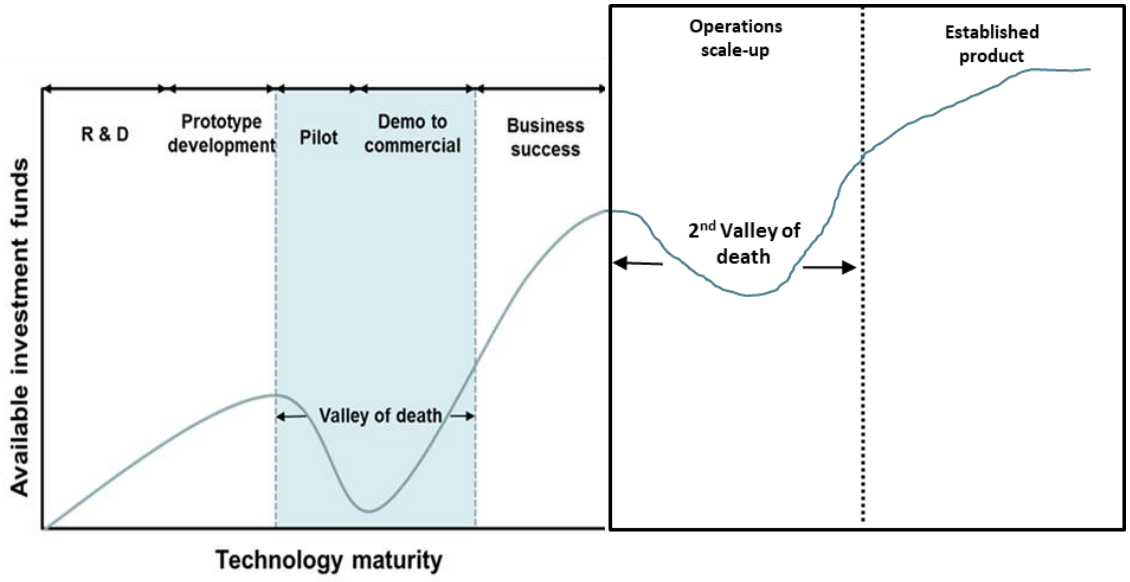

Figure 5 - The two "Valleys of Death"
(Tedim et al.,2015)

In the case of the first valley, it usually happens around the transition from “Commit” to “Organize” and can be defined as the between the technical invention or market recognition of an idea and the efforts to commercialize it (Markham, 2002). Usually, in this case, the problem was a misidentification or a failure to identify the target market for the product, or in an alternative, the correct way to solve a customer pain.

Being able to meet with costumers’ demands correctly is important as it increases the evaluation of the company and enables investments coming into the company. The literature gives much importance to this valley, as 30% of start-ups do not pass this stage (with the number increasing to 90% in they cannot get the appropriate funding (Gompers and Lerner, 2002).

Companies in this stage should look out for the warning signs: lack of structure, resources, and expertise to bring the technology from lab to the market will lead to death in this first obstacle (Lévesque et al., 2012; Markham, 2002)

On the other hand, once passed that stage the company is not yet free from danger: there is the second valley of death.

Later, when the start-up already had its proof of concept, the company must generate sufficient funds and bring enough sources into the company to grow and to keep up with growth. Sometimes problems happen: maybe the company is burning money so much faster than it can attract (in the form of revenue or investment capital), or maybe it cannot attract enough talent to keep innovating and gets left obsolete. Either way, all these reasons can lead to failure, sometimes brings great losses to all stakeholders.

In resume, in this stage companies should be on the lookout for bad practices that will lead to failure: they should dedicate efforts to assure needed levels of resources and capabilities are incorporated into to company to meet market needs (Vohora et al., 2004; Sutton and Rao, 2014)

In fact, research data stats that around 80% of financed start-ups fail, and that number rises to 95% if they run out of capital or forecast their investment needs in an inaccurate way (Ghosh, 2012). All this makes highlights the importance of a correct design of operations, fundamental to be a part of the 20% of already financed start-ups that manage to pass through the 2nd valley of death (Lévesque et al., 2012),

So, start-ups must overcome two major challenges in order to become an established player in the market: They need to successfully make a commercial proof of concept (1st valley of death), and then they need to scale-up their operations: the usual get big or die trying (2nd valley of death).

Difficulties in product commercialization evidence the need to create flexible and robust operation strategies in order to scale-up operations and ensure firm survival (Lévesque et al., 2012), and that is why in this study we will focus more on the challenges of company's that already proved their concept but struggle to grow: the 2nd valley of death (Figure 6).

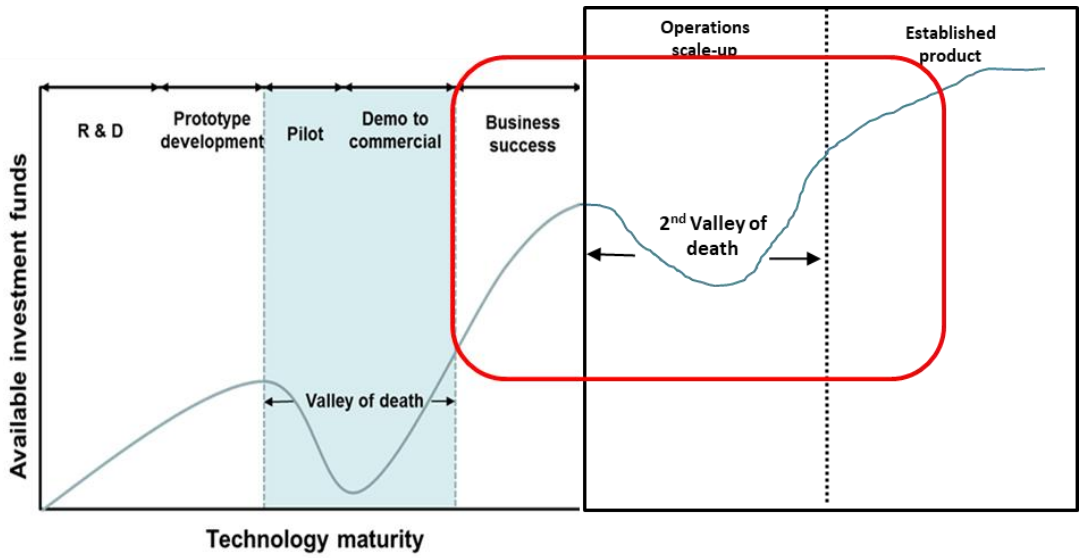

Figure 6 – Focus of the study - 2nd Valley of Death challenges (Tedim et al.,2015)

2.3 - Frameworks as Strategy Design Tools for Businesses

Taking the official Cambridge dictionary definition, a framework is a supporting structure around which something can be built (Dictionary, 2017). So, in this context, a framework should be something that helps a start-up create its strategy by providing some kind of structure or guidelines it can lean on to avoid making mistakes.

With regards to established companies, the literature already presents two different frameworks to guide managers in the decisions towards new product introduction. First, the technology – product – market (TPM) framework from the entrepreneurship literature aims at helping managers establishing the logical links between technical capabilities and enduring customer needs using the product attributes (Markham, 2002; Markham and Kingon, 2004). Still, once in the market, start-ups need to develop the capabilities rapidly to create and scale their resources, routines, and reputation (3R's) (Joglekar and Lévesque, 2013). Therefore, a second framework from the field of operations management, that aims at helping managers to align the design of product, process, and supply chains (three-dimensional concurrent engineering, 3DCE), could, in fact, be of help to address this challenge (Fine, 1998). However, individually, these frameworks fail to address comprehensively the fundamental needs of start-ups: while 3DCE helps design the product and process to meet future supply chain opportunities and threats, it lacks guidelines regarding the interplay between market characteristics and operational decisions. On the other hand, while TPM can take a particular technology and assist

in finding different products and market needs for that technology, it lacks on helping start-ups make strategic operations decisions based on their product and market.

The already stated fact that around 80% of already financed start-ups fail (Ghosh, 2012) opens the need for a more integrative framework, which can connect the product and market concerns while at the same time regard supply chain as a strategic enabler for the company scale-up.

An example of such is the Product-Market-Supply Chain Framework (P-M-SC) (Tedim et al., 2015), aimed to explore how start-ups integrate product, market, and supply chain decisions to build-up market entry capabilities. In fact, the P-M-SC framework mainly seeks to help companies overcome the challenges after having their proof-of-concept validated, and commercial interest tested. At that point, most start-ups need to scale-up their operations, attract more investment to answer market needs and become an established company in order to assure firm survival (Vohora et al., 2004).

Due to the integrative and innovate character of this framework, it was selected to be the framework used throughout this document as means of obtaining useful insights into start-ups strategy definition. The theoretical base of this framework will be detailed further in the next section.

2.4 - P-M-SC - A Special Type of Framework for a Special Type of Business

In this fast-paced world, every company faces great challenges derived from the ever-changing needs of the customers and the alterations to the commercial and social environment itself. However, in the case of start-ups, this is even more severe, as dealing with the changes of the outside environment very often means that start-ups also must change their internal operations (Kickul, 2011; Vohora et al., 2004).

In the first few months or years of a start-up, as it still thrives to understand and test its business model, there is a great need of a list of “good practices” and strategies to find out analytically the best decisions to take and how to measure their success (Joglekar and Lévesque. 2013). This is even more evident in the technological sector, in which very often a consumer market or business model appears out of thin air by a technological breakthrough of scientific discovery (Markman et al., 2005).

Previous literature has tried to understand how start-ups behave, how their environment works and why they are different from established companies (Vohora et al., 2004). In the case of technological start-ups, some of this initial literature focuses mainly on the challenge of finding existing consumer needs that may be addressed by technological advances (thus

creating a market), and in the subsequence process of creating and developing a product based in that technology, that can adequately fill the needs of that specific market (Markham, 2002).

The Technology – Product – Market framework or TPM (Markham, 2002), characterized in Figure 7, addresses this problem by guiding managers in the process of discovering products that can be based on a certain technology and consumer needs (markets) that may be filled by those products (as seeing in the figure below).

By identifying and analyzing the right market for a specific product, a further specification for the product attributes is expected to arise. In the case that those attributes are impossible to achieve with the current research, they will undoubtedly guide the technology development in the path of unveiling those lacking characteristics.

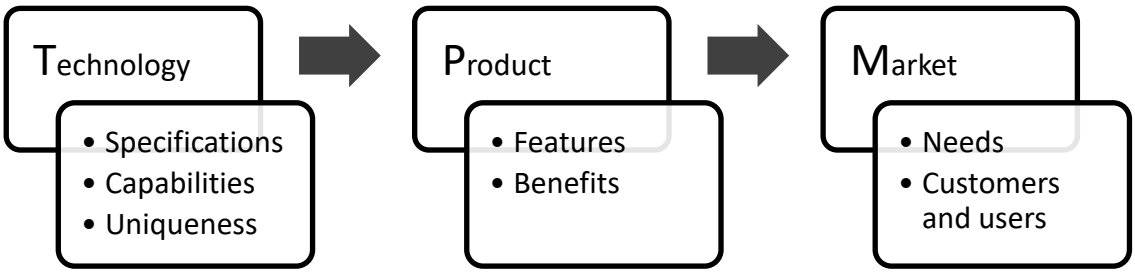

Figure 7 - Technology – Product – Market framework
(Markham, 2002)

The Product - Process - Supply Chain framework (or three-dimensional concurrent engineering, 3DCE) on the other hand, aims at helping managers to integrate their product and process development process with the design of the supply chain network and configuration (Fine, 1998; Marsillac and Roh, 2014). By integrating supply chain design with product and process design, companies can speed up their new product introduction process and avoid future setbacks (Figure 8).

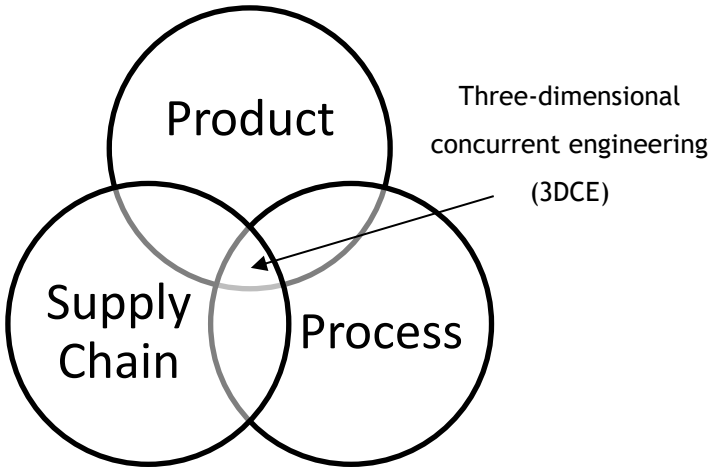

Figure 8 - Product – Process – Supply Chain framework
(Fine, 2006)

Start-ups in the growth or scale-up phase (Joglekar and Lévesque, 2013) have their focus no longer in the technology development, but in acquiring resources and continuously re-configuring them along their market discovery process (Vohora et al., 2004). Furthermore, typically start-ups focus on their core competencies related to product and market and build up strategic partnerships with suppliers to whom they subcontract the manufacturing processes (Barros and Claro, 2012; Tedim et al., 2015). Therefore, it seems adequate to consider the Product – Market - Supply Chain framework to assist start-ups in their decisions during the scale-up phase (Figure 9).

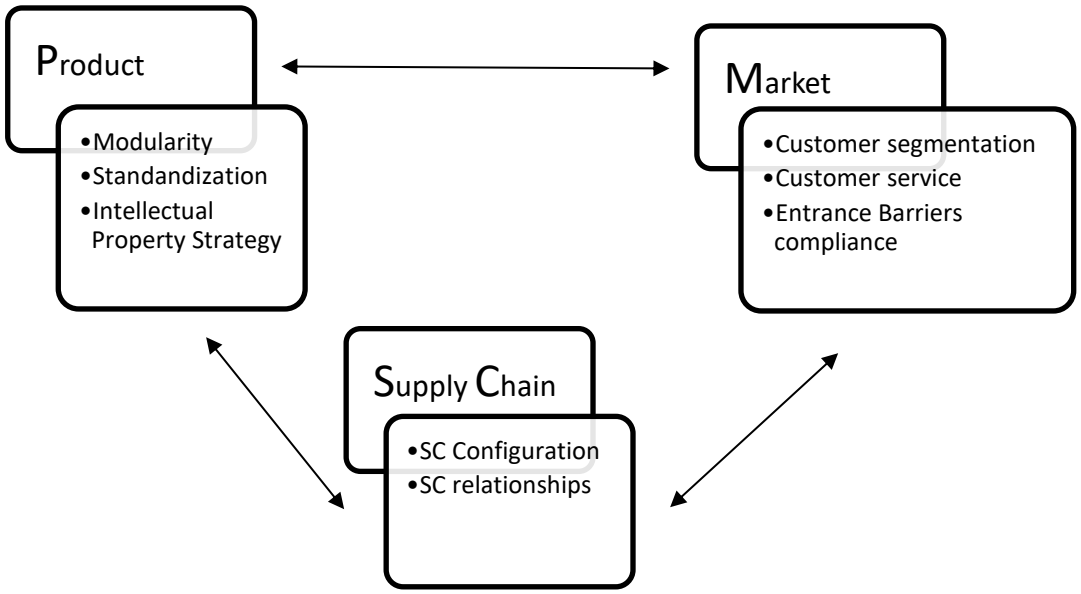

Figure 9 - Product – Market – Supply Chain framework

The Product – Market - Supply Chain framework helps start-ups integrating the following decisions:

Product decisions:

- Modularity: How may we design a product in modules of components that reduce product development time (thus keeping costs down), increase time to market, reduce the overall complexity and reduce the dependence from suppliers? (Droge et al., 2012; Khan et al., 2012; Marsillac and Roh, 2014; Park et al., 2009)
- Standardization: Did we use as much as possible standard components in order to reduce product complexity, lower supplier lead times, and minimize the risk of stock disruptions? (Ulrich and Eppinger, 2000; Khan et al., 2012)
- Intellectual Property Strategy: Do we have an IP strategy to protect our innovation from replication by others? (Pitkethly, 2001; Reitzig, 2004)

Market decisions:

- Customer segmentation: How did we segmented and prioritized the markets in order to reach each customer target better? How did the overall supply chain adapt to each specific segment requirements? (Osterwlader and Pigneur, 2010; Osterwalder et al., 2014)
- Customer service: Do we take advantage of possible revenue streams by offering the clients additional services after the sale? Are we creating established feedback loops so that we can notice product problems and user trends as fast as possible? (Osterwlader and Pigneur, 2010; Osterwalder et al., 2014)
- Entrance Barriers Compliance: Are we identifying the barriers and requisites needed for each market? Do we have a plan on how to surpass them? (Sweet and Maggio, 2015; Doruk and Soylemezoglu, 2014)

Supply Chain decisions:

- Supply chain configuration: Are we defining the right supply chain partners? Is subcontracting the production the best option, and if so, who has the responsibility for the detailed engineering? (Jafarian and Bashiri, 2014; Fine, 2006)

- Supply chain relationships: Do we need to maintain an inventory to meet customers' demands, and if we do, where should it be and to whom should it belong? Are we making the right agreements with our partners? (Lambert et al., 2004; Saccani and Perona, 2007)

Another way to view the advantage of using P-M-CH with regards to the other two frameworks can be phased as follows.

TPM tell us about a framework that helps entrepreneurs take technological breakthroughs and create viable commercial products, while at the same time matching existing real market consumer needs to the products they just created. By such, this iteration allows technology to be sometimes devolved and research with the pains of the consumers on the mind (which is essential to have a good product).

On the other hand, start-ups are not isolated from the rest of the environment: they need suppliers and clients to survive. And each partner has their own specific needs and goals that must be addressed when developing the product.

To help this matter, the 3DCE framework was created: Integrates product and process development with SC Design and configuration, hoping to speed up NPD introduction process

We have these two frameworks, but they are not ideal: the focus of this study is especially about start-ups in the growth phase, where the technology development is sometimes secondary, and the production process development is sometimes outsourced to a different company due to (due to being very capital intensive).

So, in order to survive a start-up needs partnerships with suppliers and subcontractors, and to acquire core competencies of product and market, making it more adequate to consider a product – market – supply chain framework to assist start-ups in this phase (figure 10).

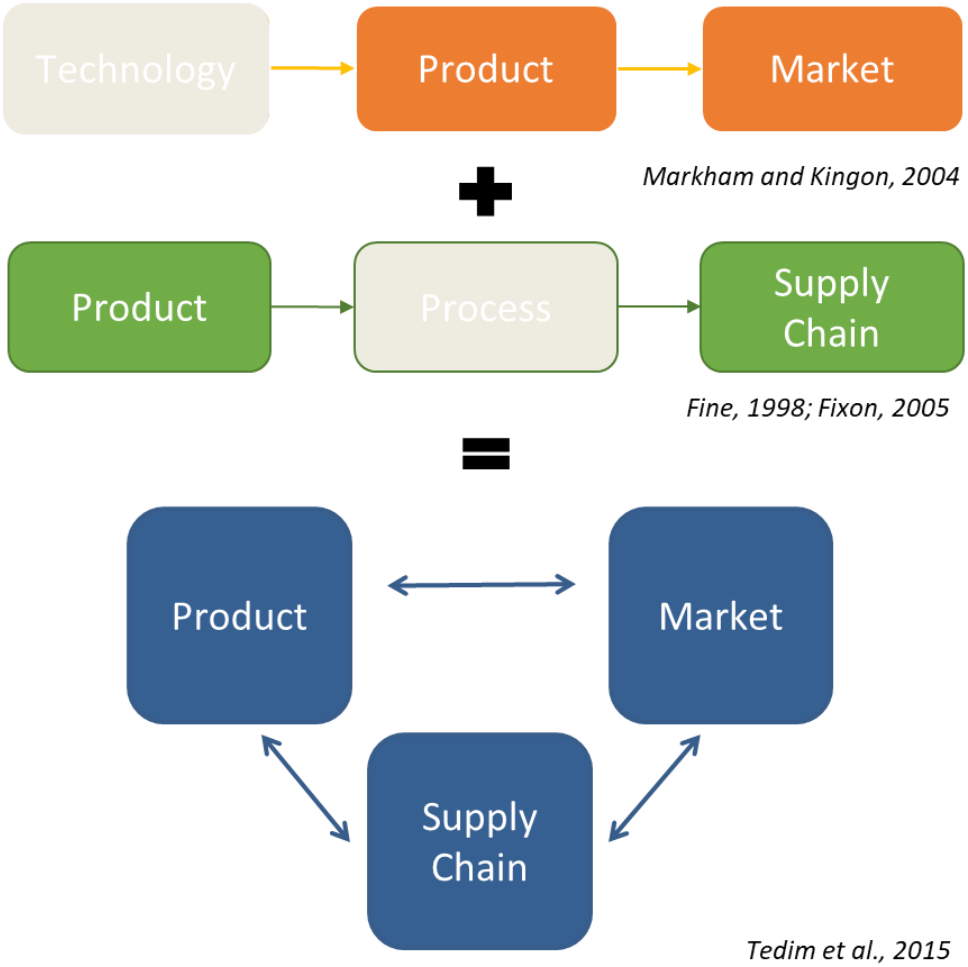

Figure 10 – Overview of the advantages of P-M-SC framework

Being an adequate tool for the purpose required, in Chapter 4 this said framework will be used as a basis for analysis of several interviews with start-ups, as part of the methodology of the case study research.

Chapter 3

Research Methods

This chapter describes the research methodologies used in order to develop tools and enablers of an efficient start-up strategy design.

Starting initially with case research, throughout the work many research methods were used first to develop insights about start-up strategy and then test their quality in real life using an action research approach, a process-based cost model approach and also simulation modeling. The next sections present these methods, which are then discussed separately in the next chapters.

3.1 - Case Research

The Product – Market - Supply Chain framework presented in the previous section was applied in exploratory case research (Yin, 2003; Voss et al., 2002) in order to understand how start-ups, integrate product, market, and supply chain decisions.

Given that the unique challenges of technological start-ups vary significantly based on their geographical location (namely funding, production and sales channels), this study considers Portuguese technological start-ups only.

Portugal is an adequate environment to study start-ups because it has been building a tech ecosystem and has today a large number of start-ups, incubators, and acceleration programs (Hinchliffe, 2018). As a matter of fact, the growth of the start-up ecosystem in Portugal is twice the European average, possibly due to favorable legislation regarding tax deductions, residency programs and other government incentives (Farmbrough, 2018; Ruivo, 2018)

3.1.1 - Unit of Analysis and Data Collection

The unit of analysis of the case research is the technology-based start-up and the data collection method used was structured interviews (N=7) with start-ups founders and C-level managers. Since the primary goal is to study how start-ups integrate different decisions to overcome the scale-up phase, the cases selected are companies that are at the scale-up phase or had already passed it (Table 2).

Table 2 - General data regarding the start-ups interviewed in the study

Case Study	Market	Interviewee position	Number of employees	Year of Foundation
A	Location Trackers	COO	10	2014
B	Medical Equipment	CTO	10	2012
C	Clinical Analysis	COO	8	2011
D	Gases Emission Reduction	CEO	15	2009
E	Wearables (medical)	CEO	15	2010
F	Wearables (medical)	COO	8	2007
G	Wearables (medical)	COO	19	2013

The following table presents the interview protocol used. Interviews took place between 2015 and 2016 and had a duration of approximately 40 minutes each. They were recorded, transcribed and coded in order to carry out the analysis in the light of the P-M-SC framework (as described in Table 3, Table 4 and Table 5).

Table 3 - Structured interview protocol for Product Design

Dimension	Questions	References
	Product Design	
Module Configuration Strategy	Do you make use of modular configuration in your products? Why? What are the advantages?	Droge et al., 2012;

	At which level do you use modular configuration? (system, subsystem)	Khan et al., 2012; Marsillac and Roh, 2014; Park et al., 2009; Ulrich and Eppinger, 2000; Khan, 2012; Pitkethly, 2001; Reitzig, 2004
	How did you surpass problems related with the modules compatibility?	
	How modular configuration have influence in your supply chain? In each way is this configuration of benefit for your customers?	
Standard vs Customized Components / Products	Do you use customized or standard components? Why?	
	Do you take into account the customer preferences even with standard components?	
	The customization of your product has affected your supply chain? Why? What are you doing to increase customer acceptance of your customized products?	
Strategic Management of IP	How did you protect the intellectual property of your product?	
	Why have you decided to protect your product?	
	How did you manage the IP rights with your partners?	

Table 4 - Structured interview protocol for Market

Dimension	Questions	References
	Market	
Customer Segment Definition	What are your customer segments? (geographic, jobs to be done)	Osterwlader and Pigneur, 2010; Osterwalder et al., 2014; Sweet and Maggio, 2015; Doruk and Soylemezoglu, 2014
	How did you prioritize them?	
	How has your customer segment influenced your supply chain? (suppliers and distribution channels)	
Customer Service	What are the services that your company provide to the customer after selling the product?	

	Are these services provided at a local or global level? How they influence the supply chain? How did you have feedback from your costumers regarding your after selling services?	
Entrance Barriers Compliance	What kind of barriers did you have to deal with and how did you surpass them?	

Table 5 - Structured interview protocol for Supply Chain

Dimension	Questions	References
	Supply Chain	
Supply Chain Configuration	What are your main supply chain partners? How did you find them? (suppliers, customers, service providers)	Jafarian and Bashiri, 2014;
	Do you subcontract the production? If yes, who has the responsibility of functional specification and detailed engineering?	Fine, 2006;
	What is the counterfeiting between your product IP and subcontracting?	Lambert et al., 2004;
Supply Chain Management	Do you maintain inventory? To whom does it belong to? Why?	Saccani and Perona, 2007
	How did you build partnerships?	
	What kind of contractual agreements do you have with your supply chain partners? (short, long-term, arm's length, strategic)	

3.1.2 - Data Analysis

The analysis of the raw data was performed in steps, by means of a two-phase analysis.

First, a within-case analysis was conducted, detailing the data gathered about each case, looking for insights into the main categories of product, market and supply chain decisions.

Later, a cross-case analysis was performed, aiming to make a comparison between the findings of all cases to find patterns, commonly used strategies and their respective contribution to build market-entry capabilities.

3.2 - Action Research

The use of case study for research for research purposes in business and management is widely spread and recognized as a methodology that can help train and understand processes and realities in a wide variety of circumstances.

To achieve it, one must gather information using all various means at the researcher's disposal. For example, the analysis of a particular process can require the use of observations that resulted from the researchers own experience, presence and – sometimes- even needing experience created of the researchers own intervention in the actual topic he was examining (Gummesson, E., 2000).

So, we are present with two different kinds of approaches: one being an observation approach (normally referred as the core of anthropology and ethnography), and the other an approach that requires an active intervention of the researcher in the own process that he is exploring, usually referred to as Action Science or by some, Action Research (Gummesson, E., 2000).

3.2.1 - Definitions

Action research is often referred to as the most demanding method of doing case study research and has various (sometimes conflicting) definitions. Some suggest that the term action science is the only correct term, as some action research works do not meet the specific requirements for being called scientific and are closer to consultancy (Argyris, C. et al., 1985). As no consensus exists literature appears to give researchers free will to choose from using either term – as and such, in this work the method will be referred to as Action Research.

Generally, action research can be defined as an approach in which the action researcher and an organization collaborate in the diagnosis of the problem and in the development of a solution based on the diagnosis (Bell, E. et al., 2018).

So, we can say that action research is a way of collaboration between the researcher and an organization in order to develop tools to solve a specific problem, in a social world constantly changing where both researcher and research are part of the change.

The purpose of this study is to help start-ups strategy design, and while a case study observation research can be useful to find insights, it could, in fact, be of interest to have a

way to test those insights in a real-world scenario. So, is action research appropriated in this case?

Action research is based on action, evaluation, and critical analysis and as such is normally applied to improve specific practices based on collected data, in order to introduce an improvement in relevant practices (Dudovskiy, J., 2011). It is normally adequate to be used in cases where there is interest in gaining in-depth knowledge about a problem (using quantitative or qualitative data), especially in cases when the desired output of the business research must be of practical relevance: as it is in this case, therefore proving its relevance for this present study.

3.2.2 - Characteristics and Goals

There is some division in the literature regarding action researches main topics and practices. Some authors claim that it can be divided into three categories: interpretive, critical and positivist (Dudovskiy, J., 2011).

Interpretive action research perceives business reality as socially constructed, focusing on organizational factors while conducting research. On the other hand, while critical action research usually uses a critical analysis approach towards business processes (aiming for improvements), it's in positivist action research (also known as classical action research) that action research is perceived as a way of testing hypothesis in the real world (Dudovskiy, J., 2011).

Other authors have different takes for the action research paradigm (Gummesson, E., 2000) states ten points to specify what he calls "management action science". Among others, he states that action research is specified for when the research assumes the roles of a changing agent of the processes they are studying and could even be applied if the researcher is an employee of the said organization. Another important take is that action science has dual goals: contribute to improve science but also to improve the organization it is using as a study vehicle to test a real-life hypothesis.

In the process of improving, action research is also responsible for understanding, planning, and implementation or change in business and can include all types of data gathering methods. Informal conversations, observation, and other qualitative methods are valid methods as an integrant part of action research methodologies.

The cycle suggested in the literature as a methodology for action research also advice that the research should be conducted in real time (gathering data and acting on it), to emphasize the recursive nature of the process (Figure 11)

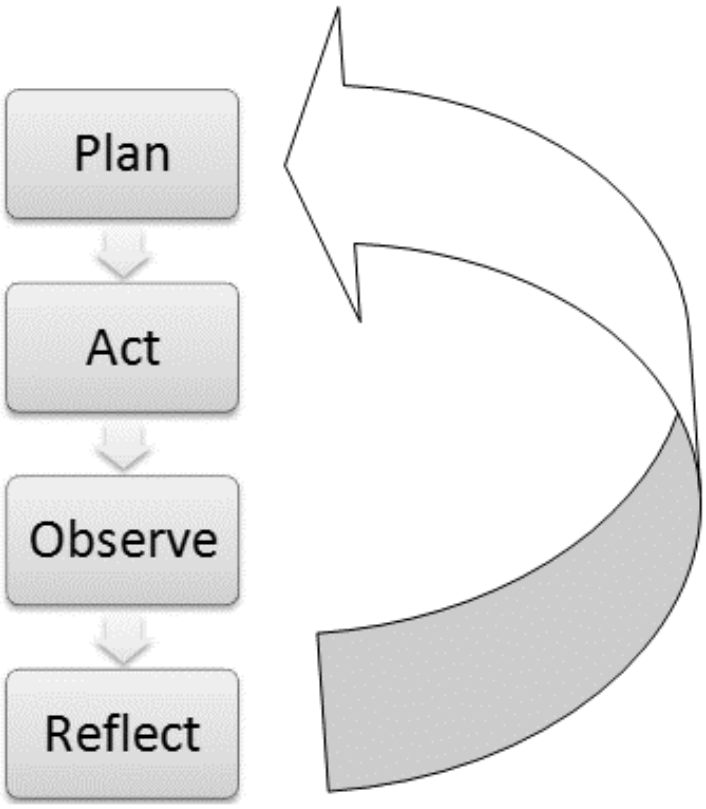

Figure 11 – The cyclical nature Action Research
(Dudovskiy, 2011)

3.2.3 - Unit of Analysis and Data Collection

Since the action research is interactive and must contribute to both science and an organization, there was a need for a vessel in which to be able to test the hypothesis for start-up strategy design. The unit of analysis was a biotechnology-based start-up, spinoff from a Portuguese-based R&D institute, who is aiming to launch new products into the global market and seeks to find a proper and efficient strategy to survive in the competitive safety and healthcare sector. In the following sections, it will be presented the organization and start-up in question with furthers detail.

As for the data collection, over the course of several months, various contacts were made with individuals and companies from all over the world, from various industry and business sectors, aiming to acquire enough knowledge about the business to be able to provide a proposition for the start-ups future strategy. Benchmark analysis of the existing global competitors of the start-up was also conducted, to hopefully provide insights regarding the path to take.

Apart from that, several industry fairs and meetings were also attended to acquired data from formal and informal meetings and interviews.

3.2.4 - Data Analysis

While there will not be for the most part formal sets of structured data (as most meeting will be informal), along the study the information and notes acquired will be analyzed in order to identify patterns and good practices, looking for emerging industry and innovation trends that can help make a specific proposal adequate and up-to-date with the sectors state of the art.

3.3 - Process-based Cost Modeling

As an additional mean of obtained feedback regarding the best strategy for a start-up, one could try to research the associated fixed and variable costs correlated to certain companies' strategies, either related to production, sales or other parts of the company.

If we can get an approximate estimation of the costs, we can evaluate the relative quality of the solution based on its cost and associated variables and can even compare to other existing solutions or companies as means of accessing the global quality of the defined strategy and its chances of surviving in a competitive market.

In this case, a methodology of process-based cost modeling was used to estimate various costs related to the desired path of a start-up.

Process-based cost modeling (PBCM) is an early stage cost estimation tool that has been used to project manufacturing or assembly costs based on part and process characteristics. While PBCM approaches have previously been used to answer research, questions related to manufacturing costs this method can be adapted to forecast engineering development costs and lead time as well (Johnson, M. D., et al., 2010).

3.3.1 - Unit of Analysis and Data Collection

The unit of analysis will be the start-up considered in the action research segment, with the focus of research being the production process of products the start-up is aiming to launch into the market.

As a means of collecting data for this research, several manufacturing and industrial fairs were attended (all of which will be explained with greater detail in later sections).

3.3.2 - Data Analysis

To construct this process-based cost models one must work backward, changing the variables that lead to the final costs and trying to correlate the effect of physical parameters on the cost-determinant parts of a process, while at the same time relating these parts to resource requirements (like materials or types of production) (Kirchain et al., 2001).

To reach the final indicators physical and statistical relations are be established between processes in order to reach an automatic computational and mathematical model that allows to output the price of each unit of product based on specific input variables (like quantity).

3.4 - Simulation Modeling

One of the great progress of our days is being able to plan and test outcomes in a virtual environment. Technics exist that remove the risk of enacting the outcome in the real world, by instead creating and analyzing a digitally modeled version of a real-world process without the risks associated with enacting it in real-life. To these replications, we generally call simulations.

A simulation is an analytical approximation developed to model some systems performance and measure the output for a given input. These developments are usually approximations that require simplification and assumptions but are however normally accurate enough to enable a test of conjunctures (Banks, J. et al., 2004).

In the business field of research, simulations have in the last decades become very popular not only among university and academy students but also among enterprises, eager to provide their employees of certain capabilities difficult to train in the day to day job. Nearly forty years have passed since the first know use of a business simulation game for teaching purposes however they seem to have flourished through the ages, with an increasing trend of more users and more different simulators (Faria, A. J., et al., 1996).

Business Simulations (often called business games) make an unavoidable solution for training Managers, because they allow theory to be applied into practice in a risk-free environment, and encourage team working in the process of decision-making. Such a simulation, using a software application as a processing tool, combined with the knowledge and skills of a trainer can boost the main features. Around 98 percent of all accredited universities in the United States are using business simulations (Schröder, H. P., et al., 2012).

The literature claims that simulation games are a suitable representation of reality, and in a way, as Managers, they experience in real life. This applies to the formulation of strategies, the analysis of different factors that influence the outcome as well as the improvement of analytical skills and team communication. (Brennan, R. et al., 2008).

With that in mind, simulation games can also be seen as a valid tool for research in terms of strategies to use in start-ups, as long as the specific simulation is tailored to the needs, challenges and obstacles or start-ups with regards to established companies. If said simulation game is to take place in a competitive environment, playing against other human players instead of against a machine/own simulator, an additional validation may arise directly correlated to the quality of the competitors in said simulation.

In this case, by using insights gathered regarding start-up strategy in a competitive real-life business game, those same strategies can be accessed for the quality and usefulness. Ideally, in a competitive business game with enough skilled real-world human participants, more insights can be gathered about which strategies work (and which don't) for start-ups.

3.4.1 - Unit of Analysis and Data Collection

There are a vast range and offer of business simulations in the market, with different targets and uses. However, in most cases the software behind said simulations is proprietary and use it as a tool of validation may sometimes come with a high economic cost.

For this reason, it was chosen as the basis for this research the use of a global simulation competition. This simulation is open to all University Students around the world and using a business game simulator it allows participants to steer the fate of an automotive start-up from day one.

The insights previously gathered in the present document will be used as a basis to make business decisions (for the simulation), and the output will be accessed according to the classification ranking with regards to the other simulation participants.

3.4.2 – Data Analysis

The chosen simulation takes place around several months (in real-life time) and several years (in simulation time) and is divided into different rounds. Each round corresponds to the beginning of new parameters and different real-life competitors, and within each round, several decisions are taken with hopes of achieving good results with respect to the competition.

As the rounds go by and the results are received notes about the outcomes and ranking will be used as feedback loops for the following rounds and decisions.

In the end, a compilation of gathered insights will be used together with insights acquired from all various sources in order to provide an integrative and complete recommendations benchmark to enable start-ups to steer their fates and design their strategies in the first times of their existences.

Chapter 4

Product, Market and Supply Chain Strategic Decisions in Start-ups: A Multi-Case Study

In this section the raw data acquired by contacting with real-world start-ups will be transformed into useful information, analyzing in the hopes of finding some patterns and providing useful insights.

The analysis will be breakdown into two parts: one dedicated to summarizing and study the insights provided in each case/category by each company, and the other will try to compile the results of all companies in patterns or useful trends.

In the end, the main conclusions of the case study research will be presented so they can be used in the following sections as a means of help to design start-ups strategy.

4.1 - Within-case Analysis

With the data gathered a within-case analysis was conducted to each individual start-up interviewed. Using this method, it is aimed to shed some light on the types of strategies that start-ups pursue in order to succeed (as described in Table 6, Table 7 and Table 8).

4.1.1 - Product Design

Table 6 – Results for Product Design

Code	Module Configuration Strategy	Standard Vs. Customized Components/Products	Strategic Management of IP
A	No module configuration	Standard to reduce complexity, but clients can choose basic features (e.g., colors)	Patent pending, to create value for investors. Partners have no access to confidential details.
B	No module configuration (abandoned due to compatibility issues between suppliers).	Standard, clients can't choose any feature	Blackbox product implementation. Partners have no access to confidential details but sign Non-Disclosure Agreement (NDA).
C	No module configuration	Customized for the critical component, standard for the rest, features can't be chosen by clients, but we previously determined based on extensive market research	Patent pending, to avoid replication. Partners have access to confidential details and sign NDA.
D	No module configuration (in the process of implementing)	Standard (for low minimum quantities) and customized (higher delivery dates), clients can choose basic features (e.g., visual finishing of the product)	Patent pending, to avoid replication and to create value for investors. Partners have access to bits of confidential details, don't sign any NDA
E	Uses module configuration (to be able to choose from a bigger pool of suppliers at lower prices). Had some problems with managing the delivery dates for different suppliers	Customized for the critical component, standard for the rest, clients can choose from three different types of models	Patent pending, to create value for investors. Partners don't sign any NDA
F	Uses modular configuration (since the beginning the product was design to be an integration of existing modules)	Standard, clients can choose some basic features	No patent. Partners have access to confidential details but sign NDA.
G	No general modular configuration (just the power plug can be sourced as a module)	Only customized components (standard do not fit the need), clients can't choose any feature (because of minimum quantities orders)	Patent pending, to create value for investors and avoid replication. Partners do not have access to confidential details but sign NDA.

4.1.2 – Market

Table 7 – Results for Market

Code	Customer Segment Definition	Customer Service	Entrance Barriers
A	USA, Canada, Asia, and Europe. Preference for big uniform markets (same regulations).	No after sales service. Feedback on the customer obtained automatically by built-in hardware	Certification, educate and recruit distributors, obtain funding for hardware
B	World (no geographic segment) as suppliers dictate most product design chooses	Aftersales service. No feedback loop implemented.	Prove the concept to investors, educate users, find suppliers for small/flexible production batches
C	USA and Europe. Preference for early adopter markets	Aftersales service. Feedback on the customer by a post-sales inquiry	Educate users, finding early adopters in Europe
D	Brazil, Malaysia, Europe, USA. Preference for markets with incoming or recent regulations change	No after sales service (product requires no maintenance and has a long life). Feedback on the customer by a post-sales inquiry	Educate users, some markets require same-country manufacture of goods (difficulty in maintaining production quality overseas)
E	Netherlands, Portugal. Preference for small and compact markets, where they may become market leaders, which would serve as a model for other markets.	Aftersales service. No feedback loop implemented.	Educate users, surpass existing alternatives
F	Africa and Brazil.	After sales service for consumables sales. Possible to integrate/ upsell more products that integrate with the first one.	Educate users, finding the right partners
G	USA, China, and Europe. Preference for early adopters' markets and high potential markets.	The product itself is structured as a service with a periodic fee. Feedback loop implemented built-in the software.	Certification, local laws that force companies to produce in the same country as the sales, find the right partners

4.1.3 - Supply Chain

Table 8 – Results for Supply Chain

Code	SC Configuration	Supply Chain Management
A	Production is subcontracted. Main partners: assembly and critical components supplier.	No inventory. Discovered partners based on company members previous experience, made a strategic agreement with main partners and arm's length with the rest.
B	Production is subcontracted (for cost and time savings). Main partner: Supplier of the finished product (does detailed engineering, produces and delivers packaged).	No Inventory. Discovered partners in industry fairs, made a strategic agreement with the main partner and arm's length with the rest.
C	Production in-house (currently testing alternatives). Main partners: critical component supplier and academia (for scientific knowledge)	No inventory. Discovered partners based on company members previous experience and company market recognition, made a strategic agreement with the main partners and arm's length with the rest.
D	Production is subcontracted. Main partners: local manufacturing suppliers (in each country)	No inventory. Prefers partners with an engineering team to help with the design. Makes long-term partnerships with manufacturers (to avoid IP infringement).
E	Production is subcontracted. Main partners: Distributer in the Netherlands (in the past a worker paid by the company was even placed there with the sole purpose of product introduction)	Inventory inside the company headquarters. Made a strategic agreement with the main partner and arm's length with the rest.
F	Production is subcontracted. Main partners: integration/assembly supplier.	Inventory inside the company headquarters. Discovered partners based on geographical proximity and company market recognition. Made strategic agreements with the main partner and arm's length with the rest.
G	Production is subcontracted. Main partners: critical components, packing, and local distributor.	Component inventory in the packing partners, belonging to the company. Discovered partners based on company market recognition.

4.2 - Within-case Matrix

While further analysis and comparison will take place in the cross-case analysis section, in this section some early considerations were obtained just out of an early inspection of the data that was then translated into a visual format for easier analysis.

4.2.1 - Product Design

Regarding product design, we can see that there is no clear tendency in module configuration. As for components and products, most use a mix of both: customized for critical components and standard for the rest. In strategic management of IP, its clear companies see value in IP. They use at least one of the two strategies: Patent and Signature of a non-disclosure agreement (Figure 12).

Case Study	Module Configuration Strategy	Components and Products		Strategic Management of IP	
		Standard	Customized	Patent	Partners sign NDA
A	✗	✓	✓ (basic features)	✓	✗
B	✗	✓	✗	✗	✓
C	✗	✓	✓ (critical components)	✓	✓
D	✗ (in implementation)	✓	✓	✓	✓
E	✓	✓	✓ (critical components)	✓	✓
F	✓	✓	✗	✗	✓
G	✗	✗	✓	✓	✓

Figure 12 – Matrix of Product design results

4.2.2 - Market

Regarding the market, we can immediately see that most companies define a segment. In the customer service, not all companies have after-sale services, and some don't have feedback loops. Also, as for the barriers that can happen, it's mostly with regards to educating users, certification and finding the right partners (Figure 13).

Case Study	Customer Segment	Customer Service		Entrance Barriers		
	Geographical	After-sale service	Feedback Loop	Educate Users	Certification	Finding right partners
A	USA, Canada, Asia and Europe	✗	Hardware built-in Feedback	✗	✓	✓
B	----------	✓	✗	✓	✗	✓
C	USA and Europe	✓	Post-sales inquiry	✓	✗	✗
D	Brazil, Malaysia, Europe, USA	✗	Post-sales inquiry	✓	✗	✓
E	Netherlands, Portugal	✓	✗	✓	✗	✗
F	Africa and Brazil	✓	✗	✓	✗	✓
G	USA, China and Europe	✓	Hardware built-in Feedback	✗	✓	✓

Figure 13 – Matrix of Market results

4.2.3 – Supply chain

Finally, in the Supply chain (SC) case, in SC configuration we can see that production is almost always subcontracted, but main partners differ greatly. In the SC management, some companies choose to keep inventory (while others don't), together with specific insights about ways to discover partners (Figure 14).

Case Study	SC Configuration		Supply Chain Management	
	Production Subcontracted	Main Partners	Inventory	Discovering partners
A	✓	Assembly and Critical components Supplier	✗	Members previous experiences
B	✓	Manufacturing	✗	Industry Fairs
C	✗ (testing alternatives)	Critical components supplier	✗	Members previous experiences and brand recognition
D	✓	Manufacturing	✗	Brand recognition
E	✓	Distributors	✓ (testing alternatives)	Members previous experiences
F	✓	Assembly	✓	Geographical proximity and brand recognition
G	✓	Critical components supplier and Distributor	✓	Brand recognition

Figure 14 – Matrix of Supply Chain results

4.3 - Cross-case Analysis

This chapter presents the results obtained from the cross-case analysis. The discussion is aligned with the strategy outlined in the previous chapter, i.e., examine the operations strategy choices and capture strategies regarding product, market and supply chain decisions. The results of the cases will be critically discussed within the methodology and framework proposed and presented above.

4.3.1 - Product Design

Module Configuration Strategy

Clearly, not all companies used modular configuration, a feature that can lead when used correctly, to product complexity reduction and the possibility to implement late customization thus increasing flexibility (Fixon, 2005). In some cases, companies reported being in the process of modularization, which indicates that start-ups in the scale-up phase are still evolving their product design to be integrated with supply chain design.

Standard vs. Customized Components / Products

The use of standard components may be cheaper due to access to a larger pool of suppliers, require smaller MOQ (minimum order quantities) and reduce supply chain risk due to the higher availability of parts in the market. Still, by using customization start-ups may differentiate from competitors, thus reaching to a larger range of potential markets and clients (sometimes at the cost of supply chain changes). While most cases used standard components (especially for non-critical parts), most companies took inputs from clients regarding their preferences even with standard components, offering some basic choices such as color or product appearance. The critical components were sometimes customized out of necessity, as standard did not meet their product design needs.

Strategic Management of IP

In the information age, knowledge travels fast and is more accessible than ever before, which causes industrial secrets to be more at risk if left unprotected. To address this issue, all companies had specific measures intended to avoid unwanted replication from existent or new competitors. To protect their property, companies often recur to patents to create a threat of litigation and black box design to keep confidentiality with certain product treats. Aside from competitors, measures were also taken with partners, avoiding to disclosure key product aspects (sometimes only integrating patent protected parts in-house), and complementing this practice with the signing of NDA's.

4.3.2 - Market

Customer Segment Definition

A start-up is per definition an entity with limited initial resources and thus must choose well where to apply their initial efforts and funds to obtain maximum return on investment. A correct definition of customer segments and subsequent prioritization can greatly influence a start-up fate. In the majority of cases, companies choose early adopting markets, preferring compact homogenous markets for their initial efforts over sparse ones (for easier market penetration). In one case a company chose a smaller market to serve as a test model for others: gaining the majority of market share and hoping their recently earned brand recognition can spread to other countries with less effort.

Customer Service

While services associated with the sold products consist of a significant part of an established company revenue stream, it can be hard for a start-up to have the maturity and

means to provide such services. Still, some of the case companies offered customer after sales services (even using them to sell consumables or upsell other products). However, the majority of companies realized the importance of accessing customer feedback and established tools to retrieve feedback from customers (built either in the hardware and software or by the traditional quality and satisfaction inquiries).

Entrance Barriers Compliance

Launching a new product is never easy, as there are several obstacles that new ventures must surpass in order to enter the desired market. The most frequent barriers are certainly related to the need to educate users about the need and features of the new product, as it sometimes competes in the market with well-established alternatives. Other well-known issue regards obtaining the required certification for operating in some markets, finding the right partners (either supplier, distributors or even investors) and in some cases the protectionist's policies that require companies to produce the goods in the same market where they are sold.

4.3.3 - Supply Chain

Supply Chain Configuration

As a new company proves its concept, it must quickly grow if it wants to survive. To do that, it usually chooses to find partners it can trust: either for production or distribution. As the funding is limited, the production is in most cases subcontracted (for money and time savings). Therefore, start-ups main partners are usually related to production: either an assembly/integration supplier or a supplier of critical components. In one case the company depended heavily from their distributor for almost their entire growth strategy to work, while in another case it was the academia/universities the biggest partners, bringing scientific knowledge and innovation to the start-up.

Supply Chain Management

One of the important decision's start-ups must take is about the type of relationship they should have with their partners, regarding how they choose and find partners, and also relative to other operational aspects such as inventory ownership of components and final goods. Some companies choose to keep inventory (mostly in-house but sometimes in the supplier), with the ownership being always of the company. The decision of partners' selection was in most case companies influenced by the previous experiences of company members, and also by the partner brand and quality recognition on that specific market. With their main partners, start-ups usually established strategic relationships (with a focus on

reliability and quality), while with the other suppliers they establish mostly an arms-length relationship.

4.4 - Main insights and conclusions

The idea that introducing new products in the market is of vital importance for a company is nothing new and has indeed been referred to many times in the literature (Kickul et al., 2011). The process that leads to entering the market is known to be of great importance and can sometimes make or break the future of the company. However, the majority of the research that was conducted in the past had its focus in companies that already had a presence in the market before the new product introduction. Only in this last decade did the research started to be more adapted to the specific reality and problems that affect new ventures like start-ups (Joglekar and Lévesque, 2013).

The objective of this case study research was to come up with a list of perceptions about the start-up reality, its problems, challenges, and opportunities so to contribute to the advancement of knowledge in this topic and come up with strategies to ensure that more start-ups survive past the valleys of death and into the growth phase.

The main takeaways for this study will be presented so they can be used for real-world strategy definition (see Table 9, Table 10 and Table 11).

Table 9 – Main insights regarding Product design

Dimensions		Opportunities	Threats
Module Configuration Strategy		Product complexity reduction	Compatibility issues between modules
		Possibility for late customization	Problems managing delivery dates for each module
Components and Products	Standard	Increased flexibility	Limited range of selectable features
		Bigger pool of suppliers	
		Reduces complexity	
		Low minimum quantities	Must be determined based on previous market research
	Customized	Differentiation from competitors	Bigger minimum quantities
		More options to choose	Higher delivery dates
Strategic Management of IP	Patent	Value for investors	May be expensive for all markets/products
		Avoid replication	
	NDA with partners	Avoids unwanted disclosure of information	Some partners refuse to sign
			May not avoid competitor's replication

Table 10 – Main Insights regarding market

Dimensions		Opportunities	Threats
Customer Segment Definition		Big and uniform markets (for expansion)	Slow adopters / conservative markets
		Small and compact markets (to be leaders, serve as a model)	Markets very regulated, with little change for a long time (no opportunities)
		E.g., USA, Canada, Europe	
Customer Service	After sales service	Potentiate sales of consumables	Fixed and variable costs
		Upsell more products	
	Feedback loop	Low cost to implement (may be automatic)	Difficulty of implementation
		Built-in hardware or post-sales inquiry	
Entrance Barriers Compliance			Need to educate users Against well-established alternatives
			Obtain the required certification for each segment and market
			Finding the right partners Supplier, distributor or investor

Table 11 – Main Insights about supply chain

Dimensions		Opportunities	Threats
Supply Chain Management	Production subcontracted	Limited funding investment	Less flexibility
		Time-saving	Fewer production choices
	Main Partners	Assemblers for production	Risk of heavy dependency from a partner to be accessed
		Academia for knowledge	
Supply Chain Configuration	Inventory	Agility of response	Increased costs (the company owns the stock)
		Can be in-house, in the assembler or in the distributor	
	Discovering partners	Members previous experiences	Avoid low quality, unknown and unreliable partners
		Brand recognition	

Chapter 5

Development of a Start-up Strategy Using Action Research and Process-Based Cost Modeling

In this section, the action research conducted will be presented. The background of the start-up will be detailed, together with its challenges, objectives, obstacles, strategies for success and recommendations for the future.

A Process-based cost modeling will also be presented as a means of comparing the effectiveness and quality of the solution regarding the current competitor's costs found through an extensive benchmark analysis.

5.1 – Phases of Action Research

Action research is a generic term, which covers many forms of action-orientated research. The outcomes of action research are both an action and research based-knowledge, contrary to traditional science which only aims to create knowledge (Karlsson, C., 2010).

In fact, action science does indeed aim to solve the practical problems of organizations, while also contributing to meet research or scientific goals. So, in this case, it was appropriate to consider action research to help understand good practices in start-up strategy using a real-life scenario, as by doing it we would not only be increasing scientific knowledge but also, hopefully, helping a specific organization thrive and succeed.

So, after choosing to use this approach, the first step would be to design the action research project. About that, the literature shows some usual phases, that usually help implement the project later on.

The first step is usually framing the issue to be studied. In this case, the issue to be studied was already widely presented in previous sections and is related to a gap of knowledge in the literature about the actions to be taken for start-ups strategy design in order to improve their chances of survival, especially regarding product, market, and supply chain decisions.

Next, the scope of the study must be defined, and more than that, it must be defined who will select the boundaries of the scope of the project, who will provide access and who will be involved (Karlsson, C., 2010). In this case, the scope of the project was defined by the company itself (more details about the start-up in the following sections), and while the main tasks of the project should be done by the researcher a constant loop of feedback was to be implemented between the start-up team and the researcher.

By this moment, it is also important to define how the access to the organization is going to take place, with literature providing two types of access: primary for the ability to get into the organization itself and perform the search from inside, and secondary where only is granted access to certain areas within the organization (and only certain levels of information) (Karlsson, C., 2010). In this case, the access was gained through the research done during the present master's thesis, with the access granted being mostly primary, with vast access to all the data and information possessed by the company that was deemed necessary for the purposes of this study.

When already inside the company, a role must be assigned to the action researcher. If the researcher is both helping the company and providing the outside with helpful scientific knowledge, the potential for an ambiguous and conflicted role is significant. To define the specific role, literature states that the action must take one of two parts: as an outside agent, where the researcher acts as a facilitator of the action of reflection within an organization (Karlsson, C., 2010), acting as an external helper to the target organization, or as an insider, where the action research is conducted from persons within the organization. In this case, over the course of the study, as the researcher became a de facto part of the organization, often dealing with external entities on their behalf, it can be considered that the role assumed was, in fact, that of what of an insider. This role is also characterized when the researcher assumes the research in addition to other everyday tasks and roles within the organization, what ended by being the case during the course of this research. It should be noted that literature recognizes that the insider role brings associated an inherent personal stake in the outcome of the research project, whose influence on the project itself may not be disregarded.

To summarize, the design of the action research project was defined in the following way:

- Frame of the issue: Address the gap of knowledge regarding optimized start-ups strategy by integrating product, market, and supply chain
- Determination of the scope: Defined by the organization with feedback and input from the researcher, work mainly done by the researcher solo

- Definition of access: The access provided was primary, with all information accessible
- Definition of the formal role: The role assumed was that of an insider, with research being accumulated with other tasks within the company.

Lastly, after designing the project, it is then important to start implementing it. It is believed that the action research method should be governed by a cycle of four steps: diagnosing, planning action, taking action and evaluating action (Coghlan, D. et al., 2014). This process should be an iteration and may be carried one or many times during the course of a project, with the following iteration running on feedback obtained from previous cycles.

Diagnosing involves naming what the issues are on the basis of the actions that will be planned and taken (Karlsson, C., 2010). It involves an integrative effort inside the entire organization so as to involve real players in the diagnosis process – as it should not be experts or the researcher the only one to come up with the list of issues to tackle. In fact, retrieving data is an essential part of the process: either formal data generated from the business (like historical data, performance indicators or internal reports) or general data from the market where the company is or will be operating. The insights are normally qualitative and can be gathered by observation, discussion, and interview (Karlsson, C., 2010). One important remark is that the data generated by the own introduction of the process (like employee's expectations or willingness to adopt change) can and should be valid data that must be taken into consideration in the implementation of the project. In the end, the data can be collected by the researcher or he may only be given access on it: however, it must be based upon an elaborated analysis of this factors that the plan of action must then be created and designed.

Next, having gathered all the necessary data, a plan must be proposed. Some authors suggest that in this step some formal questions bust be answered, regarding what needs change (and where), what type of change, what support does it need to be had in order to change, and also an analysis on the necessity of commitment by the company (or resistance to being managed (Beckhard, R. et al., 1987). Again, in this process it is important to involve the organization in the process: as a contrast to just providing a plan of action that will not be wanted or followed by the company – and even if it is, will not be received well by its collaborators.

After completing the plan is time to take action and implement it. The necessary suggested changes or plans should be carried out, even if they will involve key members of the organization. The same planed action can extend itself over several interactions of the process, and sometimes take months (or even years) to be carried out.

In the end, the final step of the cycle is reached and an evaluation on the change must be conducted so that the quality of the planned chance be evaluated as means of gaining feedback for the next cycle (if any). Without this evaluating step, it's impossible to detect and correct

errors, and it's the only way to answer fundamental questions and access if the original diagnosis was correct or if the action (and the way it was carried out) was correct (Karlsson, C., 2010).

In the following sections, the application of this cycle to the chosen organization will be presented, starting by presenting the organization and company to be diagnosed (and the diagnosis itself), the plan that was created, how it was incorporated and then some reflections aiming to evaluate the quality of the instruments created.

5.2- Introducing the Object of Action Research

As discussed in the past sections, in order to initiate action research there needs to be a target, a real-life vessel in which to base the project on and by which to gather feedback regarding the hypothesis to be tested.

In this case, the object of this research was a spinoff from a Portuguese research and development institute, which was created in the context of a multi-year international project. Both these entities and their works will now be briefly presented as follow.

5.2.1 - INESC TEC – The Parent Institution

The Institute for Systems and Computer Engineering, Technology and Science, also called of INESC TEC, is a private non-profit research institution, dedicated to scientific research and technological development, technology transfer, advanced consulting and training, and pre-incubation of new technology-based companies.

As an institution operating at the interface of the academic and business worlds, bringing closer together academia, companies, public administration, and society, INESC TEC typically applies the knowledge and results generated as part of its research in technology transfer projects, seeking value creation and immediate social relevance.

Present in 6 sites in the cities of Porto, Braga and Vila Real, INESC TEC incorporates 13 R&D Centres, hosting over 700 integrated researchers (about 350 PhDs), including staff researchers, researchers from Higher Education Institutions, grant holders and affiliated researchers. INESC TEC's team also includes trainees and technical and administrative support staff.

The mission of INESC TEC is to achieve advancement in science and technology and to enable science-based innovation through the transfer of new knowledge and technologies to industry, services and public administration.

5.2.2 - VR2MARKET - The Background Project

The VR2MARKET project (or Towards a Mobile Wearable Health Surveillance Monitoring Product for First Response and other Hazardous Professions – Figure 15) is a Stress monitoring among First Responder professionals CMU-Portugal funded project which main goal is to provide secure, reliable and effective first-response systems in critical emergency scenarios.

Figure 15 – VR2Market project logotype
(taken from the official project website)

To achieve this goal an interdisciplinary team with expertise in areas such as wearable technology for vital signs, biomedical signal processing, sensor networks, and RF Location/Intelligent buildings was formed.

The project is the consolidation of a successful line of R&D and hopes to boost the possibility to bring to the international market results from 5+ years of joint research.

The main objectives of the project, adapted from the official project website, are:

- Consolidate the developed VitalResponder system on-duty first responders health monitoring and surveillance technology, improving its scalability and adaptability to a wider set of requirements from different hazardous professions
- Improving the Data Analytics and psycho-physiology indicators to detect better trends and health threating
- Converging to a scalable, adaptable, mobile and integrated cloud services-based ICT platform
- Perform a business concept validation and a manufacturing supply chain strategy for guiding the path from prototype to the market through a start-up.

To achieve these objectives, the project is carrying out a cross-disciplinary research program covering the clinical and technical aspects of health surveillance. Clinical interventions are based on wearable and sensor technologies, connected by ad-hoc networks and supported by data mining algorithms and a ubiquitous/elastic ICT infrastructure. On the

other hand, the system's workflows will satisfy the user's requirements and the developed business concept.

The entire project is divided into 8 different tasks, namely (Figure 16):

- Task 1: Wearable and Sensors Technology
- Task 2: Ad-hoc Network
- Task 3: Data Mining and Analysis
- Task 4: Psychophysiology indications and applied interventions
- Task 5: ICT Integration
- Task 6: Business Concept Validation
- Task 7: Manufacturing and supply chain strategy
- Task 8: Field Trials and Pilot installation

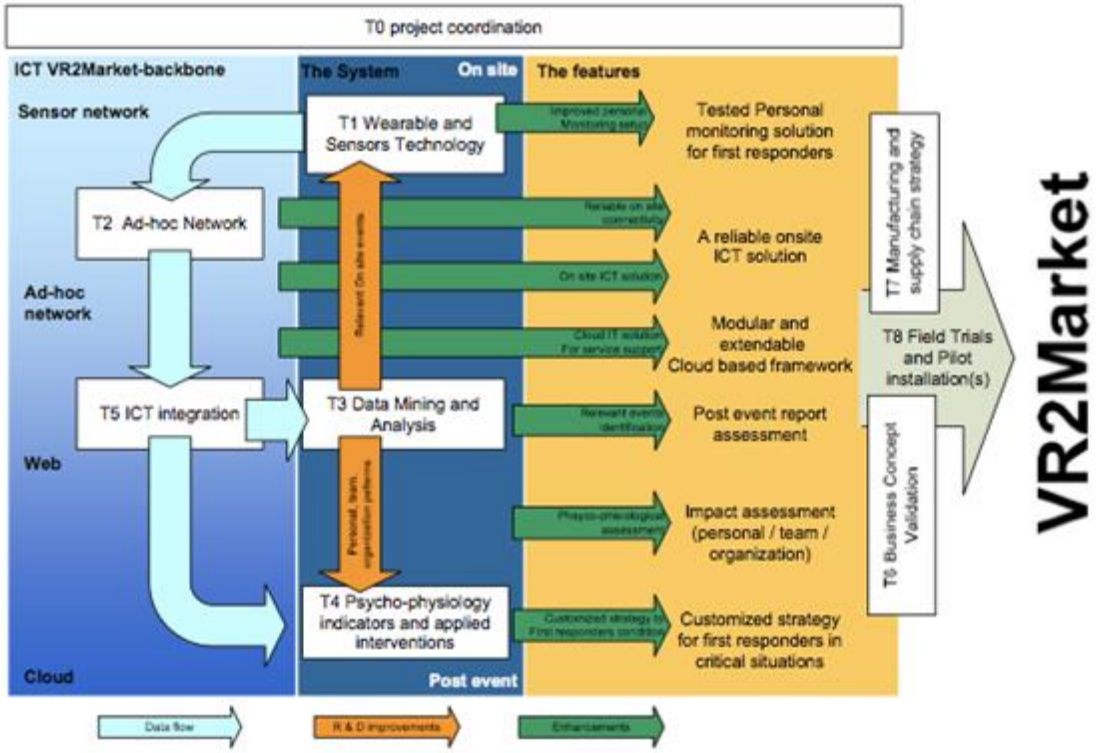

Figure 16 – VR2Market task organization, interrelations, product objectives, and planned features (taken from the official project website)

To the successful completion and evaluation of the project, all 8 tasks must be completed by the end of the project. From these tasks two things emerged which are of significant relevance to the project: from task 6, a start-up was created (further described in the next section) and from task 7 the need for a definition of a manufacturing and supply chain strategy emerged, both of which laid the foundation for the present Action Research project.

5.2.3 - WeSENSS - The Start-up

From the VR2Market project, a biotechnology start-up was created to explore the potential behind the technology created in the project on the real-life global market. (Figure 17).

Since its inception in 2017, the company had its focus on the international market, aiming to know better the needs and trends of customers around the globe. An example of that was the participation in the inRes program.

Figure 17 – The Startup logo
(taken from the official project website)

inRes (or entrepreneurship in Residence Program) is a business acceleration program for entrepreneurial teams in the area of Information and communications technology. It is organized by the Carnegie Mellon Portugal Program, funded by the Foundation for Science and Technology and supported by the Council of Rectors of Portuguese Universities, the Pittsburgh Regional Alliance, INESC TEC, SRS Advogados, and Hovione Capital.

This program pushes the teams past their comfort zones, requiring them to work at a steep pace and cope with high levels of uncertainty. Underlying to this is a constant outreach for contacts to further build and validate their business projects.

The start-up was part of the 2017 edition of this program and over the course of several months, it was accelerated in the United States of America, roading throughout the country meeting potential customers, investors and getting to know the latest tech trends by means of participating in several meetings, industry fairs, and scientific conventions.

At the end of the inRes program, the start-up returned to Portugal and since 2018 has been finishing the prototyping phase of its products (most of which had its inception aligned with the VR2Market project objectives).

5.2.4 – Start-up Objective and Initial Requested Goals

When reaching the final steps of their technological prototypes or R&D developments, start-ups need to find a way to launch their products into the market: either by producing them or by licensing the produced technology.

In this case, even though the start-up is still initially actively trying to pursue both roads, it became mandatory to have a manufacturing and supply chain strategy that can steer the fates of the company into the market. The fact that this was also one of the goals for the VR2Market made this need even more necessary (as the project and start-up teams are mostly the same, synergies can most times be found).

Initially, the challenge presented to the researcher included the definition and planning of the supply chain, production processes, and logistics, including the proposal of a supply chain design, with its pros and cons presented and discussed.

While this task will help the start-up to adjust its growth plan, internationalization and business model, it is also relevant in the context of start-up strategy research, by providing a real-life mean of studying the effect of start-up choices.

As so, in the following sections the several steps of the action research cycle will be applied to the start-up, taking the proposed challenge according to the previously established objectives and goals.

5.3 – Diagnosing the start-up

As presented before, the start-up studied in the action research project was created to try and bring to the market the technological innovations developed in the context of the R&D VR2Market Project (mainly biotechnology wearable products and sensors).

There are two different major branches of technological innovations incorporated in the company (Figure 18):

- Wearable sensors for capturing physiological signals (ECG, Respiration rate, body temperature, among others)
- Wearable sensors for capturing environmental signals (Temperature, Humidity, Air Toxicity, Atmospheric pressure, Particle sensing, among others)

Figure 18 – WeSENSS products (initial prototypes)
(taken from the official project website)

These technologies are based on state-of-the-art research, allowing for the incorporation of several other components into the solution portfolio in order to have an integrated approach into the market, namely a mobile application (for Android devices, that allow for GPS remote tracking of the user's location and vital signs) and also a web platform to serve as storage and to add one more layer of flexibility to the whole solution portfolio.

It should also be noted that both products operate completely wireless, using rechargeable battery for power supply and Bluetooth low consumption technology for communication with the smartphone, thus providing a true hands-free operation mode for the user, while at the same time allowing a hypothetical supervisor the ability to track in real-time the information regarding each one-off said devices/users.

The solution can work solo or together (just the physiological, just the environmental or both) and not only acquires data but also makes calculations based on that, using various heuristics and machine learning technics to extract not only the historical trends but also to make real-time forecast and prediction of health problems (such as heat stress, physiological stress, among others).

During the project, various real-life field pilots were conducted, resulting in more than 700h of data collection and analysis, leading to solid scientific evidence.

All those pilots helped forge a view of the markets that the start-up wanted to enter, mainly related to first responders (firefighters, policeman) but also to other markets linked to occupational health hazards where real-time tracking may be crucial like:

- Air Traffic Controllers
- Industry workers (in potentially dangerous sectors like oil and gas)

- Military
- Mining

At the beginning of the action research, the company had just reached a sufficiently mature version of the prototyping versions and after producing an initial set of products aimed to be used in test pilots, it started to converge their attention into the future: how to develop the start-up strategy so to allow for the commercialization of both products and services, namely regarding the following areas:

a) Production plan: Definition of the manufacturing process, needs, costs, and timeline.
b) Production location: Definition of where to locate production (local production partners, contract manufacturer, among others).
c) Supply partners: Definition of suppliers and possible partners
d) Certification requirements assessment: Necessary to introduce the products into the market

It should be noted that while the previous productions were made in-house (inside the laboratories of the organization, with all the parts acquired independently) this option is no longer viable for some reasons, even when it comes to producing small batches: the production is incredibly slow, there is no possibility for certification, and it is not easy to guarantee quality.

All in all, the objective of this project is to study the use of product, market and supply chain decisions to create a market entry strategy for the start-up. But before making verdicts, it's important that the action researcher pre-understands the environment of the start-up and the conditions of its business and dynamics that it operates (Karlsson, C., 2010). So, while some general insights had already been acquired by previous methods, every company lives in a specific ecosystem and sector and the problems may differ from reality to reality, thus creating the need of first learning more about the products, market, and supply chain that would need to be created (Figure 19). Essentially: more data was crucially needed.

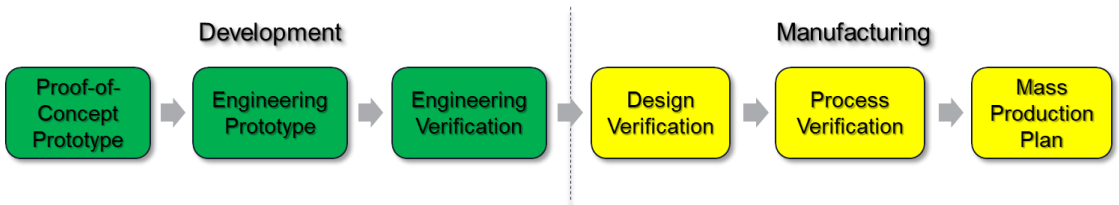

Figure 19 – Product development phases status
(yellow boxes represent the work to be done at the beginning of the action research project)

In order to gather information, the first thing that was conducted was a wide review of all the internal documentation produced in the start-up and project in the last years of research

(especially related to the company's incubation period in the USA in the context of the inRes program). By so, it was understood all the technical details of the products and said technology, which together with a Bill-of-materials (BOM) analysis and informal interviews with the start-up Chief Technology Officer (CTO) helped to understand some of the requirements and possible obstacles that might possibly appear later in the production step.

Some of the documents reviewed showed that the start-up had already in the past tried to acquire product, market and supply chain capabilities by trying to absorb knowledge from start-ups already in the growth phase (past the 2nd valley of death). These documentations provided some insights and suggestion for component suppliers, certifications, manufacturing options, and even the production process.

Some visits to potential manufactures were made in the past and general quotations had been issued, however, they were severely obsolete and unusable due to changes in the prototyping design and components.

While this information's were certainly helpful as a start, it was critically incomplete and did not provide the full picture. For example, one of the biggest problems in electronics production is the manufacture of the external enclosure. In this case, only one option had been considered (production of steel molds and plastic injection of the final product), which while a valid possibility is extremely expensive and can rapidly devote the vast majority of the production economic resources of the company into this single component. On the other hand, while some general information about possible certifications needed was found no estimation of costs were available.

It is said in popular culture that you can only control what you measure, and in this case not much analytical data existed, leading to the decision that for a correct diagnosis and plan to be made, more information should be obtained about the product, market and supply chain possible decisions and options for this company.

It was decided that there was a need for more knowledge regarding each one of the three dimensions, in the following ways:

- Product – Understand the production processes of each product and component, namely researching state-of-the-art methods for electronics enclosures production and full product assembly, and identify opportunities for product modularization
- Market – Fully identify the customer segment needs and identify barriers that might be encountered when entering the desired market, like certifications
- Supply Chain – Identify key partners and gain insights about the best in-house and outsourcing production options, as well as information about ideal stock levels

In action research, all data gathering methods can be valid, qualitative and quantitative. Less pragmatic methods like informal interviews, conferences or meetings can provide useful information in this research field (Karlsson, C., 2010). Experts are scarce and costly resources

and reaching to them for information into these topics could quickly turn into an impossibly hard task. Another option is to contact with friendly start-ups in a similar enough sector to provide us with information, as it was done in the past. However, action research aims at developing a holistic understanding of the project (Karlsson, C., 2010), and so listening only to individual companies can lead to deceiving conclusions.

For all these reasons, it was then opted to gather information in places where many companies, researchers, and experts are gathered together at the same time discussing the latest best practices and tech trends – industry fairs and entrepreneurship conventions.

In was then chosen to attend the Web Summit 2018 as an entrepreneurship convention and EMAF 2018 as an industry fair.

Web Summit (Figure 20) is sometimes referred to as the best technology conference on the planet. While originally founded in Dublin, it's been held annually in Lisbon since 2016. Several talks are given by top tier experts from all over the world from various areas ranging from entrepreneurship, technology, science, public practices, among others. On the other hand, it is also a meeting place and show booth for hundreds of start-ups and companies from all around the world to show their technological advancements, products, and services.

Figure 20 – Web Summit 2018 logo
(taken from the official website)

Before attending the conference, several meetings and contacts were carried out with start-ups, companies, and experts from all over the world for different reasons:

- Start-ups in the electronics sector but not competitors, to gather insights about manufacturing practices, challenges in certification and possible supply chain partners
- Start-ups in the biotechnology sectors but not competitors, to explore possible partnerships in technological advancements and conjunct R&D, for future product development
- Manufacturing and design companies, to explore the possibility to become part of a future supply chain and understand the normal variables associated with this topic

- Possible clients and investors, to understand what they would value most in the design and technical side of the products, to provide a chance of steering the company in that direction
- Competitors, to access their technology and help in the elaboration of a benchmark

After attending all the talks and workshops, speaking with experts, companies, investors, and competitors, an overall idea of the product and market decisions the start-up would have to design was created. However, the majority of the companies in the conference were fairly new and there were not many manufacturing companies present, thus avoiding the contact with many industrial manufacturing companies that could help with the assembling process of the product and all that comes with it. So, to better access the supply chain options, EMAF 2018 was attended.

EMAF (Figure 21) is an international Fair of Machinery, Equipment, and Services for Industry held annually in Porto, aiming in their slogan to "lead the way in the solutions and technologies of the future business with expertise". While the attended 2018 edition was focused on the fourth industrial revolution and the new challenges that arise from there, the event was mainly attended by entrepreneurs, managers, and leaders with skills on the company's production process level, senior technical staff and other experts with several decades of experience in the market.

Figure 21 – EMAF 2018 logo
(taken from the official website)

While in this industry fair, it was possible to schedule and maintain very important meetings with possible partners for the supply chain.

In those conversations, each partner was able to present their solution for the manufacturing of the products in question, either in the case of its assembly, in the enclosure manufacturing or even in packing solutions (to create a final product able to be delivered to the end customer).

With all that in regard there was now a very approximate idea of what it needed to be done and the majority of the information needed to draft a plan was already gathered. However, there was still little information about the market competition the start-up would be facing (that could potentially introduce market entry barriers to the future of the start-up). With that in regard, a complete market benchmarking research was conducted, the likes of which will be presented in the following section.

5.3.1 – Benchmarking Analysis of the Start-up Competitors

Benchmarking is the process of improving performance by continuously identifying, understanding, and adapting outstanding practices and processes found inside and outside an organization (company, public organization, University, College, etc.) (Kelessidis, V., 2000).

Benchmarking is usually done with top performing companies in the same industry sectors, focusing on enabling the improvement of a company by using the best practices, technologies, and information available worldwide instead of just the internal information available inside the company.

Companies studying best practices have the greatest opportunity for gaining a strategic, operational, and financial advantage (Kelessidis, V., 2000).

In this case, a market survey was conducted in order to first identify their potential competitors from all around the globe in the hope of bringing useful insights for the company future related to tech trends, price strategies, and other metrics.

As a result, 28 companies were identified that offered products or services similar to (or equivalent to) the ones the start-up hoped to produce. Each competitor was then categorized based on different skills and characteristics to allow for a better analytical analysis, namely regarding indicators like the funding obtained until the date (in case of start-ups), the year of foundation, the country of operation, the customer segments and many more (Table 12).

Table 12 – Benchmarking fields of analysis

General Information	Company name	**Features of the product**	Sensors	ECG (leads)
	Name of product			EKG
	Year of Foundation			Respiration
	Country of Foundation			Skin Temperature

Financial indicators	Funding			Posture	
	Revenue Info / Sales			Battery Duration (h)	
	Price of Product			Wireless Connection	
Business Model	Selling Online		App	Android	
	Price	One-time Fee		iOS	
		HaaS/SaaS	Web Platform	Real-time	
Markets	BioIdentification	Driving Wheel		Others	
		Band	Data analytics/ Algorithms	Drowsiness	
		Others		Fatigue	
	Safety Tracking	Industrial		Heart Anomalies	
		B2B		Others	
		Consumer	Certifications & Regulations	ATEX	
	Medical Tracking			FDA	
	Fitness Tracking			Others	

In this way, each company and their specific products were categorized using this kind of parameters. While it is believed to not be relevant to list all companies' names in this study, the benchmarking allowed the creation of very interesting metrics and realizations, that in turn can allow the startup to make correct and informed strategic business decisions. For example:

- Geographic distribution based on Headquarters locations: 39% in Europe (Spain, Finland, Hungary, and Portugal), 54% in North America (USA and Canada), 7% in Asia (Japan and South Korea)
    - Insights:
        - Serious competition expected in North American and European markets.
        - Potential market opportunity in emergent markets like South America and the Middle East
- Funding and Sales: 5.4M€ raised on average per company, 30% had no sales yet
    - Insights:
        - Many competitors are focusing their operations in Research and Development, survive on funding and relying on few or inexistent sales

- Average age: 6.7 years of existence (or of the existence of the initial R&D project, in cases when an existing parent company created a separated spinoff to develop the product)
    - Insights:
        - Most companies are taking many years to bring their products to market (Risk of burning all funding before sales start is significant)
        - Based on average funding values, companies take on average of around 800k€ /year to operate
- Public sales online price: 200 – 2500 € range, Average around 500€
    - Insights
        - There is a significant price discrepancy between equivalent products (intensive R&D investments and the High-tech characteristics of the products may be driving the prices up)
        - Prices are still very much based on perceived value instead of the cost of production

Apart from those figures, the benchmarking analysis also allowed the technical team of the startup to take note of the features and product characteristics more common in competitors. For example, it was found that no competitor had the certifications appropriate for use in dangerous atmospheres, opening an opportunity for WeSENSS product to enter markets that operate in those conditions and these those specific certifications (like the oil & gas segment, firefighters, among others).

On the other hand, several of the competitors had already achieved medical devices certification, which is a costly certification (economically and timewise) that allows them to sell their devices to hospitals and enter the medical equipment segment. Due to this factor, while it was entirely possible for the company to go that way, it might be a good option to reconsider aiming for that certification as the entry barriers posed by the competition already in the market may prove to be too big and deter any future profit in that segment.

Taking all this into account, it was then time to propose a plan of action.

5.4- Planning the Action

The objective in this section was to propose a plan of action for the start-up according to the objectives and goals initially requested by the company. However, it is important in action research to do the planning always in collaboration with all sectors within the company, which was achieved in this case by a constant and positive flux of information and feedback with all the company top managers and advisors.

Regarding the initial objectives of production, supply chain, and certification design, it was then proposed to create a strategy layout based on partners as modular pieces that can be

exchanged without too much trouble. For each of the singular product components (on the left) tasks and sub-tasks must be carried out in order to achieve the proposed goals, looking for suitable supply chain partners to fulfill those same tasks (or decide to make them inside the start-up), using the following criteria:

- **External Enclosure**
  - Design
    - Design Research
      - Objectives: Propose, sketch and 3d model placeholder design solutions around a concept, namely:
        - Analysis of competitor products and trends
        - Concept studies for the enclosure
        - Color revision for product identity (branding)
        - Representation of the integration of the individual parts
        - Refining of the selected concept
      - Deliverables:
        - Concept meetings with Industrial Designers
        - Digital portfolio with research, concept description and a series of sketches presenting design alternatives.
    - Computer-Aided Design
      - Objectives:
        - Turn the selected sketch into a feasible shelled 3d model with dimensions and metrics.
        - Contemplate all the product requirements and internal components (slots, ribs, external holes, lid, fasteners, among others.
        - 3d print each version/iteration for an objective analysis of the enclosure.
      - Deliverables:
        - Industrial format CAD mode (. iges or. step)
        - 3D Printed parts and prototypes
  - Production
    - Plastic Mold Production
      - Using two cavities mold in ABS-like material using PolyJet printing technology
    - Steel Mold Production

- Two cavity mold – base and cover

- Plastic Injection
  - Injection of the final piece using
- 3D Printing of Final Product
  - Using suitable technologies for the production of small batches like SLA

- **Electric Components**
  - PCB
    - Design and Initial Costs
      - Production of Stencil and Pick and Place machine Setup
    - Production
      - Production of the printed circuits board
  - Bought separated
    - Special electronic parts
      - Identify components that cannot be provided directly by the assemble and find suitable suppliers
  - Other components
    - BOM Components
      - For the majority of components, acquired through the assembler
- **Assembly**
  - Final PCB
    - Components in Board
      - Pick and place of components on the PCB
  - Enclosure
    - Board in Enclosure
      - Placement of the finished PCB on the produced enclosure and seal it by the use of suitable technology, like a 3D pen for solder
  - Packing
    - Enclosure in Package
      - Placement of the finished product inside the packing, effectively putting it ready to deliver to the final client
- **Packing & Documentation**
  - Design
    - Packing graphical and physical design
      - Create the presentation of the package and define its size, colors, and aspect

        - Documentation Contents
            - Elaborate manuals and certifications to accompany with the product
    - Production
        - Cardboard Packing Production
            - In appropriated textures and size
        - Documentation Printing
            - In appropriated thickness
- **Quality Assurance**
    - Design and Development
        - Signals measure in PCB
            - Design of test jigs for physical signals like voltage (in digital, analogic components and battery), ground and feedback to a simulated injected signal
    - Production of tools
        - Physical device production
            - Respecting the norms of the device and in a way that allows for quick and simple use during assembly
    - Tests
        - Conformity parameters check
            - Performed on the final product using tools developed
        - Multi-criteria functional tests
            - Performed on the final product using tools developed
- **Certifications**
    - Consulting
        - ATEX
            - For oil/gas/mining customer segments, according to ATEX 2014/34/EU Guidelines
        - CEM
            - For all segments (essential to CE and FCC marking), to achieve conformity
        - IP67
            - For all commercial segments, on mold fabrication to achieve to conformity
            -
    - Laboratory Tests
        - ATEX
            - For oil/gas/mining customer segments, according to ATEX 2014/34/EU Guidelines

        - CEM
            - For all segments (essential to CE and FCC marking), on EN 55024 norm (tests for immunity) and EN 55032 (tests for emission)
        - IP67
            - For all commercial segments, according to EN 60529 Norm
- **Logistics**
    - Direct
        - Shipment of final product
            - Door-to-door logistics
    - Reverse
        - Shipment of return
            - Door-to-door logistics

A schematic visualization of the data above can be show in Figure X.

Figure 22 – Tasks and Sub-tasks of the planned production plan

Each right “arrow” above represents an individual task that must be assigned to a partner. As the supply chain configuration is modular, while there is correlation between activities in most cases it the partners for each task can be chosen freely and independently.

As a matter of fact, the plan was to use the contacts acquired in the diagnosis step to reach multiple quotations for these said tasks from different partners, and then based on that, taking into account price, delivery time and trustworthiness criteria, define the final strategy design for the start-up.

It should be noted that while the benefits and prejudices of each production technique were studied previously during the planning phase, they will be presented further during the evaluating action step, on the context of the PBCM methodology.

It must also be seen that at the planning stage, it was still unknown if the final cost for the start-up production cost would be competitive enough to be worth it for the company to produce its own hardware. In fact, producing the hardware the company uses (or sells) is far from the only viable option in this case. Once in possession of all the production quotations and their relations, it will be possible the estimate the production costs and compare it with that of the competitors. If the difference is not significant, it may compensate just to use some other company’s hardware, buying it already “boxed” and ready to work for an agreed fixed value (and instead focus on the software development part of the company). In the meantime, contacts must be pre-conducted with competitors in order to study the possibility for a partnership, should such a necessity arise.

The considerations above are mostly about the product (modular configurations), however, apart from that, some things should also apply (whose proposals are based on past research). While maintaining the selected customer segments, the certifications must be acquired in the same order as that of the importance of that specific client sector to the company. On what it regards to buying components there should be a preference for standard and less customization to bring more flexibility and smaller minimum quantities. On intellectual property protection, non-disclosure agreements must be signed with every supplier prior to the sending of the inquiry. It should be noted that upon starting of the action research project all the technology was already patented (and it is recommended that new technologies follow the same path).

It is advised that the start-up initially focus its efforts in the European geographical market, so as not to invest too much of the start-ups' resources on expanding its operations overseas. In the future, other markets like South America and the Middle East may be of interest (due to a high potential and apparent low competition). That will also help with the certifications (in Europe only CE marking needed, and to get it CEM certification is in this case the only requisite).

On a final note, while the production cannot be in-house (for the reasons appointed above), low quality, unknown and unreliable partners must be avoided (giving priority to manufacturers with ISO 9001 - Standard that defines requirements for Quality Management System -

compliance, even if at cost of buying slightly more expensive components/services). For the same reason, initially for the first runs of production, the only considered suppliers should be located geographically near the headquarters of the company, so to allow for closer inspection when needed. The only exception should be the suppliers of components that cannot be acquired by the assembly partner (while buying components with the assembly partner will be more cost effective, in some special products it might not be possible thus leading to sourcing those products as close to shore as possible).

In Figure 22 an overview of the whole strategy is presented.

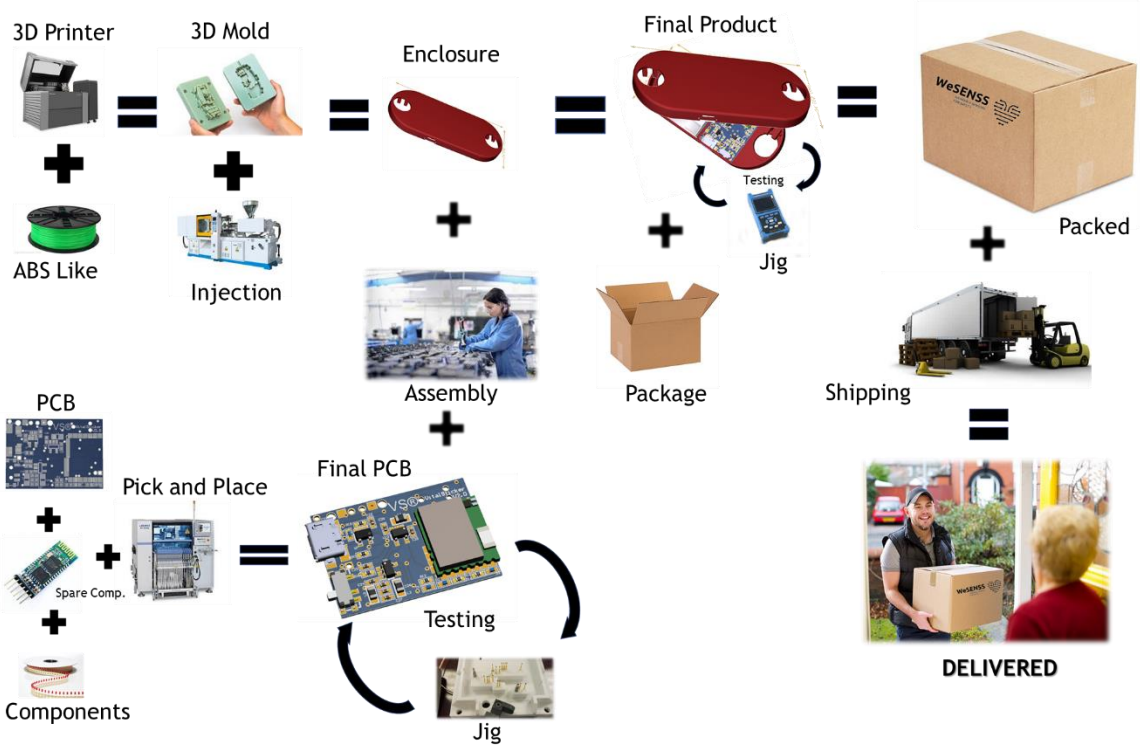

Figure 23 – Overall layout of a possible version of a product production process (images taken from the project or are open source)

It can be observed above that the design and graphics of the enclosure are different from the ones presented at the beginning of this chapter. That is because the one presented at the beginning of the chapter was an initial working prototype and the one presented here is a redesigned version of the enclosure, more tailored to the start-up and their customers' needs and desires.

5.5- Taking Action from Planning to Practice

After having already outlined a plan for the strategy of the start-up, arrangements started to be made to gather the contacts and partners necessary to put it in practice.

Over the course of several months, a wide range of contacts with companies and experts from 3 continents was carried out in order to put the strategy to work and comply with the previously defined parameters.

For each of the above tasks, it was found one (or several) partners that comply with all the functional and geographic requirements previously defined. Initially, to find those partners an extensive search was made using not only the contacts made during the previous visit to WebSummit and EMAF fairs but also by firstly contacting the industries technological centers for each of the needed activities.

For example, regarding steel molds, one of the centers that were contacted was CENTIMFE - Centro Tecnológico da Indústria dos Moldes, Ferramentas especiais e Plásticos. This center was created in 1991 and is a nonprofit institution with more than 230 associated companies, integrating different associations of the molding industry. By using their partners' network, it was able to reach to a vast number of related associated companies.

One of the strategies used was to locate assembly partners first. The requirements and restrictions selected in the planning phase (that they must be geographically located near the headquarters of the start-up, must have been certified by the highest standards and must be a fairly established company) already limited the number of possible assemblers to a small number of companies, so it was better to first start from there. Additionally, normally assemblers are integration partners by nature and so have their own network of usual partners (which can be used additionally or separately to that same partner).

Some routines were created so the contacts and meetings with each partner would be organized for future consultation (Figure 23). An easy to use database was created (using Microsoft Excel, Visual Basic, and Macros) that allowed at the same time to uniformize the information gathered in an electronic format, but also to print it in case it is necessary (to present management as a decision tool).

Figure 24 – Example of partner record

The process of gathering data was formally created (with detailed information for each step), including a visual representation of the state of the process (to keep track of tasks but also to maintain management and the entire company aware of the process (Figure 24)).

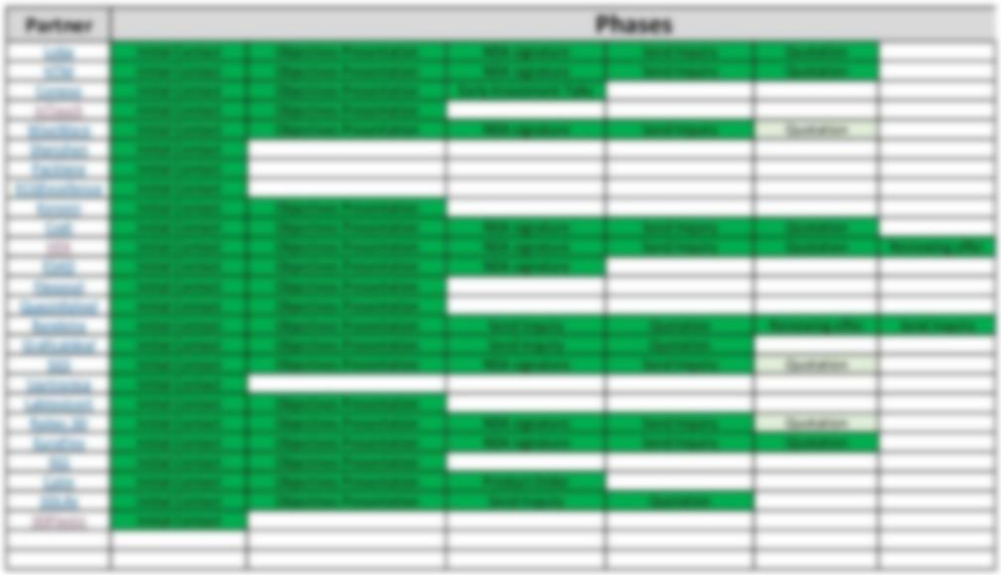

Figure 25 – Model for tracking process of contacts with each partner

As referred above, it was then defined a protocol to guide each contact. For example, in the majority of cases, a non-disclosure agreement was first sent before any kind of relevant business information was exchanged (even thought the technology behind the products was already by itself patented). The normal process is shown in Figure 25.

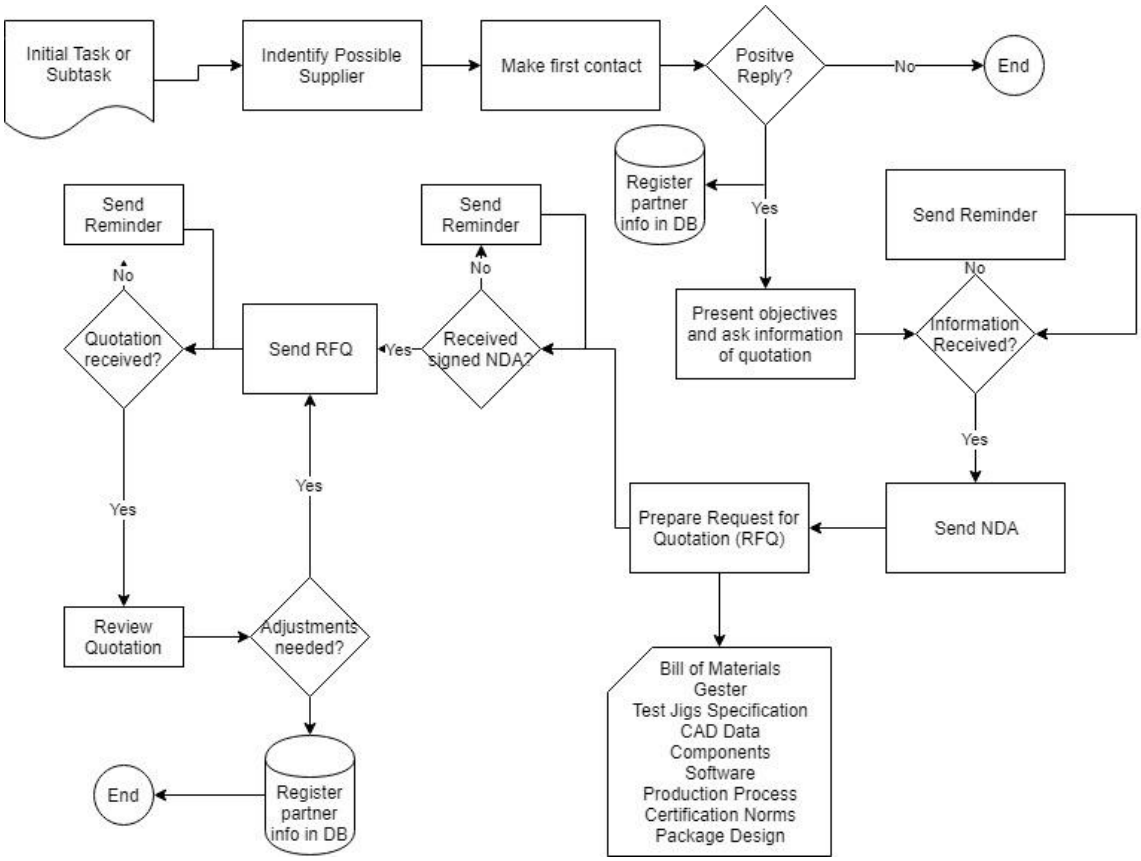

Figure 26 – Process flow for partner and quotation request

The process was fairly the same for every type of partner, independently of the kind of service/product needed. The changes on the process would be more focused on the materials included in the request for quotation (most of which were created during the project, in close collaboration with the technical and engineering team of the start-up).

As planned not only potential suppliers were contacted, but also companies that could collaborate in future technological iterations, investors and even competitors.

With investors, it was specifically tried to understand what was most valued in the company (the finding where aligned with the rest of the research and will be more detailed in the conclusions of this chapter).

As for competitors, the objective was mostly to try to access the possibility of a future strategic partnership to supply hardware (as planned in the previous section). In this case, several contacts were conducted with companies from several continents that produce similar

products. In two cases (one start-up from the USA and another from Japan), initial and sequential conversations between teams were conducted. On one of the cases, no agreement was made as teams couldn't get to pass the obvious problems behind collaborating with a competitor in such an innovative and intense environment like the one start-up's experience.

However, in the other case, an initial agreement to pursue a future partnership was agreed and an initial order was made by the start-up to that company, so to test the quality of hardware and access the technical viability of using their hardware in the future (as a safeguard option if the internal start-up hardware is not economically viable to produce). The information about the economics and cost price of their solution as how it related to our production cost will be discussed more extensible in the next section.

In total, about 30 companies from all around the world were contacted and around 20 became possible suppliers or partners. They were sorted according to the task they are focused on solving (as defined in the planning phase) and can be found in Figure 26.

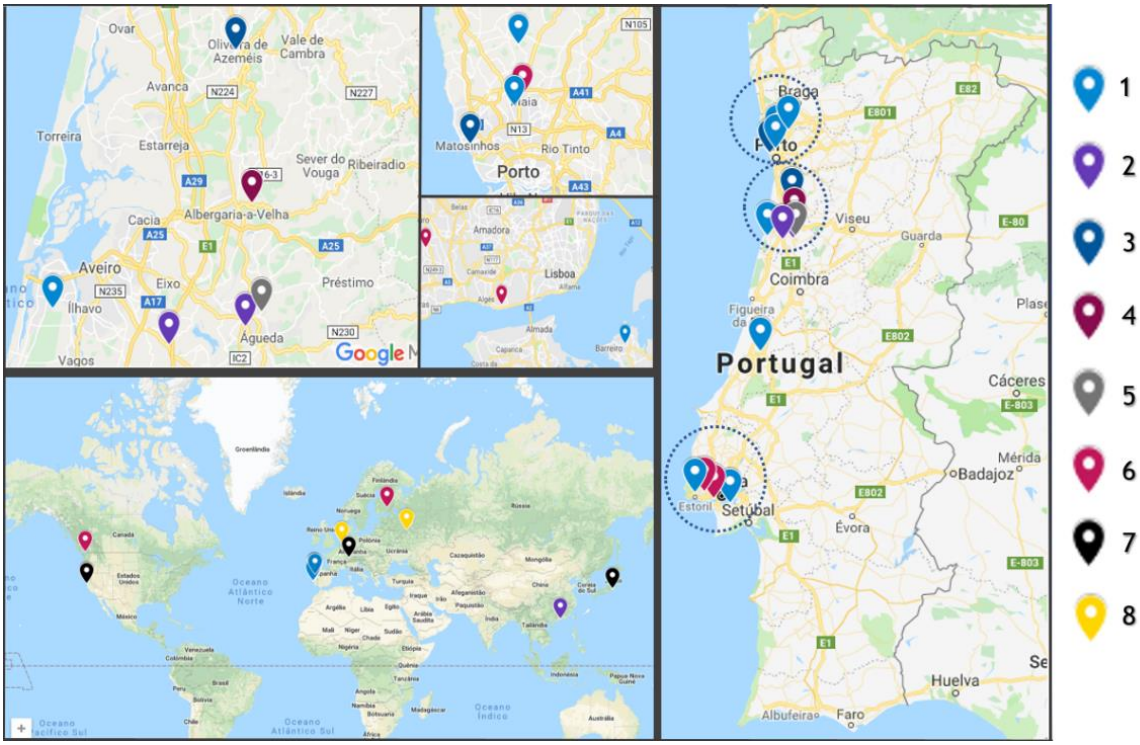

Figure 27 – Global Partner network created for the startup
(background map taken from Google Maps)

In the above figure each mark represents a start-up, sorted by their sector from 1 to 8, using the color code as follow: Light Blue for Enclosure Production and Design, Purple for Assembly, Dark Blue for Enclosure Design, Dark Red for Certification Consulting, Grey for Packing, Red for Certification Lab, Black for Competitor and Yellow for Tech Partner.

As a side note, it's interesting to note that in Portugal, the companies seem to be clustered around three big industrial and service hubs: Porto, Lisbon, and Aveiro districts. This seems

consistent with the general industrial activity in Portugal for a vast majority of sectors (Cerejeira12, J., 2000).

5.6- Evaluating the Implementation using PBCM

Evaluating involves reflecting on the outcomes of the plan of action and aim to review the process in order to improve it in the next iteration (Karlsson, C., 2010). This evaluation is the key to learn with the process and realize if the action research project was correctly diagnosed and if the implementation was correct.

One metric that could be taken to understand if the designed strategy is efficient is to take a Product-Based Cost Modelling approach to estimate the production costs considering all the studied variables, and then compare it both with the commercial price of the majority of competitors and also with the lowest cost for acquiring competitors hardware (as it was negotiated with the competitor).

The objective of PBCM is to map from process description to operation cost, informing and accessing the best decisions alternatives with regard to the technologies that exist currently in the market. It takes requirements (specifications, resources, among others) and tries to come up with a production cost estimation. In the end, what it studies is how changing technology can impact the final manufacturing cost (Kirchain, R., 2009).

While on the course of this research a product cost estimation and calculator were created for each and all of the start-up's products, for the purpose of this document and for the sake of simplicity it will be presented only as an example the product "VitalSticker", a physiological signal acquisition wearable device.

When doing this analysis, literature raises awareness to a need to look into other dimensions other than only the production cost: for example, one technology may be more expensive now, but its costs might be diluted in the near future. It also advises researchers to take a deep look into the technical and technological challenges that may arise (as some may account for hidden costs in the future).

There should also be an identification of which are the relevant costs (that should be modeled) and which are not. Normally, trivial or fixed costs like insurance, marketing, and advertising should not be modeled, in favor of other more production-related variables.

In the end, detailed relational mathematical models must be created, correlating not only processes to cost but also quantity to processes to cost (as depending on the needed quantity the price can change, thus changing the underlying relationships) (Kirchain, 2009). A schematic of the Process-based cost modeling is shown in Figure 27.

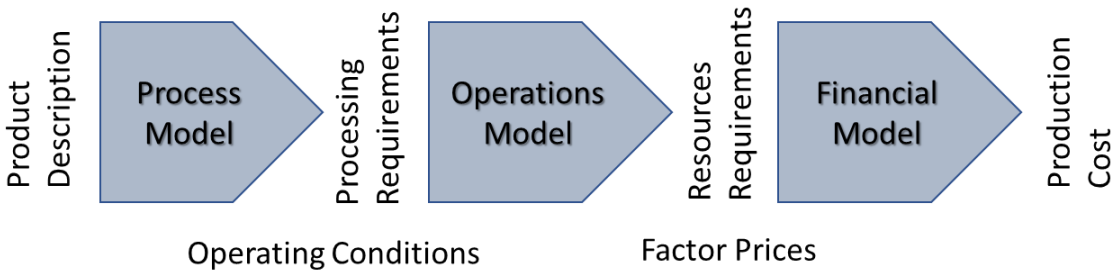

Figure 28 – Process-Based Cost Modelling (adapted from Kirchain, 2009)

So, at this moment, both the process model and the operations model are already known from past planning and implementation (and also from the diagnosis of the start-up and its manufacturing processes), thus only lacking the elaboration of the financial model.

Having all the values and quotations for each of the tasks, knowing all the relations and having the completed BOM, it's not hard to calculate the production cost for the majority of the tasks. However, cases happen when the process has some nuances that introduce some complications and restrictions in the process, namely:

- Quantity based
  - A supplier has more competitive pricing for a certain quantity, but very bad for lower or higher quantities
  - A supplier may only produce/deliver above a certain quantity (or have a high fixed cost logistic cost)
- Process/technic based
  - The process may only be viable above or below a certain quantity
  - The process may be unstable/emerging technology and cannot produce consistently without many rejected parts
  - The process may only be done by a handful of suppliers thus complicating the supply chain in case a need arises to replace the supplier

In the case of the "VitalSticker" production cost, one example of a quantity-based nuance would be the packing. The cardboard boxes that come with the majority of the electronics we buy today are easy to make and are not expensive in a per unit basis. However, the fixed initial production and setup costs associated with producing them make producing a custom-size-color-format box for low to mid batches of production to be a challenge.

Every Portuguese supplier that was contacted provided a quotation admitting that it was only competitive to use a custom sized box above around a couple thousand units, which is above the scope of needs of the start-up at an initial moment. To solve this problem, a company from the USA was contacted. They produce and deliver custom made boxes worldwide, tuned

to specific colors, designs, and shapes. Although their prices do not scale down if ordering a high volume of units, it is incredibly more compensating to use this option for smaller batches. Cardboard is lightweight and thus logistic costs are not relevant in the final product (even considering importing from the USA).

On the other hand, the enclosure fabrication is an example of a process that can pose process-based nuances in the model. Until some years ago, building a custom enclosure would almost always require a steel mold for injection and that would be very expensive, thus leading most companies to try and use standard enclosures as much as possible. In this case, being a wearable, using a standard enclosure was not an option. Fortunately, technological advancements like 3D printing now allow advancements in this field like never before.

During the action-research project, several meetings were conducted with partners in this area to try to access the best option for using 3D printing technologies as a solution.

While 3D printing is pretty advanced technology, most pieces printed using 3D still suffer from the same problems: time, consistency, cost, and composition. Firstly, they take a lot of time to produce. Then, they will not always look the same, and in some cases will require a manual finish after being produced. Third, they are still expensive, as their cost is directly linked with the time they take to be produced (the raw material can pretty much be disregarded). And lastly, they can only be produced out of specific materials adequate for 3D printing. While the available range of filaments for printing has been increasing (with more options for colors, textures, and flexibilities being added at an increasing rate), sometimes get the right color with the right flexibility can still pose a challenge.

And in this case, flexibility is indeed an important point. As the device is wearable, one of the requirements laid out in the diagnosis phase was that the start-up wanted to make the enclosure flexible so to be more comfortable for the end user – and 3D printing in flexible materials can be tricky. So apart from really low quantities of production (a couple of dozens) or productions where the enclosure finish was not a problem, 3D Printing the final product was not the answer.

Contrary to 3D Printing, injection molding can be the solution to bigger batches. Injection molding is the most common method for mass producing plastic parts. It is ideal for producing rapidly very large numbers of identical parts with tight tolerances and it can be defined as the process of creating a component by injecting under pressure melted material into a die. The material fills the hollow cavities of the mold and when it cools it solidifies, taking the form of the die, and when the die then opens, the solid part is ejected and the process repeats. Automating this process can yield very high production rates (3DHubs, 2018).

However, up until recently, injection molding relied almost exclusively on steel or aluminum molds for the injection – which although very durable, are slower to produce and very expensive.

A new alternative is to use 3D printed molds as a base for injection (Figure 28), using technologies like SLA and material jetting to print a 3D mold that can be used for low-run injection molding dies, and in environments when speed is important (as a mold like this could only cost something like 12 hours to print).

As for configurations, there are two types of 3D molds: using aluminum frames (to provide support against pressure during the injection) and standalone molds (fully 3d printed molds). In this case, we will be using Aluminum frames, as while they can be more expensive initially (due to the cost of the aluminum frame), allow to extract more pieces out of the mold without deformation and are also reusable, benefiting cases when multiple identical 3D molds are to be produced.

Figure 29 – Using 3D printing for mold injecting can bring down costs (3DHubs, 2018)

It should also be noted that during the diagnosis phase other enclosure alternatives were considered, like silicone or aluminum molds, however it was decided later that between 3D Printing the final enclosure, 3D printing molds plus injection and Steel molds plus injection the entire production quantity range would be effectively covered without the need of using other technologies.

Based on that the curves for production costs were made for enclosure production (Figure 29), and the limit/boundary quantities for each technology were found (based on the best quotations from several chosen suppliers).

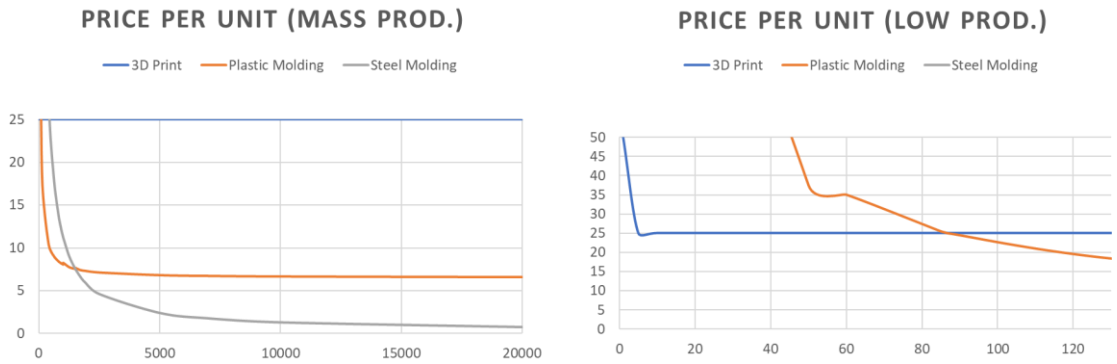

Figure 30 – Cost per enclosure (€), per quantity produced (units) based on the process

By looking at the trends it can clearly be seen that for small production 3D print is better, and then at a certain point Plastic Molding starts to be more cost-effective. At bigger productions, steel molding starts to be the right choice. By finding the mathematical equations that describe those curves and determine their intersections it was possible to reach the exact values on which it compensates to produce with each type of process:

- $0 < x < 86$, 3D printing
- $86 < x < 1500$, Plastic Molds
- $x > 1500$, Steel Molds

These values and all the other variables regarding costs where compiled and used to produce a model that can calculate the final price of the product based on the quantity, automatically choosing the best process option for production based on the quantity it is needed to produce (Figure 30). Some additional parameters (like the expected rate of returns) can also be supplied as process variables to the simulator.

Vital Sticker - Product and Price Calculator

Quantity	500
Returns / DOA / Others	5,00%

	Production Sites			
	Portugal			China
	1st Production		Recorring Productions	
	All-inclusive (Atex...)	Kickstart/Pilot	Only variable costs	
Total Production cost	54.698 €	41.111 €	39.431 €	
Per Unit	109 €	82 €	79 €	42 €

Notes:
All- Inclusive version: Includes Atex, IP67X certification and outsourcing the test jigs design and production
Kickstart/Pilot version: Includes only essencial certifications for CE marking (CEM). Tasks (like jigs production and design) must be made in-house
Only Variable Costs version: For very large productions, considering the fixed costs were already diluted
China version: Similar to only variable costs version, but with 5.000 minimum quantity and produced in China

Figure 31 – Automatic calculator of production costs for the VitalSticker

As different clients can require different products it is predicted by the model four different versions available for production: two regarding initial production and two regarding recurring productions, differing mainly in the amount of work that must be made in-house versus the number of tasks that is outsourced (Figure 31).

Based on that, some considerations can be made:

- It would cost around 41.000€ to produce 500 units, which could then be sold using Kickstarter-like of crowdfunding platforms for a profit (while also paying for fixed costs)
- China is always significative cheaper to produce (around 30% less) but is only available only for production scales over 5.000 units (as the contacted Chinese suppliers refuse to accept orders of smaller quantities). Other considerations like intellectual property protections and eventually difficulties to control production may need to be considered before moving production overseas

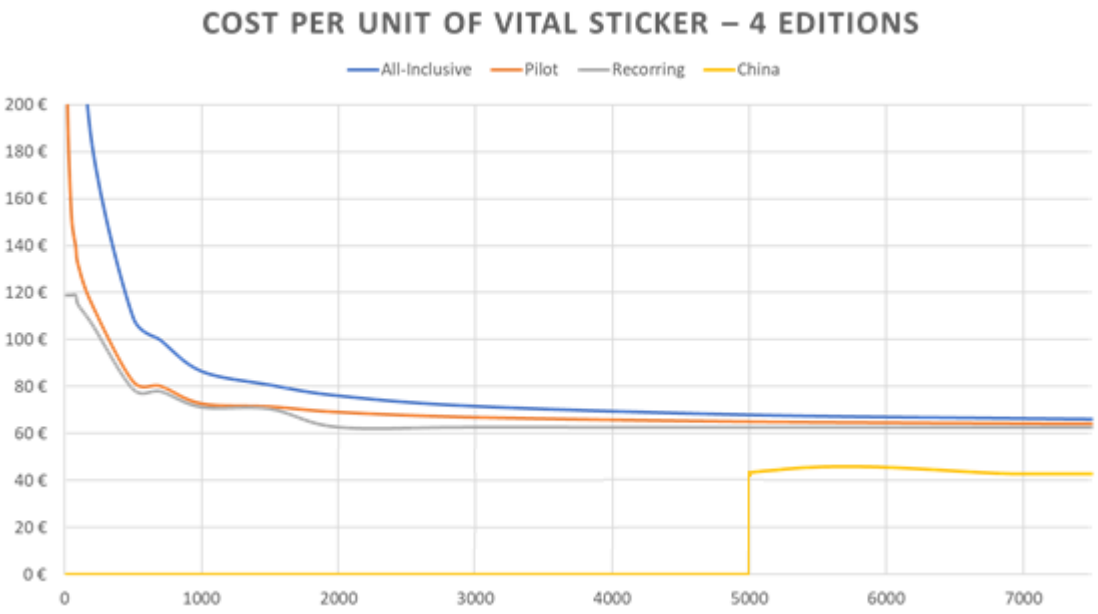

Figure 32 – Production costs in €, per quantity (unit) of VitalSticker

Another interesting analysis that can be made with the data is how do the costs add up inside the total costs: which components make up for the majority of the cost and which are less significant. Taking as an example for this analysis the "All-Inclusive" version of the VitalSticker, an analysis was conducted on the price per unit for different quantities of initial production (the results of which can be found in Figure 32).

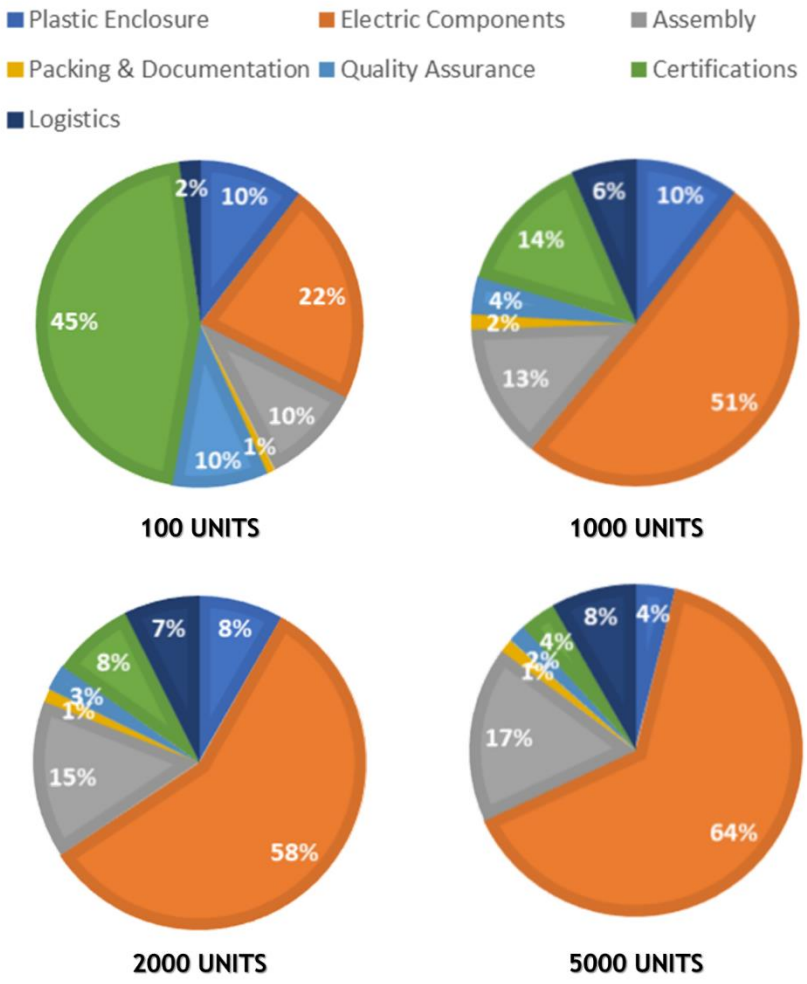

Figure 33 - Cost breakdown for an initial "VitalSticker" "All-Inclusive" Version production

As it was expected, while initially, the impact of certification in total costs is very significant (45% in an initial 100 units production batch), that impact will gradually decrease because most certification costs are one-time fees that will be diluted over time (reaching 4% with 5000 units produced). On the other hand, the electronic components cost is not a very important part of the total cost for smaller batches, but as the quantity increases and the fixed costs are diluted it becomes a much more important part of the total cost, and together with

assembly, make up more than two-thirds of the total production costs as the production scales up (together accounting for 81% of the cost with 5000 units produced).

It should be noted that the results of the said strategy would necessitate an average lead time of around 3/4 months to produce the first batch after initiating the process. If looking at each task, it takes plastic enclosure 40 days to design and production, 20 days for production of jigs of tests, 60 days for electronic components purchasing and assembly, and 60 days for certifications (namely ATEX, CEM, among others). Is can be observed that the sum of the total time for each task of the processes is bigger than the actual lead time, due to the fact that upon getting the green light for production some tasks could actually run simultaneously, thus reducing the final time for production.

As for payment conditions, for European suppliers, the norm negotiated was 60 days after delivery, although a different payment method may be requested to the partner on a case by case scenario if there is a need for so or if it seems appropriate.

However, while they may be interesting, production cost estimations are only important if the business is indeed viable. Thus, it is important to compare the achieved production costs with:

- Cost price of competitors products
- PVP / Public price of competitors products

As a way of closing this topic and conclude the action research project, the results of the said comparison can be found in the next section.

5.7- Conclusions

One important take away is if the current strategy is indeed a strategy that enables the start-up with tools that can empower its entry in the market at a competitive price while still making a profit. And as said before, the best way to verify this is to look into market indicators.

Regarding the cost price of the competitor's product, the agreement achieved with one of the competitors companies (located in Asia) allowed for a hardware supposedly equivalent to ours to be acquired for around 70€/unit (initially it was agreed that even thought that price was only valid for orders around the thousands of units, it would be used in the initial order as a base price for the few test units that were purchased)

On the other hand, as for commercial prices, the values vastly differ, from ranges as low as 200€/unit to 2.500€/unit with very little difference on the displayed features related to the products.

By comparing those values, it is clear that the production strategy is indeed viable in terms of product margin, as the production price is significantly lower than the minimum sales price

(200€). While other areas of the company will be very capital intensive (like software development) it is perfectly possible to enter the market at a lower range of prices (200€) and still turn a profit.

On the other hand, the price of production is actually pretty similar than the one we have from the competitor (for a production batch of around 2.000 units the cost for each unit produced by the start-up would be 69€, thus being lower than the 70€ of cost price that the competitor asks - although not by much). It is clear that by producing in China and probably in a larger scale the competitor has found a way to reduce the costs in a way and degree different than ours (which is why a deep technical analysis should be conducted on the physical product after it arrives from the competitor – hoping to provide insights about ways to reduce costs in our own product).

While buying the hardware to another company would be simpler and less capital intensive it might make the start-up more vulnerable to abuse of power by part of the competitor – and for this reason that option should be considered carefully.

By all this, we can say that this strategy enables and potentiates the initial objective of growing the company by giving not only the alternative to produce but also to use a mixed strategy of produce and purchase, in order to maximize profit and leave the capital available to use in other crucial departments of the start-up.

Chapter 6

Analysis of Start-ups' Strategic Options: A Simulation Modelling approach

Simulation is a technic used when the model or problem is too complex for formal mathematical analysis. While this type of research can lead to lower scientific quality results than research using mathematical analysis, sometimes the problem studied may simply be of too much importance for that to mater (Karlsson, 2010).

In this section the results of the use of a computer simulation to test hypothesis will be shown: the simulation and underlying competition will be presented. The way the simulator works, and the main variables will be described, and an overall description of the findings and results of the simulation will be presented.

6.1 – Introduction and Motivations

The computer was one of the biggest inventions of our age. With their help, we can deal with a much wider variety of scientific models than ever before – more complex, more integrative, most times leading to sufficiently robust findings.

An important part in simulation research is to justify why to use this method: with the answer normally being because the problem cannot be solved in an analytical away (Karlsson, 2010). And in our case, choosing the best strategy for start-ups is indeed a problem impractical to address only by means of mathematical equations for several reasons.

First, because the companies are not solitary beings. They exist in a social world where they must relate with other entities in order to thrive: not only clients but also suppliers and

sometimes: even competitors. In fact, the success of a company can sometimes be very much affected by the competitive scenario that it is in. The company's decisions affect each other, and so it's impossible to use an atomistic view and think that the future of a company only depends on their own decisions.

Normally, in order to make simulation research, one must first try to make a scientific model in order to test the hypothesis. However, in business research to do that from scratch would be almost unthinkable, as it would touch subjects ranging from areas very much outside of the scope of this research (like social sciences, economic theories, and others).

Our objective is to use a simulation model to test several hypothesis and strategies regarding start-ups strategy design (some of which are insights acquired from other methodologies like case study research). After recognizing that building a simulator from scratch is an impossible task, an analysis of the market and existing literature was then conducted to identify the suitable vessel for our tests.

6.2 – Business Simulations and Games

With regards to business simulations, there is a wide range of options in the market. In fact, as stated before literature states that around 98 percent of all accredited universities in the United States are using business simulations (Schröder et al., 2012), some of which use their own in-house created business simulations.

However, for this specific use, not all options are valid. There are some requirements that the simulation must meet in order to be helpful in testing at least some of the hypothesis on start-ups strategy.

The top requirements a simulation must meet were accessed, and described and followed:

a) The simulation must be developed in a competitive environment, preferably competing in markets where other start-ups are managed by real-life professionals or students, in opposition to being managed by the own simulation

b) The simulation must have a good reputation and be preferably certified by international boards that can attest the quality of the simulation and its accuracy according to real-world scenarios

c) The simulation must have a sufficiently large participant usage from all around the world, so its simulation can be tuned to different realities and can simulate the introduction of a start-up accurately anywhere in the world, preferably having itself real-life users from all around the world

d) The simulation must be offered freely or at a sufficiently low cost, so that it can be used for the purposes of this study without creating a high financial burden on its participants, thus allowing participants diversity in the user base.

e) The simulation must be detailed enough so it can allow for essential variables to be defined as suited – namely regarding product customization, supplier base and quality of component

f) The simulation must be focused on managing the fates of a company from day 1 of its existence – it has to be a start-up.

g) The simulation must be able to be completed within the time schedule of the present study

With all these restrictions and recommendations defined, a close study of the market and literature was conducted in order to find adequate software to be used.

Simulation software's and initiatives were found that meet some requirements, but not all.

For example, based on restriction a), all business simulations that don't offer a competitive business environment were discard. By doing so, all standalone software's that don't allow multiple users to compete at the same time are by so out of the equation.

So immediately the focus was turned to find a business competition simulation – which would by definition allow for competitors to use different business strategies in a competitive scenario.

However, according to restriction b) not all simulations are eligible – only the ones that are certified. In fact, there are international associations and boards that aim to regulate and rank these simulations. These associations normally operate in different geographic locations, like the following (descriptions adapted from the associations own websites):

- Latin American Council of Management Schools – CLADEA
    - An international organization that reunites both higher education institutions and international organizations committed to the teaching and research of management. Its main objectives are to support administrative and academic management, to create spaces suitable for knowledge exchange, to promote and publish applied and theoretical researches and to promote mobility accords.
    - Formed by 242 public and private member institutions that come from America, Oceania, and Europe
- AACSB International
    - AACSB connects educators, students, and business to achieve a common goal: to create the next generation of great leaders. The mission of AACSB International is to foster engagement, accelerate innovation, and

amplify impact on business education. It connects, shares, and inspires innovation and quality throughout the member network, as well as the business community. The collective strength of the organization is founded on diverse perspectives, a global mindset, and a commitment to making a difference.

- Formed by 1,600-member organizations and more than 800 accredited business schools worldwide.

- EFMD - The Management Development Network
  - An international, not-for-profit, membership organization of business schools and corporations, based in Brussels, Belgium, with offices in Asia and the Americas. A unique forum for information, research, networking and debate on innovation and best practice in management development, recognized globally as an accreditation body for quality & impact assessment in management with established accreditation services for business schools and business school programmes, corporate universities and online courses
  - Formed by 900-member organizations from academia, business, public service and consultancy in 88 countries

So, in order for a competition to be considered it should be recognized by at least one of these international boards.

Additionally, requirement c) states that the simulation must have a sufficiently larger participants usage from all around the world, so at this point, only worldwide simulations could be considered, which apart from that should be free or low cost to participate (but detailed enough so the hypothesis is tested).

From the entire market survey that was conducted (mainly by researching the international board's websites in search for credited competitions), only two business competitions were considered:

- Global Management Challenge
  - The largest Strategy and Management Competition in the world. It's the largest international event based on business simulations, in which more than 500 000 university students and company managers participating in this event throughout the world.
- Global Marketing Competition.
  - The most recognized global simulation competition at the university level. In it, teachers and students have a testing laboratory of the highest level at their disposal, that will enable participants to train and be tested in

issues required in the business world, the real world. Used by 60.000 university students and companies in 89 countries around the world.

Both competitions were accredited by boards, free to participate for Academia, take place in an internationally competitive environment, and are apart from that sufficiently popular and detailed. However, the Global Management Challenge does not guarantee a scenario in which to control a start-up – and through the different rounds of the competition, it can happen that the scenario presented is of an established company.

For those reasons, the chosen simulator to be used turned out to be the Global Marketing Competition.

6.2 – Competition Format, Variables and Objectives

The global marketing competition (GMKC) is a comprehensive simulator that tries to replicate the characteristics and behavior of a start-up (Figure 33).

It's yearly organized by the Spanish newspaper ABC, the Spanish university ESIC - Business & Marketing School, in collaboration with Santander Bank. It was originated from the merger of Business Marketing Game (BMKG), Global Marketing Game (GMKG), Latin Marketing Game (LMKG) and China Marketing Competition (CHMKG).

Figure 34 – Logo of the competition on the 23rd edition
(taken from the official website)

By using the competition, several variables are controlled, namely regarding the production planning, production systems, procurement, costs and Maintenance, publicity and media, segmentation, positioning, stock management, and wage policies.

The stated objectives (adapted from the official website of the simulation) are to provide the users an application of know-how in a market that is similar to a real market, training in market analysis and research, realization of the importance of quantitative and qualitative

decision-making, exercising responsibilities in situations of risk, the encouragement of teamwork, and an overview of the business world, and the way to manage various departments.

To incentivize participation, the competition also offers a wide range of prizes, namely a specific master at ESIC Business & Marketing School for members of the winning team, and pecuniary prizes for the first 5 positions (together with a certified diploma for all participants).

The competition format consists of teams of 2 or 3 participants + 1 professor (which can be optional). In this case, the author of this master's thesis was the team leader, forming a team with to other master's students with similar focus of interest and similar views on good startup strategy practices. The competition is divided into 4 phases:

- The first 3 are online
    - Initial phase-knockout
    - Quarterfinals
    - Semifinals
- The last is on-site
    - Final

During each round, several business decisions have to be taken considering the above topics. Each market will consist of 6 real-life companies from anywhere in the world, with each company preparing a management plan covering a one-year period into the future, starting from the same situation (Balance Sheet) and with the same data (Scenario).

The classification criteria, which will access the quality of the decisions taken, is, like in real life, based on accumulated profit. With each phase the company starts from scratch (like a true start-up) and the team that generates the highest accumulated profit will be classified as first and progress to the following round. An example of the simulator's interface can be found in Figure 34.

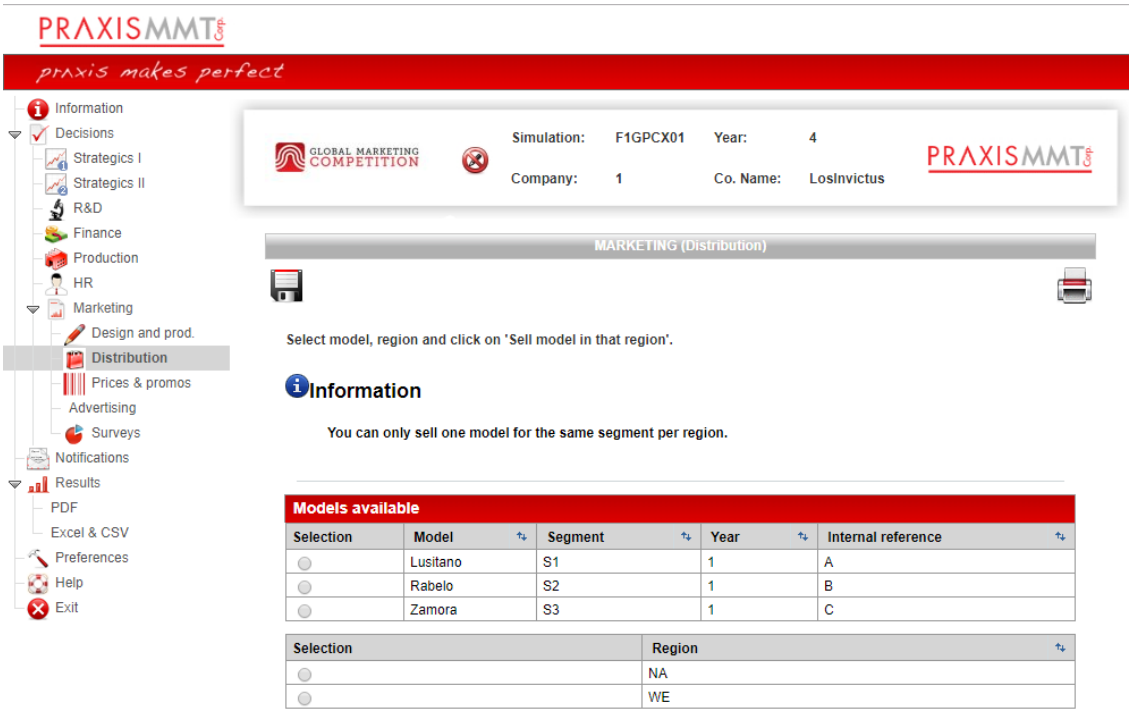

Figure 35 – The simulator interface allows for several variables to be controlled (taken from the simulator interface)

The 2018/2019 edition started around September 2018 and comprised over 5100 participants from 881 universities in 89 countries. The competition was as expected divided between 4 rounds, with each round containing from 4 to 7 business plans and spanning over 2 or 3 weeks each. The decisions would be taken on the simulation website, and after 1 day the results of the simulation would be presented in an analytical form.

The data would be available to download online, in a pdf or excel format so that it could be treated using statistical tools in order to find trends and performance indications that could help the future decision-making process. Many indicators were presented, mainly economic and financial values that allowed to access the success of the start-up (Figure 35).

ASSETS

	1	2	3	4	5	6
Current Assets						
Cash and equivalents	120,564,847,658	-78,380,132,473	29,211,935,695	-1,162,938,323	-53,648,857,318	-58,230,812,675
Financial investments	0	0	0	0	0	0
Inventory	32,386,557,225	250,001,867,801	7,900,388,776	11,541,634,482	77,731,324,642	62,005,273,300
Raw materials	1,089,605,702	55,569,438,900	247,556,819	0	0	132,578,726
Finished goods	31,296,951,523	194,432,428,90	7,652,831,957	11,541,634,482	77,731,324,642	61,872,694,575
Total Current Assets	**152,951,404,884**	**171,621,735,328**	**37,112,324,471**	**10,378,696,159**	**24,082,467,324**	**3,774,460,625**
Non-current Assets						
Assembly plants	10,350,000,000	10,350,000,000	10,350,000,000	2,450,000,000	6,100,000,000	8,050,000,000
Technical facilities, machinery and tools	3,750,000,000	2,000,000,000	3,250,000,000	500,000,000	1,500,000,000	3,250,000,000
Research and development	2,800,000,000	1,600,000,000	1,600,000,000	1,200,000,000	2,400,000,000	2,400,000,000
Depreciation and Amortization	-7,935,000,000	-6,845,000,000	-7,005,000,000	-2,675,000,000	-5,525,000,000	-6,000,000,000
Assembly plants	-4,485,000,000	-4,370,000,000	-4,255,000,000	-1,225,000,000	-2,750,000,000	-2,875,000,000
Technical facilities, machinery and tools	-1,250,000,000	-875,000,000	-1,150,000,000	-250,000,000	-675,000,000	-1,025,000,000
Research and development	-2,200,000,000	-1,600,000,000	-1,600,000,000	-1,200,000,000	-2,100,000,000	-2,100,000,000
Deferred Income Taxes	0	26,240,658,654	15,389,141,102	2,631,249,505	10,844,745,167	16,385,946,899

Figure 36 – Example of the resulting information provided about all the competitors (adapted from the simulation results)

During the participation and as time went on, over the course of several months the team kept advanced through various stages and eventually reached the world final, an on-site event in December 2018, in Madrid.

Due to the extensive nature of the number of decisions taken, variables controlled and results (many out of the scope of this study) all over a course of several months, it is not possible or plausible to cover all of them in this study.

For this reason, in the following section, it will be presented only the most important insights and strategies acquired from the final round of the competition, in what is regarded the integration of product, market and supply chain decision in designing a start-up strategy.

6.3 – Analysis and Strategy Used in the Simulation

For the final round, the start-up that was presented to be managed belonged to the automotive sector. The challenge was to steer the fate of the company starting from day 1 with zero production plants, car models, car design and over the course of 7 decisions (7 years on simulation time) turn it in a profitable business.

While some variables were related to specificities of the automotive business (like the size of each car, specific dimensions or the number of cylinders, all of this not to be covered in this study), it was our research hypothesis to be tested if there were some generic insights that could be successfully applied to start-ups of any business sectors and obtain equally satisfactory results. To obtain this insights and list of good practices is the main objective of this study and what it aims to achieve.

Starting the simulation, a specific set of data was presented to each team, comprising the general indicators of the market the start-up was operating in (including results from various surveys and data about the preferences of customers, costs for logistics routes, size of each market, among others) all of which should be the basis for the strategy definition for the start-up.

Among the indications, demand for each product segment was presented (as a result of customer surveys provided, see Figure 36).

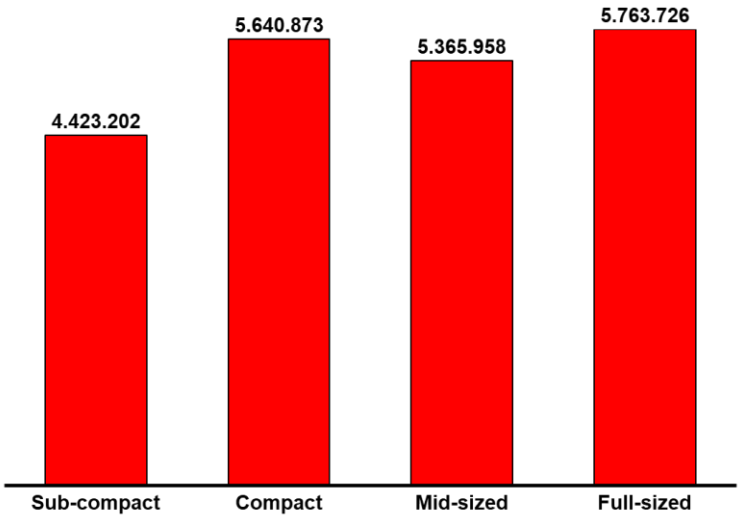

Figure 37 - Demand calculated using % demand per segment/region and total demand per region (numbers in millions €)

From that data, it was made a decision that the start-up should focus its operations in a full-size vehicle segment, as in this case, it was not only the bigger market but also the most profitable one, and the best chance for a more impactful quick-win market.

On the other hand, sub-compact vehicle shows evidence of a low market demand revealing a less impactful choice for a quick-win scenario, being also the lower profit per unit segment, reinforcing the worst choice to be the focus of our company.

At this time, it should be noted that the simulation had some restrictions: initially, the start-up starts without any car models, so it is able to choose 3 models to launch, taking 3 years from design to market. After that initial moment, only one car model per year could be launched.

It must be noted that the start-up had 3 different markets to sell on: South Europe (SE), North Europe (NE), and North America (NA). Demand data about those markets were also provided (Figure 37).

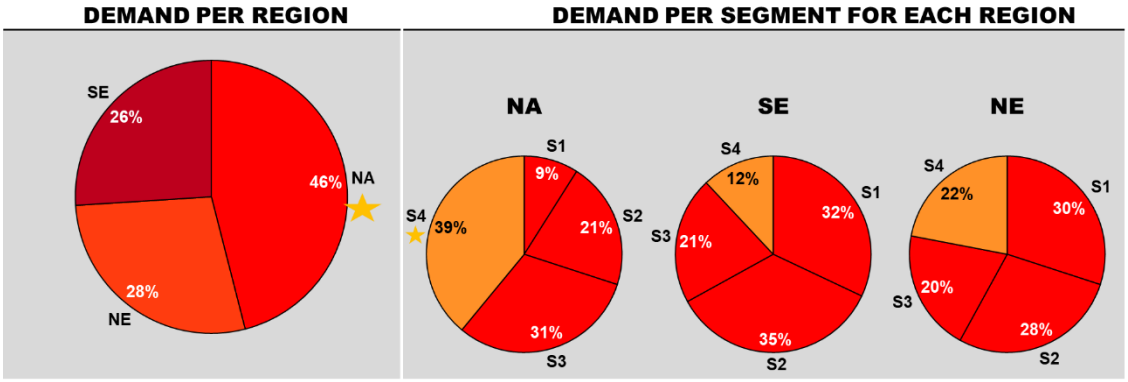

Figure 38 – Size of markets per segment / region

Based on this it was also clearly seen that the demand for North American market was overall higher, especially in the chosen segment (S4, or Full-sized), confirming the validity of the previous strategy. The other segments are respectively S1 for Sub-compact, S2 for compact and S3 for Mid-Sized. One other aspect that was studied was the customer segment regarding the economic income (Figure 38).

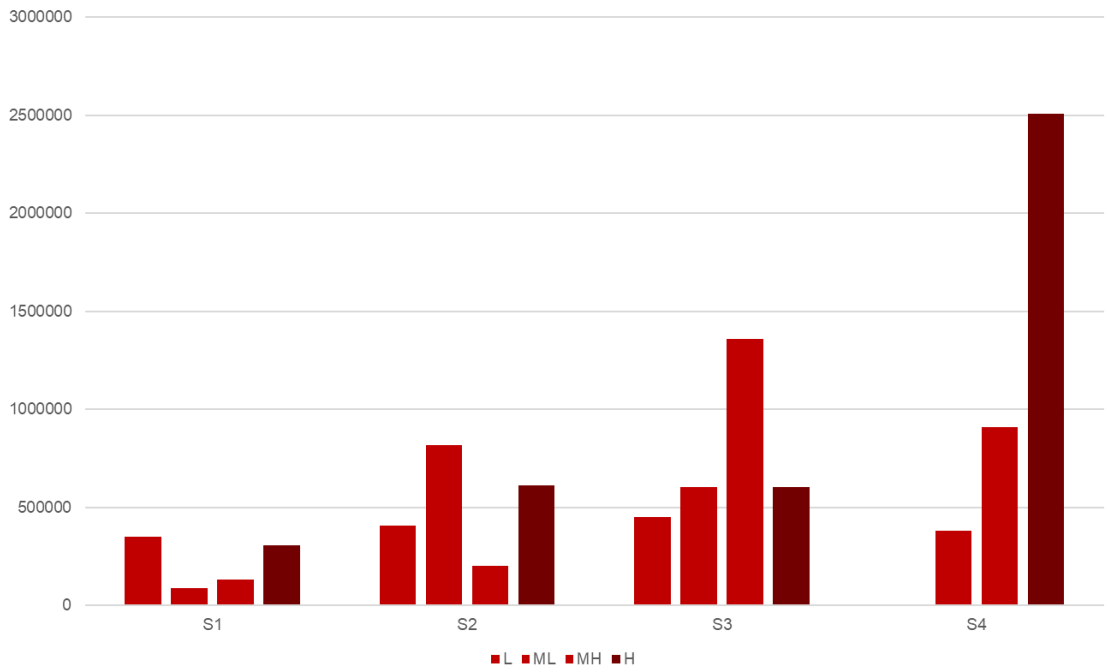

Figure 39 – Demand by income segment (numbers in millions €)

Based on that information it was again clearly seen that the chosen Full-sized market was (as expected) mainly a high-end market. A decision was then made to conditionate all further decisions to create high-end models for a high-income audience, hoping to achieve mainly large and comfortable vehicles. It should be noted that the income segments above are L (low), ML (Medium Low), MH (Medium High) and H (High).

One thing that was also defined at an initial moment was that we would be aiming to introduce as many variations as possible, in order to give clients a choice and customization (as past research suggested that offering customization could be a way to success in start-ups). In this case, the choices would be related to the sizes of the motors, the quality/comfort of cars, among others.

As it is usual in every start-up, it needs a sales channel to distribute its products. Companies are social entities that cannot exist by themselves. They must make partnerships and relationships with other organizations. In the automotive industry, like it or not, dealers are a fundamental piece of the puzzle. So, while choosing an initial strategy of focus on the more promising segments, as said before the goal was to offer a wide range of customization

eventually, and ultimately be present in every market in order to achieve a market dominant position.

While choosing to rely on local car dealers to expand sales, it was planned to recruit as many dealers as possible to ensure the company survival (calculations being made relative to forecasted demand). To keep the dealers engaged it was planned to start by giving higher than market level conditions/profitability to dealers, to achieve a high level of dealer satisfaction (which was also one of the indications in the simulations).

As soon as the sales would go up, it was planned to drop the dealer margin. With more sales, the dealer wins more in total and so could accept a smaller margin in each car. The objective was then to reach a win-win situation: in which dealers win more on volume but the start-up would be ultimately paying less by each car.

Regarding customer support, the decision would be to maintain a high service level from early on, not only to match with the premium brand strategy but also to match the findings from previous case study research.

As for production, the simulation gave the choice of choosing where to produce the products. Initially a single production factory was established (as outsourcing was not an option), locally near the place chosen to be headquarters (in this case, South Europe), as initially it would be better to maintain production closer to the development team with the promise of opening more factories in cheaper zones as sales scaled up.

Finally, the demand forecast should be made as accurate as possible as to create a minimum of inventory of final products and components. If inventory were to happen, it would be placed in the factories (waiting to be shipped to the final clients), but it should be limited at all costs in either component and final products alike.

So, as a recap, the strategy chosen was aligned with the previous finding (in the case study and in the action research), namely:

- Focus on more promising geographical markets in the initial years of operations
- Define target audience and design the products that those same audiences desire, keeping an eye in higher quality products when entering the market
- Initial relations with sales channels by providing higher than market level conditions to create good relations and attract more partners
- Initially focus on a low range of products but make plans for customizations and variety as soon as possible
- Keep service level high from early on to maintain a good brand image
- Production locations initially focused next to the headquarters for proximity with the R&D team, later development open production facilities in cheaper locations
- The inventory of components and final products should be taken to a minimum as to reduce the financial burden on the start-up fragile finances, with improved forecast to take the place of safety inventories

The rounds went on and this same strategy was followed for the entire set of the simulation. However, not all competitors followed the same strategy. Some teams choose a low-cost low-quality strategy, where they were providing inferiors goods, produced at a reduced cost at a cheaper price. Others decided to only offer few variations of their products, without customization. Others to start producing overseas from day 1. As a comparison, on the last year of the simulation (7th decision) calculations were conducted to try to understand which strategy worked best, only to discover that companies that offered low-price-quality products had not created a good image at the eyes of their customers and struggled to survive: even selling at lower prices. Figure 39 shows the comparative results regarding to the main competitor in the final round (Team "WeMotors", from India)

S4/M4A/GAS/2500/O3/T3/V5	Price	Demand	Sold
Los Invictus	47.200 €	298.817	298.817
WeMotors	24.000 €	33.822	33.822
S3/M5A/DIE/1900/O2/T2/V6	**Price**	**Demand**	**Sold**
Los Invictus	26.400 €	33.720	10.173
WeMotors	16.000 €	7.475	7.475
S2/M1A/GAS/1500/O2/T2/V2	**Price**	**Demand**	**Sold**
Los Invictus	19.900 €	31.686	31.686
WeMotors	12.500 €	25.004	25.004
S1/M2A/GAS/1300/O1/T1/V3	**Price**	**Demand**	**Sold**
Los Invictus	10.900 €	277.119	133.326
WeMotors	9.299 €	46.762	46.762

Figure 40 - Results of quality strategy led to higher sales at a higher price

It was clearly shown that the quality strategy had worked as competitors could not sell even at half the price. In fact, we're selling at a higher price at every market, with positive results (Figure 40).

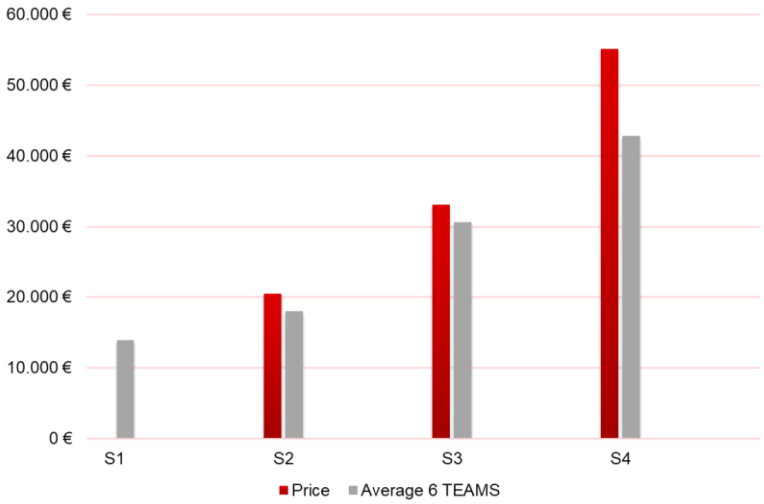

Figure 41 – Average Selling Price - The strategy was to be a quality brand on costumers' eyes

The strategy was indeed based on starting with higher prices and quality, which in that phase of the start-up could provide us with flexibility: by choosing to focus on a segment (high end) and deliver what the segment wanted (comfortable cars) it was achieved a position where clients were getting what they needed (in this case, quality).

This strategy also gave us flexibility: as our car models became older and the profit fell, we kept investing in innovation, bringing more cars and options into the market. However, as profit margins were high, we had plenty of room to lower prices to keep demand stable and profit going.

At the end of the simulation, the financial results were analyzed, and indeed, the strategy decided showed very positive results (Figure 41).

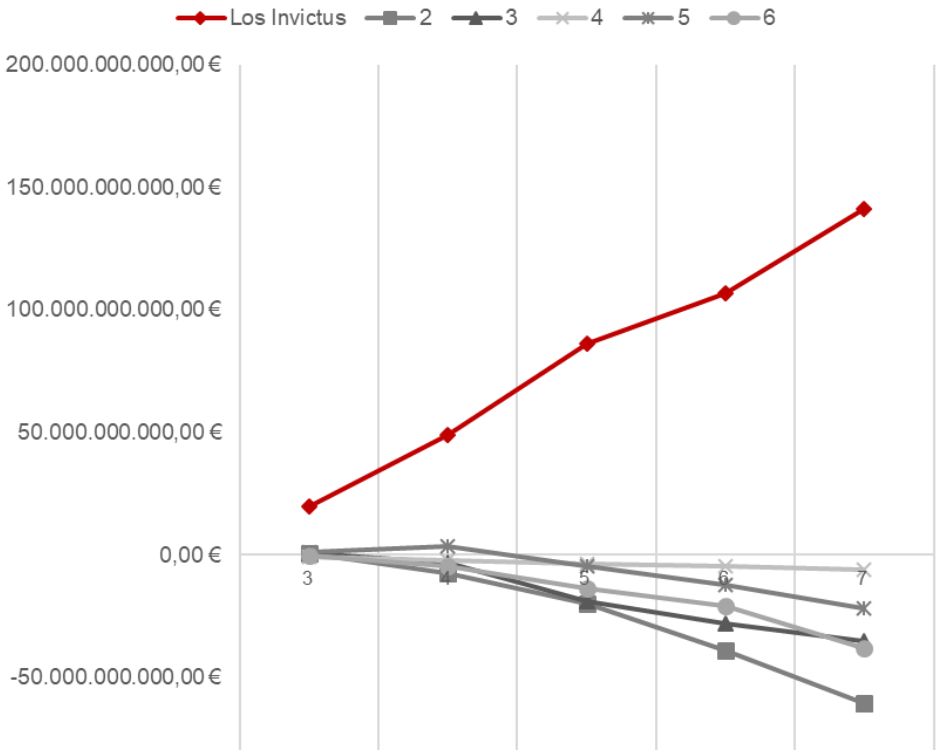

Figure 42 - Accumulated Retained Earnings

By having, by far, the biggest accumulated retained earnings, it was possible to reach the 1st place in the simulation game (in the final, out of the entire +5000 teams), validating some of the assumptions previously made about good start-up strategy definition.

6.4 - Conclusions

Despite the fact that apparently, the chosen strategy is suitable for the start-up, the biggest challenge that was encountered was without a doubt on the forecasting side. A good forecast is ideal to avoid missing demand (lost opportunity) but also to avoid too many inventory. It is important to always keep in mind that inventory takes away more than space. If you produce less, you lose sales. But if you produce more you end up with a huge inventory - and that may be a problem on the financial side. Having stock takes money, and having money also takes money. So, while it was tried to maintain the ratio between gross sales and inventory below 10%, that was not always possible (Figure 42).

Values on bilions	GROSS SALES	INVENTORY	RATIO
Year 3	61.8 €	0	0
Year 4	152.5 €	10.2	6,72 %
Year 5	171 €	11.2	6,56 %
Year 6	115 €	38.2	33,2 % ★
Year 7	175.6 €	31.3	17,8 %

Figure 43 - Maintain sufficient but low inventory levels remains a challenge

All in all, the main takeaways for future strategy design taken from the simulation experience are (in the majority of cases) aligned with the previous research, namely:

1) In respect to product decisions, give customers a choice by using customization and keep investing in innovation

2) In respect to market decisions, focus initially on the most lucrative markets, assure the right partners and maintain good customer service from early on

3) In respect to supply chain decisions, produce initially near the headquarters to keep the R&D and production in a tight loop (at least for the first stages), while keeping inventory levels of both components and final products at a minimum by producing good quality forecasts

Chapter 7

Conclusions and Future Work

In this section, the conclusions of this study will be summarized and presented, not only regarding the individual achievements from each of the research methods but also about how they all come together to provide insights in how to design a robust strategy for a start-up using integrated product, market and supply chain decisions.

Some suggestions about topics that might be interesting to revisit in future research will also be presented and discussed.

7.1 – Main Insights – Opportunities and Threats

While it has been vastly established that individual themes such as product design, supply chain management, and market segmentation have a great influence on the success of new product introduction by established companies, only in recent years did literature started to catch up regarding the same issues with start-ups (Kickul et al., 2011; Joglekar and Lévesque, 2013). Due to the constantly changing environment of start-ups, in our research, more than analyzing each issue separately, we tried to show ways to integrate the various topics together towards achieving competitive advantages, create synergies and improve the survival rate of start-ups.

In the structure of this study, it was defined that each chapter would have their own results, presented and discussed at the end section of the section. To examine those standalone conclusions individually is of vital importance for understanding the results of this work and for this reason this present section will not aim to reproduce the full detail and extensiveness of all the results achieve throughout this study. Instead, it will focus on how future start-ups can

learn by the integrations of these concepts and by choosing their strategies based on these ideals.

Firstly, it must be noted that noted that there were certain limitations in this study, especially regarding the number of companies available for the case study research within the chosen subject (Portuguese-based start-ups from a tech background), leading to a scarce number of cases considered that surely influenced the variety of the end results.

Despite that, it was able to extract some insights regarding certain topics. For example, it was clear that most start-ups innately agree with some of the best strategies to use (such as the use of patents as intellectual property protection for technological advancement, a feature used virtually by all of the start-ups analyzed). On the other hand, other cases where found where apparently no consensus exists, and where the strategies used vary greatly (as it was the example of inventory and module configuration strategy).

To validate those same results in practice (using as much of a real-life scenario as possible), two different approaches were conducted. One used an action research method and the other made use of simulation modeling capabilities.

The goal with action research (defined and described in Chapter 5) was to contribute both to the success and future of the start-up it was studying and also to improved once more the overall knowledge on this topic. While it was found that those two roles are indeed (as expected) conflicting in many ways, it was hopefully demonstrated that it is and should be possible to do both tasks without neglecting neither. Using the framework and steps suggested by the literature and the insights gathered during the case study research it was possible to successfully present a strategy that enables the company to compete in the market, while at the same time gathering valuable insights into all of this process.

Analyzing the specifics of the proposed solution it can be found that most of the findings were indeed applied to the strategy. On the product side, a module configuration strategy was fully used, where one supplier can easily be replaced by another in virtually all defined tasks, thus removing the risks of the entire strategy. The components chosen are itself standard, as that practice helps not only in the start-up procurement process but also allows many of the components to be bought through the assemblers at a significantly lower price (as a result of the assembler companies already buying those same components in bulk for their other customers). And as far as intellectual property, NDA's were extensively used between all partners with great acceptance and success (while for technical innovations, patents were already in use when the action research project started). On the market decisions, while the customer segment was already defined as focusing in Europe (and the USA in a medium-long term future), it matched with the later crafted recommendations. As for the barriers encountered in practice, they were allied with the prior findings as selecting the right certifications and finding the appropriate partners for each task were indeed top concerns for entering a market. The supply chain was also designed with the previous results in mind,

choosing to subcontract as producing in-house was not only not an option for practical reasons (like certifications) as it did not make financially any sense. The main partners such as assemblers and manufacturers were indeed discovered through the use of industry fairs (in geographical proximity), and all arrangements were made so that no inventory was needed at the production side of the supply chain. For example, in cases of components with very high minimum order quantities they are to be purchased by the assembly partner - that can then reuse the left pieces for other customers as a result of the use of standard components.

And besides all that, even after benchmarking the resulting strategy against over two dozen of competitors from 3 continents, evidence points out that the resulting strategy not only works as it can prove to be a competitive advantage when entering the market. For relatively low quantities of production the producing cost goes down and makes a case for the business being viable even when keeping the production located in Portugal (or a similar cost European Company) without the need to go to China (which although our calculations estimate would bring the costs 30% down, could also account for many other problems and introduce high-risk variables like customs regulations and tariffs into the supply chain, with the potential of influencing in a negative way the plans and strategies of the start-up). If by some reason the volume of units produced does not increase, a strategy of outsourcing the hardware completely can be followed as an initial partnership with a competitor was formed for potentially supply hardware that the start-up can later integrate and adapt to their own ends.

However, not all strategies could be used during the action research project. For example, as the company was not in the sales phase yet the likes of some market decisions (like customer segmentation) were planned but too soon to implement in practice. For this reason, a simulation modeling approach was considered, hoping to apply some of the strategies gathered in the case study research and action research project in a competitive environment, with the risk and responsibility that came with the action research now left aside, while at the same time getting practical and useful results. As presented before in chapter 6, simulations are indeed a good way to test the hypothesis in practice, and in this case, a strategy was designed for the simulation, keeping in mind the findings of the previous work, hoping to prove them right or reconsider them based on if the results were successful or not.

And fortunately, by virtually all metrics, they were successful. As the simulation was held in a competitive scenario, it is indeed a fact that the relevance of the positive results depends on the quality of other real-life competitors (as the chosen strategies were competing with other strategies chosen by other real-life competitors) and the quality and accuracy of the simulator to understand good and bad decisions and approximate their outcomes with reality. However, as presented in chapter 6 it is wildly agreed by the literature that business games are indeed a good way to simulate reality, so long as they are of good quality, certificated and with a good and vast participation base (Schröder et al., 2012). In this case, the simulation had the participation of over 2000 teams from 89 countries and 881 universities and business

schools. Additionally, the competition itself is being conducted for more than 20 years and was used by more than 60.000 students during that time, being at the same time certified by 3 independent international boards for its quality and accuracy. For all these reasons it is believed that reaching 1st place in the entire competition is the resulting outcome of the correct product, market and supply decisions. In the simulation, as far as product design, while initially sticking with standard products it was effectively given customers the opportunity for some choice and customization in a later stage of the start-up (as it was suggested during the case study research by some start-ups). On the market side, it was again given special attention to finding the right partners and maintain customer service alternatives as soon as sales were put in place (again, as suggested in the case study). And finally, in the supply chain, the production was once more initially planned near the headquarters to allow for management to keep the production close enough to inspect, keeping inventory levels at a minimum by trying to produce good quality forecasts.

It is by such expectantly proved that independently of the start-up sector of operation and large specificities, is it indeed helpful to find good practices and successfully implement them in the strategy of the start-up, with this study contributing to increasing the knowledge in the integration of product, market, and supply chain decisions and hopefully enabling more and more start-ups to survive past the valleys of death and thrive into success.

7.2- Future Work and Research

During the course of this research, there were certainly raised questions about paths that while being out of the initial focus and objective of this study could indeed be of help to further advance the knowledge of this topic and its nuances.

Future research should further analyze the interplay between product, market, and supply chain in start-ups decisions by carrying out a longitudinal study of start-ups from the scale-up phase until maturity – or until death. As in the case study research some start-ups reported to be in the process of changing their operations in various aspects, it would then be allowed verifications regarding the improvements made by those changes, surely providing useful insights for future strategy definition.

At the same time, a greater effort should be made to try to quantify and collate the types and kinds of operational decisions with the survival (or survival rate) of companies, hoping to expand knowledge not only of good practices but also of practices and decisions to be avoided. While statistics are known about the general survival rate of a start-up it can be deducted that certain decisions increase (or decrease) the chance of failure, and in a world when so many start-up companies are of vital importance to our everyday lives, every path that can lead us to understand why they fail and how to help them succeed can certainly be a path worth taking.

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