Development of a Business Model adapted to a R&D organization

INEGI Case Study

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ABSTRACT

Additive manufacturing (AM) is being used for the past 30 years. However, it is only now that its full potential is being explored by companies. Until recently, AM was mainly used to produce prototypes of products in early development stages. Yet, the increasing demand for customised solutions created an opportunity for companies when using AM technologies: customised products and solutions at a much lower price than the ones produced by conventional methods.

The purpose of the present dissertation is to analyse the attractiveness of a potential new service that takes advantage of AM technologies. This study was ordered by the Institute of Mechanical Engineering and Industrial Management (INEGI) and will serve as base for a this Master's dissertation where a Business Model will be presented for this particular service, taking into account INEGI's reality as a company and the industries that it serves.

To propose such a model and to have a better understanding of both the company and its macro environment, it was carried and internal and external analysis. To frame the problem, several areas were researched: AM technologies, services industries, business models and business plans.

By the end of this dissertation, it was possible to conclude that the best suitable option of a business model for the new service would be one of complementarities. The advantages pointed out by potential clients relied on productive systems, and since there is a team specialized on this matter within the business unit where this new service will be inserted, it would be of value for both of them to combine their knowledge.

Keywords: *Additive Manufacturing, Services, Internal Analysis, External Analysis, Business Model, Business Plan.*

RESUMO

A manufactura aditiva (AM) tem sido utilizada nos ultimos 30 anos, principalmente nas áreas de desenvolvimento de produto. No entanto, apenas agora as empresas começam a ver todo o seu potencial para além da prototipagem. O aumento da procura por soluções unicas abriu portas a novas oportunidades: desenvolvimento personalizado de produtos e soluções utilizando tecnologias AM. Quando comparado com os métodos de fabrico tradicionais, a AM permite às empresas oferecer um maior leque de produtos a um preço reduzido.

Esta dissertação surge como um estudo à atractividade desta tecnologia perante a indústria, bem como perceber quais as suas vantagens e desvantagens. Este estudo foi feito a pedido do Instituto de Ciência e Inovação em Engenharia Mecânica e Engenharia e Gestão Industrial (INEGI), tendo como principal objectivo a criação de um modelo de negócio para um novo serviço que utilize a AM. Para isso, foi importante perceber os ambientes em que a empresa opera, tanto a nivel macro como micro-economico, tendo sido realizadas análises internas e externas à mesma. A nivel teórico, várias áreas foram abordadas tanto a nivel tecnológico como a nivel de serviços, modelos de negócio e planos de negócio.

Em jeito de conclusão, foi possível aferir que a melhor solução para este novo serviço seria reger-se por um modelo de negócios de complementariedade. Sendo que as vantagens mais apontadas pelos clientes/futuros clientes se baseam no apoio à produção, seria de valor para o serviço em questão trabalhar em conjunto com a unidade especializada em sistemas produtivos – tirando proveito do seu conhecimento e da sua carteira de clientes já existente.

Palavras-chave: *Manufactura Adivitiva, Serviços, Análise Interna, Análise Externa, Modelo de Negócios, Plano de Negócios.*

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ABBREVIATIONS INDEX

AM – Additive Manufacturing

BM – Business Model

BP – Business Plan

BS – Business-bases Services

CAD – Computer Aided Design

CNC – Computer Numerical Control

EMAF - International Fair of Machinery, Equipment and Services for Industry

ESA – European Space Agency

FDM – Fused Deposition Modelling

FEUP – Faculdade de Engenharia da Universidade do Porto

INEGI – Institute of Mechanical Engineering and Industrial Management

INESC – Instituto de Engenharia e Sistemas de Computadores

ISE – International Submarine Engineering

IST – Instituto Superior Técnico

PSD – Product and System Development

SL/SLA - Stereolithpgraphy

SLS – Selective Laser Sintering

SM – Subtractive Manufacturing

SRE – Soluções Racionais de Energia

STCP – Sociedade de Transportes Colectivitos do Porto

TRL – Technology Readiness Level

AKNOWLEDGMENTS

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To my mother and my father, who have always been my greatest supporters and never questioned my choices. Also, to the person who had a great influence on my life and will always be my role model, I would like to thanks to my brother Diogo.

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Last but not least, I would like to mention the biggest loss of my life until now. To my grandfather, a man that I had always admired and whom, without even knowing, shaped me into the person that I am now. I just hope I made you proud.

1. INTRODUCTION

1.1. Problem contextualization

For the past 30 years, Additive Manufacturing (AM), commonly known as 3D printing, has been developed in order to represent a viable alternative to mass production. However, this type of production has been mostly used in the development of prototypes on the early stages of product development. This is due mostly to the reduced time needed to create a functional model when using these techniques, which enable companies to identify errors on the early stages of development leading to cost savings.

Nonetheless, given the evolution of consumers' preferences, the demand for customized products has increased. According to a study performed by Deloitte in 2015, more than 50% of individual consumers search for customized products and services and are willing to wait and pay more for them (Deloitte, 2015). This change in preferences, from mass production to customization, can be seen in almost every type of products and services as shown in Figure 1.

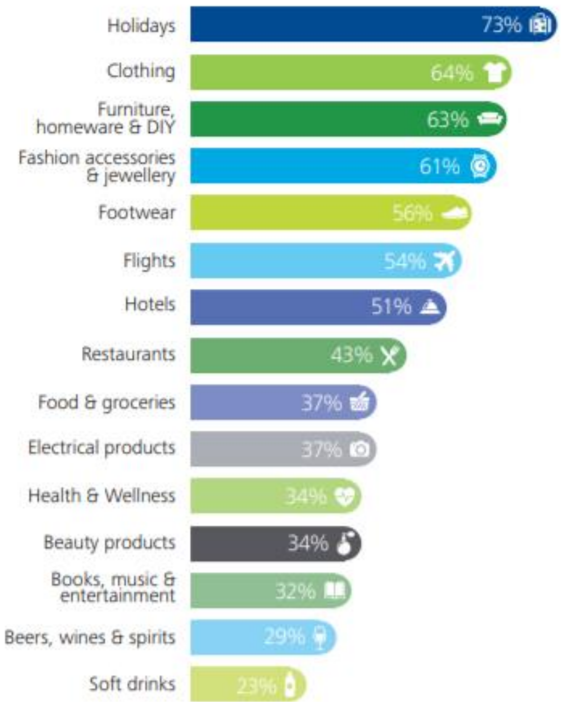

Figure 1 Consumer´s awareness of product or service customization by category (Deloitte, 2015)

With this in mind, it is possible to see the potential of AM in the fulfilment of this demand. The common machines used in manufacturing need to produce a large amount of products to achieve scale economies and to cover the investment. By using AM the costs per part produced can be reduced and it becomes much cheaper to produce unique products according to customers' specifications and needs.

Unlike the conventional production techniques, with AM it is relatively easy to produce different types of products in a single machine.

Not only individual customers but also companies want to have unique solutions for the problems they face. In a world that is becoming more and more industrialized, AM appears as a way to respond to specific problems that companies face with their operations. Since not all companies have the economic power to have their own business unit of research and development, or to invest in equipment and training on these areas, this is also an opportunity for other companies and organizations that do have this know-how on AM and the required machines to try and explore this emerging market of providing services related with AM technologies.

Being a national reference on engineering research and product development, the Institute of Mechanical Engineering and Industrial Management (INEGI) wants to start offering the aforementioned services. This will be offered within by the Product and Systems Development (PSD) business unit that has the necessary experience to endure this challenge. Since producing parts by using AM technologies require special design methods, INEGI also aims to be a specialist on this matter- product design for AM. This happens due to the method of production in AM, i.e. using AM machines, the part is produced by adding a layer of material on top of another layer. This is exactly the opposite of the traditional processes, which subtracts material from a solid block of raw material to build the wanted part. Being the two methods so different from each other when it comes to their productive methods, it is important for INEGI to acquire the necessary knowledge to be able to design parts that can be produced by AM machines. Not only is the design of the model important for them, but also to acquire knowledge on the new and emerging techniques of Additive Manufacturing such as the production of models in Metal.

With the ever growing possibilities for the use of this type of manufacturing process aligned with the experience of INEGI in its usage and with a strong network of clients, this e aims to be an introduction for a market study.

1.2. Motivation

This research was ordered by INEGI so they could know how to make a more efficient use of their capabilities and resources, such as their experience, know-how and customer relationships. After studying technological and market trends, the company became interested in developing a business plan for the use of AM technologies. The potential use of this type of technologies is very high (EY, 2016), so INEGI believes that they have the capability to introduce a new service, by taking advantage of the experience that the PSD business unit already has on this subject, and, with it, add value to their clients. Combining the resources of the business unit with the emerging demand for customized solutions, it is possible to say that INEGI will be able to fulfil the demand and explore new emerging markets.

1.3. Objectives

This dissertation intends to provide not only information but also a justification so INEGI can be able to evaluate the market attractiveness and to find the best way to allocate resources. Also, it intends to find market gaps, or niches, for the organization to explore and keep its position as one of the leading development centres in Portugal.

The business plan to be developed is expected to answer the following questions:

- What is the potential of Additive Manufacturing for industries?
- What technologies should INEGI choose in order to provide the best solution for customers?
- How will the creation of a new service be advantageous for INEGI;
- What is the best way to explore the company existing resources in order to create the new service?

1.4. Methodology

In order to propose a business model, several steps were followed, which included meetings with INEGI's engineers, strategical analysis of the organization, research of how the AM machines they own work, and evaluating the growing relevance of business-based services. After that, it was necessary to research about ways of creating market space or how to find a gap and explore it so the organization can take advantage of its know-how and the already established network of clients. Lastly, several meetings were conducted, both internally and externally, to evaluate the needs of the market yet to explore and to confirm that the company's business proposition is aligned with them.

1. Meetings – The first step involved a set of meetings with the engineers from INEGI. These meetings allowed a better understanding of INEGI's motivation and the definition of objectives for the dissertation. Besides that, it was also possible to identify the technologies used by them, their capabilities and potential services.
2. Strategic Analysis – The analysis of the organization's strategy was crucial to understand how INEGI's work and how it interacts with the clients, together with its strengths and weaknesses. It was also important to perform the external analysis to see how the macro aspects influence the organization and to understand the sector itself.
3. Technological research – The research performed for this dissertation was based on scientific journal articles, books, and companies' case studies. This was important to understand how the machines work, to understand the differences between technologies and their respective advantages and disadvantages. Also, it was important to use case studies and press to seek for market trends to get a glimpse of the attractiveness of the service to be proposed.
4. Business research - It was necessary to perform a research regarding the way of creating market space or identifying a new market to explore. For this it was carried a research based on books and papers on the subject.

5. Interviews – In this step, multiple semi structured interviews were performed in order to confirm that both parts, INEGI and clients, had their interests aligned. At first, internal interviews were carried out to have a full understanding of what the company can and is willing to offer and the way that they intend to do so. Following that, it was necessary to see if what the company is proposing to offer is aligned with the needs of the market. To do so, interviews were made to both existent and potential clients. This last set of interviews it was allowed a deeper knowledge of the actual needs of the market in the different engineering fields which INEGI works with.
6. Data process and analysis – After the interview, it was mandatory to process and organize all the information that came with them. Once all the data was processed, it became much easier to analyze it and withdraw the necessary conclusions.

1.5. Dissertation's Structure

The dissertation's structure will follow the scheme presented by Figure 2.

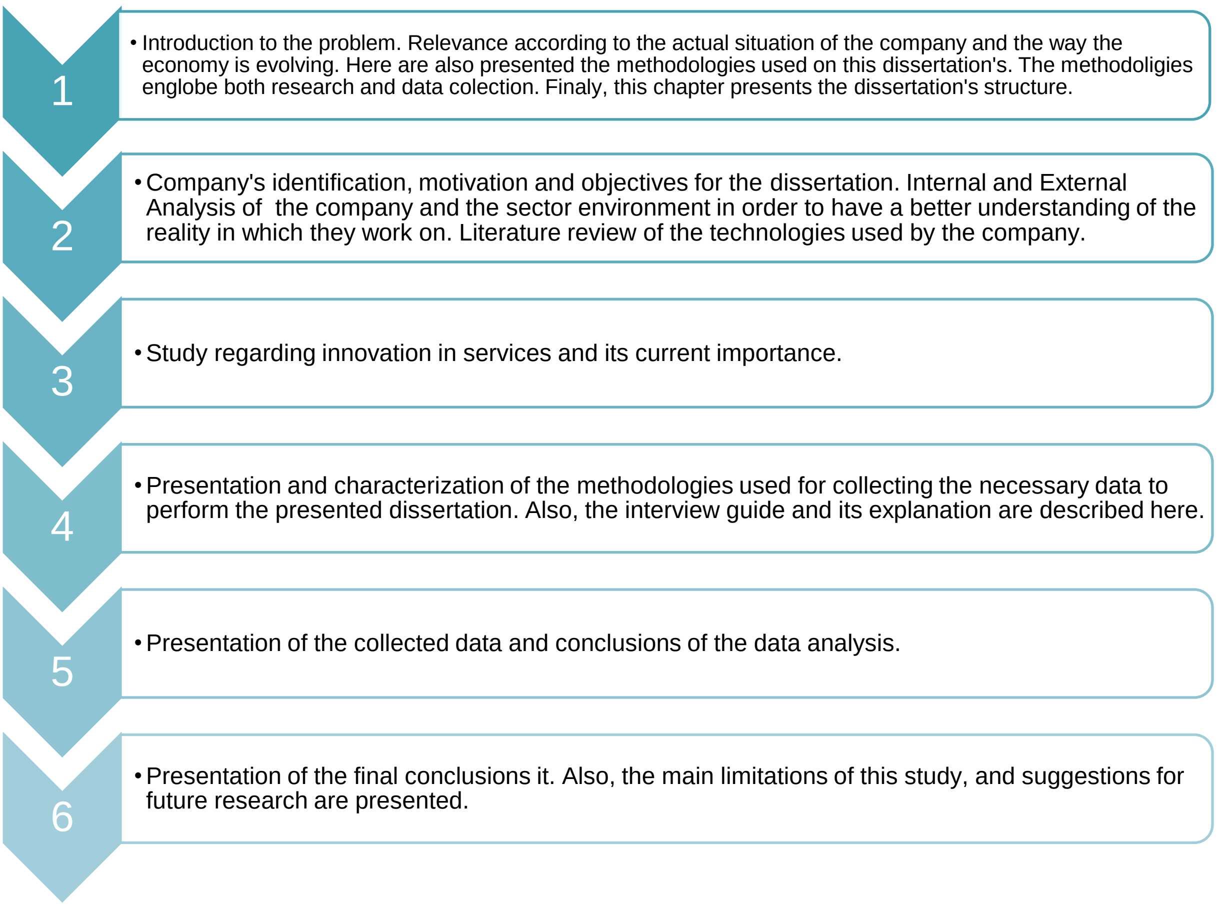

Figure 2 Dissertation's Structure

2. PROBLEM CHARACTERIZATION

The following section presents a strategic analysis of INEGI. This allows a better understanding on how the company works and how it deals with internal and external factors that have an influence on its business. A general description of the company is presented, as well as an internal and external analyses to see if they have the capabilities needed to enter a new market without compromising the company's good functioning.

It was also performed a study on the technologies used by INEGI so it would be possible to understand how the machines work as well as their advantages and disadvantages.

2.1. Internal Company's Analysis

The Institute of Mechanical Engineering and Industrial Management (INEGI) is a Portuguese nonprofit private institution created to bring closer universities and the industry. As a private institution, INEGI is not a governmental institution and seeks to make profit but its revenue comes not only from private investment but also from public funding, which is a characteristic of nonprofit organizations (Kaplan, 2003).

Founded in 1986, in the city of Oporto, by the combining efforts of the departments of Mechanical Engineering and Industrial Management of the Faculty of Engineering of Oporto University (FEUP), their main goal is to develop the knowledge in these two fields in order to improve the Portuguese industry. The following description of the organization was written according to the information available on the INEGI's curriculum and on their financial and activities report of 2017.

2.1.1. Mission

"Contribute to the increase of the competitiveness of the national industry, through Research and Development, Technology Transfer and Training, in the fields of engineering design, materials, production technology, energy and industrial management"

2.1.2. Vision

"To be recognized as a National reference Institution in technology based innovation and technology transfer area and became a relevant player in the European Scientific and Technological System"

2.1.3. Values

The organization rules itself according to a set of five pillar values:

- Client orientation – By satisfying and trying to exceed the expectations of the customers, financial supporters, associates and the general society;

- Ambition – Never settle and always trying to create value by the means of knowledge;
- Responsibility – Work hard, seriously and with professionalism. Fulfil their commitments and follow high ethical standards;
- Cooperation – Sharing knowledge with associates and work as a team;
- Urge for innovation – Always searching for new and creative solutions.

2.1.4. Offered Services

The institute offers several types of services, which vary from product development to individual training and technological consulting. In order to fulfill their mission, there are mainly five types of contracts that are offered within the organization:

- Knowledge Creation and Technological Development – this type of projects are usually financed by research programs both on a national and on an European level;

- Industry Development Support Programs – contracts co-financed by a private company and by a research program. These represent the most common type of contracts within the institute;

- Privately Financed R&D – an uprising part of the performed contracts are completely private ones, with the purpose of developing new products or new processes;

- Scientific and Technology Consulting – for the consulting services, the institution aims to improve and support companies that work in the field of Engineering, Product Design, Technological Process and Industrial Management;

- Specialized training – this is done by offering highly specialized training programs within the institute facilities.

2.1.5. Fields of Knowledge

INEGI mainly works on Mechanical and Industrial Engineering related areas such as Biomechanics, Structures and Systems, Energy and Materials. The main projects developed by the institute are focused on the following sectors of activity, which they consider to play an important role on the economic development of the organization:

- Energy and Environment
- Aeronautics, Space and Defence
- Automotive and Transportation
- Metal working and Capital Goods

The Energy sector represents one of the larger areas that contribute to the organization’s revenue, the developed projects are driven from collaboration with other Portuguese research centres, such as Soluções Racionais de Energia (SRE) and Instituto de Engenharia e Sistemas de Computadores (INESC). The main objective within the several projects is to find ways to reduce gas emissions into the atmosphere and explore the ingrowing hydrogen economy. INEGI is also one of the first enthusiasts of wind power energy. With a specialized team since 1991, they develop optimization models for wind farms production, technical an economic feasibility studies, support and project evaluation. They started to work only in northern Portugal, but since 1999 they work in all the extended territory and with some foreign countries (i.e. Brazil, Spain, Angola and France).

Another important sector is the Aeronautical, Space and Defence sector. On this field INEGI has projects for companies like the European Space Agency (ESA), where they developed a project based on material improvement, and worked with, among others, Lufthansa on the development of a system capable of identify and misguide a missile. The projects regarding Aeronautical and Space are mostly of a product development and material improvement nature, but there is also a big control systems component that it is crucial on this specific sector. For this sector, AM production is beneficial for parts that have a complex structure and where its robustness and weight are the most important features to be considered, (Ferro, et al., 2015).

When it comes to Automation and Transportation, the most important projects are related to turning vehicles more efficient and eco-friendly by reducing their CO2 emissions. There is also an important component regarding vehicle components. INEGI participates in several projects of parts improvement to turn vehicles safer as is an example the development of magnetic brakes for the historical trams used by the Sociedade de Transportes Colectivos do Porto (STCP). Besides that, INEGI also develop parts with the purpose of weigh and/or cost reduction. For these they team up with companies such as CADFLOW or Moliporex.

In the Metalworking sector, INEGI's main focuses rely on enhancing security of productive processes and increasing their clients productivity rates. As an example it is possible to look at a methodology for modelling mechanical properties of real components developed by INEGI. This methodology allows to predict failure of real components using adhesive joints, hence increasing safety during the assembly process of products that use this technique. Another interesting project in this field of knowledge was the development of a machine that is able to work around a piece with an amplitude of 360º, improving the customer's productivity rate.

To bring an innovative and effective response to the problems they have in hand, INEGI teams up with other entities in order to reach the best possible solution for their customers. A list of partners divided by each sector of activity aforementioned is presented in Table 1.

Sector	Partners
Energy and Environment	Italdesign, PUK, Oxford University, CIMNE, UPM, Polymer, KTH, Caetano Bus, ZOLLERN, EFACEC, PAUL, CONTRAC, INESC, FEUP, IM, ICAT, SRE, SCTN, STI
Aeronautical, Space and Defence	DIEHL-BGT, EADS, LUFTHANSA, ONERA, SAGEM, THALES, Austrian Research Centers, Carbon Future, EADS, Piepe, EADS-Astrium, Lockheed Martin INSY, HPS-GmbH, UPatras, DLR , Kayser-Trade, Arianespace, OHB Systems, ICOTEC
Automotive and Transportation	STCP, CAETANOBUS, CADFLOW, MCG, Moliporex
Metalworking and Capital Goods	John Deere, CHETO, CABELETE, Sobinco

Table 1 Project Partners

2.1.6. Associates

INEGI was created through the combined efforts of four Portuguese entities listed on Table 2, with the purpose of creating a link between university and industry, empowering the last one by creating a research and developing centre focused on the different branches of Mechanical and Industrial Engineering.

Founding Associates	
1	University of Oporto
2	ADEMEC – Associação dos Antigos Alunos do Departamento de Engenharia Mecânica
3	APGEI – Associação Portuguesa de Gestão e Engenharia Industrial
4	AIMMAP – Associação dos Industriais Metalurgicos, Metalomecânicos e Afins de Portugal

Table 2 Founding Associates

Throughout time, more and more companies became associated to this organization, as shown in Table 3, allowing it to grow and improve its knowledge. The complete list of effective associates, companies that own a part of INEGI, extends to more than 90 entities.

Effective Associates	
1	Sonae Industria – Consultadoria e Gestão S.A.
2	EDP Renováveis Portugal, S.A.
3	PARUPS, S.A.
4	Amtrol-Alfa – Metalomecânica, S.A.
5	APDL – Administração dos Portos do Douro e Leixões, S.A.
6	Banco BPI, S.A
7	Corticeira Amorim, SGPS, S.A.
8	Sakthi Portugal, S.A.
9	SOCITREL – Sociedade Industrial de Trefilaria S.A.
10	EDF EN Portugal, Lda.

Table 3 Top 10 Effective Associates according to the financial and activities report (2017)

2.1.7. Capacity

2.1.7.1. Human Resources

From the data presented on its curriculum, in 2017 INEGI had around 226 employees. Besides the staff that works under a contract, this workforce is also composed of university staff working in a part-time regime, and researcher trainees divided in three main categories that meet the core activities of the institute: Research, Innovation & Technology Transfer and Consulting & Services. This non-permanent workforce was composed of 122 affiliated PhD researchers plus master dissertation students performing their dissertation research within INEGI's facilities. Whenever they feel that it is necessary, they work together with board members of several universities in the country such as FEUP and Instituto Superior Técnico (IST).

2.1.7.2. Financial

The available data regarding INEGI's financial resources is shown in Figure 3, it is possible to see that from 2013 to 2015 INEGI's financial resources had a growing tendency, only having some small turnover decrease in 2016. However, the growing tendency is expected to continue and by the end of 2017 they have reached the 9 million euros mark in total turnover. If this growing tendency is to continue, it is safe to say that INEGI will have enough financial resources available to introduce a new service in the market.

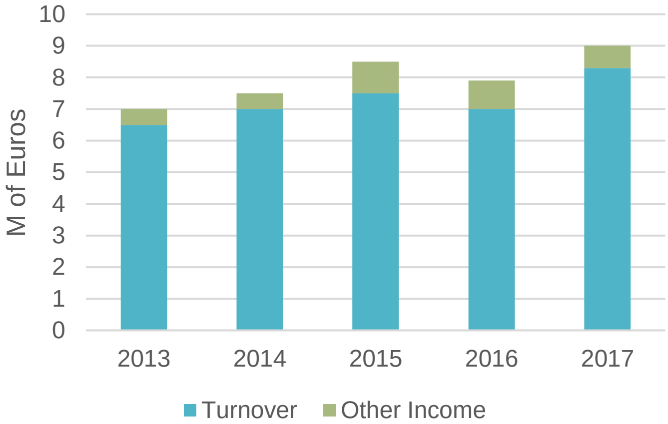

Figure 3 INEGI's Turnover

In Figure 4 we can see that most of the turnover of the company comes from public funds (Research and Investigation Grants) and from contracts with companies. By analysing the image it is possible to see that their turnover is roughly composed by 50% public and 50% private funds, which shows confidence from their private clients.

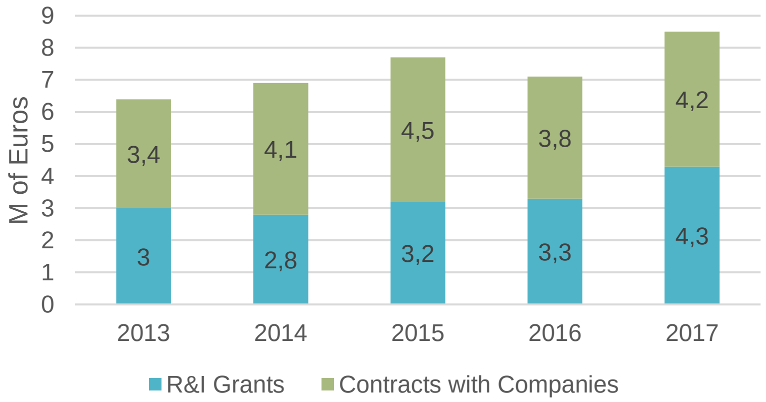

Figure 4 Turnover Source

2.1.7.3. Technological

In order to help them find the best possible solution for their clients, INEGI holds several resources to support its activities. Among these resources it is possible to find several laboratories for experimental work specialized in a great variety of areas, such as Combustion, Industrial Automation and Rapid Prototyping and Rapid Tooling.

Regarding the computerized tools, INEGI uses several engineering programs for design (CAD3D, SOLIDWORKS and CATIA), structural simulation (IDEAS, COSMOS, ABAQUS), industrial processes simulation, atmospheric simulation (WindFarmer and WAsP) and geographic information systems (ArcGIS).

The technological resources are a crucial part of the organization, since they depend on it to develop most of their work. Therefore, it is important that the institute follows innovation so to offer the best possible service to its customers.

2.1.8. Technology Transfer

INEGI's main objective is to contribute to increase the competitiveness of companies with the help of research and technological improvement. To do so, the services offered are based on an added value point of view. This added value can go from social aspects to technology transfer through innovative projects as well as consulting services.

The technology transfer englobes all stages of product development, from the design to the prototype and the manufacturing process.

For the prototypes and some end-parts, they commonly use an AM method for polymers known as Stereolithography (SLA) and Fused Deposition Modelling (FDM), which can produce parts with a high level of precision and detail in a much faster way comparing to traditional manufacturing processes (Hull, 2012). They also use Rapid Tooling for some of the prototypes and finished goods. This technique combines AM methods with traditional manufacturing processes, such as injection moulding, to fabricate parts from CAD data, avoiding drawings misinterpretations (Levy, et al., 2003).

When it comes to the machines capacity of production, a small piece can be produced in just a few hours. Since there is no need for human intervention once the production process is initiated, it is possible to have the machines working all day without constant supervision. At the time, INEGI owns two machines for SLA production, in small scale, and around 5 machines for FDM in the material that it is used to make the final product. Besides this, also has in the facilities a machine capable of producing parts in wax, resin and cast. By the end of 2019, it is expected that the institute will own a Selective Laser Sintering (SLS) machine and, with that, INEGI can acquire the necessary knowledge to provide solutions that use this type of technology.

Besides the presented methods, INEGI is also capable of producing parts from sheet metal with subtractive methods by using pre-programmed sequences using Computer Numerical Control (CNC) and bending techniques, however these techniques require the parts to have a relatively simple design when compared with SLA and Rapid Tooling (Ashley, et al., 2006).

2.1.9. Subtractive Manufacturing

Subtractive Manufacturing (SM) is the most common form of production. This technique is used worldwide and generates an end-product, or intermediate product, by removing extra material from an initial block. In order to manufacture products by using SM, a series of processes may be used, depending on the characteristics of the final product (Watson & Taminger, 2018):

- Turning (Figure 8)
- Grinding (Figure 7)
- Milling (Figure 5)
- Drilling (Figure 6)

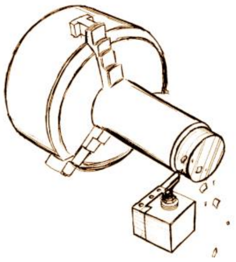

Figure 8 Turning

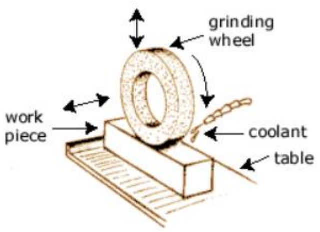

Figure 7 Grinding

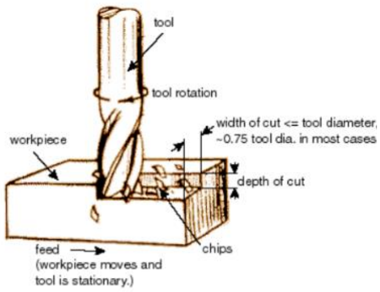

Figure 5 Milling

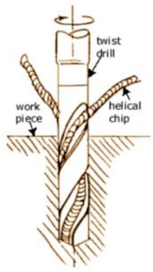

Figure 6 Drilling

This technique often results in a great amount of waste due the excess of raw material that is required to remove from the original part. Also, this type of process is not adequate to produce parts in a reduced number since it will not take advantage of scale economies (Frank, et al., 2004). From an energetic point of view, the machines used for SM consume a great amount of resources (Allwooda, et al., 2011).

Nevertheless, SM techniques originate parts with a high level of precision at a relatively fast rate, and with almost no necessity of finishing operations since they are capable of producing smooth parts – depending on the material that is used and the final part complexity (Hällgren, et al., 2016) .

SM methods are commonly aided by machines using Computer Numerical Control (CNC).

2.1.9.1. Computer Numerical Control

Traditional CNC machines (see Figure 9) use, as previously said, an initial metal block and remove material until the final shape is obtained. This type of manufacturing had always a great acceptance from manufacturers. The increased sales volume led to an increase in productivity and a substantial decrease of costs of the CNC machines. CNC manufacturing allows the production of solid prototypes without the interior geometry which would enable a detailed analysis of the project and desired tests (Alves, et al., 2001).

Giving the characteristics of the machines, the produced parts need to have a low level of complexity. This is a consequence of the machine not being able to perform rotation movements on its own, something that is necessary for most desired geometries (Bandari, et al., 2015).

For a part to be produced, it is necessary that an expert or an engineer decides the right tools to be used, the spindle speed, the cutting path and how to reposition the part when it is needed. This makes this process labour intensive since human intervention is need for it to be completed, which makes the process slower and more expensive. However, it has the advantage of producing parts ready to be tested that do not require any kind of treatment after being removed from the machine (Varotsis, 2013).

Figure 9 CNC machine example

2.1.10. Additive Manufacturing

Additive Manufacturing (AM) is becoming more and more relevant due to the importance given by companies to value creation and increased competitiveness. This manufacturing process differs from the traditional ones because, instead of removing material from an initial block of raw material, the products are built by adding material layer by layer (Bikas, et al., 2016).

With AM, companies are able to produce more complex parts than when using SM and with an accentuated decrease in wastes. Although it is difficult to take advantages of scale economies with AM, giving that these platforms are not capable of support mass production (Baumers, et al., 2016), these processes represent an advantage especially when it comes to customized products. A good example of this is the personalized service offered by Mini, where customers are able to design some parts of the car that will then be produced by using AM. Replacement parts for older car models is also a good application example of the utility of AM technologies in modern companies such as Mercedes-Benz, which started to produce spare parts for car models that are no longer being produced. Another significant advantage of manufacturing parts with AM is the decrease in the weight of the products, which in some industries, like the aeronautical industry, is very important and difficult to obtain with traditional methods (formnext, 2018).

Following, the top three used methodologies in AM, which are also the ones used by INEGI, will be presented as well as their advantages and disadvantages.

2.1.10.1. Stereolithography

Sterolithography (SL/SLA) was one of the first AM methods to be developed and it is still one of the most commonly techniques when it comes to rapid prototyping (Wong & Hernandez, 2012).

The process used in this method is called photopolymerization where an Ultraviolet laser beam will make the liquid raw material, an epoxy resin, solid in order to produce the desired part. By taking advantage of an electromechanical system, the final part will be produced layer by layer on which each of them will correspond to a local cut of the part, as shown in Figure 10. The model is produced in a liquid environment with the help of an elevator, so that by the end of the process the no solidified material is easily removed from the final part. Since this method uses liquid resin, all the pendant parts will need a previous support to be made. Without these supports it wouldn't be possible to build models with pending parts (Alves, et al., 2001).

Since the polymerization of the resins is not total, the parts produced through this technique receive a treatment after they are out of the machine. This treatment will ensure that the mechanical properties of the material are not compromised.

Although resins do not have a great strength resistance, which means that they cannot endure much stress before permanently becoming deformed (Ashby, et al., 2007), they present a high temperature resistance, stiffness and flexibility (Alves, et al., 2001).

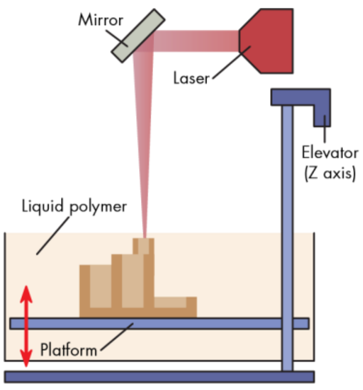

Figure 10 SLA machine diagram

2.1.10.2. Selective Laser Sintering

Selective Laser Sintering (SLS) is a similar process, being the main difference between these two methods is the fact that in SLS the raw material is on the form of dust, while in SLA it is a liquid.

In a pre-heated chamber, a thin layer of dust is heated until a state of partial fusion giving structure to the model. Since the raw material is dust, the final product will present some porosity and an uneven surface that will require resin impregnations or painting to ensure the model's permeability. This process is represented in Figure 11. Besides needing more finishing operations, SLS assures better mechanical properties products and a lower production time when compared to SLA (Alves, et al., 2001).

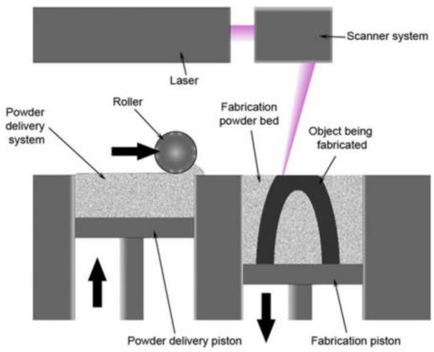

Figure 11 SLS machine diagram

2.1.10.3. Fused Deposition Modelling

To produce parts using Fused Deposition Modelling (FDM) methods, a filament of the desired material is heated up until it reaches the glass transition state and it is deposited on a platform layer by layer, the different layers of the model get together during the solidification process that occurs when the material starts to cool down (Ning, et al., 2015). The most common materials used in FDM are thermoplastics polymers, with ABS being the most commonly used material (Novakova-Marcincinova & Kuric, 2012).

The models produced by FDM present better impact resistance then the ones produced by SLS and SLA, mostly due to the inherent mechanical properties of the materials used. They also have a higher toughness, chemical resistance and their properties do not change much with variance of temperature. When using FDM, the produced models do not require any additional treatment after they are printed, so once they are out of the machine they are fully functional and ready to be tested (Alves, et al., 2001).

Since these machines are able to produce models of wax, this method is also very interesting when it comes to metal parts conversion, or investment casting. By producing wax moulds, it is possible to significantly reduce the time of production of metal products since we are able to skip a few initial steps and start the casting phase of the wax moulds (Pattnaik, et al., 2012).

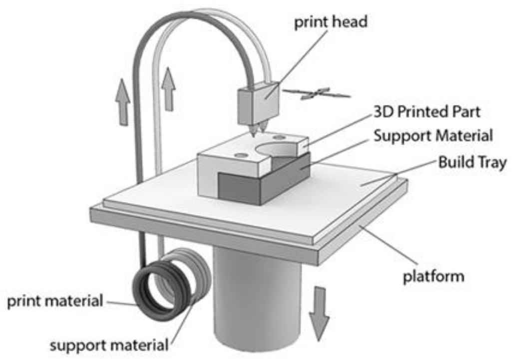

Figure 12 FDM machine diagram

2.2. External Analysis

2.2.1. PESTEL

For a better understanding of the organization's reality, a macro-environment study was carried using the PESTEL framework. This method allows us to have an insight on how some external factors may affect the organization's activities, and it is important to understand how the different factors interact with one another.

Political: The political stability of a country enables the investment on research and development by the government and external entities, since investors tend to avoid businesses located in countries that are politically unstable. Another important issue that is determined by the political environment is related to the bureaucracy and intellectual property laws that have the power to facilitate research studies and product development. Also, a government has the power to conduct the research made in a country according to its needs, i.e., if there is a need to improve one sector the government can create funds for projects related to that specific sector (Crow, et al., 1990).

Economical: Economic stability will raise the probability of new investments from the government and from private entities. A R&D type of company has an increased need of governmental investments when compared to the classic industry, where the economy status will have influence on its profit rather than on its capability to develop work. So, if a country has a favourable economic climate, it will increase the level of trust of foreign investors which will lead to more financial support for projects regarding research and development in the country.

Social: The conducted researches and developed products are affected by the social needs of the general society. Since most of the technological advances are made to solve an existing problem of society or to facilitate human life, social factors can influence the way the research of the organization is orientated. Besides that, society itself can influence the amount of workers available to contract. A few years ago the most wanted jobs were the ones related to the production industry, nowadays we can see a shifting of preferences and an increase of young people interested in research and development (UNESCO, 2015). The increase of interested people can bring an increase of attention by the government and private investors, which will result in higher available funds.

Technological: Technological development is the factor that has most influence on R&D organizations since the quality and quantity of the research and of the developed products is correlated to the equipment's quality (Wilson, 1976). If the company has a slow rate of adaptation to new technologies and methods, it will fall behind its competitors that are able to adapt quicker. This can be a concerning since it can lead to a decrease of private investments due to the lack of technological improvement, which is a key success factor for R&D companies. Since INEGI gives technological support for industries that require a high level of quality from the parts they use, like the aeronautical and space sector, it is important for the company to adapt easily to new technologies.

Environment: Ecological awareness and decrease of available fossil fuels creates the need for the companies to search for new energy sources and ways of productions. This is usually achieved by cooperating with R&D organizations in order to develop more ecological products and production methods that do not require fossil fuels or that have a higher efficiency rate. INEGI has been doing this for the past few years by working closely with companies in the energy sector. By doing this they were able to become a reference in renewable energies, especially wind energy. Also, due to its layer by layer method of production, AM helps reducing raw material waste – that becomes close to zero if there is no need for additional tooling – which increases production efficiency.

Legal: As previously mentioned, the amount of bureaucracy needed to start a project can influence an R&D organizations. Besides that, intellectual property laws have also influence on the work developed.

2.2.2. Porter's Five Forces Analysis

The analysis of Porter's five forces model compares the strength of each factor that is capable of affect the attractiveness of an industry or area of business. By looking into them, a company can evaluate its competitive position regarding the market. With that in mind, the Porter's Five Forces framework was also used to gather more knowledge of INEGI's external environment by identifying critical issues that need to be taken into account regarding the services they want to offer. Porter's analysis also let us analyse the attractiveness of markets that may benefit by the usage of AM technologies (Michalisin, et al., 1997).

Threat of Entry: The services supported by AM operations constitute a relatively new market. This may mean that, if the services are not launched in time, the available market may be served by another entity turning it difficult for INEGI to launch itself in these services. Even though the demand for services requiring AM is growing, this type of technology requires a large initial investment, both on training and on equipment, something that may not be accessible to everyone which will make it difficult to offer services that use these technologies. Another aspect that can scare companies into entry this market are the sunk costs. Given that these machines can only operate AM functions, if they do not approach the market in the correct way this investment will most likely never be recovered.

Threat of Substitutes: The substitutes in this case will be the parts manufactured on a traditional way, subtractive manufacturing. Since AM is very suitable for customized parts and replacement parts, subtractive manufacturing does not represent a major threat due to the associated cost. Besides that, there is the threat of individual AM enthusiasts that can use personal printing machines or by access a FabLab - workshops equipped with 3D printers open to anyone who desires to use them (Walter-Herrmann & Büching, 2013) - to produce their own products and try to sell them to companies as an alternative. However, this is highly unlikely to become a threat due to the high cost of the machines that are able to produce a part that can endure certain operating conditions, such as high temperatures, high pressures, and so on. As so, it is more likely that these enthusiasts use Am for their own benefit.

Power of Buyers: The buyers will be the ones to have the major influence on whether or not the proposed services will be successful or not. If the clients do not accept well the new services means that business model to be developed has failed. Also, the bargaining power of buyers increases with the number of companies that provide AM services. However, the number of companies offering services in the AM market is low. To the date, in Portugal there are only 5 companies that offer AM related services (EuroPages, 2018). From this 5 companies, none of them is using AM in the way INEGI wants to use it. INEGI wants to help companies to improve their production rates by offering adapted solutions for each client. This can be either by developing productive systems that take advantage of AM products or by decreasing the time between the idea and the actual product. The existing companies are either specialised in producing a certain final product, or perform just the design and production of a part that is ordered by a given costumer, i.e. they do not present innovative solutions. The reduced number of companies in the market will reduce the bargaining power of buyers.

Power of Suppliers: Most of the suppliers for raw materials used in AM machines are located in the United States of America and in the European Union (EY, 2016). There are quite few raw material suppliers, so, and knowing that the bargaining power of suppliers is higher when its number of available is small, it is expected that suppliers would have a significant bargaining power. However, for the current demand on this products, the number of suppliers may not be as low as one thinks and the bargaining power of suppliers may decrease due to that. Also, this type of materials has a high price and that it must obey a certain level of quality. If the offered material is not able to fulfil such quality requirements, companies like INEGI will not buy the raw material they need from them, since it can compromise the quality of the solutions they offer to their clients hence putting at risk their reputation among their investors. For this type of materials, vertical integration does not make sense since it will lead companies to deviate from their core business, R&D or manufacturing, and since the used materials are not all the same for every project it would not bring economic advantage for the buying entity.

Rivalry: Rivalry comes from the pressure that competitors put on each other when competing for market share, sales and competitive advantages. Since the use of AM technologies to produce a unique solution for customers is a new market, gaining market share becomes easier the sooner a company decides to explore it. All the existing competitors will be highly qualified, which will increase the need to provide high quality solutions and to gain trust among customers so that the customers' switching costs increase.

Once all the five forces were analysed, it is possible to reach the conclusion that this is indeed an attractive business area. There is a low threat of entry, mostly due to the high investments needed, and the existing substitutes are not suitable for industrial use, being focused on recreation activities and domestic use. The bargaining power of buyers would be low, given that there are very few companies that offer this type of services and none of them with the expertise that INEGI is able to provide. Giving the reduced number of companies operating on this market, we can conclude that this is an oligopoly. This market structure implies that every action of a possible rival will have an effect on the company's performance, i.e. if a company lowers its prices the rivals will do the same, but if the company increases them it is most likely that the rivals won't do the same (Branco, 2003).

The two forces that demand more attention are the bargaining power of suppliers and rivalry among competitors. In this case, suppliers have a significant level of influence because of their reduced number. Also, although the number of companies offering this type of service is low at the moment, rivalry will be one of the, if not the most, relevant forces to have influence on the business. Right now, the market is new so it is relatively easy to gain market share by taking advantage of economies of scope that appear from the machines' capacity of producing several products, allowing to cover more demand that traditional methods would, without the need of additional hardware investment (Hague, et al., 2003). However, once other entities start to notice the attractiveness of this type of services, rivalry will increase rapidly and INEGI will have to keep ahead of the rest of the competitors in order not to lose clients.

2.2.3. Stakeholder Analysis

The purpose of performing a stakeholder analysis is to have a better insight on how the different actors can influence the decision-making process. This analysis will allow us to outline a picture of the possible behaviours, intentions, interests and influences of the relevant parties (Brugha & Varvasovszky, 2000).

Having in mind that this analysis is being done for a specific INEGI's business unit, PSD, three important actors were identified:

1. <u>INEGI</u> – The reputation of the organization will be at stake, so this is a part that is expecting good results from the accepted projects. Besides that, INEGI as the employer will be the one that provides the necessary resources, both human and technological, to perform each project and it is expected to be informed once an important milestone is reached.
2. <u>Product and Systems Development business unit</u> –This business unit will be the one responsible for the results of the solutions presented to the customers. They can be contacted by the customers to solve a previously identified problem, or they can suggest some project to increase productivity of customers.
3. <u>Customers</u> -The customers will be the ones to order and approve the final offered solution. It's important that the customer is involved during the developing phases of the product or system in order to avoid miscommunication and misunderstandings of the necessary features that need to be present in the final solution.

2.2.4. SWOT Analysis

By performing a SWOT analysis one can compare a company's strengths, weaknesses, opportunities and threats. With this an organization can quickly know where its focus has to be placed by enhancing strong points, taking advantage of the identified opportunities, beware of the threats and trying to apply some corrective measures to turn the weaknesses irrelevant. In Table 4 it is presented a SWOT analysis referent to the PSD business unit capabilities of providing a new service based on AM technologies.

The advantages of using a SWOT analysis is to shed some light into the strategies that will be more adaptable to the INEGI's current situation regarding their experience on AM technologies.

Strengths	Weaknesses
• No need for significant investment in technology or training • The existing clients may also use the services to be developed, which means that they already have a working network • The suppliers are already selected • Customized service	• Economies of scale are very difficult to achieve while using AM methods • Dependency of external investment
Opportunities	**Threats**
• Unexplored markets • Small companies do not have the economic power to invest on this type of technologies by themselves • Growing interest in all types of industries • Economies of scope from the capability of producing more than one type of product in the same machine, reducing the cost of joint production	• This type of technology is becoming more and more popular among the manufacturing industry, so it is possible that competitors may appear before the services are launched. If that happens, they lose the pioneer advantage.

Table 4 SWOT Matrix

2.3. Chapter Conclusions

The business unit of Product and Systems Development wants to start to provide a product based service by taking advantage of their knowledge on AM technologies. The idea is to improve their knowledge in the technologies they have and to gain experience on other emerging techniques. By doing so, they will be able to provide technological solutions that will improve the automation of their customers. Besides that, they want to be a specialist in product development for AM, which goes from the design of the product to the final development when it is ready to be sold to the customer.

For the past years, it is possible to see an increase of AM technologies for prototyping usage. However, it is becoming more common for companies to use these technologies to improve their products and production. By taking advantage of the capabilities of these machines is possible for companies to produce smaller batches and lighter parts. This is particularly important when referring the increasing demand of customized products by the average customer. By allowing the decrease of costs for customized parts companies can enlarge their offer, become more attractive in the public's eyes and, therefore, increase profits.

Another interesting feature of AM technologies regards the Aeronautical and Space industry. Besides being considered for a long time a very conservative sector, this industry was one of the firsts to explore the potential of AM produced parts. The ability of producing lighter and more complex parts seduced this industry that is now one of the biggest user of 3D printed parts for end use.

3. LITERATURE REVIEW

In this section a brief analysis of the applications of AM will be presented. This will help to understand the potential applications of these on this technologies by exploring their benefits and constrains that were identified by companies that already use AM in their production process.

Since the final objective is to propose a business model for a new INEGI's service, a study about the economies of services and the importance of services in modern economy is presented. Besides that, "some" literature regarding business models and business planning will also be covered.

3.1. AM Applications

According to the Wohlers Annual Report of 2017, the number of companies using AM for the production of end parts has increased exponentially in the last few years. Since 2003 it is possible to see that the modern industry has been shifting its way of producing towards AM. Nowadays, roughly 60% of AM production and services are for end uses and not for prototyping. This tendency can be confirmed in Figure 13

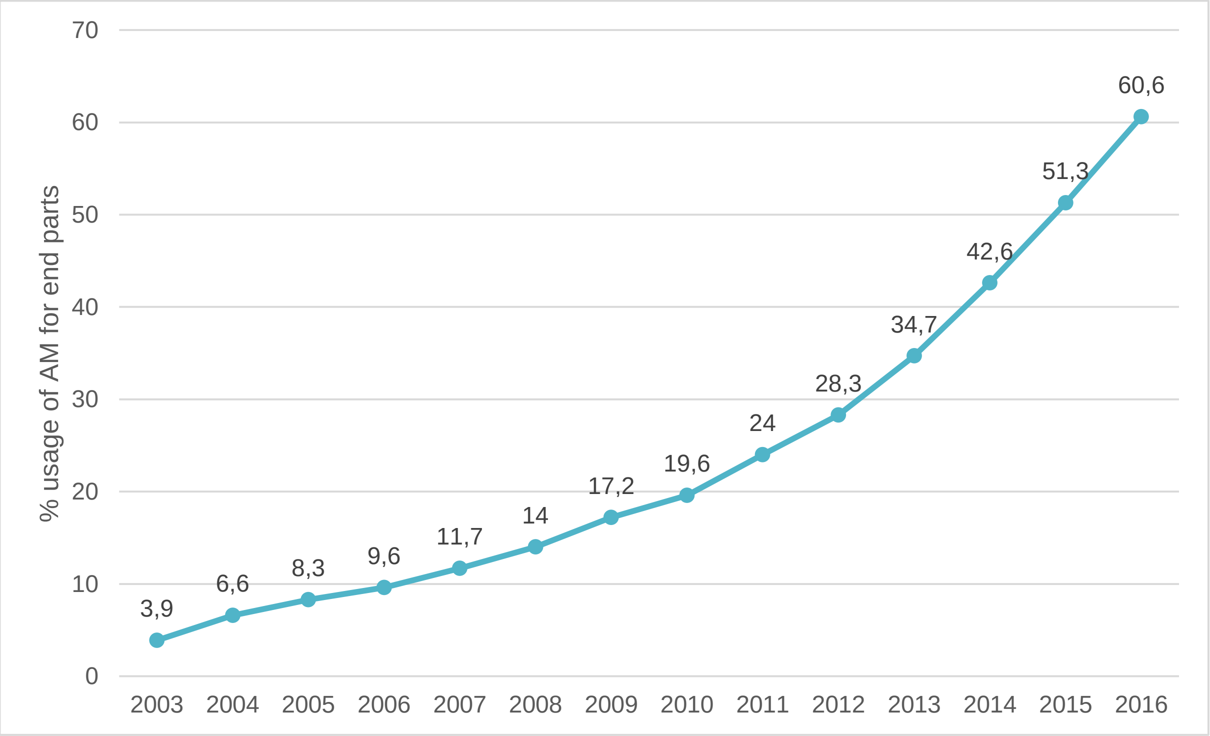

Figure 13 Percentage usage of AM for end parts (Wohlers Associates, Inc, 2017)

Following, a few industry examples of the relevant areas for INEGI will be presented, as well as the benefits associated with the use of AM for the companies that chose to start using this type of production methods. Finally, a summary of benefits and constrains based on the Wohlers Report for the use of AM will also be described.

3.1.1. Aerospace Industry

According to the Wohlers Report of 2017, the aeronautical and space sector is one of the biggest enthusiasts of AM technologies. Despites being considered for a long time as a conventional type of industry, given the characteristics of its final products, it is in the aerospace sector where we find the largest investments on this type of technologies. Companies like GE Aviation, Airbus and Boeing have invested on the development of AM produced end parts.

GE Aviation uses metal as the material used for producing parts. GE engineers found out that 40% of the CT7 helicopter engine could be redesigned and produced via AM. The final result of changing the production methods from the traditional ones to AM ended up in a reduction of the parts needed. By simplifying the engine structure, the production cost was reduced as well as the assembly time. Besides that, since there is no need for tooling, the period of testing and design of new elements has also decreased. Another very important feature for the aerospace industry, which is possible to achieve with the increasing use of AM produced parts is the decrease of weight of the aircraft. The weight reduction is very important in this case because it implies an increase not only of the aircraft's performance but also of its top speed.

Regarding Airbus, they not only invested on metal AM, but also on polymers. This made possible the replacement of plastic parts of the aircrafts whose production was then outsourced, to new, lighter ones produced within the company's facilities. A great amount of plastic brackets, clips and security devices for cables, wires and whooshes are being used in several models of both civil and military aircrafts made by Airbus. These simple replacements enabled weight and cost reduction and made possible a greater control of the components' design by the engineering teams. To develop their knowledge on metal AM, one of Airbus' subsidiaries, AEROTEC, opened an AM metal production facility. They are currently redesigning and producing ten structural titanium parts for the A350 model.

3.1.2. Automotive Industry

When it comes to the automotive industry, Wohlers identifies it as one the earlier enthusiasts of AM production. In fact, this is where one can find the biggest diversity of usages for this type of technologies, going from merely esthetical aspects to structural components of the vehicles.

Among the many examples that can be found in the auto industry, BMW is probably the one who takes most advantage of the benefits that come along with AM. With a history of more than 25 years of research and development on this field, BMW soon realized the potential of its use as an integrating part of its production process. Besides the already mentioned cost saving and decreasing in lead times, AM also allowed BMW an increased design flexibility, being able to produce parts that were once too complex and costly to produce by the traditional methods. Also, it made possible the offer of a different customizing experience for their clients. Now, it is possible for clients to create customized parts for their vehicles as it was mentioned in section 2.1.10 regarding the Mini case study, which is part of BMW group. Not only that, but when it comes to the replacement of parts of car models that are no longer produced, AM is also used. Before the incorporation of AM in BMW, replace parts of classic models was a very costly and time consuming task, since it was the need to keep tooling for older parts or to adapt its production to the new machines. Now it is possible to scan or design the part in need and print it out, reducing drastically the process time and cost since there is no need of special tools.

Another interesting possibility of AM is the decentralization of manufacturing. The common process of parts production is that one factory located somewhere around the world would produce it and then ship that part to the manufacturer. Even if this process happens between factories of the same company, it always has a shipping cost associated and there is always the need for having stocks in the final destination of the parts. Daimler Trucks has been exploring this characteristic of AM production. By having machines capable of producing the same part in different factories will help to decrease cost related with shipping and stock levels. In fact, if this can be applied in crucial parts for production it also reduces the risk of stocking out and of delays in delivering the products.

Others companies like the Japanese Honda and the French PSA Group, detainer of brands like Citroën and Opel, are investing on replacing some structural elements and body shell components on its cars' design with the goal of cost and weight reduction.

3.1.3. Marine and Energy Industry

Regarding the naval and energy sector, the use of AM is still on its early stages. Contrary to the two industries explored earlier, the marine and energy's industries shift from traditional manufacturing processes to AM is being studied and developed.

However there are a few examples of possible uses for it. The International Submarine Engineering (ISE) is one of the companies that has been actively trying to incorporate AM for its products. With the purpose of minimizing lead times and costs, ISE is studying the possibility of including a ballast tank subsystem on its autonomous underwater vehicles. Also Maersk, the largest shipping company in the world, is currently using AM to produce parts with a high-failure rate (Lloyd's Register Energy, 2015). This type of research is not only being done be private organizations but also by public ones, especially by the military forces. An example of that is the United States Navy that is studying the possibility of including AM in order to produce parts with a high level of accuracy in a much faster and sustainable way (Belfort, 2018).

Regarding the energy sector, the projects are also in a pilot phase. Companies like Shell and Halliburton are exploring the possibilities of AM. The studies conducted by the two companies both conclude that AM will bring great benefits especially for repair parts and on simplifying the systems (Lloyd's Register Energy, 2015). Lloyd's Register Energy also sees a great opportunity for offshore platforms to take advantages of this type of production. As previously mentioned, AM offers the possibility of decentralizing production thus simplifying the replacement and repairing of obsolete parts, since these parts could be produced within the offshore facilities.

Also, the materials used in AM such as thermoplastics offer a much greater resistance to corrosion than the materials that are used nowadays in both industries. So, if it is possible to substitute the material of some parts that are heavily exposed to damaging weather conditions, this could translate in to a substantial amount of savings in replacements and repairing.

3.1.4. Benefits and Barriers

The main strategic goal of all companies is to reduce costs without compromising the service level, or even trying to increasing it. To demonstrate how the use of AM in production could help manufacturing companies to achieve this goal, a summary of its benefits is now presented on Table 5. The content of the mentioned table was written after analysing the case studies presented from section 3.1.1 to section 3.1.3 of the present dissertation, and as well as according to the conclusions of the Wohlers Report of 2017 for the AM state in the industry.

Benefit	***How?***
Cost Reduction	Opposing to traditional manufacturing methods, there is no need for special tooling when it comes to producing different parts in AM. This aspect helps to decrease the overall production costs since one machine is able to produce several parts without the need of additional tools and machines.
Lead Times Reduction	With AM is possible to reduce the number of parts needed to assemble a given product. By simplifying the assembly process, it is possible to decrease the amount of time needed for a product to be ready to be shipped for the client – the lead times will decrease. Also, if the product as less parts and it is simpler to assemble, the amount of errors is also expected to fall.
Increase of Production Agility	There is no need of new tooling when the companies wants to make some changes in their products. Because of this, it is possible for them to have a quicker response and a faster adaptation to the changes in market demand. By increasing the agility of the production, companies will be able to improve their service level without the need of much investment.
Stock Level Reduction	The decentralization of the production of certain components will have an impact on the number of parts that need to be in stock to ensure that production does not stop. By decreasing the value number of the safety stock, companies will see a decrease in warehouse costs as well as a decrease in the risk of some components stocking out and hence stopping production.
Customization	With AM, the cost of producing small series is much lower when comparing it to SM. This enables companies to offer a bigger product mix and facilitates the inclusion of the customer into the production process. Since the customer will be able to adapt the product to its own will, the service level and customer satisfaction will increase.
Sustainability	Contrary to the traditional SM processes, AM requires less raw material in order to produce a component. This aligned to the energy consumption, which is lower in AM, makes the process much more eco-friendly.

Table 5 Summary of Benefits of using AM in Production

As all new production methods, also AM encounters some barriers for its use. Again, as a result of the analysis of the case studies and of the Wohlers Report, a summary of the identified barriers for the implementation of AM in production can be found on Table 6. A brief explanation of each recognized obstacle is also presented.

Barrier	***Why?***
High Investment	The need of a big initial investment may be a setback for companies that do not have enough financial power. To introduce AM technologies as an integrative part of the production requires to invest not only in machines but also in employees' training or new employees' acquisition. For big corporations this may not be such of an obstacle, but for smaller ones the benefits that come from using AM may not be sufficient to invest on the acquisition on their own machines.
Product Quality Assurance	All the manufacturing industries require a high level of quality on the parts they use. Although AM is already capable of producing functional parts with great quality, there is still no process of monitoring and control of that same quality. Besides that, AM for mass production is still not sufficiently evolved to guarantee the quality standards required by such industries.
Attitudes	When referring to new technologies one of the common barriers to them all is the people's attitude towards it. It is difficult to convince companies that a given process is beneficial for their business when companies themselves do not recognize the need for change. This is a difficult challenge since its solution requires a change in the mind-set of those in charge. However, with research and partnerships with more prone to change companies, this is possible to overcome.

Table 6 Summary of Barriers to the use of AM in Production

3.2. Product Development Flow

It is commonly known that to develop a new product a company must undergo several steps in order to assure the quality of the final product. From a strategical stand, companies are more successful if the time to complete this cycle is shorter, since it will generate products in a much faster way (Meyer & Utterback, 1995). However, there are a few cases that show that companies do not achieve a significant improvement of performance if the cycle of product development is shortened. This is due to the decrease in quality of the final product given by the urge of finishing each phase in much less time than required (Ittner & Larcker, 1997).

To better define the duration of each stage of the product development flow, a new discipline appears, Business Process Management that will analyse the modelling of the activities, data, time, and function perspective in order to define a better process for the development of the different products (Aalst, et al., 2016).

From a Business Process Management point of view, the product development flow (see Figure 14) can be divided into three main steps (Jeston & Nelis, 2014):

- **Design and Modelling** – on this stage the main features of the product are defined, such as materials, dimensions, manufacturing operations, etc.
- **Execution and Tracking** – during the second stage, the feasibility of the product manufacturing process is tested. This can be altered if the processes aren't easy to understand or are incapable of generating results in the needed timeline
- **Performance Management** - analysis of the final product. This must attend the customer's requirements and offer high quality standards.

A new product, or modification of an existent one, adds value to a company if it meets the specified requirements and reduces the overall costs by resulting in a great waste reduction. To ensure that these two goals are achieved it is necessary that the aforementioned steps are prepared in detail and rigorously followed. By doing so, it will be easier to identify problems on an early stage and correct them so the trades between costs, speed and quality are not affected by them (Oppenheim, 2004).

Figure 14 Product Development Flow

3.3. Services oriented economy

The demand for services as both an intermediate of the manufacturing industry and as the end product for the final consumer increases with the company's profit and the per capita income. This happens due to the elasticity to income inherent to services, which suggests that more services will be required as income increases. On a corporate point of view, the increase in service's demand is explained by the opportunity of companies to focus on their core business by externalising activities that were once made by them but are not where they are specialized (Guerrieri & Meliciani, 2005).

Industrialized societies tend to give more importance to life quality than to product quantity (Inglehart, 2015). This rises the need for services as health care and education, which, for itself, will increase human life time and personal qualifications. Traditionally, due to the high number of workers in the shop floor, the manufacturing industry has a lower ratio of qualified employees when comparing to the service industry. Therefore, it is only expected that the quantity of offered services will increase with the number of people that get access to higher education (Fitzsimmons & Fitzsimmons, 2011). As shown in Figure 15, the majority of EU citizens work in services providers sectors. And while the Primary sector & utilities and the Manufacturing sector are intended to decline their workforce until 2025, it is expected that tertiary sectors will rise (Cedefop, 2016).

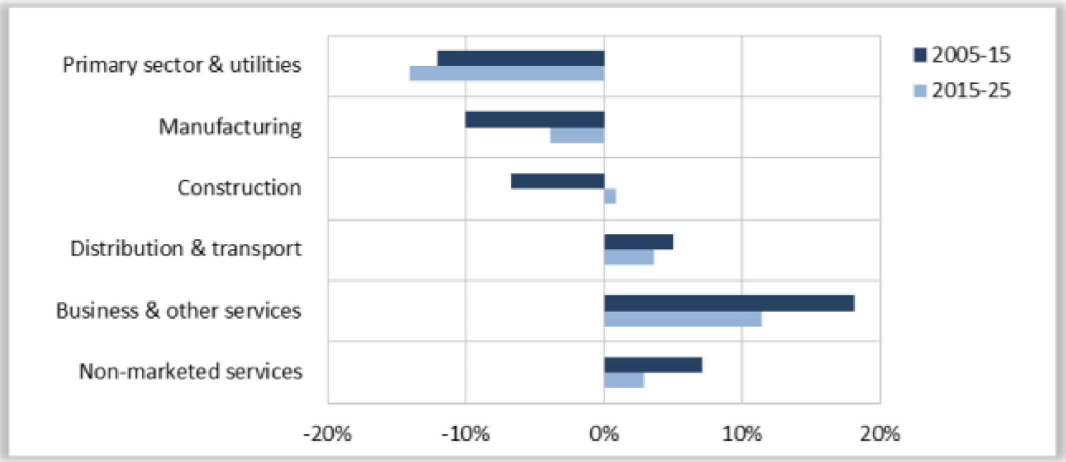

Figure 15 EU workers distribution by economic sector - Cedefop (2016). Future skill needs in Europe: critical labour force trends.

In the past, it was easy to differentiate services from products where services included all activities that offered intangible goods and products were tangible goods that fulfilled a need (Claessens, 2015). However, and mostly due to technological advances, the line between products and services is starting to become blur since some new services are also products and processes. Business-based services deal with most of the business-to-business transactions in the manufacturing industry, which has seen a great development along time mostly due to the technological developments and the uprising of new needs from customers. Giving this, a new type of service emerges, the so called science-based services, where innovation activities are involved and new technologies are used or developed in order to provide the customer with a unique solution (Tuominen, et al., 2009).

Business-based services (BS) work mainly as intermediates between companies and not with end consumers. These type of services are the ones that will have an impact for the project so they will be the ones studied.

3.3.1. Business-based Services

As BS work as an intermediary of the manufacturing industry, it is expectable that they are vulnerable to economic cycles that can influence their growth rate. As said, if the manufacturing industry is through a rough phase, the externalization of activities will decrease as well as the fall in consumers' income which will lead to a decrease in the demand for services. Also, manufacturing industries tend to have a high rate of firms births and deaths, 57% of firms that try to enter the manufacturing industry are not able to be successful (Beesley & Hamilton, 1984). This phenomenon has a significant influence on the services way of functioning. Some types of services also function as an investment for other industries, like software development. Giving that investments tend to be cyclical this is also demonstrates the vulnerability to cycles inherent to services. The investment level also depends on international markets and competition which also turns services more vulnerable (Kox & Rubalcaba, 2007).

However, BS have some characteristics that allow them to contradict this tendency. For example, the most common BS is consultancy. By performing consulting jobs, BS providers will gain knowledge from each one of their clients, and this can be useful in critical situations, since by creating knowledge companies may be allowed to perform new types of services that will enable them to avoid failure (Emmanuel & Zenker, 2001) (Hertog, et al., 1995).

3.4. Business Model

A business model (BM) can be defined as a tool that describes the way a company should act to enhance value creation and its delivery to the customer, as well as to capture and retain its employees (Teexe, 2010). This is possible because on these models it is shown how the different departments of a company are inter-linked and how one's activities influence the rest of the sectors (Zott & Amit, 2010). Most managing directors find BM a crucial tool to ensure and increase a company's competitive advantage, finding it crucial for a successful financial performance. As a result, from a study performed by IBM in 2009, companies with a well-defined BM tend to present better financial results when compared to other companies (Wirtz, et al., 2016). Although the process of coming up with a well-built BM is not yet consensual, a few aspects will need to be answered (Chesbrough, 2018):

- How does the company create value to the customer;
- Identify the market segment that is to be served;
- How will the company create and deliver its offer;
- What will be the cost structure and the expected profit;
- Identify the company's distribution channel, as well as potential complementary products and substitutes;
- Convey a strategy that must be followed in order for the company to keep a competitive advantage regarding its rivals. If a BM is hard to reproduce by the competitors then the competitive advantage of a company will increase.

In sum, a BM will need to explain how the company's activities will articulate between themselves and bring value to the company (Wirtz, et al., 2016). And, giving that the market itself is not a static environment, a company's BM should be in constant update as shown in Figure 16.

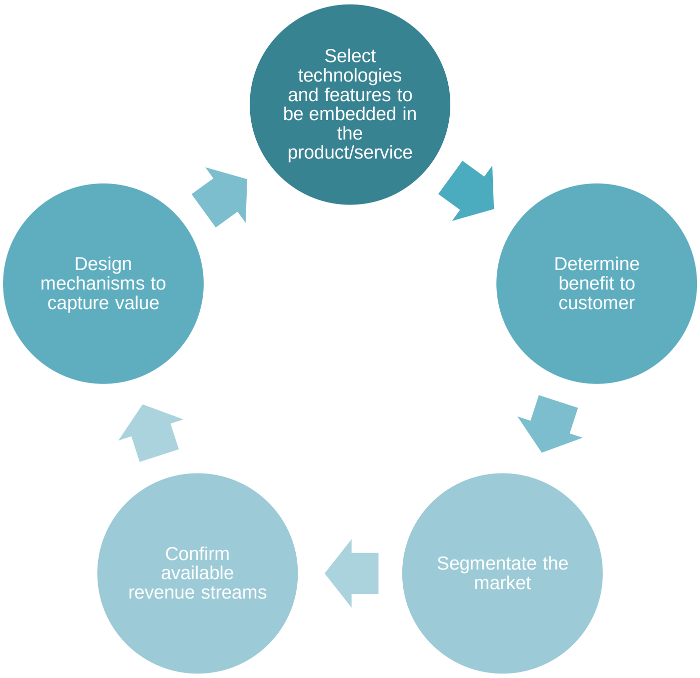

Figure 16 BM cycle (Teexe, 2010)

Before starting to design a BM, it is important to have a well-structured company strategy since BM will be based on this strategy to define how the company will create value to clients. Besides that, BM will also present an intelligible way of implementing the aforementioned strategy (Dahan, et al., 2010). So, business strategy and BM differ one from the other as business strategy is related to medium and long-term decisions while BM is a guide on how to reach the defined objectives within the formulated strategy.

To be effective, a BM must be composed of three different modules that will include sub-models that are considered crucial for a company's success (Wirtz, et al., 2016):

- **Strategic components**
  - Strategy model, where the strategic positioning of the company and the paths it wants to take will be presented, as well as the BM value proposition;
  - Resources model to indicate what are the core competencies of the company and its resources;
  - Network model to show the company's partners and external interactions of the company;

- **Customer and market components**
  - Customer model that will indicate who are the company's customers and their relationship with the company, as well as distribution channels;
  - Market offer model to understand who are the company's competitors, how the market is structured and to analyse the value of the product/service offered;
  - Revenue model so the company can understand what is its biggest revenue stream. This is important because revenue streams are the ones to support the BM.
- **Value creation components**
  - Manufacturing model where the allocation of the available resources will be defined and explains how the product/service will be generated;
  - Procurement model where the suppliers are defined;
  - Financial model to have a model that justifies the BM regarding income and costs of the company.

A diagram of the BM structure is shown in Figure 17.

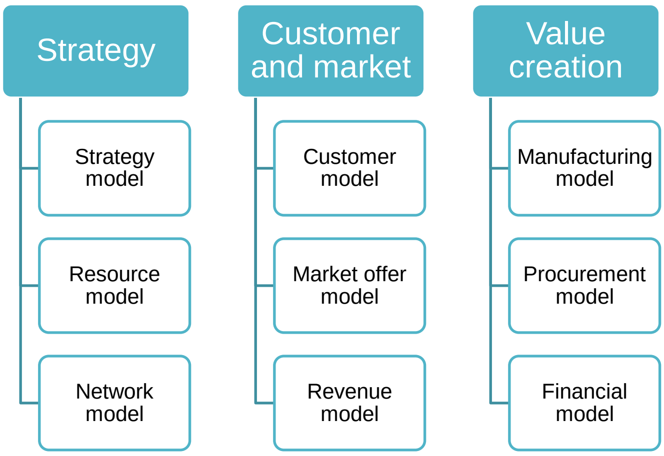

Figure 17 BM structure diagram

Once all the referred aspects are covered, it is important to perform a critical analysis on them. By doing so, one is capable of understanding the risk and the feasibility of the resulting business model. Since with each BM comes a set of available choices for the future (Casadeus-Masanell & Ricart, 2010) it is crucial to understand if that set of choices is feasible within the company's resources and autonomy level (Johnson, et al., 2014). For example, if the BM is being built for a specific subsidiary, its autonomy level will probably be low so there may be some choices, such as operational changes, that are not viable for them.

Also, another important characteristic of BM relays on the difficulty of competitors in copying it. If a company adopts a certain BM and it is successful, competitors will want to change their own BM to be more like the one of the company. So, it is necessary to come up with a BM that it is not easy to imitate (Johnson, et al., 2014).

3.5. Business Plan

While BM deals with more conceptual elements, often being called a statement, a business plan (BP) deals with more concrete aspects (Morris, et al., 2005). A BP can be understood as a *"comprehensive, written description of the business of an enterprise"* (United Nations, 2002). It describes both past and present of the company and, therefore, should be updated regularly. The most important use of BP is to inform the interested entities within the company of the current state of the business, as well as its objectives, strategy and financial performance (Delmar & Shane, 2003).

According to the United Nations Conference on Trade and Development (2002), a BP should include the following components:

1. Executive summary – small introduction of the BP with tits purpose, main objectives and financial needs;
2. Background – brief description of the company. It should give the reader enough information regarding the company's business;
3. Products and services – description of products and services offered by the company;
4. Markets and clients – characteristics of clients, competitors, market position and strategy;
5. Business operations and organization – information regarding the activities that take place in the company;
6. Human resources – description of the company's management structure and personnel;
7. Legal framework, and environmental and social factors – social compliances and benefits, legal aspects that need to be taken in concern;
8. Financial planning – expected profit, cash flows and investment needed.

BP are an important tool when for companies that need financial investment or other resources to start a given a project or service, or to continue growing. As planning allows companies to test various scenarios with a minimal cost, they can present viability studies of their businesses before applying to any type of funding or loan (Rogoff, 2003). As so, and giving that investors and capital firms receive several BP every day, the most important part of a BP is the *Executive summary*. On average, each BP goes through a quick overview of roughly five minutes on which the decision maker will briefly analyse the attractiveness of the BP (Schilit, 1987). So it is important that a BP has a well written *Executive summary* so it can be able to catch the attention of the one that is giving its first evaluation.

Schilit (1987), also gives some guidance for the ones we are trying to build an extraordinary BP. Despite the *Executive summary*, there are some aspects that should be taken into account while writing a BP:

1. Keep it short and simple: it is important to keep in mind that most bankers and investors do not have a technological background. As so, the best solution is to try to explain your proposal in the simplest way you can came up with. Also, very big BP can become harder to read and the one analysing can easily loose its course, so a BP should not be very long either.
2. Identify the market and draw a plan for the future: it is very difficult to come up with a product or service that will serve everyone, so it is important to identify the market where the companies' business will act and show evidence that they are receptive to it. Also, it could be interesting to

develop some forecasts that can support the choice of a certain market and how it is expected to develop in the following years.

3. Be realistic: when showing potential sales, it is better to present all three potential case scenarios – best, worst and most likely. This way the investors can have a better understanding of the different ways the business can go hence avoiding future disappointments if something does not go as expected. Also, the current and potential problems should also be described as well as their solutions – this can show investors that the company is capable of identifying problems before they appear.
4. Show the investors how they will their money back: investors do not want to lose money. So if it is possible to have a simulation of when and how they can get their money back it would add a lot of value to the BP.

It is common to all the authors mentioned above that a BP is a crucial toll for companies to be successful and to obtain investment. Contrary to BM, that is more abstract, the BP structure is common to all of them and it was exposed on the begging of this section. Within that structure a few aspects are mandatory to be clarified:

- Business' value proposition;
- How to attract and retain customers;
- The differences between what is done now and the company wants to offer;
- How much each product/service will cost?
- What will be the financing source?

If a BP is able to cover all these five points, then it can be considered a good BP that will bring advantage for the company that wrote it (Rogoff, 2003).

3.6. Chapter Conclusions

The uprising of AM methods opened doors for new types of service that are becoming more important in today's economy. Not all companies have the financial power to acquire and train personal so they can have a development department on their own. So, seeing this as a business opportunity it is possible to offer services that will perform the entire development of products, from conception to the final product, in order to improve industries competitiveness. Since most of these improvements do not require mass production, AM technologies come as a suitable option due to its inherent characteristics. With this in mind, it is necessary to study the new trends in services innovation towards providing unique solutions to companies in need.

Not only traditional companies may find these services beneficial for their business, but also the most variate industries from biomedical to fashion can find this type of services attractive to them due to the customization possibilities given by these techniques. By exploring the benefits and oppositions of implementing AM as a production method, it is possible to find some aspects where INEGI should bet in order to be successful as provider of an AM service. Giving that INEGI wants to start offering solutions supported on AM for productive systems and products, it should try to work in a way that overcomes the mentioned barriers while enhancing the qualities and benefits of AM.

However, if a company is to succeed with the implementation of a new product or service it should plan in advance all the requirements it will imply for the company. It is important to have a good BM so the managers can see if the new product or service fits the company's strategy and if it has the necessary capacities to develop its implementation. Also, a good BP should be written so one can preview the expected results that will come with the new offer.

Further on this dissertation, the way of interconnecting the existent services with the new one will be exposed and the cost structure will also be analysed. Besides that, the communication plan and the way of attracting new clients and retain the already existent ones will also be studied.

4. METHODOLOGY

As a product of this work, a Business Model (BM) will be proposed, so that INEGI can enter a new market that provides services based on AM technologies. To build an effective BM, it is necessary to gather information from both parts – company and clients. By doing so, it will be possible to have a better view of the market needs and how INEGI can contribute to satisfy those needs.

The methodology used in this dissertation for data collection consists in a case study analysis. This type of research allows us to have a better understanding of the reality of the company and industries that will be studied since it will give us a very detailed description of how they work and what they do (Flick, 2014). A simplified diagram of the method to be used can be found in Figure 18.

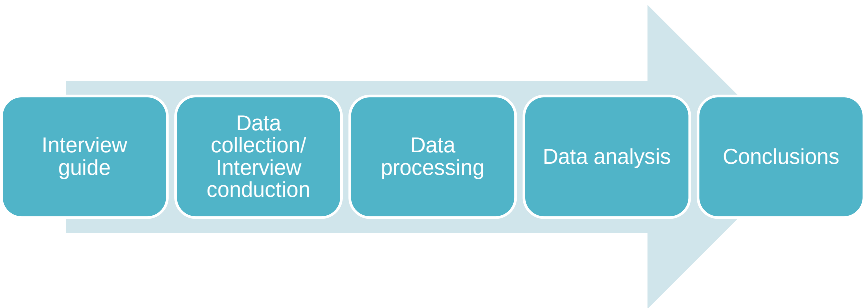

Figure 18 Case study research method

To gather information for a case study analysis one can use either qualitative or quantitative data, so it is not necessary to be restricted to one type of data which enables to have a wider information source (Yin, 1981). Since the purpose of this dissertation is to find potential applications for AM technologies, the interviews will be based on qualitative data rather than on quantitative. Another advantage of this method is that it enables to relate theory with the obtained data in a simpler way since it forces us to gather information by performing field investigation (Saunders, et al., 2009).

The necessary information will be obtained through in-depth semi-structured interviews. This type of interviews is composed of open questions that will lead to more spontaneous answers and enable more detailed information (Flick, 2014). This is possible because the interviewees will possess a high level of knowledge on the subject of study. Two different sets of guides were prepared, one for the internal interviews and other for the external ones. The companies to be interviewed were chosen together with INEGI's representatives during their interviews, and its selection had its field of activity as the main criteria.

Before each interview, it was explained to the interviewees the purpose of the work that was being developed. Besides that, it was also clarified that the interviews participation were voluntary and that the final results were to be exposed on this dissertation. As so, the internal interviews result was reviewed by INEGI's CEO to check if some of the information was confidential. For the external interviews, since these interviews included questions about the production process of the companies, the interviewees were also asked, if they desired to remain anonymous during the results presentation for purposes of corporate confidentially.

Regarding the environment where the interviews were undertaken, is was important to find a place where the interviewees felt comfortable to answer the questions. This was important because the purpose of using semi-structured interviews was to allow the development of a conversation with them. By not following a strict guide, it was possible to gather more information about the processes the companies' use, their knowledge regarding AM technologies, as well as their concerns and expectations regarding this technology and its uses. With this information it was also possible to understand how INEGI could approach companies regarding this subject and what would be the best areas to start working on.

4.1. Interview Guides

As previously mentioned, to collect the necessary insights to propose a BM, a set of semi structured interviews was carried out. This type of structure was selected since it allows the interviewer to have a line to conduct the conversation without limiting the interviewee's answers. Also, given that one of the objectives was to find possible market gaps, by interviewing clients it was possible to understand in a more detailed way what their needs are. Once one knows the needs of the market as well as the possibilities offered by AM technologies, it becomes easier to identify possible gaps and then define a way to tackle them.

Two distinct set of interview guides were created:

- Internal interviews
- External interviews to current and potential clients

This approach was used so it would be possible to create a well-structured BM that will be able to use INEGI's capability and capacity to fulfil the market demand.

4.1.1. Internal Interviews

The first set of interviews was focused on the internal perspective of the company. The purpose of this was to understand how the company intends to approach the market and how the new offered service will be integrated within the company's current capacity and competences.

As mentioned in section 3.3., a BM should cover three aspects:

- Strategy
- Market and customers
- Value creation

To collect the relevant information, an interview guide was built. This guide was then used to conduct three interviews. Next, the interview's structure is detailed:

- **Value creation and communication** – this set of questions was made with the intent of defining a market segment to approach, how to create value for future clients and discuss in which way the service will be promoted.

1. What is the value proposition that INEGI wants to create with this new service? What will be the benefits for the customers?
2. Which will be the target market? In what industries INEGI wants to be present? What are the priority industries, according to the INEGI's fields of knowledge?
3. What will be the size of the company's you are aiming to attract?
4. Does INEGI intends to work with the existing clients' portfolio? What is its size?
5. How does INEGI intends to attract new clients?
6. How will the service be promoted among the existing clients? And among the new?
7. What will be the differentiating factor about this service when comparing to others who are able to offer the same type of service?
8. Does INEGI foresees an increase in competition to this service? In which time frame? Both on a national and international level?

- **Activity network** – with this section, the purpose was to analyse the current capacity and the need of future investments. Also, on this set it was possible to have an overview of how the new service was going to be integrated with the remaining offers of the business unit where it would be included.

9. What is the current resources capacity (machines and human resources)?
10. What is the current offer of the business unit?
11. Is there excess of capacity that can be used to perform this service?
12. In which way will the service be integrated with the remaining activities of the business unit?
13. How will be the resources allocated between the different activities of the business unit?

- **Cost structure –** the final set of questions of the internal interviews was related to the inherent costs of the service.

14. Will it be necessary to do any type of investment regarding resources (machines, human resources, training, etc)? If so, what will be its value and where will it come from?
15. What will be the associated costs of the service (average value)?
16. How will the costs be distributed?
17. What is the share of revenues that is forecasted for this new service? What are its financial goals?

4.1.2. External Interviews

The second phase of the interviews' process was the interviews with clients and possible clients. This part was very important since it enables the company to confirm if the service they are trying to sell is aligned with the needs of the targeted market. By meeting with clients, it is possible to know what they are looking for and adjust the initial strategy to the real needs and wants of the market.

The guide was divided in two sections depending on whether the company was already a client or not. If it was not, it was important to check if they were aware of what INEGI is and what its offers were. And since the PSD business unit works on product development, it was also important to know how this was made by the company. If it was an entirely internal process, the company was not a suitable client for INEGI.

If the company that was being interviewed was an existing client of INEGI, the interview started on the second part. The second part of the guide was focused on AM and the perception of the selected companies regarding this type of technology. The guide went as follows:

1st part

1. Have you ever heard of INEGI? Are you aware of what are its offers?
2. Does your company outsource any type of service? If yes, which ones?
3. How is the product development made within the company? Is it an external or internal process?

2nd part

4. How the company keeps up with new technological developments that may be useful for its business?
5. Do you have any knowledge regarding AM technologies?
6. Has your company ever used this type of technology?
    1. If yes: For what? Are the machines owned by the company or are they rented? What type of difficulties did you encounter?
    2. If not: What are the main reasons? Do you think you will be recurring to AM in the future?
7. Do you see your company increasing the use of AM produced parts?
    1. If yes: What type of parts and how many do you think will be substituted? What type of materials are you thinking of use?
    2. If not: Why?
8. Do you see any type of strategic and/or financial advantage that comes with the use of AM?
9. Does your company intends to develop its own AM capacity or do you think it will be more beneficial to outsource it? Why?

4.2. Sample Selection

Regarding the internal interviews process, the number of people to interview was not a key aspect rather the quality of the information. So, during the time period given to collect data, three interviews were made within INEGI's personal, as shown in Table 7. This table describes the interviewees, their business units, and their position. For this set of meetings, two members of the PSD business unit and one of the cluster business unit of Innovation and Technology Transfer were chosen. The selection criteria for this part of the dissertation was based on the knowledge of the current offer of the business unit and what was intended to offer. Also, it was important to talk to people who understood the cost structure of the projects and how the communication between the company and clients took place.

Name	Position	Business Unit
João Paulo Pereira	Head of Business Unit	Product and System Development
Luís Oliveira	Researcher	Product and System Development
Catarina Cardão	Business Development Manager	Innovation and Technology Transfer

Table 7 Presentation of the internal sample selection

The second phase of interviews consisted in meeting up with possible clients. The list of selected companies is presented in Table 8. The list describes the companies' names, location and activity.

Company	Location	Activity
Adungem	Paços de Ferreira, Porto	Manufacturer of productive systems
Amob	Louro, Braga	Manufacturer of productive systems
Anadirobotic	Anadia, Aveiro	Manufacturer of productive systems
Bresimar	Aveiro	Manufacturer of productive systems

Companhia de Equipamentos Industriais	São João da Madeira, Aveiro	Manufacturer of productive systems
Cortimetal	Águeda, Aveiro	Manufacturer of productive systems
Engenharia, Soluções e Inovação	Vila Nova de Famalicão, Braga	Manufacturer of productive systems
Europneumaq	Serzedo, Porto	Manufacturer of productive systems
INESCTec	Porto	Research and development
International Iberian Nanotechnology Laboraty	Braga	Research and development
Metalotrofa	Ribeirão, Braga	Machining

Table 8 List of Interviewed companies

For this phase, it was important to collect information from the greatest number of companies possible within the available time frame. Although the total amount of interviewed companies may seem low, it covers almost 100% of the principal industry to study (Manufacturers of Productive Systems). Given INEGI geographical location, the identified companies are all located in the northern and centre regions of Portugal. As a consequence of the limited amount of time available to perform these tasks, it was agreed that the interviews were to be made during the International Fair of Machinery, Equipment and Services for Industry (EMAF). This solution made possible to reach out every company that was considered to be important for this dissertation as well as speed up the process of collecting information. Since it was proven difficult to schedule a meeting with the different companies, this was seen as the most viable solution. Also, given that it was a fair for companies to create new contacts and partnerships between them, the interviewees were still individuals that are deeply involved in the activities of the companies and were able to provide valuable data.

4.3. Conduction of Interviews

To be sure that the relevant information for the case study is gathered while using interviews as a source of information, it is necessary to go through three different steps (Flick, 2014):

- **Data recording:** the internal interviews were made within the INEGI's facilities. To be sure that all the information was collected, the three interviews were recorded with previous permission. Regarding the external interviews, since they were made during an event, it was not possible to record the conversations due to the background noise. Therefore, several notes were taken and some aspects were repeated by the person that was being interviewed to be sure that everything was noted down.
- **Data editing:** once the interviews were made, there was a need to put them into text. For the internal interviews, to assure that all the relevant information provided by the interviewed was analysed, a transcription of the conversations was made. Besides this, it is known that part of the information is passed through the way things are said rather than the exact words that are used (Flick, 2014). So the interviews were listened carefully more than once, in addition to their transcription. For the external ones, the collected info was then separated into categories to facilitate the analysis process.
- **Data analysis:** for the internal interviews, since it it was possible to have a full text of what was discussed during the conversations, it was needed to interpret those same texts. To do so, the collected information was matched to the questions of the interview guide and was then arranged into the different categories that were being analysed (Saunders, et al., 2009). Once that was done, the combined result of the interviews could be exposed as a full text as shown in section 5.1. Regarding the interviews to existing and potential clients, since it was not possible to recreate the full conversations, the collected data was separated into different topics. The answers to the questions were firstly separated into general topics. Secondly, they were separated in order to have filtered groups of answers, or subtopics of the ones were they were initially matched. Finally, it was possible to have a structured source of information, divided by topics and subtopics that were matched to the questions presented on the external interviews guide. With this, it became feasible to analyse the answers without the fear of losing crucial input, something that was most likely to happen if this algorithm was not followed (Flick, 2014). The collect information was also arranged in a way that made it possible to show it in a more visual display (Saunders, et al., 2009). With this it became easier to withdraw and justify further conclusions.

4.4. Chapter Conclusions

The chosen methodology to approach the problem in hands was the case study methodology. To do so, it was identified two main groups of research: internal personal and clients and possible clients. After that, two different sets of semi structured interviews were created. The semi structured interviews have the advantage of allowing open responses that may originate a deeper knowledge of the companies' ideas and the needs of the market they are trying to tackle.

The two sets of questions were written in a way that a conversation may flow naturally and still collect the necessary information from both parts. For the internal interviews it was necessary to know the differences between what is done and what will be done. Besides that, it was also necessary to understand how INEGI captures and retains clients, i.e. what is their value proposition. On the other hand, the second group of questions had the sole purpose of understanding the companies' position regarding AM. Another important information that was collected from the interviews was how the companies searched for new technologies to incorporate into their own facilities and products.

For the internal interviews, the chosen sample was based on its role either on the creation of a new service for the PSD business unit or due to its role as business developer for INEGI as a whole. On the other hand, the external interviews sample was selected based on the interest shown from INEGI in approaching them.

5. DATA ANALYSIS

In this section, the results from the conducted interviews are discussed. The internal interviews content, giving its nature, was organized into continuous text in order to have a clear understanding of what are the PSD business unit ideas for this project. And since the business unit is an integrate part of a bigger organisation, INEGI, it was important to understand what can and cannot be changed within its strategy.

5.1. Internal

The subsection was entirely written with information obtained from the meetings with INEGI employees. As better described on subsection 4.1.1, the interviews were focused on understanding what the PSD unit currently does and what it wants to offer. So, the results will be presented accordingly to the different focus areas of the BM:

- Network activities
- Value creation and communication
- Cost structure

5.1.1. Network Activities

In this part of the interview, the purpose was to understand the differences between what the business unit does now and want they want to start offering. Also, the way of how they intent to integrate the new set of activities within the already existing ones.

Being a unit focused on product development, the PSD business unit concentrates its efforts in all the phases of conception and development of new products and systems. The business unit usually works through all the different phases of product development and Technology Readiness Level (TRL). TRL is a method of evaluating the state of maturity of a given technology, this scale goes from TRL 1, referring to the basic technological research stage, to TRL 9, which is referring to the system and operation launching.

As shown in Figure 19 Product and Systems Development Process, the PSD is capable to intervene in all stages of the product development. This goes from the initial idea (TRL 3) to the production ramp up (TRL 8). However they can act on specific parts of the process, depending on customer's needs.

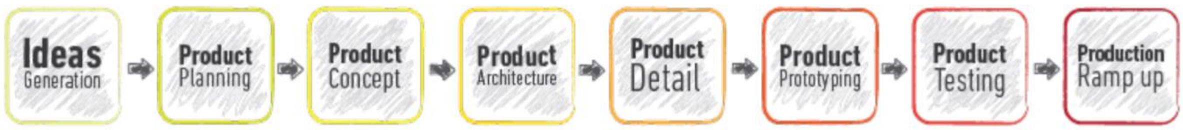

Figure 19 Product and Systems Development Process

This unit has four core competences:

- Conception of complex products and systems
- Sustainable conception and eco-efficiency
- Additive manufacturing for products and systems
- Advanced automation and movement control

However, this dissertation will be focused on the third subject, additive manufacturing for products and systems, and the way it co-relates with the other three competences.

The business unit has assigned teams for each field of knowledge, with the goal of reaching a team of 40 employees divided by all the sections of the business unit by the end of 2018. The conception of complex products and systems is the one that has more allocated members and the advanced automation section the one with the less capacity in terms of human resources – currently there is no one assigned to it. Regarding the AM, currently there are only three researchers working on this field. When it comes to the number of available machines, at the moment INEGI owns around eight machines of the different AM production types referred on this document.

The additive manufacturing for products and systems is a relatively new area for INEGI. Until now they have been gaining some know-how by designing system parts as well as conceiving systems to help production become more efficient. Their main goal is not to be present in every possible area that AM can cover, but to focus on the productive advantages that can come from companies including this technology in their productive operations. Aligned with the company's mission of contributing to the improvement of the national industry, the goal would translate into by being a reference on parts and system design that take advantage of these technologies, so industries can be able to increase its productivity and minimise errors and costs. A big focus, if not the most important of all, would be concerned with Advanced Manufacturing where it is possible to identify multiple usages for AM.

As a next step, INEGI wants to explore partnerships with other companies in order to promote AM technologies and their strategic and financial advantages. There are a few areas where this can be achieved such as:

- Robot parts
- Handling systems
- Internal logistics
- Assembly line

All of these fields would be improved if AM was used more often. For instance, in handling systems it may exist the need of having different grinds for different pieces. By using AM, it is possible to build grinds that are specific for handling a certain type of material at a significant lower price than by using conventional machining. Also, regarding its uses in the assembly line, it is possible to use AM to build auxiliary parts that help to reduce errors, such as misplacement of security bolts on wheels.

5.1.2. Value Creation and Communication

The purpose of this section is to analyse how the business unit intends to create value to the customer and the way the new service will reach potential clients. To do so, it was necessary to identify market segments, communication and publicity plans and possible competition.

Among the expected benefits for users of AM technologies, the most appealing ones for the manufacturing industry are the decrease of time and costs of production without discarding the quality of the produced parts. This can be achieved either by having machines that are capable of handling several types of parts or that are capable of performing multiple tasks. Also, in case of the need for a part replacement arises, it is important for the replacement time to be the lowest possible, so the production process won't be affected. Having this clear, INEGI's value proposition for this service is to offer a solution that can be integrated in the manufacturing industry, taking advantage of AM methods for production. By doing so, the business unit in study, PSD, takes up the challenge of improving production systems with the purpose of helping companies to take the next step into Advanced Manufacturing.

Giving the characteristics of AM, there is no need to concentrate efforts on a specific type of economic activity. Although, taking into account the already acquired knowledge and existing network of the business unit it is possible to identify some niches that would be interesting to explore, companies that are specialized in manufacturing production systems. These companies are usual of small dimensions, going from micro companies (less than 10 workers) to medium sized companies (less than 250 workers), but are the ones that seem to be more interesting to approach on a first level. On this type of companies, the produced machines need to perform a certain set of specialized operations that usually require different parts for each operation. If these companies start to use AM, the need for machined components or moulds would decrease because it is possible to build a completely functional part with AM. Also, another interesting feature of using AM would be the decreasing of the risk in production. If a part needs to be replaced it is possible to have a new one in the time spawn of only 48 hours. So, in the course of the interviews, it was possible to conclude that these would be interesting companies to approach first and that would possibly be active partners in the development of these techniques.

An identified setback on the internal interviews was the fact that the companies of the northern region of Portugal are usually reluctant to change, what can become an obstacle when it comes to introducing new technologies and work methods. The team responsible for commercial communication in INEGI is relatively new and was created to fix the gap that existed between clients and INEGI. This is within the Business Development structure and englobes all the commercial functions of the organization such as communication, marketing and sales as illustrated in Figure 20. Also, this unit is responsible to attract and retain customers, something that was done by each unit individually.

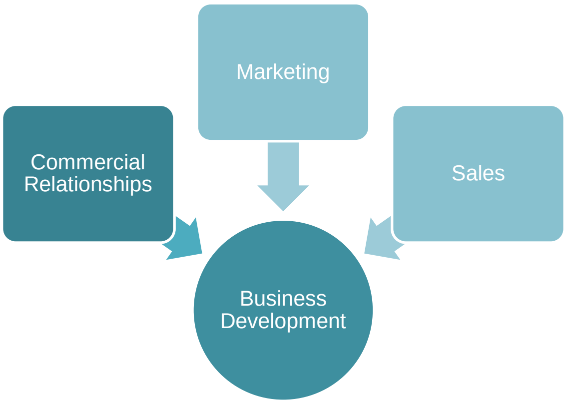

Figure 20 Functions incorporated in the Business Development unit

Before the creation of this new unit, INEGI did not had a commercial unit dedicated to attract new clients, hence making the process of gaining new customers longer than necessary. Since possibly interested companies did not had a specific contact to establish communication between the two entities, they often recurred to personal contacts they already had in the company. By doing so, the information could not reach the right person in the most effective way and, in extreme situations, it could even get lost somewhere in the process of passing by information and requests for meetings.

In order to minimize these aspects, INEGI has become more active in hosting conferences and participating on technological fairs in order to show its current services and to give visibility to the new ones. However, the most common way of publicity and communication used by INEGI is the door-to-door method. On this approach meetings are set up between INEGI and the possible client, in either ones' facilities, and the benefits of a partnership are explained to a representative member of the customer in question. This way, it is possible to understand the client's position and dissipate the reluctance in adopting new technologies by explaining the process of developing a new system or product. Another way of gaining trust from reluctant companies is to show them examples of the organization's successful projects. Since big organizations like ESA are prone to new technologies and are willing to invest on them, it is possible to see an opportunity for INEGI to work with them on the field of AM – taking advantage that ESA has already collaborated with them in other projects.

When it comes to competitors, it was concluded that at the moment there are no significant competitors that can provide AM based services. There are a few companies that offer such services but none of them for an industrial purpose, having as the main market the common user instead of companies. This comes from the necessary expertise to operate AM devices and the investment needed to purchase such devices. Companies often find attractive the idea of owning an AM machine in their own facilities, but the lack of know-how and financial capacity draws a setback for them and tend to not invest on this type of equipment. Besides that, the type of materials that PSD is becoming a specialist on are very hard to manipulate and the machines that are capable of handling them require some know-how to produce functional parts. The materials in question belong to the category of thermoplastics. This type of material is capable of endure high temperatures and presents a great set of mechanical proprieties that make them the ideal material for the aforementioned companies to use. With that being said, if the business unit specializes itself on the development of products and systems that use thermoplastics, there is no perspective of competition in a close future.

5.1.3. Cost Structure

The final part of the internal interviews was related to the cost structure of the company. As a part of INEGI, the way costs and profits are calculated by the business unit follow a standard procedure common to every other business unit. This same procedure will be exposed in this section, as well as the need for investments and revenue percentages.

Giving the technological nature of the company, the need for investment is constant. If the PSD business unit, and INEGI itself, wants to keep its position as a technological leader, it is necessary to invest not only on machines and software but mainly on people. Although having state of the art machines is important for business, INEGI's true value are its co-workers. They are the ones that are able to transform knowledge into real-life solutions for clients. So, it is required to attract and retain more people to contribute with their knowledge, or willingness to acquire knowledge, to help PSD start offering the AM service in study. Something that illustrates well the confidence that INEGI's clients have on its services is the fact that needed funds are equally divided into public and private investments, as it was already explored earlier on this document (see section 2.1.7.2). A scheme of the origin of INEGI's investments is shown in Figure 21

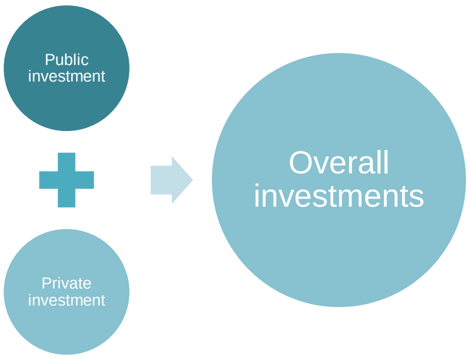

Figure 21 Investments' Origin

This particular feature is important when it comes to approach new customers since it shows that private companies are keen to take in partnerships with INEGI and to make use of its services for their own profit. For the machines, for example, the investments are typically around the dozens of thousands euros. These costs are then distributed within the different projects where they are needed. Ideally, for the overall business model of INEGI, each machine should have a depreciation period of three years.

In order to determine the price of a given project, the PSD business unit takes into account parameters such as:

- A – Cost of producing a part;
- B – Percentage for indirect costs and unit margins associated to the project;
- C – Percentage of related overheads costs.

These three parameters are then multiplied as shown in the equation below:

$$Price = A * B * C$$

The A parcel is related to the inherent costs of producing a product using AM machines. Considering costs such as the hourly costs of using a machine, the costs of raw material and the costs of both pre and post processing operations. The final cost of using the machine is calculated by multiplying the hourly cost (C_h) with the number of hours necessary (h) to produce the needed part. These three different costs are then all summed up to find the final value of A:

$$A = C_h * h + Raw\ Material + Processing\ Cost$$

The hourly cost will vary depending on four different aspects:

- Purchasing price of the machine
- Depreciation period of the machine
- The number of hours per day that the machines needs to produce the part
- The total amount of hours that the machine will be working during the year

This parcel is calculated by correlating the aforementioned aspects as follows:

$$C_h = \frac{Price\ of\ the\ Machine * Working\ Hours\ per\ Day}{Depreciation\ Period * Total\ Working\ Hours\ per\ Year}$$

The depreciation period is usually fixed in three years, so it will not vary from machine to machine. When it comes to compare the cost between different machines, the variables that have more influence will be the price of the machine and the total working hours of the machine - since the number of hours of producing a part will be the same regarding the machine that is being used.

Regarding the raw material related costs, these will be as higher as the quantities used and the price of material per kg:

$$Raw\ Material = Quantities * Price\ of\ Raw\ Material$$

The selection of material will depend on the properties needed for the product. The raw material will also have influence on the machine that will be used, since there are machines that are not capable of handling some types of materials.

The last segment of the costs regarding production are the ones concerned with processing parts. Depending on which material and machine is being used, it may exist the need for pre and post processing operations. The extension of these operations are variable, while the cost per hour of a specialized worker is fixed. The processing costs are calculated according to the following equation:

$$Processing\ Costs = (Pre\ Processing\ Cost + Post\ Processing\ Cost) * Hourly\ Cost\ of\ a\ Technician$$

The second part of the project's cost (B) is related with the percentages of the indirect costs that are associated to the project. These costs cover all the necessary expenses indirectly associated to production, such as water and electrical expenses. Also, this parcel contemplates the profit adjacent to the project – unit margin. Combining the unit margin with the indirect costs, these two will contemplate 50% of the final price. Factor B is calculated as follow:

$$B = 1 + Indirect\ Costs\ \% + Unit\ Margin\ \%$$

Finally, the last part of the costs (C) is concerned with the overheads percentage, i.e. all the non-labour related expenses like accounting and legal expenses. This is a fixed percentage so it is the same for every project and represents 20% of the final price:

$$C = 1 + Overheads\%$$

Both unit margins and overheads can vary, depending on the nature of the project (internal or external), while the indirect costs do not change and always represent 25% of the price. For internal projects, there are no overheads to add since there is no need of invoicing, and the unit margins decrease 20% and only represent 5% of the price.

To calculate the price, if the project is external, it is usual to add a commercial discount. This discount is fixed on 5% and by adding this it is possible to have the final price of the project:

$$Final\ Price = Price * (1 - commercial\ discount)$$

5.2. External

The purpose of this set of interviews was to understand the position of the industry regarding the use of AM. As so, it was necessary to approach the identified companies to see if they already use this type of technology and if its advantages are well known for them. Also, it was vital to see what are the concerns and setbacks when it comes to AM.

Although INEGI has already a few clients that are of interest, one of the objectives when launching a new service is to attract new clients. So the interviews were performed to both clients and potential clients, with emphasis on potential clients. The distribution of percentages for the two categories is shown in Figure 22.

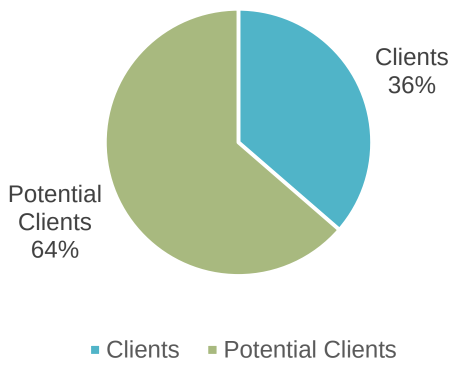

Figure 22 Percentage of clients and potential clients interviewed

From all of the interviewed only 4 of them use AM technologies and owns at least one machine, as shown in Figure 23.

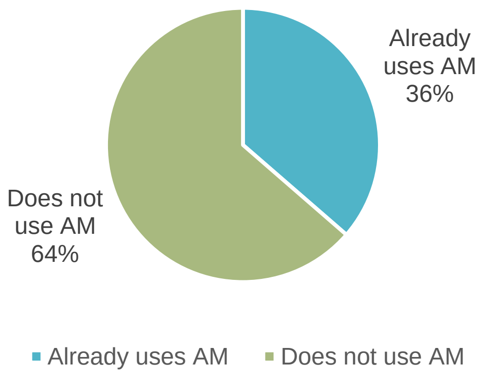

Figure 23 Percentage of the use of AM technologies within the interviewed companies

5.2.1. Companies that already use AM

Although the percentage of approached companies that already take advantage of AM technologies is fairly low, they all agree that this will be something that has the potential to change the way productive processes operate. It is a common opinion that sooner or later all companies will either have its own AM machines and specialized technicians or will recur to entities that are able to offer services capable of fulfil this emerging need. Due to confidentiality, the companies asked to not have their names revealed. As so, from now on they will be referred to as company A, B, C and D.

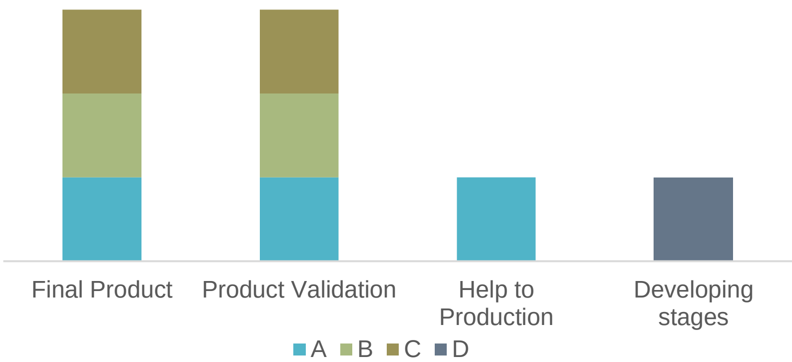

Figure 24 Uses of AM technologies

Once it was assessed which companies already use AM in their facilities, it was interesting to analyse for what they are using it. Four different uses were identified, with some companies using this technology for more than one purpose. The graphical information is displayed on Figure 24 and a more detailed description can be found next:

- **Final product** – companies that use AM for components of the final product or to build the entire product out of AM. Three companies answered that they use AM for either the entire final product or for its components. One of them mentioned that their products and research work would not be possible, or it would be very limited, if not for AM.
- **Prototyping** – on this stage it is possible for the companies to show the client how will the final product look like and how it will behave. So, this stage is important to check the client's requirements as well as defects of the part. This is where all the interviewed companies admit to use AM and recognise its potential, mainly due to the speed of altering and produce a prototype. Company D is the only one that does not produces prototypes using AM at the moment, however is working towards that.
- **Help to production** – Company A also uses AM to produce parts not for the final product but to help its production. By producing elements that will help the final product in place, for example, it helps to reduce manufacturing errors and, therefore, the number of complaints for defects.

- **Developing stages** – Company D is now trying to introduce this technology on its productive processes. As so, they are still gaining the necessary know-how to do so. Besides being in a developing stage, they fully recognize the advantages of using AM and that is the reason they are trying to incorporate it on its product development process and, later, on its productive process as an end product or to help production.

From the conversations with the companies, it was possible to conclude that they all see that AM is full of potential and they do not question that if the industry wants to stay competitive it will have to invest on AM and turning it into an integrated part of their product development and productive processes. By grouping the obtained responses, it was possible to come up with three notorious advantages within AM users, as shown in Figure 25.

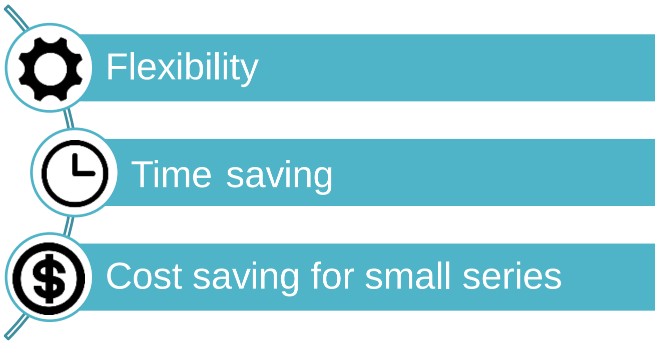

Figure 25 Identified advantages

The explanations given by the companies for each of the identified advantage:

- **Flexibility** – AM techniques allow for a greater diversity of products to be made. Products that were once too complex to produce can be simplified by combining multiple parts into one, which besides making the part simpler also makes it cheaper. Also, the diversity of products that can be produced with AM contributes to the enhancement of this advantage. A more flexible method of production can represent a bigger diversity of offered products.
- **Time saving** – this category was often mentioned when referring to the product validation. Creating a prototype with AM is significantly less time consuming than using conventional techniques, allowing companies to have a proof of concept much quickly than what they had. Also, when the clients want some kind of alteration to be done in the model it is easier to do it when using AM. The developers just have to change the design in the CAD file and the part is ready to be printed. Another application where AM can reduce times of production is in the moulding industry, where it can reduce the time between the design of the mould and the actual mould for mass production.
- **Cost saving** – regarding costs, the interviewed companies all agreed that AM has a great potential when it comes to unique solutions and small series production. In AM, the cost of producing one piece tends to be the same. This opposes the traditional methods where the production costs tend to decrease with the amount of produced parts. With this it becomes more

feasible for companies to adapt their products and solutions to the reality of each client, an aspect that will increase customer's satisfaction and will attract more customers since companies will be able to offer a more fitting option than the competition.

Despites the acknowledged advantages, the companies also identified some disadvantages or negative aspects of using this type of technology. Again, by combining the received answers into categories it was possible to group them into three different topics as shown in Figure 26.

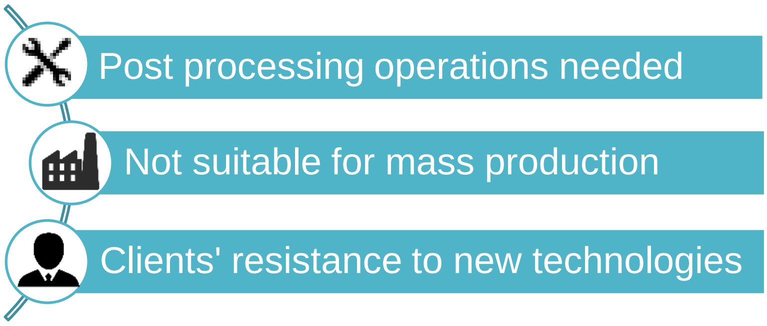

Figure 26 Identified disadvantages and dificulties

To fully understand why these topics are seen as a negative constraint, the collected information during the several conversations was put together as follows:

- **Post processing operations** – for some materials used during AM fabrication there is the need of performing some kind of finishing operations, with polishing being the most common one. This is seen as a disadvantage of this technology when compared to the traditional methods. Nowadays, once the product is out of the machine it is ready to be packed and sold. So, the use of AM for creating end products loses some of its purpose since the product it is not ready to be used once the process is finished and needs to go through additional ones. However this is a more common complaint when referring to materials other than plastics, thermoplastics and metal. If one of these materials is used, the need for extra processing is almost null, except when the client wants a perfect polished part. This disadvantage is often pointed out when referring to materials like cast that, giving the material's properties, needs some after work so it won't have a wrinkled surface.
- **Mass production** – as previously mentioned, AM has a great potential when it comes to small series production. However, when speaking about mass production AM is not able to compete with traditional methods. Although it is faster and cheaper to produce unique products or small series, when it comes to mass production using AM becomes very dispendious and time consuming. Given that most companies are still focused on mass production rather than customized products this comes up as a serious disadvantage for the use of AM.
- **Clients' attitudes** – this is a common issue that companies face when dealing with new technologies. The industry in northern Portugal is very traditional, which means that they will

not accept change easily. Also they tend to not trust the quality of products that were made using a different technology which they are not comfortable with, or do not fully understand. This type of attitude slows down the development of such technologies since companies are usually not interested in perform partnerships with entities that do want to develop new know-how. The resistance to change means that companies also need an extra effort to be convinced of the advantages that AM may offer, because they often have difficulties in seeing other ways of production. As is, this may be the biggest setback or disadvantage of using AM. If clients are not prone to give this technology a try, it will be difficult for companies to develop their skills.

All of these four companies keep up with new technology developments in the same way, i.e. they often participate in technological events where new machines and processes are presented and follow up technological magazines. When approached with the possibility of any type of partnership regarding AM technologies, all of the companies seemed very enthusiastic to collaborate with INEGI if contacted.

5.2.2. Companies that do not use AM

The first thing that was cleared during the interviews, was how well the companies knew this type of technology. It is possible to see in Figure 27 that most of the companies (57%) already had a good level of understanding regarding to AM. However, the remaining 43% had very little knowledge about it or had never heard of it. Once again, for purposes of confidentiality, the companies will be referred as company E, F, G, H, I, J and K.

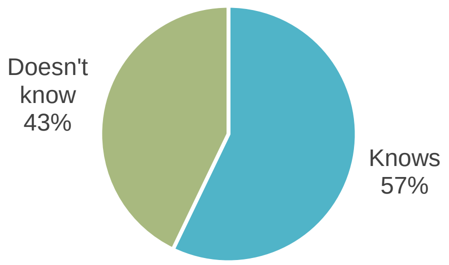

Figure 27 Percentage of companies that knew or not AM

From the companies that already knew AM, it was possible to collect some information regarding the aspects that made them not use this technology on their business. As in the previous section, the responses were grouped into distinct categories, as shown in Figure 28.

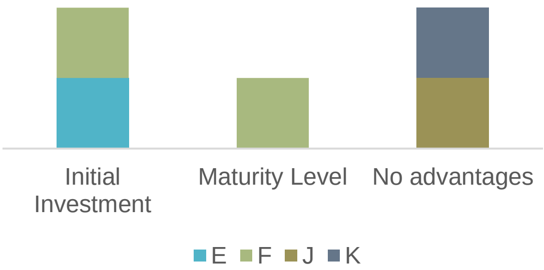

Figure 28 Reasons why companies that have knowledge on AM do not use it

This is an important aspect since it allows INEGI to focus on the parameters that companies recon as a setback and use them to their advantage. With this information, it is possible to know how to tackle clients and future clients in a more effective way, since INEGI will be able to nullify or clearify some of those points. As so, the different explanations por each category can be found as follows:

- **Initial investment** - for small size companies, like company E, the required investment to incorporate AM into their productive systems is something that is not feasible. It is not only necessary to invest on equipment for a company to start using a new type of technology, but is also needed to invest on human resources. This last investment requires either to train the already existing personnel or to hire new employees that already have some know-how regarding the given technology, and even sometimes it is required to do both. This represents a big expense for companies, and small companies often lack the financial power that allows them to do so. On the other hand, company F argues that they will not see a significant turnover of the investments needed in an acceptable time frame. This comes mainly because AM is not suitable for mass production, which frightens most of the companies that will possibly benefit from it. The last argument stands on the fact that companies are still not able to see other applications of AM if not for producing end parts, while it has a wide range of applications that could mean an economic and productive advantage for them. This shows that, even in companies that have knowledge on the subject, there is lack of information when it comes to the full potential of using AM technologies. It is possible to look at this as an opportunity for INEGI to expose to potential clients its projects and ideas that require AM for other purposes than producing end parts.
- **Technology's level of maturity** – the usage of AM in anything more than prototypes is something new to industries. As so, it is comprehensible that those companies do not fully trust it to be able to include it in their productive process or to fabricate components to use on their machines. The lack of evidence that it is possible to have fully functional parts, or that AM can help reduce the time between an idea and a new product seems to push away potential users

that may benefit from it. Because of that, companies prefer to wait for this technology to become more developed and for other companies to start using it so they can have evidence that this is something worth of investing on.

- **No advantages** – two of the questioned companies see no advantages worth investing on AM due to the nature of the services. However, they also share the opinion that for most of the manufacturing industry this will be something that will revolutionize the production methods. By allowing companies to have better productive performances and to offer customized solutions to their clients, these companies do recon that AM is the way to go when it comes to the manufacturing.

To the companies that did not knew AM before the interview, it was necessary to introduce them to this topic for the conversation to continue. As so, it was explained to them the processes involved in AM fabrication, as well as its applications, and also some brief examples. After that, it was possible to talk to every company in order to check if they could recognize some advantage for their business. Instead of pointing out to them how AM could improve their business, this was made in a way that the companies identified by themselves the potential benefits. By doing so, it was possible to have more detailed answers and to identify potential market gaps for INEGI to explore. The advantages point out by all the companies are described on Figure 29.

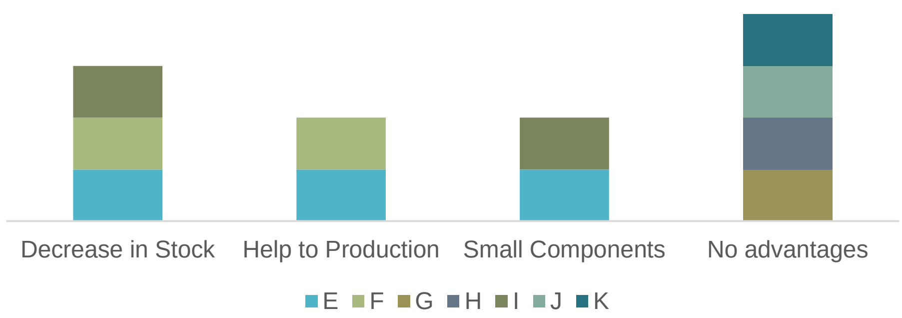

Figure 29 Advantages identified by all the companies that do not use AM

- **Decrease stock level** – all of the interviewed companies use some parts that are purchased rather than produced in their facilities. This implies that they need to have some safety stock level to ensure the production flow. If the companies were equipped with some AM machines they could decrease this stock level since they would be able to produce those parts within their facilities. This also applies for spare parts stock. Most of those companies perform repairing tasks as an additional service to their clients. Since these are non-planned tasks, they have two options: 1) have a given number of parts designated for repairing operations; 2) order the needed part once the broken machine arrives to their facilities. If they could use AM for this service, for each case, they would: 1) decrease the stock level because they could print the necessary part when they have that specific need; 2) increase their service level because it would be a much faster process than order a part and waiting for it to arrive.

- **Help to production** – as company A mentioned (see section 5.2.1), companies E and F also believe that AM will be helpful to improve their current production. In the same way, they see the greatest potential in producing support parts to introduce in the current process. This can be, for example, stabilizing parts that can help to reduce precision errors by preventing the misplacement of the product in the assembly line. This could give more stability to the product while it goes through the different phases of production hence reducing manufacturing errors. Another example of identified advantages by these companies, was the time reduction for moulds production. AM could allow a reduction in the number of stages needed to have the final mould ready for production. By doing so, it will improve companies productivity because they will be able to start to fabricate a given product in a much faster way than by the traditional methods.
- **Small components production** – companies like E and I also believe that the use of AM could be beneficial for the production of small components of the final product. This is due to the characteristics of these components and the materials that are used to produce them. These companies are manufacturers of productive systems, which means that the machines they produce will be used by their clients as a productive machine. This machines have some parts that are different from client to client, and it is regarding this aspect that they see a competitive advantage in using AM technologies. The companies believe that AM can be an advantage when it comes to the production of small plastic parts that will incorporate the final product. Usually, this parts are made in different machines or, if made in the same machine, there is the need for re-programing the machine for each different part. By using AM technologies, they can be produced in the same machine with just a few adjustments for the different parts, hence decreasing the process complexity and production time. Also, for the interviewees' point of view, this techniques should only be used to produce the parts that will not need to endure high temperature or pressure once the final product is in use. The reason for these last two mentioned aspects comes from the lack of proof that this type of technology is capable of producing high quality components, which shows the low level of trust on that companies have on this technology.
- **No advantages** – after the interview, companies J and K, given the nature of their services as explained previously, still did not see any advantage on the use of AM. Additionally, there were two other companies (G and H) that did not see any advantage on recurring to AM technology as well. These last two companies mentioned that for AM to be attractive to them it would need to be able to produce metal parts, yet they do not believe that this technology will bring any financial or competitive advantage for their company.

During the interview process to each company, it was also possible to analyse the interest they had demonstrated in getting to know more about AM. As so, three distinct behaviours were identified as shown in Figure 30.

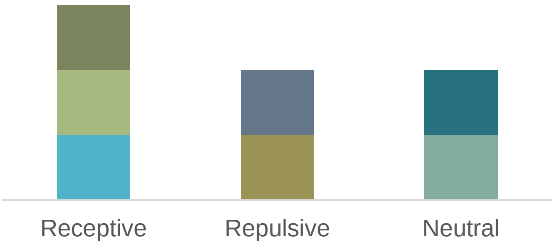

Figure 30 Analysis of companies' behaviour during the interviews

The companies that are classified as *"Receptive"* were the ones that showed a real interest on the technology. They were enthusiastic about it and wanted to know more details about it such as applications and success stories of other users. With this set of companies, the interview went smooth and the conversation flew naturally as the interviewed people also asked questions that they had regarding this technology.

The "*Repulsive"* ones were the companies that did not show any type of interest in AM. These companies revealed a more closed attitude and it was very difficult to just expose this technology to them. As a consequence, these two interviews were very hard to conduct since the responses were mainly short answers. Given that, the conversations did not evolved as there were no space to explore their opinions regarding this subject. It is possible to notice that the two companies that have shown a repulsive behaviour, company G and H, are also the ones that did not identified any advantage on the use of AM in their business.

Finally, the two companies classified as having a *"Neutral"* behaviour were the ones that showed some interest in knowing a bit more about AM, but that did not show the same enthusiasm as the "*Receptive*" companies. These two companies wanted to have some general insights regarding the process, without getting into much details, and also have shown interest in the author's opinion regarding the subject as well as the overall opinion of companies. However, this interest was moderate as it was more of a personal interest from the interview than for the purpose of using AM as part of their processes. Once again, this can be explained by the nature of the services these two companies provide. As aforementioned, both company J and K provide a different type of service than the rest of the studied companies and do not see advantages on using AM.

When asked about the possibility of a partnership for a project involving AM, the results were different according to the presented categories. Both *"Receptive"* and *"Neutral"* pledged that they were keen to develop some sort of project with INEGI, if they approached them with at least an idea for a project. The companies classified as *"Repulsive"* did not discard the possibility of a future partnership but not on a near future. Also, for these companies it will be necessary to bring more stories of success cases and a concrete project in order for them to consider the partnership.

5.3. Results Discussion

On this subsection the main conclusions will be presented. The proposed Business Model is based on the Activity System Perspective (Zott & Amit, 2010) since this was the one that considered the creation of a new activity within an existent company and not from an entrepreneur's point of a view. Also, the conclusions regarding the three main focus of a BM will be exposed – Activity Network, Value Creation and Communication, and Cost Structure.

5.3.1. Proposed Business Model

According to Christoph Zott and Raphael Amit's research on BM design (2010), we could consider four different types of models:

- **Novelty** – where a new activity, linkage of activities, and/or ways of governance of the existing activities is created in the organisation. The greatest example of this type of BM is Apple. The development of the iPod and iTunes reveals a case of activity novelty, since they were the first company in the world to have an electronic device linked to a platform of music distribution.
- **Lock-in** – here the customer becomes dependent of an organisation for a given product or service. The client, in the scenario, cannot search for a different supplier without substantial switching cost. A good example of this BM is Gillette: the body razors they sell are substantially more expensive than the competitors, however their blades are cheaper. With this they create a customer lock-in since the blades are not compatible with any other body razor.
- **Complementarities** – the complementarities BM makes sense when the bundling of activities enhances them both, i.e. it brings more benefit to the company to have the two activities working closely together. An example of that is the fact that commercial banks also accept bank deposits besides their primary activity of issuing loans. Bank deposits contribute as an additional funding that is capable of support these banks in difficult situations such as financial crisis.
- **Efficiency** – this last design of BM aims to reduce transaction costs hence reaching a greater financial efficiency. The outsourcing of some activities by a company can be seen as an efficiency BM, since it allows the company to focus on its core business by delegating certain tasks that were previously made in-house to specialized companies that can perform them in a more efficient way.

Taking into account the nature of INEGI and the main goal of the proposal in study, it is possible to say that a business model focused on complementarities is the best solution. The PSD business unit is specialized in productive systems, so they already have a deep knowledge on this subject. If we look into the advantages pointed out by the companies who do not use AM, it is possible to see that they fall into this subject. As so, it would be beneficial for both parts to work together. The new AM based service could benefit from the knowledge of the team who works with complex system production, and this last one could start offering more advanced and unique solutions while working alongside the AM specialized team.

The course of action will be explored in the following sections and will be separated into the three main focus areas of a BM.

5.3.1.1. Activity Network

The AM service that is being studied can benefit from the knowledge of the other three valences that PSD unit offers, especially with the conception of complex product and systems. Since the main goal of this new service is to provide advanced and unique solutions for productive industries, it may be beneficial for the two sections to work together. By working closely, the new AM service could benefit from the large amount of existing clients that this area already has and use it to gain visibility among them.

The other two fields of knowledge, sustainability and automation, may also be of value to this new service. Since one of the pointed advantages of AM is that it is more eco-friendly than the traditional methods, it would be interesting to have some cooperation between these two areas. The automation and movement control may also be useful since the identified applications includes handling parts and robot parts, since this would be parts that would not be static and would require some motion. This would imply some design adjustments that would not be necessary if the part did not needs to perform any type of movement during the process.

For the new service to be successful, there needs to be an investment on human resources capable of handling AM technologies and develop solutions based on it. As so, there are three solutions that can be used either separately or combined:

- Hire more people that have experience on the subject. Since it is a new technology and it is not easy to find experienced personnel, it would be an interesting move to give opportunity to people who use AM in an amateur way. A good way to find new talents is to organize competitions regarding AM that are oriented to university students.
- Use the existing workforce and provide training on AM. This can motivate employees to learn more about this technology and promote internal co-operation between the different business units.
- Improve INEGI’s publicity in universities. Young graduates are usually more motivated to learn new skills and are more willing to learn it in a more autonomous way.

5.3.1.2. Value Creation and Communication

The value proposition of the new service is to create innovative solutions that take advantage of AM technology in order to improve the competitiveness of INEGI’s clients. To do so, it is imperative to continue developing the knowledge on this subject. Besides the acquisition of new employees with know-how on AM and/or the training of the existing workforce, another way of deepening the knowledge regarding AM is to approach companies that already use it. This type of partnership would beneficial for both parties since by sharing knowledge they could increase rapidly their skills on the topic. Also, by combining efforts they would collect more success stories, something that is important when it comes to attract new clients to this service.

Despite what was expected, the companies that do not use AM technologies were in majority receptive to the idea of preforming some type of partnership to develop solutions on this area. However, they have shown some concerns regarding the maturity level of this technology. To nullify this aspect is important to collect the great amount possible of success cases to present them, so they can be convinced of the advantages of using AM. Also, it is important that when approaching future clients to enhance the fact that this technology can be useful for more than the production of end-parts, but could also represent an advantage when applied to the productive process. Since the major advantage identified by the companies that do not use AM were its applications regarding stock decrease, it could be a good idea to start exploring this subject first. Also, if they could take advantage on their knowledge of productive systems, this could also be an interesting field to start with.

The organization of events and participation on technological fairs are very important to promote the new service. By exposing it in an attractive way, it will be possible to gain the attention of new clients and new investors. Also, it is important to continue to develop the Business Development unit, since this will be one of the key links that will connect new customers and the company. It is convenient that the ones that belong to the Business and Development unit have also some knowledge on this subject so they are capable of informing clients that are not aware of this subject and, by doing so, trying to understand if AM would be a suitable option for them.

5.3.1.3. Cost Structure

Regarding the inflow of income, it was possible to see that these comes from both public and private investments in a roughly equal way. This is important because it shows that private investors have trust on INEGI's work and, giving that, could be more willing to invest on new projects and ideas.

With the interviews it was also possible to inquire the openness from other companies to participate in projects that would help INEGI gain experience on AM. Despite the reluctance shown from a few companies, there were quite few companies that are interested in being a partner of INEGI on this subject. Once INEGI starts having more projects, it will be able to show more proofs of this technology advantages and could explore more industries where it could be useful to use AM. If they are able to do that, an increase in private investments should be expected.

Although the presented cost structure (see section 5.1.3) is still a draft, there are not much aspects that could be altered since they are INEGI's standards for project pricing. This fixed parameters are:

- Overheads
- Indirect Costs
- Unit Margin.

The percentage for each of these three parameters is setup and is equal for every INEGI's project. Together they represent 70% of the project's price before applying the commercial discount to it.

However, the cost structure must be dynamic and revised from time to time in order to take full economic advantage of the projects.

5.4. Chapter Conclusions

After interviewing the companies that were the focus for this dissertation, it was possible to see that only a small number was already using it (4 out of 11). However, from the companies that did not possess an AM, only three did not have any knowledge regarding the subject.

Focusing on the companies that do not use AM technologies, the main problems presented by the companies that had some knowledge on the subject were:

- The initial investment that can be too high for small companies to support;
- The level of maturity of the technology that may not ensure the necessary quality for their products;
- The lack of advantage for them due to the nature of the businesses.

During the interviews with the non-using companies, a few advantages were pointed out:

- Decrease of stock levels;
- Help to production
- Production of small components

Some companies not foreseeing any advantage on the use of AM, revealed what was classified as a "*Repulsive*" behaviour, with a strong resistance to change.

From the companies that already use AM, it is possible to assess the major difficulties that INEGI will face while trying to develop this service. The main one would be the lack of knowledge of potential clients that are still not able to see the potential of this technology besides being used for mass production – that in fact is not the best usage for it. As so, the best approach to tackle this problem is to show them success cases for other applications. This can be made either by going directly to the customer or, in order to reach a greater number of customers at the same time, host events where such success cases can be presented.

On a first stage, it would be appropriate to focus on the advantage that most potential clients identified during these conversations (decreasing stock levels). Also, it would be of value to take advantage of the already existing knowledge of the PSD business unit in productive systems to start offering solutions that include AM to help customers' productive processes.

For this service to be successful, the main focus at moment should be the attraction of people who already have a certain knowledge of these technologies and/or invest in training for the existing employees.

6. CONCLUSIONS AND FUTURE RESEARCH

The increased demand for customized products aligned with the strength of services in economy, made room for new types of services that companies can provide to their customers. In a society that searches for unique products and solutions, AM technologies appear as a suitable and economically viable options for companies to enlarge their offers.

In contrast with traditional production techniques, AM facilitates the creation of products with more complex structure at a relatively low price of manufacturing. So it is expected that more and more companies start to look at these technologies as something to invest on. Also, the great variety of materials that AM machines are capable of handling turns them into an important resource for every type of industry, from the aeronautical industry to the fashion industry.

However, AM requires a great amount of investment, both financial and in human resources, that most companies are not able to perform. So, organizations focused on Research & Development that already are in possession of AM machines and have the necessary know-how to handle them, like the one studied in this project (INEGI), can have here an opportunity to expand their offer of services.

In order to find market gaps for INEGI to explore, the proposed method on this dissertation consisted of case study analysis. This implied carrying out interviews to experts and possible customers to see if this is an attractive business or not. After the collection and analysis of the data obtained with the interviews, a proposal of a business model was proposed so that the company can have a better understanding on how to approach the identified market gaps. The proposed model stands on the fact that this is a service that is being developed within an existing business unit that has already a business model of its own. As so, the suitable option would be one of complementarity. By doing so, it is possible to exploit the existing knowledge and clients of the unit and use it to start offering AM based solutions. To enhance this choice comes the fact that the PSD business unit is specialized in offering advanced production solutions, whose competences can be easily adapted to this new business.

At the end, it is possible to conclude that this is an attractive business for INEGI to explore. However it has some aspects that need to be improved – mainly the commercial communication and the attraction and retention of talented people. Nevertheless, these two aspects are being improved, which indicates that soon they will not be an impediment for the success of the service. It is also important to exploit the opportunity of establishing partnerships with the companies that already are using AM in their facilities to enhance their knowledge on the subject. Since there is still a bit of scepticism from potential clients, these partnerships would play an important role in convince them of the potential of the usage of AM technologies.

As future work, some of the limitations faced with the realization of this dissertation should be explored and corrected. The main limitation associated with writing a dissertation is related to the time frame given to complete it. As so, this required a decrease in the number of interviews made, as well as restricting them to a single type of industry to have a relevant sample. This could be rectified by enlarging the number of companies to be interviewed and their industry. It could be interesting to analyse the receptivity of this technology in other industries rather than the one that was mainly studied -

manufacturing of productive systems. Since INEGI works closely with both the automotive and the aerospace industry, and being these two sectors, where we can see more enthusiasm regarding the use of AM, it should be interesting to speak with some companies that work on these two areas. These could work out well for both parties since INEGI could gain new partners or get the chance to participate in new and innovative projects, and companies would be able to expose their needs, expectations and doubts regarding AM.

Another aspect that should be improved would be the interview environment. To collect the information needed to perform this dissertation, the interviews were conducted during one of the biggest industry events – EMAF. Although it allowed to carry all the necessary interviews in a short period of time and to explore other industries than the one initially targeted, it was not possible to record the interviews, despite the openness and patience of most the interviewees. Also, by not performing the interviews neither in INEGI's facilities nor in the interviewed companies' facilities it was impossible to have a close look on their productive process or to show them what is being developed by INEGI. If this was made, maybe more advantages could have been pointed out and that could have facilitated the process of convincing clients to participate in projects that include AM. By not having these conversations in a more formal space also made it impossible to expose the technology with anything more than words and enthusiasm, which may not be enough for companies to start showing interest in the subject. If the interviews were complemented with a presentation of some success cases, it is possible that the conversations could had evolved much more than what they did.

In this dissertation, only a brief guide of a business model was exposed. Despite the three main focus points of a business model being approached, again due to the limited amount of time, it was not possible to describe a full business model where all the aspects were more deeply exploited. From the subjects included in a Business Model (as described in section 3.4), the ones that require more attention would be the ones related to the cost structure – revenue, procurement and financial models – since it is the part that is less developed at this stage. However, it is important to remember that business models are dynamic and must be revised from time to time so they can adapt to the real time stage of the business.

As exposed on this work, communication and publicity will take an important role in the success of this service. This involves exposing the work that is being developed to potential clients and to approach them with partnerships proposals in a more attractive way. This can be done in a more personal way, by contacting directly the companies that INEGI has an interest in working with, or in a more dynamic way such as organizing events that are focused on the use of AM for industry. These two options have advantages and disadvantages that need to be taken into account. For example, by going directly to the client it is possible to see how they perform their work and make suggestions of how AM could improve their performance. This approach would be slower than organizing events, nevertheless it would allow for a more personal treatment that could be advantageous when companies are reluctant to change. By organizing events, the presentations must be more general and the content exposed in an attractive way. However, this would allow reaching a greater number of customers at the same time and showing them what INEGI is able to offer them – this can include tours, showing recent parts made with AM, and so on. For both scenarios it is important to deepen the knowledge on what it is already being done with AM, to search for success stories that can convince the more traditional companies that AM represents a good option. This would also be good for INEGI since it would also be able to be more aware of the possibilities of AM and to come up with better and more attractive solutions for their clients.

INEGI has all the tools it needs to turn this new service into a success and to become a leader in AM solutions in the country. If they are able to hire skilled personal or give the opportunity to existing employees to explore their abilities in AM, their only set back will be to convince their customers that AM can be a very powerful tool for. If communication is well done, this obstacle can be easily overcome.

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