PUBLISHED BY bookboon

Jordi Olivella Nadal

Technology evaluation for entrepreneurs

JORDI OLIVELLA NADAL

TECHNOLOGY EVALUATION FOR ENTREPRENEURS

Technology evaluation for entrepreneurs
1st edition
© 2018 Jordi Olivella Nadal & bookboon.com
ISBN 978-87-403-2360-3
Peer review by Prof. Jordi Vinaixa Serra, ESADE, Spain
Prof. Torsten Fransson, KTH, Sweden

CONTENTS


ANYTIME, ANYWHERE
LEARNING ABOUT SAP SOFTWARE HAS NEVER BEEN EASIER.
SAP Learning Hub – the choice of when, where, and what to learn
SAP Learning Hub
SAP

PREFACE

An entrepreneur needs a wide variety of capacities and knowledge to be successful – or to have options to be so. Entrepreneurship teaching, an activity that started in the ’70s, tries to provide these qualities. A number of knowledge fields are involved, from law to finance and from operations management to motivation; however, technology is not always considered. Technology could be seen as something that should be dealt with separately by experts. According to this point of view, an entrepreneur should mostly be concerned with marketing and finance. This is a reasonable assumption if the technology is well established and easy available. However, it is certainly not when technology innovation is at the base of an entrepreneur’s development initiative.

It is reasonable to think that an entrepreneurial project using technology have to be based on a deep knowledge of technological characteristics, their present state of development, the parameters that determine their appropriateness for a certain use and the prospect of their evolution. It does not mean that the entrepreneur was necessarily a technical expert in the area or areas involved; in fact, in most projects it is not feasible to be an expert in every area of technology used. However, it is necessary to be able to obtain, understand and analyse the main characteristics of the technologies involved.

The objective of this book is to present a number of concepts and methods to analyse the technical aspects of a technological entrepreneurship endeavour. Specifically, the aspects below are addressed:

- Obtaining and analysing scientific, technical and professional information.
- Determining the stages of the development of the projects under way
- Establishing a set of parameters that are useful for the analysis
- Performing a technology forecast
- Identifying the potential customers and the market prospects of the technology under development

The material presented has been used by the author in engineering master’s level courses. The concepts and methods presented here are not particularly complex. However, comprehensively analysing the prospects of a technology requires an appropriate background. Naturally, students of other specialities and professionals who are used to or willing to technical initiatives can also take advantage of the work methods presented here.

ABOUT THE AUTHOR

Doctor of Business Administration and Insurance Actuary. Professor at the School of Industrial Engineering of Barcelona (ETSEIB), of the Universitat Politècnica de Catalunya (UPC).

The author graduated with a bachelor's degree in Economy from the Universitat de Barcelona (UB), qualified as an insurance actuary and obtained a PhD in Business Administration from the Universitat Politècnica de Catalunya (UPC).

After working in the private sector, notably in the insurance industry, he joined the UPC as a professor. His activities have encompassed several positions at the university involving research, the development of industry consulting work and a diversity of lecturing responsibilities. He has been a visiting professor at Know Center, Graz, Austria; Penn State University, Pennsylvania, USA; and at KTH Royal Institute of Technology in Stockholm, Sweden.

He specialises in operations management, particularly in:

- Cross-training, training and occupational safety policies.
- Process improvement and lean management.
- Technological entrepreneurship.

His teaching activity focuses on international students and in international contexts; his students have originated from more than 25 different countries. He applies active learning methods and uses e-learning materials to fully develop the capacity of the students to manage their own projects.

Additionally, his research activity includes more than 100 contributions. He has published in international journals such as *Computers & Industrial Engineering, the European Journal of Operational Research, the International Journal of Production Economics, the International Journal of Production Research, the Journal of the Operational Research Society, the Journal of Manufacturing Technology Management and Production Planning & Control*, among others, in addition to several books and book chapters.

He has developed consulting works for organisations such as AECOC, the Association of Spanish Distribution and Retail Companies, AENA, Barcelona Airport, Delphi Diesel and Fundación Conocimiento y Desarrollo (FCyD), among others, and has been a speaker at both public and in-company seminars.

1 INTRODUCTION

Learning objectives

In this chapter you will learn

- How to decide whether a technology evaluation should be developed
- How to define the priorities of a technology evaluation
- How to perform a technology evaluation.

1.1 IMPORTANCE OF THE TECHNOLOGY EVALUATION FOR THE ENTREPRENEUR

Management approaches based on continuous testing of hypotheses dominate the entrepreneurship world. Paramount examples of that trend are the methodologies Lean Start-up (Ries 2011) and Discovery-Driven Planning (McGrath & MacMillan 1995). Nowadays, entrepreneurs mistrust analysis developed far from the real activity. Naturally, there is no objection to the development of as much testing as possible, particularly before committing large resources. However, this 'call to action' should not lead to developing projects without having enough knowledge of the technical field involved.

Before starting the development of an entrepreneurial project, it seems clearly advisable to accumulate as much knowledge as possible about the different aspects involved. To undertake an entrepreneurial project without appropriate knowledge is not so much taking a risk as waiting for a stroke of luck. This is particularly true when technology is involved.

It often happens that what seems to be an interesting technological opportunity, in the end, is not. In particular, this happens with many scientific research results. When researchers obtain new results they often think, excited by their achievement, that many advantageous applications based on these results can be developed. Only after detailed analysis, tests and comparisons with alternatives will the real possibilities start to be known.

In fact, for researchers, discovering a new method that improves the performance or expands the range of applicability of a certain technology is interesting by itself. They will obtain the recognition of the scientific community by achieving results like this. Researchers can be legitimately proud of this kind of research, as they are expanding the general knowledge in a certain area. In spite of this, the fact that a piece of research is accepted as valuable by the scientific community is no guarantee that it is applicable and surpasses other alternatives.

The same happens with the initiatives that come from technology innovations consisting of new ways of using or applying technologies. Even when the ideas deserve to be classified as brilliant, success is not guaranteed.

A lot has been written about how entrepreneurs are able to generate ideas that, sometimes, are at the origin of big new companies and, in some sense, change the world. The talent and creativity behind the great new ideas is admirable. However, very often an attractive and imaginative idea ends in nothing. In fact, this is what usually happens. Even in the case of the most brilliant innovators, only a small part of the ideas that come to their mind can be developed and successfully implemented.

Therefore, a deep analysis is necessary before spending significant resources on the development of an idea. In particular, the technological aspects have to be considered. The evaluation of the technology is a critical step in the analysis to perform when a technological innovation is central to the idea to be developed.

When we develop an entrepreneurial idea based on technology, the final aim is to identify a convenient combination of the technology considered and a specific need to be addressed. To this end, it is necessary first to have some knowledge of how the technology or technologies work. However, some aspects of a technology's performance can only be assessed in relation to one application area. Thus, we will also need information that helps to determine the appropriateness of a technological solution to solve the problems or needs that the idea under consideration addresses. Technology evaluation takes into account all these different aspects.

In entrepreneurship, technology evaluation is not more important than, say, creativity, market analysis or finance. All this is very important indeed. However, we should be aware that technology analysis is critical, particularly when considering an entrepreneurial opportunity that involves a new technology or a new use of an existing technology.

Consequently,

Technology evaluation is critical when considering an entrepreneurial opportunity that involves a new technology or a new use of an existing technology

The next section deals with how to identify the entrepreneurial opportunities that are based on technology. After that, the different steps of the entrepreneurial process are presented and technology evaluation is formally defined and contextualized.

1.2 CONCEPTS

Technology-based entrepreneurial opportunity

As one would expect, there is no single definition of concepts such as entrepreneurial opportunity and technology-based entrepreneurial opportunity. Specialists on the matter do not coincide. However, there is a general agreement on some aspects. An entrepreneurial opportunity refers to the chance to generate profits through the offering of goods or services in the market – although it can be not the only motivation (Aceytuno & Cáceres 2012). The possibility of obtaining an economic profit, then, is a necessary condition. However, activities that can generate profits, such as investments, are not by themselves considered entrepreneurial activities. The development of a product or service is also required.

In general terms, a technological opportunity refers to the ease of achieving innovations and technical improvements (Fung 2004). In the context of entrepreneurship, the concept is more specific. In this area, an entrepreneurial opportunity is considered to be based on technology when it is originated by scientific and technological advances (Aceytuno & Cáceres 2012). This definition could be considered ambiguous. Most, if not all, activities nowadays have some kind of relation to science and technology. However, the fact that the opportunity has some relation with technology is not enough. An entrepreneurial opportunity will be considered technological when a scientific and technological advance is at its origin.

In some cases, the origin of an idea is clear; in other cases, it is debatable. Think of, for example, a new pharmaceutical drug: there is no doubt about the role of research in this case. However, when, for example, geo-localization is used in an augmented reality game, to what extent does the value provided come from technology and to what extent does it come from creativity?

Sometimes, the novelty of an innovation comes from the application of an existing technology for a new use. Also in such cases, doubts can arise about where to classify some initiatives. It is not always clear if a certain innovation should be considered an existing technology with a new use or, in fact, a new technological development.

To clarify the nature of an opportunity, it is helpful to consider what the uncertainty about the new technological solution is. In some cases, and although the technology is sophisticated, the adaptation of the technology to the new use does not seem likely to be particularly difficult. In these cases, the innovation will not be strictly technology-based. In contrast, when the appropriate functioning of the technological solution in a new context is in doubt, the innovation affects the technology itself. In this case, the opportunity can be considered technology-based.

In sum,

An entrepreneurial opportunity is based on technology when the development or adaptation of the technology is critical for its success

When an entrepreneurial initiative comes from an opportunity based on technology, a deep technology evaluation is necessary.

The entrepreneurship process

An entrepreneurial process starts from an idea and ends with the creation of a company, or a new unit of an existing company, including the first stages of the life of the new company or unit – a long road. The process involves a number of different activities which, to name a few, involve the generation of an idea; an approximation process to define, first, and test, later, a business model; finding appropriate partners and financing; detailed planning of the start-up process; and, naturally, launching the business.

The analyses to perform and the decisions to make in the various stages of the entrepreneurial process require appropriate analysis tools and methodologies. In view of all the elements involved, it is no surprise that the tools and methodologies are very diverse. We can find handbooks and courses on entrepreneurship that have little in common. What do we really need to know to be able to create a new company? There is no single answer. The activities initiated and the contexts in which they are started are multifarious. What are the most important aspects depends on the stage of the development and the specific circumstances of each case.

We can divide the entrepreneurship process into three main phases, according to the activities we need to develop and the outcome we seek:

- Preliminary phase. This phase is intended to check the possibilities of the activity that we would like to develop. Since the opportunity is very uncertain, the least possible time and resources should be spent. The outcome of this phase is a business case for carrying out a more in-depth analysis – not yet the launch of the new activity.
- Planning phase. The objective of this phase is to further analyse the opportunity and prepare a detailed plan for launching the company. The plan will include a precise definition of the product or products to offer, a team proposal, the investment needs and a sales forecast. In this case, the result is a plan that will typically be presented to possible investors and partners.

- Launch phase. In this phase, the company has been set up and the production and sales start. However, the main outcome is the experience acquired and that makes it possible to adjust some decisions adopted previously according to the reactions of the customers.

The fact that an entrepreneurial project is based on technology affects all phases of its preparation and development. Every analysis and forecast depends on the performance that the technology involved is able to provide. This is particularly true in the preliminary analysis. The preliminary or initial analysis should include a detailed evaluation of the technology.

Technology evaluation and other related concepts

In general, to evaluate is to judge or determine the significance, worth, or quality of something. When referring to technology, the term 'technology evaluation' can be used with related but different meanings. The concept appears in both public decision-making and business domains (Tran & Daim 2008). Besides, in technological entrepreneurship the concept has particular characteristics.

We can distinguish different possibilities:

- In public decision-making, technology evaluation involves the assessment of a technology's potential economic and social impact.
- In business, technology evaluation considers the implications of a technology for a certain business activity, and often involves technology selection.
- In technological entrepreneurship, technology evaluation aims to determine if a technology and one or more application areas of this technology can generate, in the future, a successful business.

In this book, we will focus on technology evaluation in the field of technological entrepreneurship, although most of the methods described can be used in the two other analyses.

In technological entrepreneurship, technology evaluations focus mainly on future possibilities. The objective is to know about the possibilities and prospects of a technology and one or more application areas of this technology. We need this information before making specific plans. Technology evaluation corresponds to the preliminary phase of the entrepreneurship process.

It is important to distinguish a technology evaluation from other related but different entrepreneurship concepts. Some of these analyses and their definitions are presented in Table 1. While technology evaluation is intended to obtain general knowledge of a technological opportunity, the other concepts mentioned in the table refer to specific business aspects.

Value propositions describe what is offered to the customers. To transform a technology opportunity into a successful product, a value proposition has to be defined. On the other hand, business models refer to the general approach of a business activity. To bring to the market the new products and services that a technological innovation makes possible, it is necessary to define an appropriate business model.

Finally, business plans are developed in the planning phase of the entrepreneurship process. They refer to specific contexts. For example, a new product can be launched by a company that already exists and markets some related products, or by a brand new company. Although the product is the same, their business plans will be very different. The availability of resources, the geographic scope and the characteristics of the promoters largely determine the content of a business plan.

Concept	What is involved
Technology evaluation	Analyses what a technology will make possible now and in the future in relation to one or more application areas
Value proposition	Describes the bundle of products and services that create value for a specific customer segment[1]
Business model	Describes the rationale of how an organization creates, delivers, and captures value[1]
Business plan	Describes and communicates a project and how it can be implemented, either inside or outside an organization[1]
[1](Osterwalder & Pigneur 2010)	

Table 1. Definitions of technology evaluation and other related concepts

The technology evaluation, value proposition, business model and business plan are developed consecutively. The degree of specification is increasingly high. A technology evaluation can give insight into how different possible value propositions based on it can be defined; a value proposition can be exploited through different business models; and a business model can be implemented by following a number of alternative business plans. Figure 1 shows a simplified scheme of the process that starts with technology evaluation and ends with the preparation of a business plan.

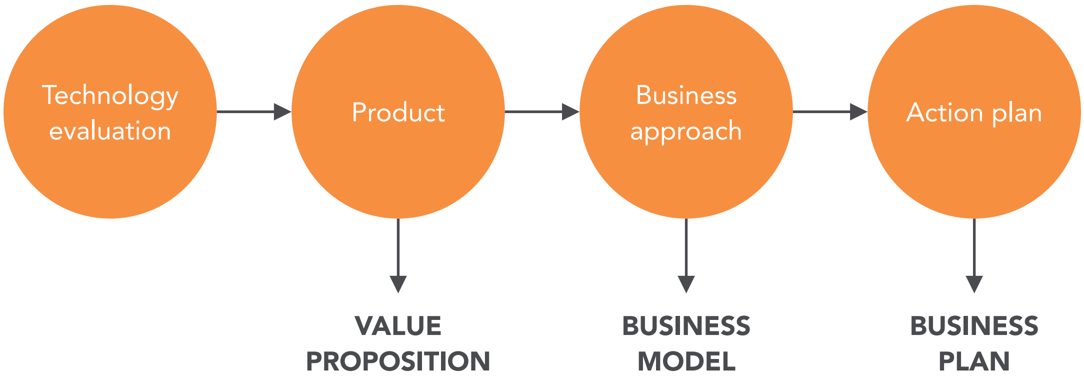


Figure 1. From technology evaluation to business plan

In the process that goes from technology evaluation to business plan, different aspects are progressively defined. Some of these aspects are shown in Table 2.

Concept	Aspects defined
Technology evaluation	Matches between the technology and specific applications, and future prospects of the technology
Value proposition	Product and/or service plus delivery, complementary services, image and others
Business model	Relations between different stakeholders involving actions, value and funds
Business plan	Team; financing; marketing and operations plan; and investment, cash-flow and profits forecasting

Table 2. Some elements of a technology evaluation and other related concepts

1.3 CUSTOMER FOCUS AND TECHNOLOGY FOCUS

It is often said that, in business, customer needs are paramount. Some experts recommend that the entrepreneur should ‘hear the voice of the customer’. This sounds apparent to many business people: obviously, the customer view is the most important thing to a business.

An owner of a business or a salesperson, for example, is always fighting to satisfy their customers. What else can they do? To remind them that the customer is very important seems almost insulting, especially when the recommendation comes from a trainer who has never sold anything to anyone.

However, the importance of the customer is not always so clear. There are different reasons for this. One possible reason is the big size of some companies. It often happens that some departments and senior management have no direct contact with customers. Besides, not all the details of the consumers' behaviour are directly observable – marketing is there to help with this.

In the case of the entrepreneurial opportunities based on technology, usually some aspects of a technology and its application are still under development. For obvious reasons, the customers' reactions cannot be known in detail. However, the degree of uncertainty is not always the same. Sometimes we start from a clear and well-known customer need. At other times, an entrepreneurial opportunity is based on a new or improved technology whose possible uses are still very unclear. Finally, it is possible that both the customer needs and technology are far from known. Table 3 shows three combinations of customer needs and technology uncertainty and some insights about how the analysis will be addressed in each case.

	Need to cope with	Technology	Start of the analysis
Clear customer needs	Clearly defined	Doubts on the technology's appropriateness	The technology evaluation is focused on the appropriateness of the technology for the need
Technology clearly defined	Doubts on the need	Clearly defined	The technology evaluation considers different needs that can be addressed by taking advantage of the technology
Opportunity detection	Doubts on the need	Doubts on the technology's appropriateness	An initial evaluation of the potential customer interest is performed, followed, if positive, by a technology evaluation focused on the needs initially detected

Table 3. Different combinations of customers' needs and technology uncertainty

What the doubtful aspects are determines the focus of the analysis to perform. When the customer needs are clear, for instance, the focus will be put on the technology evaluation, although customer needs should also be considered. Assume that we are considering taking advantage of a new technology for mobile phone batteries. The essential need is clear – longer duration. The analysis will focus on the present and possible future performance, from this point of view, of some alternative solutions. However, other aspects of the customer needs will also be taken into account.

When a new solution is developed, it is because it offers improved features from some point of view. It will almost certainly also have some inconveniences and, maybe, some additional advantages. In the case of mobile phone batteries, the inconveniences could be, for example, an increased cost or weight. The question is whether the advantages surpass the inconveniences. Assume that a new battery technology doubles the battery lifetime and, additionally, increases the price of the battery by 100€, the weight by 20% and the size by 20%, while reducing the recharging time by 50%. Would this new option be interesting for some customers? Probably it will be for some of them, but we will need further analysis to have more information about this.

In other cases, we think that a certain technology or family of technologies could have a commercial application, but both the final features of the technology and the needs of the customers are not clear. Consider, for instance, holograms, an appealing technology. It has been considered an appropriate technology to use to watch sports in the future (Charlton 2016). It seems promising but its application is certainly doubtful. What the reaction of customers will be is far from foreseeable. Will people like feeling as if they are among the players? The future will tell.

In a situation like this, the first thing to do is to assess if some market interest could exist in the future. If the answer is positive, the next step is to analyse in detail how the technology can address the need identified. Later, it is necessary to perform a more detailed analysis of market interest. In the case of holograms, that they could be used for entertainment seems clear. However, only after knowing the details of a specific solution and developing further analysis will we be able to evaluate the opportunity. Assume a particular holograms generator. Is it necessary that the intensity of the light is low in order to see the holograms? What is the range of colours and the degree of definition? Do you need a big and complicated piece of equipment to project them or not? After defining these aspects, further analysis of customers' needs should be developed.

1.4 CONTENT OF THE BOOK

The objective of this book is to present tools and methodologies to develop a technology evaluation when considering a technology-based entrepreneurial opportunity. The sequence of the chapters corresponds to the most common sequence of analyses.

When performing a technology evaluation, the first task is to analyse in depth the information available, as described in CHAPTER 2. Once the information is in our hands, the technological aspects of the entrepreneurial opportunity will be analysed, based on it.

The development of a technology-based project often involves considering technology solutions that are not yet fully developed. By doing this, we put ourselves in a good position to take advantage of the new technologies before or, at least, not later than, the others. In order to know the current state of the technology, it is critical to assess its level of development. CHAPTER 3 explains how to determine the Technology Readiness Level (TRL), and, when appropriate, the SRL (System Readiness Level) and the level of dissemination of a technology.

To develop a comparison of alternatives, a set of technical evaluation parameters have to be defined. After defining a complete list of relevant parameters, the most important are selected. These parameters make it possible to compare a technology with other alternative solutions in relation to a specific use. In addition, they can be used to establish an appropriateness map, that is to say, the set of external circumstances in which an alternative technology solution considered is appropriate. CHAPTER 4 is devoted to these topics.

Technology evolves over time. Hence, technologies that today are still not fully developed will be available in the future. New features and possibilities will be added to present solutions and their performance will improve. If we are analysing a technology solution that is going to be applied only at a specific time in the near future, we might be tempted to neglect the prospects of this technology and of the other alternative solutions. However, we must remember that the technology solution will probably be used for years.

Furthermore, when companies adopt a technology, they acquire knowledge on this technology and its applications. The value of this experience depends on the evolution of the technology. For these reasons, the future possibilities of a technology should always be taken into account. Technology forecasting methods are presented in CHAPTER 5.

To evaluate the technological aspects of an entrepreneurial opportunity, it is necessary to consider market aspects. To do this, the first step involves the consideration of the possible customers and uses of the products that the new technological solution will make possible. Later, some factors defining the possible match between customers' interests and technology features have to be taken into account. Finally, the most promising combinations of possible customers and uses are identified. CHAPTER 6 is intended to show how to perform these analyses.

After identifying possible customers and uses, the market prospects should be analysed. To do this analysis, customer preferences, industry structure, regulations, and the possible social, economic and environmental impact are taken into account. Based on this, some insights into the market prospects of the technology and the area of application under scrutiny can be provided. CHAPTER 7 deals with this analysis.

Finally, CHAPTER 8 is intended to show the contents and structure that a report that presents the technology evaluation performed should have.

The structure of the contents of the book is presented in Figure 2. The predominance of technology analysis or opportunity analysis in each block is made clear. The technology analysis tools and methods are intended to obtain details of the technology. The opportunity analyses are devoted to relating the technology with possible uses, customers and markets. The opportunity-focused analyses then make it possible to evaluate a technology from the point of view of the business opportunities it can generate.

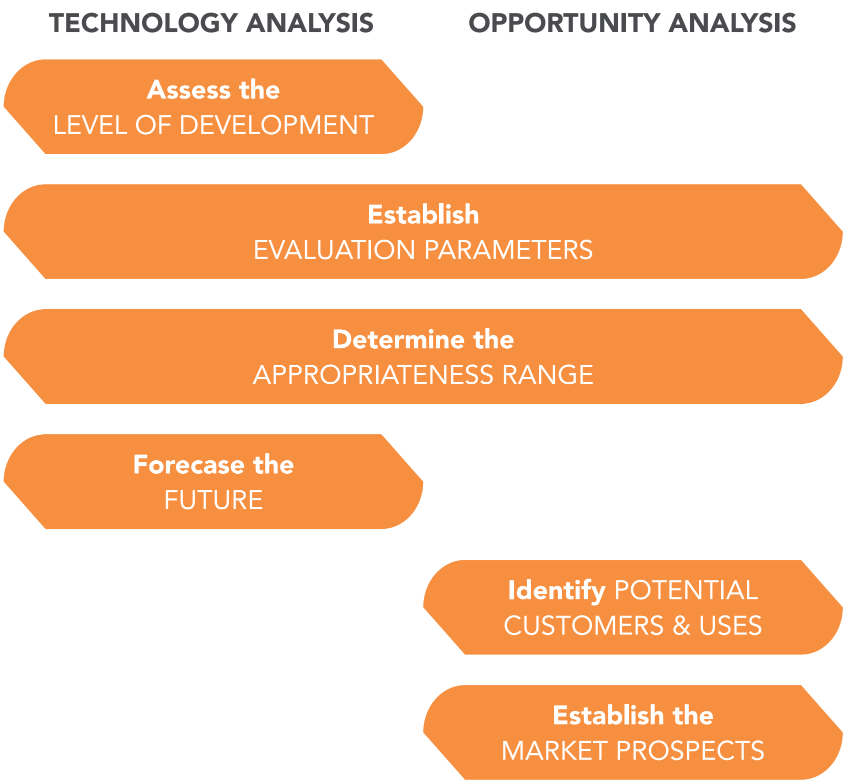


Figure 2. Structure of the book's contents

2 HOW TO OBTAIN INFORMATION

Learning objectives

In this chapter you will learn

- How to identify the sources of information to consult in order to evaluate a technology-based entrepreneurial opportunity
- What are the most appropriate sources to take into account
- How to assess the trustworthiness of the information obtained.

2.1 INTRODUCTION

When evaluating a technology-based entrepreneurial opportunity, we need high quality information and an in-depth analysis of the technology involved and the specific application area under consideration. The first step is to obtain information. In the process of developing a technology-based entrepreneurial opportunity, it is necessary to undertake technical and market analyses. However, at the beginning, we usually rely only on existing data. Even when we develop our own analysis, we need to check the results and the opinions of others.

Who knows about it?

If we are going to evaluate the technological aspects of an entrepreneurial opportunity, we need to be aware of what others know in relation to the technology and the area of application analysed. To do so, we need to identify the different technological knowledge involved and the organizations or groups that have information that is relevant for the analysis that we are going to undertake.

Think, for instance, of high-speed travel in tubes, an idea that has captured the dreams of the public since the Hyperloop proposal of Elon Musk (Musk 2013) – as well as the doubts of some specialists, to be frank (Ross 2016). The areas of knowledge involved are numerous. The Hyperloop project involves different knowledge fields, including aerodynamics, thermodynamics, mechanical engineering, civil engineering, dynamics & controls, electromagnetics, and power electronics.

We should identify the groups and the organizations that are working on the different aspects relevant to the project, whether they are participating in the project or not. The information that comes from organisations that are directly involved will not be enough. To identify the organisations to consider, we have to take into account that the innovation process develops in complex environments. Different phases have been identified in the innovation process, such as (Liu & White 2001):

- Education
- Research (basic, development, and engineering)
- Implementation (manufacturing)
- End-use (customers of the product or process output)
- Linkage (bringing together complementary knowledge).

The different phases are undertaken by a diversity of interconnected agents. Table 4 presents several of the agents involved in technological innovation. Besides, their typical innovation activities are highlighted.

Innovation agent	Typical innovation activities
University	Basic research and applied research
Research institutes	Applied research and first phases of development
Technological start-ups	Product development and launch of the product
Consolidated companies	Exploitation and improvement of the innovation
Public administration	Support and promotion

Table 4: Typical activities of several innovation agents

We need to search for details of the achievements and plans of the organizations and groups involved in activities that are relevant for the entrepreneurship initiative that we are considering. To do this, we can consult a list of sources, which are mentioned below. Before doing this, some initial ideas about how to search for and analyse information are presented.

Initial ideas

When we are searching for information about a project that we intend to develop, it often happens that what we should search for, and what we would like to search for and find are not the same thing. Usually, we are willing to obtain information confirming the good market prospects we envisage. However, at this stage, what we should check are the real possibilities of the technology. It is useful to be aware that our desire to find information that is favourable to the idea can lead to a bias in the gathering of information. The recommendations that follow are intended to help to avoid this risk.

The first recommendation is

Question your previous knowledge

When we decide to analyse the applicability of a technology, we usually have some information about this technology. In fact, we often like the technology very much, and that is why we are working with it. Besides, we would like the favourable view we have about the future of the technology to be confirmed by facts. However, the initial information we have is often incomplete or even biased. Our background and position in the industry determine to a large extent what we know and what we do not know. Therefore, this initial information has to be put in doubt.

A second recommendation refers to the focus of the analysis:

Focus on the specific information to be used in the analysis of the technology

When proposing a project, it is common to insist on the main positive aspects – for instance, that it is innovative or that it will create a great market opportunity. Even if the advantages are clear, a good technical analysis is still always necessary. If we participate in a project as technical experts, it is expected that we will analyse the technology in depth. To evaluate the technology in relation to an entrepreneurial opportunity, we need to know the requirements, features and performance of the technology applied to the specific use considered, how it compares with other alternatives, and what can be expected from its future evolution. We should focus on these aspects for the time being.

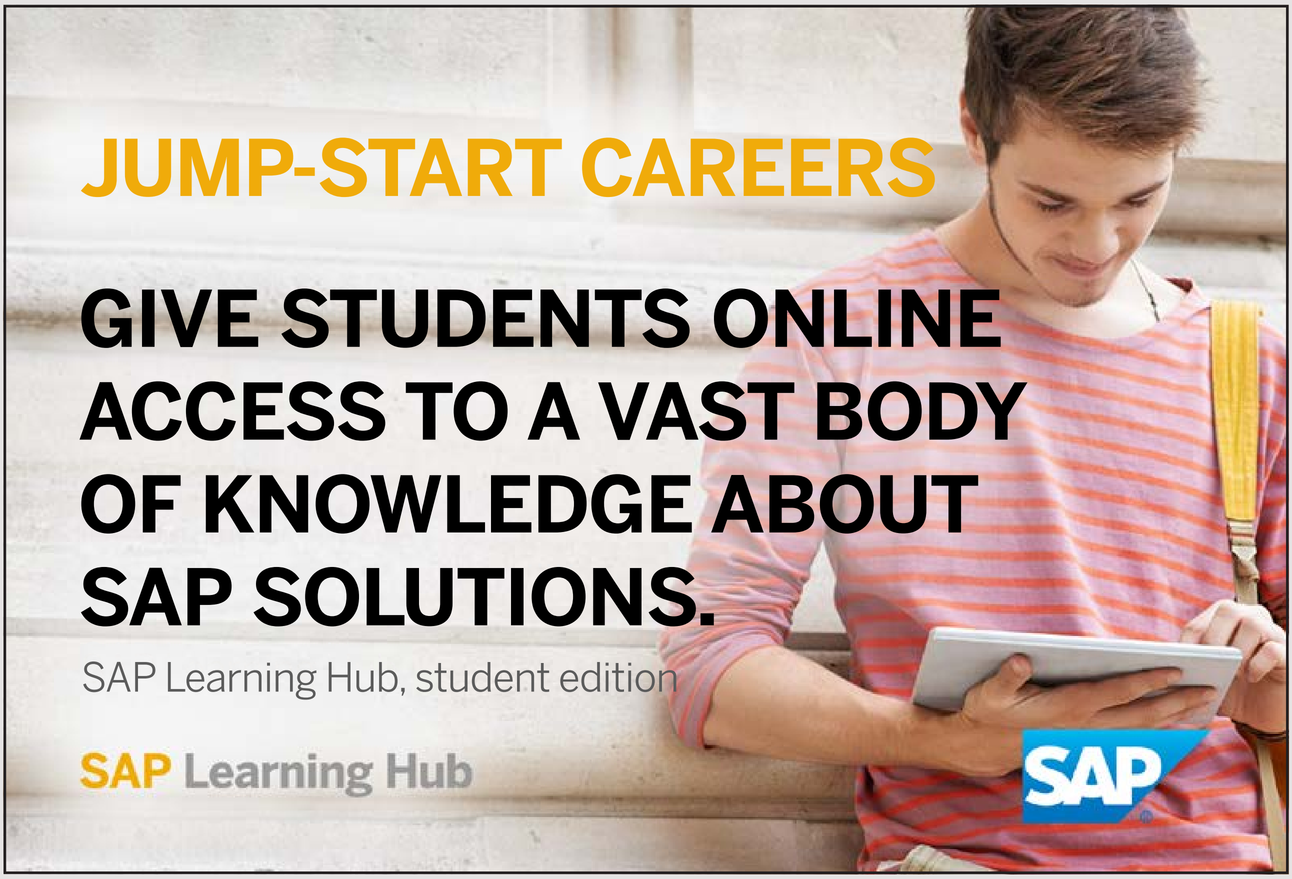
Finally, it's also important to be open-minded in relation to the kind of sources to take into account:

Use trustworthy sources, but do not totally dismiss others

It is tempting to say that we are only interested in highly trustworthy information. Naturally, we need this kind of information and it is, in fact, preferable. However, there is a lot of relevant information that cannot be obtained from the most trustworthy sources, such as the most recent discoveries, details of products, the latest works in progress, and the future plans of companies and research groups. We have to consult a variety of sources to know as much as possible about these aspects. Next, we will review several alternative sources of information.

2.2 SOURCES

When analysing the technological aspects of an entrepreneurial opportunity, we should first identify the organisations and groups that work on it. We are interested in obtaining as much as possible of the information and knowledge they already have. Some of it will be available from publicly available sources – a considerable part, hopefully. These sources include scientific sources, professional sources, media outlets and unpublished sources, as schematized in Figure 3. The arrows reflect a typical temporal sequence.



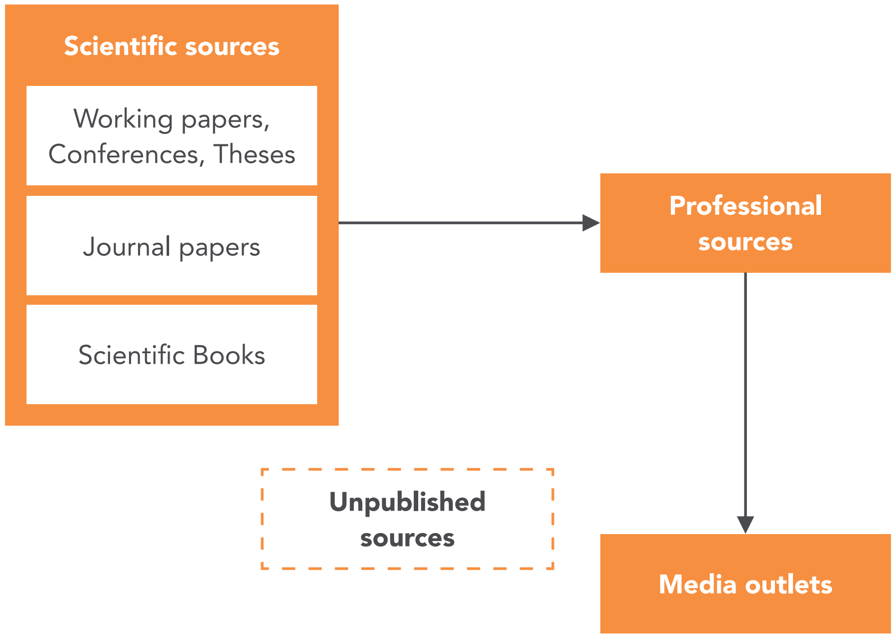


Figure 3. Alternative sources of information

Scientific literature

Scientific literature is central to the science and technology world. Researchers from around the world publish the results they obtain. When you are going to develop research, you start from the previous knowledge, in order to complement or, occasionally, to refute it.

It is clear why you should consult previous research, but it is interesting to consider why researchers publish. A genuine will to contribute to general knowledge in the area cannot be overlooked. In addition, the prestige of academics depends largely on what they publish. Job offers, promotions and the position of universities in ranking tables are strongly related to the publications trajectory.

Basic research is mostly intended to be published and, thus, to obtain prestige. When research is applied and potentially used, it is not clear what should be done with it. Publishing it would imply giving full details of the research and making it available for public use – published research cannot be patented. Yet, if you do not publish, you and your institution are not going to be recognized by the rest of the academic community. This makes it possible for us to have access to a large part of the results obtained by researchers at universities and research institutes.

Scientific literature includes scientific journals, scientific books, conference contributions, master and doctoral theses, and working papers from universities and research institutes. We should distinguish these documents according to the research phase in which they are used:

- The first versions of a research work are presented as conference contributions, master and doctoral theses, and working papers. The findings included in these works are not always fully verified. These documents can be used as sources that contain research results not yet published in a journal or details not included in the paper that is eventually published.
- Journal papers are the most important scientific publications. The fact that a research work is published by a scientific journal implies that the scientific community, or at least part of it, has accepted it. Papers are published in scientific journals after peer review. However, in spite of the powerful reviewing systems of scientific journals, mistakes are sometimes detected by readers, i.e. other scientists in the field. Thus, a single paper presenting a certain result or theory is not a total guarantee that it is correct. When a number of papers develop different aspects of the same topic with coinciding results, we can be reasonably certain of their validity.
- Scientific books also play a relevant role in scientific literature. Papers present the latest findings, and therefore the sequence of papers on a topic reflects how knowledge in that area is evolving. Some books have a similar content. However, other scientific books summarise the knowledge on a certain topic when the book is written. When research in an area is wide and consolidated, these scientific books are a recommended source. However, they must always be complemented by the most recent papers.

Professional sources

Professional sources must also be taken into consideration. Professional magazines belong to this category. Professional magazines are specialist publications aimed at professionals in a particular field. They are focused on applied solutions and the evolution of the industry. They are very diverse and may be highly influenced by advertisers, so their content can be biased. However, some of them are rigorous and highly prestigious. Even the magazines more clearly tied to some companies give interesting information, because they transmit the vision of these companies. Some of these magazines are available free online, others can be found in specialised databases, while others are only available under subscription.

Patent awards deserve special attention. They are intended to protect intellectual property rather than disseminate knowledge. In fact, some companies prefer not to patent in order to keep their technology secret. When companies do patent their technologies, they show details of what they do and others could take advantage of these details. However, patenting a technology does not guarantee good performance. It is recommended to verify that the patented technology has been successfully marketed.

Other published materials worth looking at include

- Annual company reports, company brochures, internal newsletters and internet homepages of organisations.
- Announcements of new equipment, facilities or other resource commitments.
- Reports of government agencies and professional societies.

These documents reflect the position of an organisation. They can be considered less than objective. However, they often provide first-hand and detailed information and should be taken into consideration when the organisation responsible for the document is trustworthy. Even in these cases, however, they are necessarily partial as they reflect the point of view of an organisation.

Media outlets

General newspapers and magazines are aimed at the public. A strong presence of a certain topic in newspapers and magazines implies that it is important for, at least, part of society. A relevant scientific discovery or the launch of a breakthrough new product is published even by general newspapers and magazines. The situation of business industries or companies is also addressed. Information in newspapers and magazines is not usually detailed or rigorous, but it can be very useful. Some newspapers and magazines are regarded as particularly reliable. Among them are The New York Times, The Financial Times, The Wall Street Journal, The Guardian, Fortune, Forbes and Bloomberg Businessweek.

Unpublished sources

Some unpublished sources can provide interesting information, which goes beyond formal statements of published material, such as undisclosed facts, personal experiences or views, and very recent results. We can consider the following unpublished sources:

- Expert opinions
- Reverse engineering and benchmarking
- Industry contacts and friends
- Internet blogs, chats and social networks
- Trade shows and exhibitions

The information we can obtain from these sources is clearly different from the information provided by formal sources. There would be little sense in consulting informal sources to obtain information about clearly established facts. Some initial information can be obtained initially from informal sources on these topics, but at some point in our analysis, we must consult formal ones. Thus, only formal sources can be mentioned in a technical document when referring to well-founded facts. In contrast, informal sources can provide some insights about aspects that the formal sources have not addressed yet.

2.3 HOW TO MANAGE THE INFORMATION OBTAINED

It is important to obtain as much information as possible, but it is equally important to use it appropriately. In the technological world, we like to work with verified data. In fact, we are particularly happy when we can work with data we have verified ourselves. However, this is not possible in the initial stages of our analysis. We have to rely on data obtained by others. Besides, we often have to use information that is not fully verified. It is clear, for instance, that we do not have exact information about what companies and research groups are currently working on.

Based on that, the first criterion to apply when analysing the information we obtain is

Use the best information you have for each aspect you are considering

If a certain aspect, say, the performance of a certain technological solution, has been addressed by scientific literature, use these data. If the scientific literature does not include results on performance, but a professional magazine does, use the information from the magazine. Additionally, take into account that, regarding the future, no verified results will be available. We can only rely on forecasting and opinions. Select the most trustworthy forecast analysis and the most reliable opinions you can obtain.

It is also important to give readers complete information, and then we should

Specify the level of reliability of each information source

Sometimes we have to use unreliable information to address aspects about which we do not have enough information, or that are still not very clear. However, we must remember that doubtful information remains doubtful. We should specify the level of reliability of the information we provide. In addition, unreliable information has a limited importance when drawing conclusions. For example, an insider's comment can be a clue, but it is only a clue, not a fact.

Table 4 summarises the above sources, the information we usually find on technical details and in-progress and future developments, as well as the level of reliability of the sources.

Source	Information on technical details	Information on in-progress and future developments	Reliability
Scientific books	Verified and consolidated knowledge	In general, only clear prospects	Very high
Articles from high level scientific journals	Recent results from authoritative sources	Present as a secondary content	High

Source	Information on technical details	Information on in-progress and future developments	Reliability
Working papers, conferences and theses	Latest or uncommon results	Included but difficult to select	Medium
Professional sources	Global analysis and perspectives. Specific details. Plans of companies and research groups		Medium
Unpublished sources	Insider insights and expert opinions. Lead to other sources		Low
Media outlets	Lead to other sources. Expert opinions		Low

Table 5. Information sources and their characteristics

2.4 PRACTICAL ASPECTS

Databases and search services

We have to distinguish between where we obtain the document and where it comes from. Let us assume that we consult a scientific paper that has been published in a prestigious journal. It is irrelevant whether we obtain it from a library, the publisher's or the author's website, or a peer-to-peer service. The paper is reliable because it has been published in a first-class journal, and this is what is important. This means that we can know about a relevant document because someone recommends it to us, we read about it in a forum or we obtain it from a search on Google, but this is irrelevant. The original source is what matters.

Therefore, we have to check the relevance of the original source of the papers we consult. To do this, we can use some specialized databases, which are also used as information searchers. The most important general databases are Journal Citation Report (JCR), Scopus and Google Scholar.

A selection of scientific journals is listed at JCR, which can be consulted in Web of Science (see Figure 4 for a screen capture of this service). JCR is highly selective and is widely used by the scientific community to identify the most relevant journals. In JCR, the journals are classified by discipline and ranked according to the number of times that their papers are cited by other papers. The journals of each discipline are divided into quartiles. Journals in Q1, that is to say, in the 25% first positions according to the citations received, are widely recognised as the most important. The papers published by these journals are the preferred sources. Another general database that is widely used is Scopus. This database covers a larger number journals and it works similarly to JCR. Some professional magazines are accepted as academic knowledge and can be found in these sources.

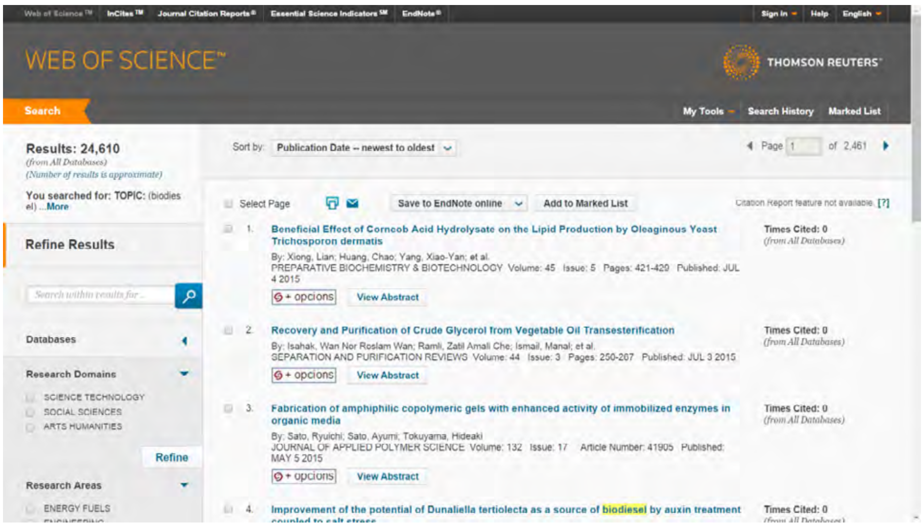


Figure 4. Web of Science

Google Scholar, a free access service, is also very useful. Google Scholar is less selective than the above services. However, all its contents other than patents can be considered scientific. Google Scholar includes scientific journals, conference proceedings, working papers and patents. In Google Scholar, the documents are neither classified nor ranked. The documents are obtained through searches. The results of the searches are ordered according to undisclosed criteria. Google Scholar indicates the number of times that each document has been referenced by other Google Scholar documents.

Note that papers, in general, are not directly accessible from JCR, Scopus and Google Scholar. They can be accessed through library online services or webs of departments, institutes or authors. Additionally, the databases ScienceDirect, Springer Link and IEEE Explore distribute the content produced by Elsevier, Springer and IEEE, respectively, and these are some of the most important editorials in the field of science and technology.

The databases of the editorials distribute not just journals, but scientific books, and can be used as searchers to find the books we need. Besides, Google Books or Amazon can also be useful to find books dealing with the topic of interest. All these services allow books to be bought, since they are not usually freely accessible. However, often we can access them through libraries.

Another useful tool is Factiva. This database allows us to consult most newspapers and general and professional magazines in the world. It is possible to limit the search to a list of media and a range of time. Some web contents are also included. A screen capture of Factiva is presented in Figure 5.

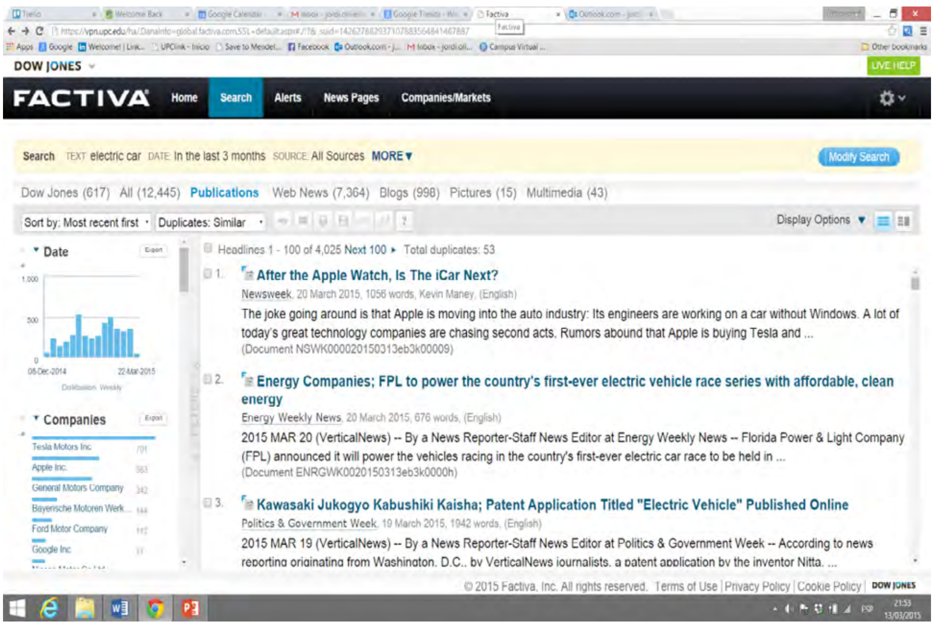


Figure 5. Factiva

Referencing

It is important to reference the sources we use appropriately. Our analysis is based on these sources. Our final objective is to develop our own solutions, but at this stage, all we have at our disposal is the work of others. It should be possible for our readers to verify that our interpretation of the mentioned information is correct or to review it in more detail. Complete bibliographic references have to be provided. However, the most interesting detail has to be mentioned in our reports.

The idea is to make the work of readers as easy as possible. To do this, it is important to point out briefly what the cited authors did. For instance, analysing one case is not the same as analysing one hundred cases. If an organisation is particularly trustworthy for some reason and its analyses deserve special consideration, this should also be explained. Perhaps some readers do not know this information.

2.5 EXAMPLE OF THE PROCESS OF OBTAINING INFORMATION

Obtaining information about Li-Fi.

General information

Li-Fi uses the visible light spectrum to transmit data. The same bulb can be used for light and for internet connection. Direct vision is needed. The big advantage is that you use neither the electromagnetic spectrum nor any kind of cable. Apparently, it can be very useful in factories, where electromagnetic waves can suffer from interference and cables limit flexibility.

Some general information can be found easily on Google. We can know, for example, that the Li-Fi concept was proposed by Harald Haas at a TED conference in 2011 (Haas 2017). Note that announcements, talks and/or other dissemination works are not a source of detailed and trustable information. However, sometimes they can illustrate some aspects of the history of the technology. This is the case of the talk by Professor Haas, which had a wide impact.

Technical information

First, we are interested in some basic technical information. Surprisingly, we found few scientific and technological references about it. We made a search in Google Books with the words Li-Fi and Springer, to narrow the search to the books of this scientific editorial. In this search we found an interesting book, "Optical wireless communications: an emerging technology" (Uysal et al. 2016). In this book, the term Li-Fi is used only secondarily. A more technical name, Optical Wireless Communications, is used.

Still searching for books, we were able to find another interesting reference, the book "Visible light communication", published by Cambridge University Press (Arnon 2015). We believed that these two books would cover the necessary technical background.

Then, we searched for more recent and specific works in Google Scholar – in a search undertaken in February 2017. We found some works that were clearly relevant for the technology under analysis. Two of the works are mentioned next as examples.

A first contribution deals with the establishment of continuous communication in a public space by using Li-Fi (Zhang et al. 2016). It was presented by a set of researchers from the University of Wisconsin on the 3rd of October 2016 at the 3rd ACM Workshop on

Visible Light Communication Systems (VLCS 2016). They designed a system and applied it. Promising results were obtained and were presented in their contribution.

The second work compares available wireless communication technologies to be used in machine-to-machine communications (M2M) (Alonso-Zarate & Dohler 2017). M2M communications go beyond but include communications in factories, the opportunity on which we are focusing. According to the work, the different wireless communication technologies that are mentioned will be part of the 5G networks. The work is a chapter of a scientific book published in 2017.

Researchers and industry activity

We needed information about who is working on the topic, the results they claim to have obtained, their projects and so on. We performed a search on IEEE Xplore. It includes the content published by the Institute of Electrical and Electronics Engineers, which seems quite appropriate. An example of what can be found is the paper "Li-Fi Gets Ready to Compete with Wi-Fi" (GreyB 2016), which shows a panorama of the groups that are working in the field.

Some information about companies working on these solutions is also necessary. We searched on Google and we were lucky. In Quora, a website devoted to questions and answers about any topic, someone asked, "Which companies are working on LiFi technology and have developed products now?", and they obtained an answer (Quora 2016). The answer mentions and summarizes a report from the consultancy company GreyB (GreyB 2016).

In this report, we can find some interesting data, such as the fact that Samsung is the company that has the most patents related to Li-Fi. A UK company that specialises in this technology, pureLiFi, is also mentioned.

Starting from the information from the report, the website of the company mentioned, pureLiFi (purelifi.com), is clearly a source to consult. We consulted it. They claim to be at the prototype stage. Next, we used the name of this company to obtain more information. The name of a company that specializes in a technology is a key to obtaining information from professional and business outlets. Factiva was the tool of choice in this case.

The results did not disappoint us. We obtained a report forecasting future leaders in the Visible Light Communication market (Technavio 2017). We also found that pureLiFi raised 7 million pounds in July 2016 (The Times 2016), and the developments that the company presented in the Mobile World Congress 2017 (IEEE Spectrum 2017).

Conclusion

The information obtained would probably be enough to have an initial idea about the various aspects involved in the analysis of the entrepreneurial opportunity. However, it should be widened, according to the needs that arise during the analysis, and be continuously updated.

Besides, the information could be used to develop reports or proposals, according to the needs. In these documents, we should mention and give full details of the sources, as they are the basis of our reasoning and statements. However, in general, we will not specify the process of obtaining the information.

3 LEVEL OF DEVELOPMENT

Learning objectives

In this chapter you will learn

- What the stages of development of a technology are
- What to take into account to establish the level of development of a technology
- How to use the scales of the level of development.

3.1 INTRODUCTION

The first step in performing a technology evaluation is to obtain information. Then, the information has to be analysed. An advisable start of the analysis is to identify the level of development of the technology or technologies in relation to the specific applications involved.

As entrepreneurs, we need to consider not only the latest technologies but also the alternatives to come. Thus, we should consider cutting-edge and future technologies and obtain information on their prospects. However, when a technology is not yet available, there is always a certain degree of uncertainty about when it will be ready and about its final features.

Most often, the application that we are considering is already under development by other researchers and companies. We have to establish the level of development of the technology, especially in relation to the specific application areas that we are taking into account. We want to know the details and the current situation of the projects in progress that are developing the technology of interest.

We may be tempted to take into account everything that has been done in relation to the technology we are considering. However, we should examine only what is useful to the analysis of the entrepreneurial opportunity. Generally, it is not worth spending time on the projects developed in the past. If we obtain information about a project that was conducted several years ago, we will try to determine whether it is still in progress and what advances have been made. In the case of projects that have been abandoned, or that have neglected the technology that we are considering, we will try to find out the reasons.

In short,

Consider past events only when they help to analyse the present and predict the future

We should be particularly cautious with information from research groups and companies about their advances in the development of a technology. They might want to hide their progress or exaggerate results to get attention and attract investors. We have to assess the credibility of their statements and the details provided, as well as the prestige of the group or company. It is common to say that "they claim to have obtained [such and such result]". That is, we do not fully accept those results until they have been verified.

We have to take into account that,

When analysing projects under development, to check the trustworthiness of the information is particularly necessary

Beside, our partners, potential investors, possible customers and so on, will be interested in knowing the situation of the related projects underway. However, we can be quite sure that they do not want to spend time learning every detail. We need to have succinct and clear information on these projects.

For this reason,

Use common concepts and standard scales to categorize the level of development of the technology

Next, some concepts on the level of development of a technological project are presented.

3.2 STAGES AND SCALES OF DEVELOPMENT

The use of common concepts and standardized scales is useful to categorize the level of development of the projects we are considering. They also help to present our analysis to others. We present in this section the stages of development and the Technology Readiness Level (TRL) and Systems Readiness Level (SRL) scales. A schema representing the temporal sequence of the stages of development and the standardized scales is shown in Figure 6.

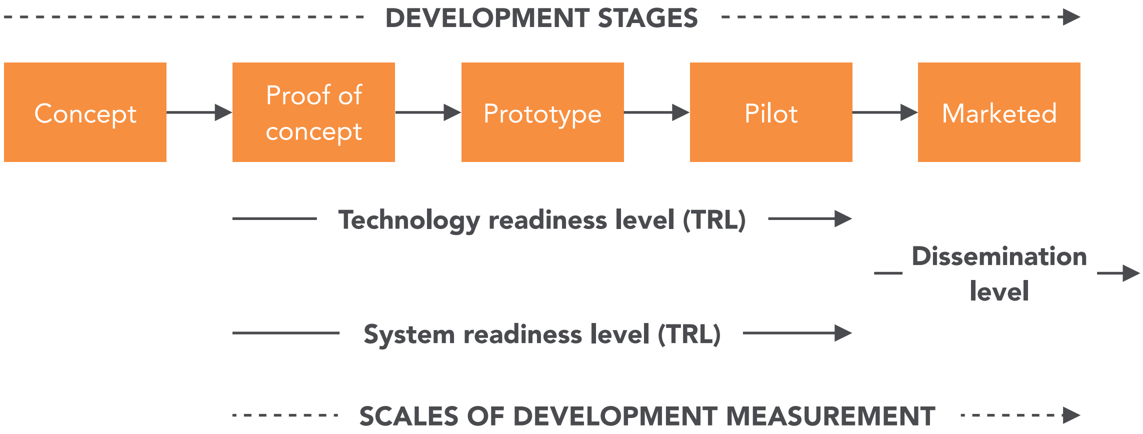


Figure 6. Stages of development and measurement scales

Stages of development

The development of an entrepreneurial opportunity goes from the idea to a marketed product. The process can be divided into several stages, which are described next.

Conceptualization

Before the first search for information, analysis, experiment or consultation, there is an idea. Sometimes we know very precisely how an idea comes to our mind. It is common that successful entrepreneurs give details about how some of their ideas came to them. At other times, the origin of the idea is unclear. However, anything starts with an idea. This is the first stage of any initiative.

Proof of concept, prototype and pilot

Proof of concept, prototype and pilot are three related but different concepts that have to be clearly distinguished. They can be defined as follows (Hoffman 2014):

- A proof-of-concept is a realization of a method or idea to demonstrate its feasibility. The demonstration may not meet the form, fit, and function of the prototype or the final product.
- A prototype comes close to meeting the form, fit, and function of the final production unit and is used to validate the idea.
- A pilot is a limited run of the product using the full production system, and tests its usage with a subset of the intended audience.

Marketed product

The final objective of an entrepreneurial initiative is that a product is sold to someone who will use it. When we plan to take advantage of a technology that has already been commercialized, it will be necessary to check what the results obtained are.

Technology readiness level (TRL)

The Technology Readiness Level (TRL) is a metric to describe the maturity of a technology. TRL was initially developed in the context of NASA (Mankins 1995), and later adopted by the European Union (Héder 2017). TRL is nowadays widely used in the technology and innovation world.

TRL does not replace the obtaining of detailed information. We need complete information to develop our analysis. TRL is widely used to specify the stage of development of a technology solution in a succinct and standardised way. For example, if a technology investment company says that they specialise in projects at TRL 3 or 4, everybody will understand what they mean. TRLs and their definitions are given in Table 2, along with the stage corresponding to each level.

Level	Name	Stage	Concept
TRL 1	Basic principles observed	Concept	This phase corresponds to the pure science field. The results can be found mostly in scientific papers.
TRL 2	Technology concept formulated	Concept	In this phase, research focuses on a specific application area.
TRL 3	Experimental proof of concept	Proof of concept	Some solid results are obtained in relation to the functioning of individual phenomena.
TRL 4	Technology validated in lab	Prototype	A first prototype is designed and successfully tested in the laboratory.
TRL 5	Technology validated in relevant environment	Prototype	The prototype is successfully tested in a realistic context and this proves the viability of the concept in this context.
TRL 6	Technology demonstrated in relevant environment	Prototype	The experiments give solid proof of the correct functioning in a realistic context.
TRL 7	System prototype demonstration in operational environment	Pilot	Most functions are available. The test takes place in a real operational context.
TRL 8	System complete and qualified	Pilot	The system is fully developed and tested in a real operational context.
TRL 9	Actual system proven in operational environment	Marketed	The system is successfully implemented and used in real applications.

Table 6. Technology Readiness Levels

Although TRL was initially intended to establish the level of development of a new technology rather than subsequent refinements and improvements, it is currently applied to any kind of development. When the technological base is not new, the first levels are skipped.

It is often the case that several companies or research groups are developing the same or very similar technologies simultaneously. However, the TRL of the projects can be different. We will consider that the TRL of the technology is the highest TRL level of all the projects. We will say, for example, that a technology has TRL 7 because one of the solutions proposed by one of the companies has reached this level.

We must bear in mind that TRL does not consider the difficulty of reaching the next level or the quality of the final solution. After all, a project that is currently in a very advanced stage of development might eventually fail completely, and vice versa.

Systems readiness level (SRL)

The objective and use of the System Readiness Level (SRL) is the same as that of TRL for the case of systems. In this case, the technological solution under development involves several technological components that are already fully developed and tested. The technological innovation consists of using these components together.

SRL was proposed by a group of researchers in 2006 (Sauser et al. 2006). The different SRL levels proposed are presented in Table 7, along with the stage corresponding to each level.

Level	Name	Stage	Concept
SRL 1	Concept Refinement	Concept	Refine initial concept. Develop system/ technology development strategy
SRL 2	Technology Development	Proof of concept	Reduce technology risks and determine appropriate set of technologies to integrate into a full system.
SRL 3	System Development & Demonstration	Prototype	Develop a system or increment of capability; reduce integration and manufacturing risk; ensure operational supportability; reduce logistics footprint; implement human systems integration; design for producibility; ensure affordability and protection of critical program information; and demonstrate system integration, interoperability, safety, and utility.
SRL 4	Production & Development	Pilot	Achieve operational capability that satisfies mission needs.
SRL 5	Operations & Support	Marketed	Execute a support program that meets operational support performance requirements and sustains the system in the most cost-effective manner over its total life cycle.

Table 7. System Readiness Levels

Level of dissemination

An entrepreneurial opportunity can rely on a technology or technologies that are already in use but have not yet been used in the particular context or in the same way that is now under consideration. In this case, we must provide some information about the dissemination of the technology or technologies and the products that use them.

In most cases, a technology is used at the beginning in a niche application and adopted by early adopters. This happens when the technology is particularly appropriate for a specific use. The ideal situation is when the future customer has a problem that the new solution can address very well. The customer will probably be open to considering the new technology even though it has not been used before. Even in these circumstances, usually only customers that tend to be early adopters of new products decide to be among the first customers.

After this stage, if all goes well, sales figures rise and the number of customers increases. In this phase, the sales are still concentrated on some specific types of customers. Only later is the technological solution of general use. Naturally, not all projects complete all the stages and end with being widely accepted.

As far as the dissemination of the marketed technology or technologies that we are considering is concerned, we have to establish if each technology is

- Marketed in a niche market for a very specific use
- Marketed to a diversity of customers
- Dominant in the market.

3.3 ESTABLISHING THE DEVELOPMENT LEVEL

Technological opportunities are very diverse. The steps to establish the level of development of the different elements involved have to take into account all the possibilities. The analysis will include establishing the units to consider. For each one, the development stage will be established. Finally, the appropriate scale of development measurement will be used, when applicable.

The steps proposed are the following:

1) Determine the technologies and application areas to consider
   A technology-based entrepreneurial opportunity involves, at least, a technology and an application of this technology. However, it can be more complex. In some cases, we have to check different developments including several technologies, projects consisting of the integration of technologies, and projects aimed to apply the technology to some need. We have to determine which of these elements have to be taken into account.
2) Check what information we have on each technology and application
   Since we are basing our analysis on what others did, we have to review the information available in relation to each technology or application. It is usual for the same document to refer to more than one technology, since they can be used together. The information that corresponds to the technology or technologies we are analysing has to be identified.
3) Analyse the details
   The specific aspects to consider depend on the phase of development. Some questions to answer are suggested in Table 8.

Stage	Questions
Concept	Who is proposing the idea? Are they trustworthy?
Proof of concept	What evidence is offered that the product will work effectively? (Drawings, theoretical analysis, computer simulation)
Prototype	What is the nature of the prototype? Has it been evaluated by one (or more than one) potential customer?
Pilot	Has the product been tested in the environment where it will be used? Have the details of manufacturing been worked out?
Marketed	Does the product offer the expected performance? How does it compare with other options?

Table 8. Questions proposed for checking the details of the development level of a technology, based partially on (De Coster & Butler 2005)

4) Determine the development stage
For each technology or application, we will use the information available to establish whether the stage of development is Concept, Proof of concept, Prototype, Pilot or Marketed. When we have information from more than one group or company that are working on the technology or application, the levels of development can differ. In principle, the level of the technology or application is the level of the most advanced project. In any case, we should take into account all projects. It is possible that a project that is not currently the most advanced one will, in the end, be the first to succeed.
5) Use a scale of development measurement when applicable
The scales of development measurement are useful to standardize the results of the analysis of the level of development. The scales to apply are
    - For an individual technology or application under development in the phase of proof of concept, prototype or pilot, the Technology Readiness Level (TRL).
    - For a system involving an integration of technologies under development in the phase of proof of concept, prototype and pilot, the Systems Readiness Level (SRL).
    - For a marketed technology, the level of dissemination
6) Systematise the data obtained
When evaluating a technology, determining the stages and scales of development of the projects involved is not enough. We need to analyse the rest of the details obtained on what is happening with the technology. This information should be systematised, since it can be used in the subsequent phases of the analysis.

3.4 EXAMPLES

Development stage and TRL: Generation of Electricity by the Movement of People and Vehicles

Waydip is a start-up based in Portugal that is developing Waynergy People and Waynergy Vehicles, which are specialized tiles/floor-plates that produce usable energy from people and vehicles movement respectively. The product captures the kinetic energy imparted onto its surface and transforms it into electrical energy (Innovation Seeds 2016).

Waydip is currently in the preparation stage for commercial testing. The final design is virtually complete, and various operational tests have been completed, with the system and functions almost completely operational and at the operational scale. More real-time experiments are also planned in the future to analyse the amount of energy produced and the CO_2 savings resulting from the product's use.

Starting from this information, the stage of development corresponds to the prototype stage, and the TRL is 7. The development of the pilot stage is planned to be developed next.

TRL of components: Innovative European Launcher Concept SMILE

Fourteen European SMEs and research institutes are joining forces in the European research program "SMall Innovative Launcher for Europe" (SMILE). The project aims at designing a launcher for satellites up to 50 kg and a European-based launch facility at Andøya, as well as demonstrating critical technologies in the areas of propulsion, avionics, and manufacturing of cost-effective solutions (Kuhn et al. 2017).

The level of development of the critical technologies involved has been defined by using the TRL nomenclature, as presented in Table 9.

Item	TRL
Launcher concept	2
Hybrid rocket engine	7
Liquid rocket engine	5/6
Advanced materials	3
Automated manufacturing of composites	5
Printing technology	8
Advanced avionics	4
European launch facility concept	2

Table 9. TRL levels for critical technologies in SMILE (Kuhn et al. 2017)

4 COMPARISON OF ALTERNATIVES

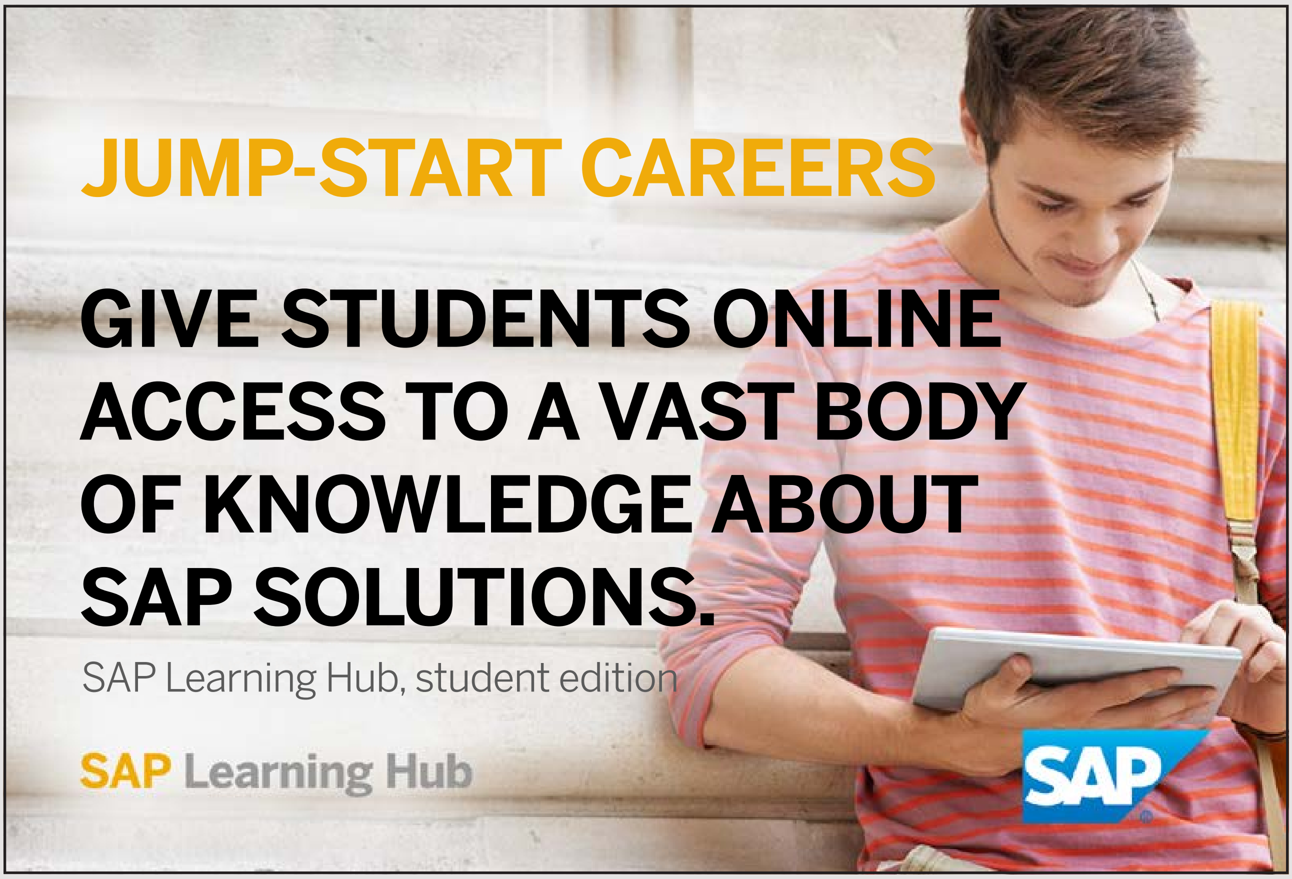
Learning objectives

In this chapter you will learn

- How to define technical evaluation parameters
- How to compare alternative technologies by using technical evaluation parameters
- How to define the applicability range of a technology.

4.1 INTRODUCTION

The next step in technology evaluation is to compare the technological solution under analysis with other alternatives. When we develop a technology analysis, our objective is that the analysis is objective and verifiable. To do so, we need data. When an analysis is based on data, the assumptions and the deductions are clear and can be checked by ourselves and by others.



That is because

A technology evaluation should be based on data

We need therefore to obtain data concerning various aspects involved in the technology evaluation. This information has to be analysed, first, and presented, later. Appropriate technical evaluation parameters make this easier. Technical evaluation parameters are a particular type of indicators. Indicators, in general, are used to measure a relevant value. They can be qualitative, such as a number, proportion, percentage, ratio or value, or qualitative, such as level, presence, evidence, availability, quality, existence, sustainability, and improvement.

The list of parameters to consider has to include both technical parameters and performance parameters. Technical parameters refer to the internal functioning of a technology solution. They do not depend on the context or the specific use involved. Technical parameters are essential but not enough for the analysis.

Performance parameters refer to the results obtained from the use of the technology in a certain context and use. Ideally, they are based on tests developed in the context where they would be used. Laboratory tests and the results of simulations can also be considered.

Thus,

Technical evaluation parameters involve a combination of technical parameters and performance parameters

Technical evaluation parameters are applied in different analyses, such as to compare different alternative technological solutions, to define the applicability range of one or more technological solutions and so on.

It is not common for a technology to outpace all the other available options in every aspect. Usually, the result of the comparison is the range of applicability of the technology, that is to say, a set of conditions under which the technology is superior to any other. In this chapter, the technical evaluation parameters and their use to compare alternatives and define applicability ranges are developed.

4.2 CHARACTERISTICS OF TECHNICAL EVALUATION PARAMETERS

How technical evaluation parameters should be

As said before, technical evaluation parameters are indicators. Indicators are defined for a specific purpose. They should be designed to serve this purpose. In general, indicators should be:

- Objective. An indicator can be considered objective when it does not depend on a subjective criterion. In some cases, it is necessary to take into account the opinions of experts or some other kind of qualitative evaluation. This is not the preferred option, because doubts concerning the validity of the evaluations can arise when the criterion is not objective.
- Easy to obtain. Cost and time are relevant factors when deciding how to perform an analysis. We will give priority to the use of data that is already available. When more information is necessary, we will prefer data that can be obtained with little effort.
- Easy to understand, clear. The technical evaluation parameters that we are searching for will be used not only to base our analysis but also to present it to others. The use of complicated concepts makes it difficult to comprehend our report and, in practice, limits the real utility of the analysis.
- Small in number. It is commonly said that too much information is no information. We cannot take a decision based on, say, 200 parameters. It is not easy to discard parameters. There are many details that are, in fact, important, because they can influence the functioning of the system we are analysing. However, we necessarily have to select a limited set of technical evaluation parameters.
- Tied to a relevant characteristic. The technical evaluation parameters are not important by themselves, but because they reflect a relevant characteristic for the specific analysis that we are developing.
- Useful. We should always have in mind the reason why we are defining a set of technical evaluation parameters. Our selection has to depend on the specific needs of the analysis that we are performing. That is to say, we have to define a set of parameters that are useful for the analysis.

Types of technical evaluation parameters

We can differentiate three kinds of technical evaluation parameters, according to their level of generality, as follows.

Generic technical evaluation parameters

When analysing the technological aspects of an entrepreneurial opportunity, we will need first to consider the general aspects of the technology. To do so, the preferred option are parameters that are applicable to all the solutions to a problem or to a whole set of technologies. We can call these parameters generic technical evaluation parameters.

Some of the generic evaluation parameters are well known from the beginning. For each kind of technology or product, we can identify some parameters of general use. Consider, for example, calories or percentage of the different kind of ingredients when taking into account food, maximum speed and fuel consumption for cars, clock speed and RAM memory for computers, speed and some measure of reliability for internet connections, and so on.

Generic parameters refer usually to

- Capacity, that is to say, the total output that it is possible to generate.
- Consumption, which relates input and output.
- Cost (investment and operational), which refers to the financial expenses.
- Duration, which refers to the foreseen lifetime for the element under analysis.
- Reliability, which will measure the probability of discontinuity of the service.

Technical evaluation parameters for a specific set of technologies

While general parameters are useful to compare different kinds of technologies, other more specific parameters are used to compare similar technologies. These technical evaluation parameters make sense only for a specific set of technologies. The reason is that different but similar technologies share some aspects that allow a direct comparison. For instance, recharging time is a critical parameter to compare electric cars with different kinds of batteries, but not for gasoline cars.

Technical evaluation parameters for a particular need and context

Each specific need and context has particular circumstances that the technical evaluation parameters should address. These lead to some concrete parameters. The biggest challenge when defining them is to identify a very limited number of parameters which can be easily obtained and provide information on all critical aspects of the alternative technological solutions involved.

4.3 THE PROCESS OF COMPARISON

Steps of the analysis

The process of comparison of technologies is formed by three consecutive steps, which involve

- Defining a set of technical evaluation parameters and selecting some as the most useful basis for decisions on the technology.
- Comparing the technology and the application analysed with other alternative solutions by taking into account the technical evaluation parameters.
- Analysing the appropriateness of the technology in different scenarios and establishing applicability ranges.

Details on these steps are presented next.

Defining and selecting technical evaluation parameters

In order to compare alternatives, we will start from the definition and selection of technical evaluation parameters. We work in the technical field and a qualitative decision is therefore unthinkable. As mentioned before, we will base our analysis on data.

The selection of the technical evaluation parameters is the most important single step of the analysis of a technology-based entrepreneurial opportunity. These parameters summarize the information we have obtained before and are the basis of the subsequent analysis. Naturally, it is necessary that the parameters selected refer to important characteristics of the technology and the application that we are considering. The fact that we are able to identify which the critical parameters are is proof that we have a good knowledge of what we are analysing.

Thus, we have to

Select parameters reflecting relevant characteristics of the technology and the application area considered

As experts in some technologies, we are interested in all the details of the solutions that we are considering. Both the scientific basis and details of the functioning deserve our attention. In relation to the technical evaluation parameters, all relevant data will be taken into account when analysing a certain solution. Thus, when analysing a certain solution, we can take into account a considerable number of parameters.

However, to consider a big number of parameters is not recommended. It is certainly possible to define decision rules that consider a long list of factors, but these methods are counterintuitive and thus, very difficult to stand up for and communicate. Therefore, the selection of a very short number of parameters is unavoidable.

It is necessary to identify the technical evaluation parameters that make a significant difference between the alternatives. Details of the functioning and aspects in which the differences are not significant are not important for this purpose. In addition, we will focus on the aspects that will be taken into account to make decisions in a specific context. According to the need or problem we are addressing, the set of parameters to consider will be one or another.

In short,

Take into account only the parameters that make a difference between alternatives

Comparison based on parameters

After the technical evaluation parameters have been selected, we should obtain the values of these parameters corresponding to the alternative technologies under consideration.

The selection of these alternatives is not always easy. The existing technologies are used in different products and in different places and the performances obtained are usually very variable. The projects under development are also diverse and their outcome is uncertain. There is no simple way to select the technologies to take into account.

Despite the difficulties,

We should compare the technology and the application considered with the most important current and future alternatives

A simple and explanatory presentation of the parameters values facilitates the analysis and the posterior communication of the results. It is convenient to normalize the data of the different parameters in a way that makes them comparable. For instance, if one parameter goes from zero to 10 and another from zero to 1 million, no helpful graphical representation including both is possible. Table 10 shows how the information can be presented.

	Raw data			Normalized data		
	Tech. 1	Tech. 2	Tech. 3	Tech. 1	Tech. 2	Tech. 3
Parameter 1						
Parameter 2						
Parameter 3						
Parameter 4						
Parameter 5						
Parameter 6						

Table 10. Scheme of the comparison of alternative technologies

Graphical representations are of great help when comparing alternatives. In particular, bar charts are helpful to represent the results parameter by parameter, and radar charts display all the results together, as shown in Figure 7 and Figure 8.

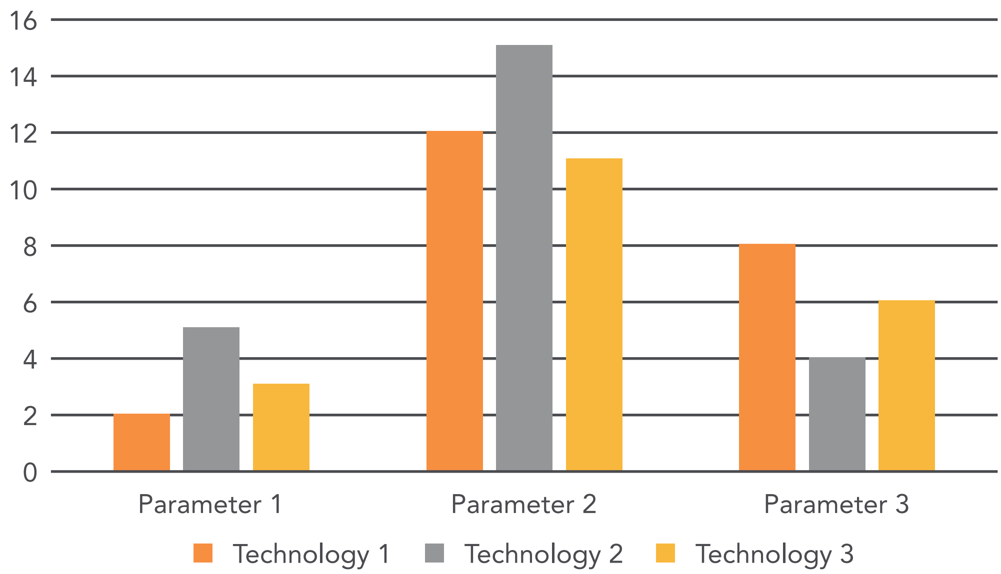


Figure 7. Scheme of the comparison of alternative technologies. Bar graph

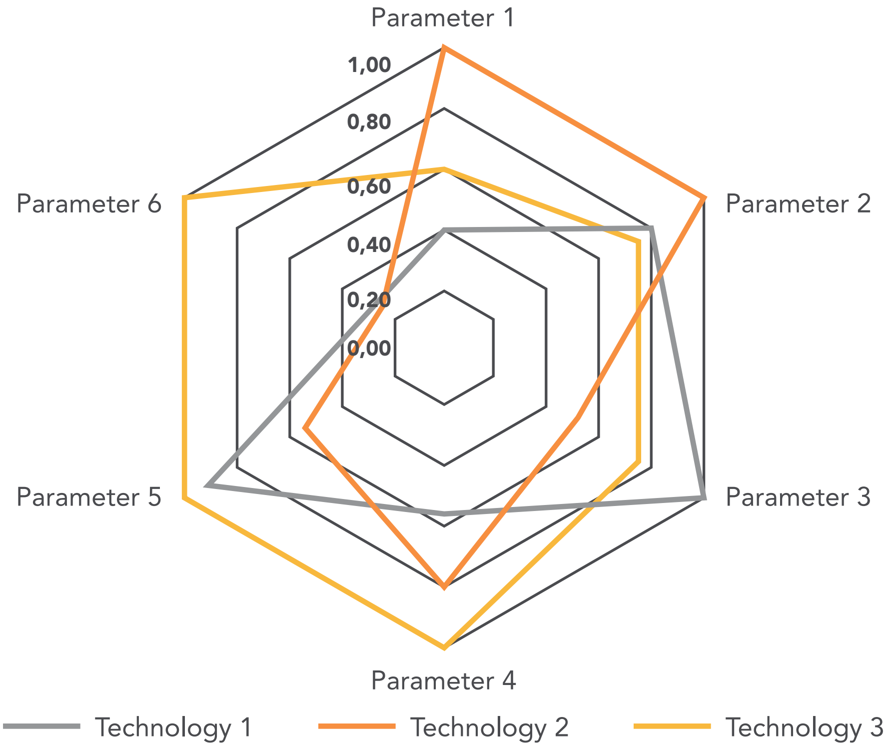


Figure 8. Scheme of the comparison of alternative technologies. Radar graph

Applicability range

We are often not searching for a solution for a specific case but considering a range of possible circumstances. Assume that we are analysing energy generation solutions for isolated areas. Isolated areas are not all the same. Accessibility, availability of resources and weather conditions can differ a lot. What we are interested in knowing is in which situations the technology or technologies are applicable. Usually, a technology is more appropriate than the alternatives in some circumstances, but not in others. If a technology is not the technology of choice, or at least one of them, in any case, there is no chance for this technology.

We will take advantage of the evaluation parameters to identify the circumstances in which one or another technology is more appropriate. The set of combinations of parameters values identifying when a technology is appropriate is called the range of appropriateness. These ranges are graphically represented by appropriateness maps – see Figure 9.

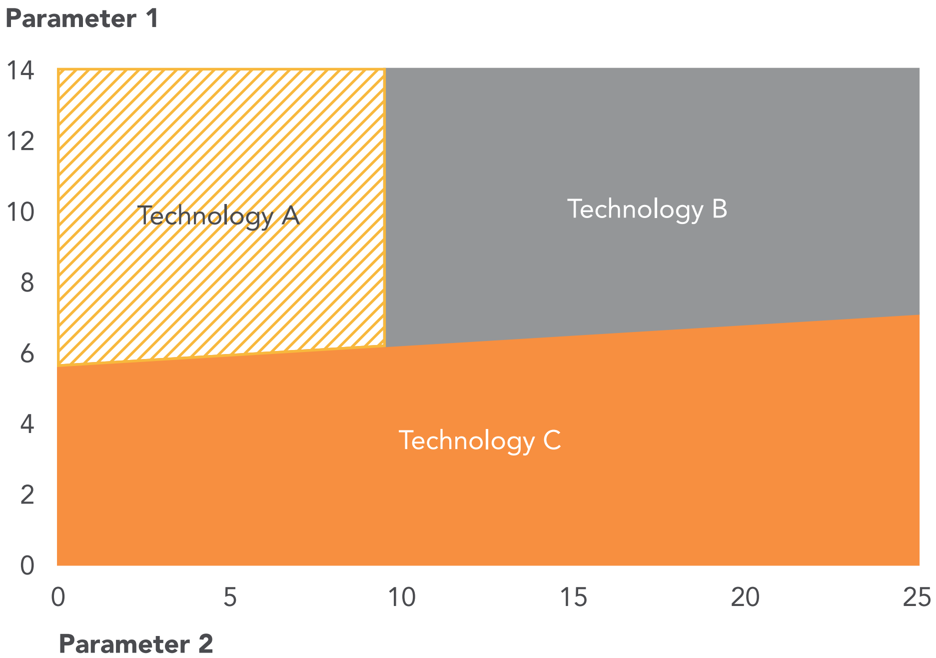


Figure 9. Graph representing technology applicability ranges or appropriateness map

4.4 EXAMPLES

Definition of parameters: energy sources

Energy sources provides a very good example of the use of technical evaluation parameters to evaluate a technology. The decisions on energy involve a list of different aspects referring to the technology or technologies used and to the external impact.

The factors proposed by (Kassem et al. 2016) are a good example of how the different factors can be taken into account. The factors are presented in Table 11. These factors refer to any energy source and context, that is to say, they are what we call generic parameters.

Area	Performance measure	Description
Technical	Maturity	Maturity of the technology
	Efficiency	Percentage rate of output energy to input energy
	Reliability	System's ability to perform its intended function
	Deployment time	Time needed to establish a power plant
	Experts availability	Availability of experts (manpower)
	Safety	Safety of energy system based on accidents count
	Scalability	Capacity for later expansion of the utility
Economic	Capital cost	Initial cost required for each technology
	O&M cost	Operation and maintenance cost
	Energy cost	Cost of produced electricity
	Operational life	Estimated number of years before decommissioning
	Market maturity	Market availability, commercial competitiveness, and compatibility with existing economic system; it is expected that greater maturity facilitates financing opportunities
Environmental	Required area	Area of land needed
	Emission reduction	Capacity of each technology to reduce greenhouse gas emissions, including CO_2

Area	Performance measure	Description
Social	Job creation	Potential for job opportunities
	Social acceptance	Public attitudes towards each technology
Political	National economic benefits	Through local manufacturing share
	Logistical feasibility	Existence of supporting legislation and administrative regulations
	Political acceptance	Politicians' attitudes towards each technology

Table 11. Factors to take into account in the evaluation of energy sources (Kassem et al. 2016)

Specific analysis requires specific parameters. Kassem et al. (Kassem et al. 2016) propose also some factors to consider when working on solar thermal power technologies. These factors are additional to the general factors referring to any kind of energy source. They are thus parameters for a specific set of technologies. The parameters for the case of solar thermal power technologies are presented in Table 12.

Area	Performance measure
Technical	Storage hours
	Availability of key components
	Hybridization
	Level of complexity
	Technology advancement potential
	Microgrid suitability
	Augmentation capability
	Temperature
Economic	Economic feasibility
	Fuel cost
	Offsetting infrastructure cost

Area	Performance measure
Environmental	Water consumption requirement
	Eco system disruption
	Land requirement
	Life Cycle Evaluation (LCA)
	Environmental conditions
Social	Local industrialization possibilities

Table 12. Supplementary factors for the case of solar thermal power technologies in developing countries (Kassem et al. 2016)

In some cases, the specificity of the parameters originates in the particular needs and context that we are considering. Mainali and Silveira (Mainali & Silveira 2015) present an example of the use of technical evaluation parameters. They analyse how to assess the energy technologies for rural electrification. A complete set of indicators considering technical, economic, environmental, social, and institutional indicators is defined. The set of parameters is presented in Table 13.

Technical	T1. Energy availability (MWh/kW/yr)
	T2. Efficiency of energy conversion (%)
	T3. System reliability
Economical	EC1. Capital investment (USD/kW)
	EC2. Operation and Maintenance (O & M) cost (UScent/kWh)
	EC3. Fuel cost (UScent/kWh)
Environmental	EN1. GHG emissions in gCO_2 eq/kWh
	EN.2 Land use (m^2 per kW) consumption considering life cycle
Social	S1. Local employment generation (jobs per MW installed power)
	S2. Number of direct local employment opportunities created (considering mainly operation of the plant)
	S3. Compatibility of the technology with different end uses
Institutional	I1. Operational & Management capability required

Table 13. Example of parameters: Selected indicators to assess the energy technologies for rural electrification (Mainali & Silveira 2015)

After defining the parameters that are most appropriate to the case, we will select some of them to perform the comparisons of the alternatives we are considering.

Selection of parameters: supersonic aircraft

The company Tom Johnson Design has proposed the development of a supersonic aircraft, the Cygnus M3 (Tablang 2017). How can we compare the proposal of this company with the present options? Tom Johnson Design presented a document with the features they think that the Cygnus M3 will have (Tom Johnson Design 2017). Thus, we can compare the proposed features with the characteristics of other planes, whether existing or projected.

The first step is the selection of the aircraft to compare with the Cygnus M3. To do this, it is necessary to specify the application of the technology – the supersonic plane, in this case. Tom Johnson Design mentions specifically that they are addressing commercial flights. Besides, a supersonic aircraft is clearly not appropriate for short radius routes. Additionally, they remark that, due to problems with noise, the plane will be used for flights over water. Thus, the application to address is long-range over-water commercial flights – typically the Atlantic or Pacific routes.

The comparison of Cygnus M3 with a set of other existing or projected aircraft is presented in Table 14. The comparison is based on four parameters: seats, range, fuel per seat, top speed and cost. The first flight year is included as complementary information, since this data is not available for Cygnus M3. We compare the speed in Mach because this is the relevant magnitude in this case.

Model	First flight	Seats	Range	Fuel per seat	Top speed	Average cost (M$)
Airbus A330neo-900	2017	300	8,610 km	2.48L/100km	<Mach 1	234
Airbus A380	2005	544	11,000 km	3.16L/100km	<Mach 1	437
Boeing 787-9	2013	304	9,208 km	2.31L/100km	<Mach 1	265
Boeing 777-9X	2020	395	13,300 km	2.85L/100km	<Mach 1	
Boom Supersonic	2023	45	16,668 km		Mach 2.0	200
Cygnus M3	Unknown	32	10,800 km	8 L/100 km	Mach 3.0	120

Table 14. Comparison of Cygnus M3 with some other aircraft. Own elaboration based on (ATWOnline 2017), (Reid 2017), (Tom Johnson Design 2017) and (Wikipedia 2017a)

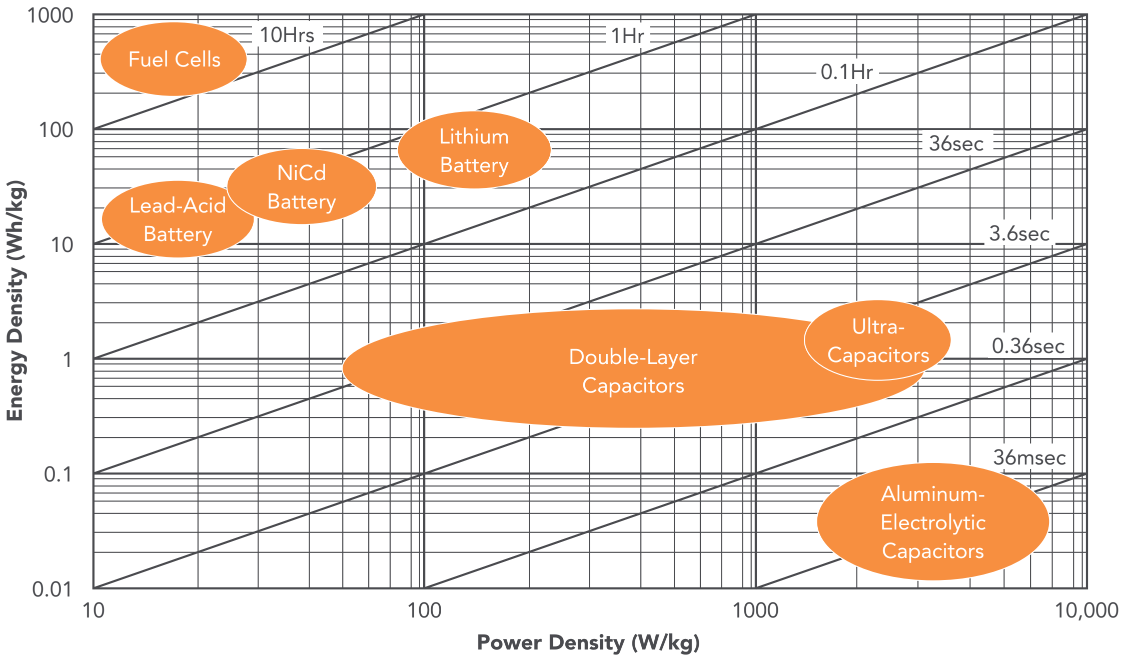
Cygnus M3 is still in the concept phase. This makes it impossible to be sure about its final features and the features of other competitors when the plane finally exists, if it does. However, the comparison puts in context the particular characteristics of the project.

In this case, it is clear that the high cost, limitation to over-water flights and the fact that there are no clear plans for development are negative factors of Cygnus M3. However, the high speed gives the project good opportunities in the market for flights crossing the Atlantic or Pacific and in the highest level of commercial flights. In relation to the other supersonic aircraft included in the comparison, Boom Supersonic, the Cygnus M3 project offers a higher speed.

Applicability range: batteries

A good example of an applicability range is the Ragone chart (Lee & Jung 2016). An example of a Ragone chart is shown in Figure 10. The Ragone is used to compare energy storing devices. In the Ragone the values of energy density (in Wh/kg) are plotted versus power density (in W/kg). That is to say, the vertical axis describes how much energy is available while the horizontal axis shows how quickly that energy can be delivered. The sloping lines indicate the relative time to get the charge in or out of the device.

The objective of this kind of analysis and representation of the results is that the differential characteristics of the technologies become clear. The next step will be to analyse the requirements of the specific application that we are considering. Then, the features of the various technologies and the requirements will be compared.



Source US Defence Logistics Agency

Figure 10. Example of applicability range: the Ragone plot

Comparison of alternatives: Comparison of therapies in lumbar degenerative disc disease

The objective of the work referenced (Zigler et al. 2017) is to compare the efficacy and safety of total disc replacement, lumbar fusion, and conservative care in the treatment of single-level lumbar degenerative disc disease (DDD). A network meta-analysis was conducted to determine the relative impact of lumbar DDD therapies on the Oswestry Disability Index (ODI) success, back pain score, patient satisfaction, employment status, and reoperation.

The results of the analysis are presented in Table 15. In this case, the results obtained by applying the alternative techniques are random. Five performance factors have been selected (Oswestry Disability Index success, Back pain score, Patient satisfaction, Employment status and Reoperation). The techniques considered are included in the first column. The table indicates the probability of each technique being the best performer in relation to each factor.

	ODI success	Back pain score	Patient satisfaction	Employment status	Reoperation
Rehabilitation	0%	7%	0%	2%	-
Circumferential fusion	0%	4%	-	2%	41%
ALIF	0%	0%	2%	5%	0%
ProDisc	8%	25%	41%	14%	3%
Charite	1%	0%	-	1%	2%
Maverick	13%	2%	0%	14%	24%
Kineflex	5%	1%	5%	-	27%
activL	72%	61%	0%	62%	3%

Table 15. Probability of being the best treatment (%) across outcomes (Zigler et al. 2017)

5 TECHNOLOGY FORECASTING

Learning objectives

In this chapter you will learn

- How to forecast the future of a technology by using various methods
- How to prepare a technology roadmap
- Which forecasting method is preferable according to the circumstances.

5.1 INTRODUCTION

After the comparison of the technology under analysis with other options, the future evolution of the technology should be considered. It would seem logical to perform this analysis together with the analysis of the present situation of the technology, presented in CHAPTER 3. However, the prior development of the comparison of technologies make it possible to focus on the most relevant aspects.

When evaluating a technology, the future has necessarily to be taken into consideration. Technology is continuously evolving. The future development of the technology has a clear influence on the projects that we are developing now. We can consider these different aspects:

- The technology considered is usually under development or at the first phases of its implementation.
- Sometimes the solution that we propose admits that some of its elements can be updated with new technology developments. In this case, we can prefer a certain solution not due to its current performance but because it will make it possible to adopt an improved technology when available with little change.
- The solution will compete during its lifetime not only with the other solutions developed at the same time or before, but also with new developments.
- When we develop a solution, we are acquiring experience in a specific area. The usefulness and value of this experience will depend on the future evolution of the technology.

For all these reasons, the future evolution of the technology has to be taken into account when developing a technology evaluation. That is because, we will develop a technology forecast.

Technology forecasting aims to provide information about the direction and rate of technology changes. Various methods can be used to develop a technology forecast. Technology forecasting methods use logical processes to generate explicit information to help industry and government anticipate the practical, ecological, political, and social consequences of developments in technology (Fleisher & Bensoussan 2007).

Technology is critical for a company to be competitive. For this reason, technology forecasting is also used to support decision-making in companies (Martino 1993). Technology forecasting methods can also provide very relevant information when analysing the technical aspects of a technology-based entrepreneurial opportunity, since an entrepreneurial opportunity is about the future.

Therefore,

Technology forecasting is an essential part of the evaluation of a technology-based entrepreneurial opportunity

A technology forecast takes into account four elements (Martino 1993):

- A time horizon, including when the forecast is done and when the forecast should be realized
- A specific technology
- Some parameters of the technology, that reflect some characteristics and capabilities
- A probability statement about the outcome or range of outcomes predicted, when it is possible to obtain this.

There are several methods to forecast the future of a technology. These methods can be grouped according to their basic approach. Expert consultation methods are based on the knowledge and opinions of experts. Monitoring measures the volume of activity developed in relation to the technology by using indicators of this activity. Methods based on parameters are based on the analysis of the historical evolution of one or more critical parameters. Finally, a technology roadmap is based on the decomposition of a technology development into specific components and stages.

Next, further details of these methods are provided.

5.2 TECHNOLOGY FORECAST METHODS

Monitoring

Monitoring techniques take advantage of indirect information on the activities around a technology. First, we have to consider technology forecasting based on the monitoring of patents and research papers. As patents and research papers are a reflection of research in universities, institutes and companies, they can anticipate future practical innovations. Several services, both commercial and non-commercial, help us do this kind of analysis. Commercial services are available by subscription or, sometimes, through libraries. Non-commercial services include Espacenet, from the European Patent Office, and Google Scholar.

Besides, we can perform our own analysis of the popularity of a technology. Databases allow us to check the number of documents that mention a certain technology and its evolution over time. Some Google services are particularly useful. Using Google Trends is a simple but powerful way to detect the interest in a topic by counting the number of searches that include a specific word. Additionally, Google Books Ngram Viewer counts the number of times that a word appears in books over time.

A technology is popular because many people believe in it, are working on it or are willing to use it. Thus, although knowing that a technology is or has been popular is not very useful by itself, in combination with other information this can provide useful insights into the prospects of this technology.

Critical parameters evolution forecasting

Critical parameters evolution forecasting methods are based on the analysis of the evolution of one or more critical parameters defining the possibilities of a technology. Trend extrapolation and growth curves belong to these groups of methods. They use information from the past to predict the future. Typically, these methods analyse the future from the perspective of one factor of change.

As already mentioned, to compare alternative technologies it is convenient to establish appropriate technical evaluation parameters. Sometimes, one of these parameters is particularly relevant because it allows us to synthesise the evolution of a technology or a group of technologies. In these cases, trend extrapolation and growth curves are useful to describe the previous evolution and forecast what will happen in the future. As these analyses are based on real data, they can be perceived as more objective than other approaches.

Trend analysis can be performed when you assume the continuity of the rate of evolution of the specific parameter under consideration. That is to say, we need the rate evolution of the parameter to be approximated by a function, such as a linear or a logarithmic function. This makes it possible to forecast the future based on this function. The graphical representation of a trend analysis looks like the graph shown in Figure 11. The point represents some specific instances of the performance-time pair and the line represents the trend.

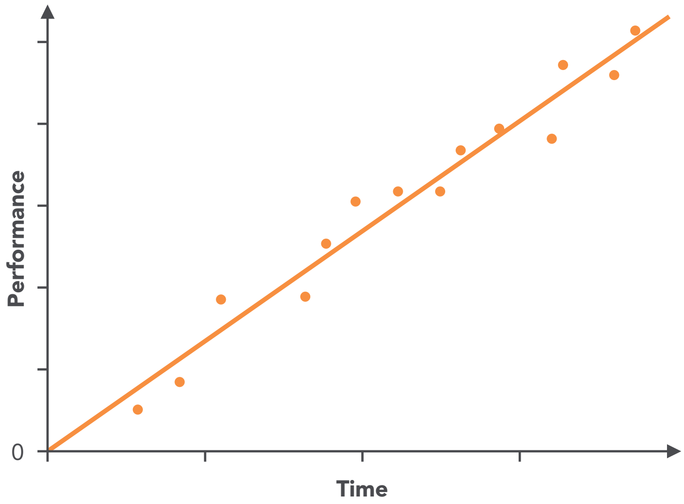


Figure 11. Trend extrapolation

The long-term evolution of the technology cannot follow a constant rate because physical limits make this impossible. The long term is better reflected by what is known as an S curve. In this curve, the growth of the performance parameter considered is first increasingly intense but, after a certain point, it decreases and, finally, the parameter level tends to stabilise – see Figure 12. The reason for this behaviour is that, at the beginning, the technology still has a lot of unexploited possibilities. In the last phase, the limits of the technology are near to being reached.

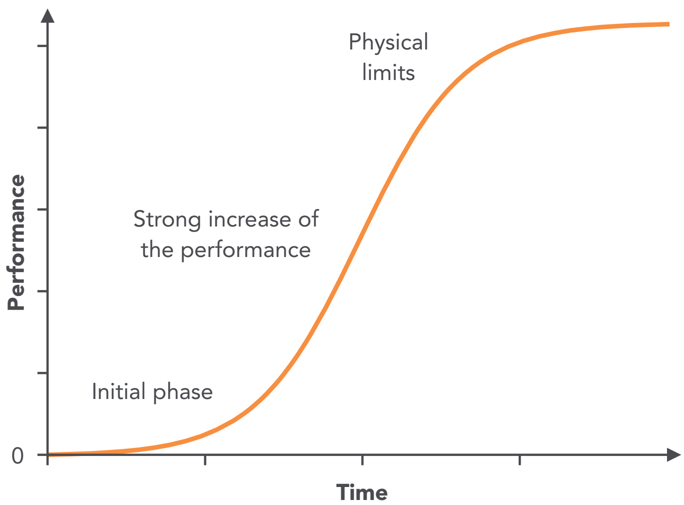


Figure 12. S Curve

Trend extrapolation and growth curves are very useful when a single parameter is able to reflect the evolution of a technology and it evolves in a continuous way. Disruptive innovation cannot be foreseen by these methods. However, when disruptive innovation takes place, the performance of the old and new technology can usually be represented by two consecutive S curves, as represented in Figure 13.

Typically, a technology that has been dominant for a while and has almost exhausted its possibilities of increasing performance is surpassed by a new technology. At the beginning, the performance of the new technology is lower than the performance of the old one. In this phase, the new technology is used only in very favourable circumstances or because of its potential. After an experimentation period, the new technology unfolds all its potential, and surpasses the old one.

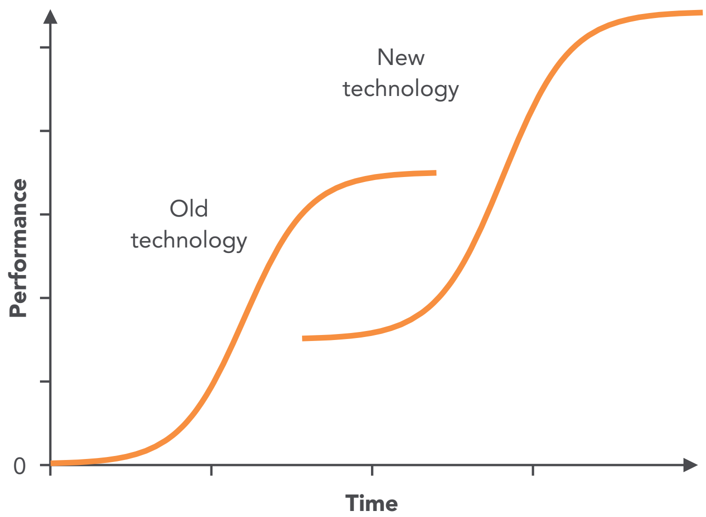
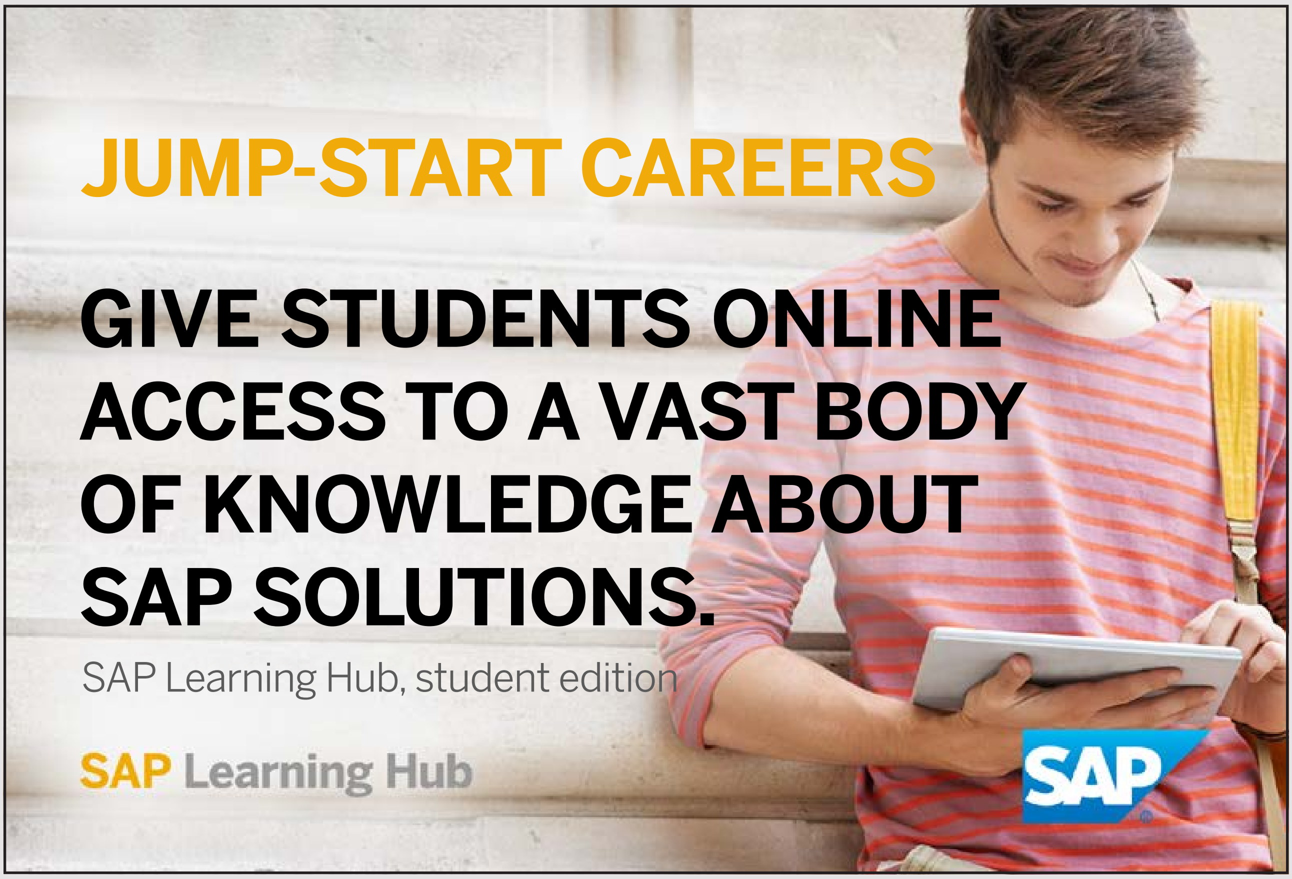


Figure 13. S Curve and disruptive innovation



Expert opinion

Predicting the future is a very complicated task. A reliable method often cannot be obtained. High-level professionals possess the information and knowledge to make reasonable predictions. Consulting experts is therefore a good option to establish future prospects. Experts including several stakeholders, academics and consultants can be consulted.

The Delphi method is the most well-known formal method for consulting experts. It involves several rounds of consultations with experts until consensus is reached. The rationale behind the Delphi survey is to address and overcome the disadvantages of traditional forms of consultation by committee, particularly those related to group dynamics. The Delphi method is recommended when the questions posed are simple, such as a program of a technical nature with few objectives, and for establishing a quantitative estimation of the potential impacts of an isolated intervention (European Commission 2014). One of the circumstances in which the Delphi method is appropriate is when the heterogeneity of the participants must be preserved to assure the validity of the results.

The results of the Delphi method depend on the analysis capacity of the experts. The appointment of properly qualified experts is critical to the results. If the panel or a portion of the panel is not experienced in the area investigated, the opinion will not truly be an expert one. Besides, even experts do not have a full knowledge of the future evolution of a technology, since it cannot be fully known. Expert consultation methods therefore have strong limitations, but they can provide some interesting insights into the future of a technology.

Technology roadmap

Technology roadmapping is used widely at both firm and sector levels. There are many types of roadmaps. The most common format comprises a graphical framework that shows how technology and product development align with business and market goals, as a function of time (Phaal et al. 2006).

A technology roadmap takes into account the different specific technological components necessary to develop a certain new product or kind of products. When the roadmap is developed at industry level, it takes into consideration the projects that the different companies or other organisations are developing. The roadmap of a specific company includes only its own projects and the projects of others that the company plan to use.

The establishment of the development stages of the different projects involved is an essential part of a technology roadmap. Both present and future stages have to be taken into account. Thus, the roadmap will include

- The current development stages of the different components of the technology
- The expected development stages of each component at different moments in time
- The time when the product or products are expected to be fully available and marketed.

Technology roadmapping is very demanding from the point of view of the information needed. To develop a technology roadmap, it is necessary to have a good knowledge of the projects under development and the future work plans of the company or companies and other organizations involved.

5.3 WHAT METHOD SHOULD WE USE?

As has been shown, there are several alternative methods to perform a technology forecasting analysis. None of them is predominant. According to the specific circumstances of each case, one method or another is selected. Often, several methods are used and the conclusions are obtained by taking into account the different results obtained. The information available and the phase of evolution of the technology determine largely what method or methods are applied.

Thus,

According to the information available and the phase of the evolution of the technology, one or another technology forecasting method is applied.

Monitoring techniques are general procedures to analyse the present and future possibilities of a technology. They are strongly dependent on the information available and the capacity of analysis. It is not possible to guarantee that the same result will be obtained by a different analyst. The conclusions obtained are, in general, uncertain. However, monitoring techniques are useful when little information on the product is available and we therefore have to turn to indirect information. This is what usually happens at the initial phase of the development of the technology.

Trend extrapolation and growth curves reflect the evolution of one or more parameters over time. These tools provide very useful information when the values of a parameter or a set of parameters reflecting the general evolution of the technology are available. Since these methods need information on the evolution over time of the parameters involved, they can only be used after the initial phase of the technology. Trend extrapolation reflects well the evolution of the performance of the technology when it increases at a constant rate. This usually corresponds to the middle phase of the technology life cycle. In contrast, growth curves usually reflect well the final phase of the technology life cycle.

As mentioned, monitoring techniques, trend extrapolation and growth curves are used in different phases of the technology life cycle. Figure 14 shows this relation graphically.

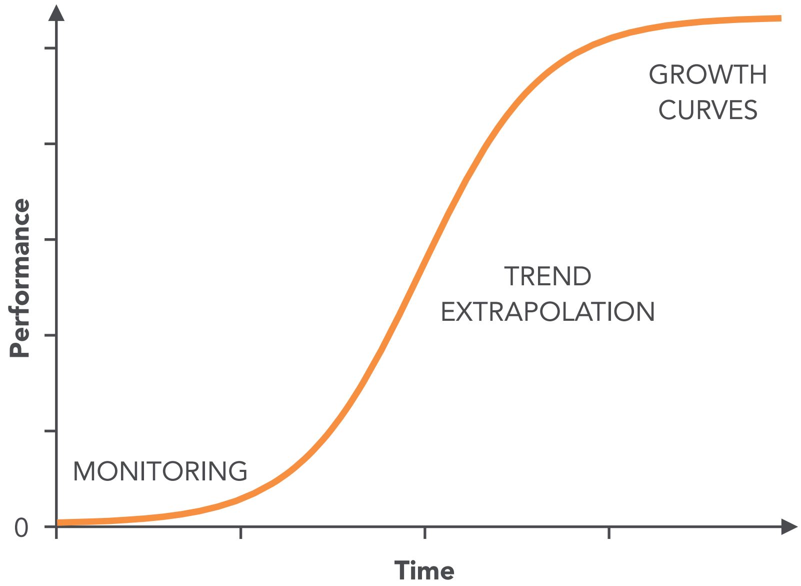


Figure 14. Forecasting method to select according to the technology evolution phase

Expert analysis and technology roadmapping can be used at any phase of the technology life cycle. Expert analysis is the most widely applicable method. The validity of its results depends on the knowledge of the experts, but does not require that the analyst has any particular information. In contrast, detailed information on the projects under development is necessary to prepare a technology roadmap. The information needed when applying the different technology forecasting methods is summarized in Table 16.

Methods	Information needed
Monitoring	Indirect information – patents, scientific papers and general searches
Critical parameters evolution forecasting	History records of the critical performance parameters of the product
Expert opinion	None
Technology roadmap	Detailed information on the current and future projects of development

Table 16. Technology forecasting methods and information needed

Additionally to our own analyses, it is recommended to take into account the analysis prepared by others that we were able to consult. When we analyse the technological aspects of an entrepreneurial opportunity or we develop a specific project, usually we cannot spend a lot of time and resources to perform a complete technology forecasting analysis. Anyway, the future evolution of the technology has necessarily to be taken into account. Combining our analyses with the analyses of others can be a reasonable option.

5.4 EXAMPLES

Popularity of biodiesel and electric cars

Biodiesel and electric cars are to some extent alternative solutions. An analysis of the use of these expressions can give us some insights into their changing popularity.

The number of searches on the internet can be obtained by using the tool Google Trends. The results are shown in Figure 15. We can see a decline in the searches for the term ‘biodiesel’, which were surpassed by the searches for the expression ‘electric car’ around 2009. Note that ‘electric car’ is used only in English, while the term ‘biodiesel’ is used in other Western languages. This problem can be addressed by applying geographical restrictions to the analysis.

Another option is to check the use of the same expressions in books. This can be done by using the tool Google Ngram Viewer. In this case, the search is restricted to English texts and is limited to books edited up to 2008. The results are shown in Figure 16. It can be seen that there is a big interest in electric cars around 1900. The decline in the interest in biodiesel is not reflected here, possibly because, as mentioned, the last year considered is 2008. Other similar analyses can be performed by considering patents or research papers.

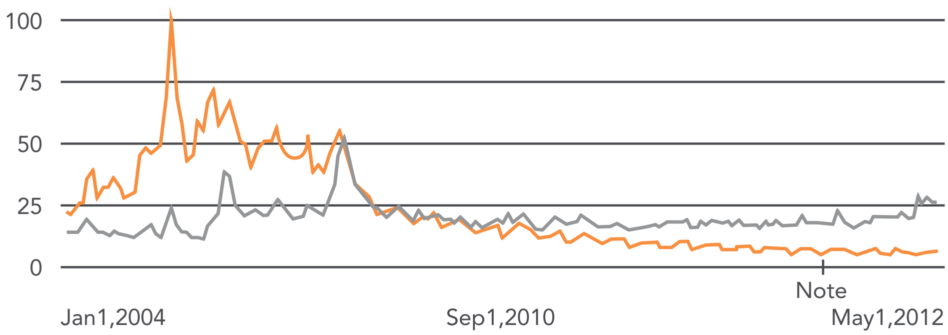


Figure 15. Searches on internet for the terms ‘biodiesel’ (blue) and ‘electric car’ (red) obtained from Google Trends (own elaboration)

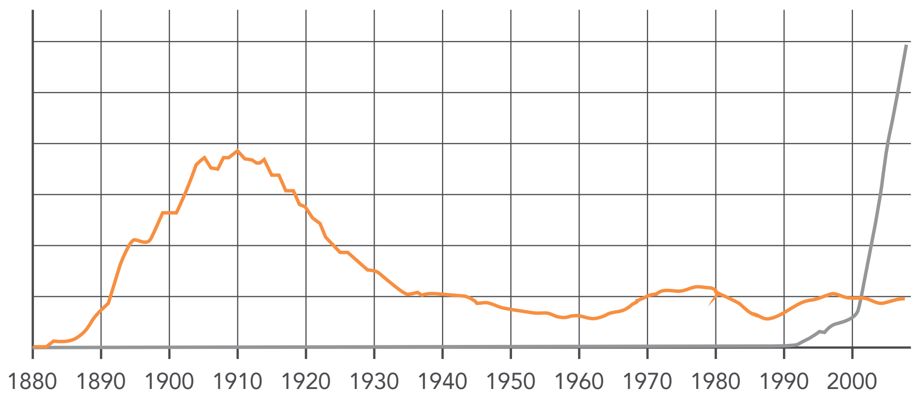


Figure 16. Searches on internet for the terms ‘biodiesel’ (blue) and ‘electric car’ (red) obtained from Google Ngram Viewer (own elaboration)

Critical parameters: number of transistors in a processor

A typical example of trend extrapolation is the number of transistors in a processor. We use trend extrapolation because we think that the evolution trend will continue. In the case of the number of transistors in a processor, this figure has evolved by following approximately Moore's Law, which states that the number of transistors per square inch on integrated circuits doubles every two years – see Figure 17.

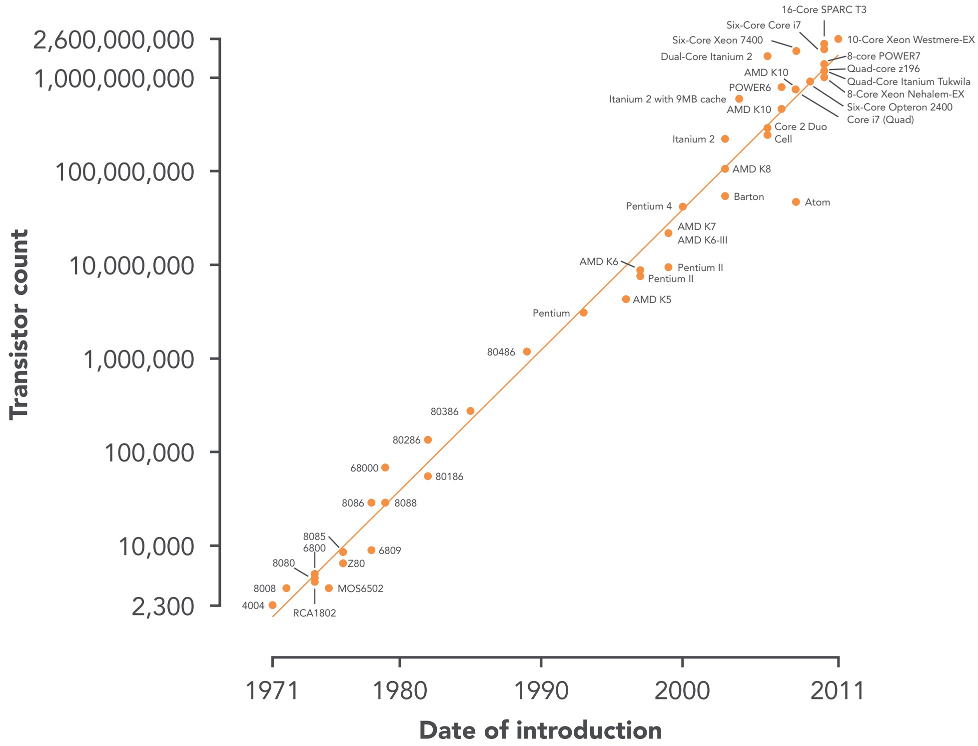


Figure 17. Moore's law (Wikipedia 2017b)

Critical parameters: price of photovoltaic systems in Italy

A second example of trend extrapolation refers to the price of photovoltaic systems in Italy expressed in Euros per watt, as shown in Figure 18. Prices are represented by blocks of total generation capacity of the systems. The costs of modules, inverters and other elements are separated. Naturally, this trend cannot continue indefinitely because the price would eventually reach zero. However, further reduction can still be expected.

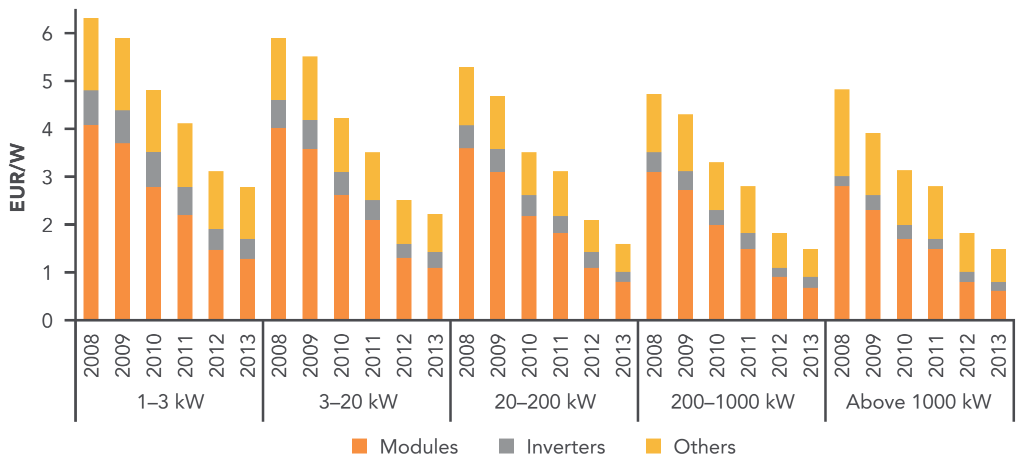


Figure 18. PV system prices in Italy, 2008–2013 (IEA 2014)

Technology roadmap: IATA Technology Roadmap

The aviation industry has committed to a set of ambitious high-level goals to reduce its carbon emissions at a global level. The TERESA project (Technology Roadmap for Environmentally Sustainable Aviation) is intended to forecast the evolution of the world fleet's fuel burn over the next two decades (IATA et al. 2013).

Table 17 shows an example of how the assessment of the situation and the prospects of the technologies are presented. The information involves the expected impact of the technology on reducing fuel consumption, the TRL of the technology when the report was presented, and the year when it is foreseen that the technology will be available.

Concept	Fuel Reduction Benefits	Current development status (TRL#)	Availability of technology (calculated)
Geared Turbofan (system arch)	10 to 15%	7	2016
Advanced Turbofan (system arch)	10 to 15%	7	2016
Counter Rotating fan (system arch)	15 to 20%	3	2023
Open Rotor/Unducted fan (system arch)	15 to 20%	5	2019
New engine core concepts (2nd generation)	25 to 30%	2	2026
Embedded distributed multi-fan (2nd GeN System)	< 1%	2	2026

Table 17. IATA Technology Roadmap. New engine Architecture technologies (IATA et al. 2013)

6 POSSIBLE CUSTOMERS AND USES

Learning objectives

In this chapter you will learn

- How to identify the market aspects to address when evaluating a technology-based entrepreneurial opportunity
- How to establish the factors to consider in order to identify possible customers and uses
- How to use relevance trees and morphological analysis to generate and select combinations of possible customers and uses.

6.1 INTRODUCTION

In the context of entrepreneurship, the evaluation of a technology aims to determine if a technology and one or more application areas of this technology are able to generate a

successful business. We have proposed to analyse when the development of the technology will be completed, its appropriateness under different circumstances and its future evolution. After these analyses, we will know the possibilities and the prospects of the technology. However, what about market aspects? Do we have to consider them?

Naturally, we have to. Market prospects can determine, to a large extent, whether an entrepreneurial opportunity deserves to be further developed or not. In addition, when the entrepreneurial opportunity is finally developed, the analysis of market prospects can be used to focus the future product or products to the most profitable customers.

However, one doubt remains. Does this mean that we should prepare a business plan? The answer is no. As mentioned in SECTION 1.1, technology evaluations and business plans correspond to different stages of the entrepreneurship process.

There are different possible relations between the evaluation of the technological aspects of an entrepreneurial opportunity and a business plan derived from the opportunity, as follows:

- The technology evaluation has been ordered by someone who is interested in the technology, but will not develop a business activity based on it. This interested party can be a research group, a public organisation or a company that offers a substitutive product, for example. In this case, no business plan will be prepared.
- The technology evaluation is a first step to prepare, later, a business plan.
- Only a business plan is developed. When the interest in the opportunity is limited to a very specific use, it is possible that a general technology evaluation is not developed.

Thus, it is possible that we will develop a technology evaluation, and next a business plan, or only one of the two reports. In any case, the contents and context of the two reports are different. The analysis of market aspects when developing a technology evaluation refers to the possibilities originated by the technology, which are independent of who and how the opportunity will be exploited. In contrast, business plans consider specific circumstances such as geographical scope, promoters and terms, and include an action plan.

In sum,

In entrepreneurship, a technology evaluation should address market aspects depending on the technology and independent of any specific context and plan

We are analysing the possibilities of a technology when applied to one or more application areas. Thus, it has to be possible to identify some potential customers who could take advantage of the new solution. The identification of these possible customers and the analysis of their interest will be of great help for the analysis of the entrepreneurial opportunity.

Sometimes, it will be said that a technical solution you propose has to have technical and economic feasibility. Naturally, it has, but this is not enough. Customers do not take decisions based only on the fact that the product works and is cheap. Customers have their own priorities, which may not always seem logical to us. The objective here is to check whether the technology will be able to provide, under certain circumstances, solutions in which the customers will be interested. This will depend on the match between the features of the technology and the interests of the customers from different points of view.

For this reason,

We have to analyse the relation between the technology characteristics and customers' needs and preferences

For a meaningful analysis of possible customers and uses and market prospects, a global analysis is not enough. Different groups of customers with specific characteristics have to be identified and analysed separately.

To divide customers into different groups is not a new idea. In fact, market segmentation is one of the essential concepts of marketing. Market segmentation divides a market into well-defined slices. A market segment consists of a group of customers who share a similar set of needs and wants (Kotler & Keller 2016).

When the entrepreneurial opportunity will not lead to new products but to improvements of the existing ones, the segmentation of the current market is usually applicable to the analysis. In general, this is not the case in the technological entrepreneurship area. Most often, the development of a segmentation analysis faces several limitations, such as

- The specific features of the products based on the technology under consideration are still uncertain, and the features of their future competitors also are not fully known.
- The diversity of possible customers comes not only from the customer characteristics but also from the possible uses. Since the analysis is developed in the preliminary phase of the entrepreneurial process, many different possibilities should be considered.
- As real transactions are not taking place, we do not have data about customers' behaviour and we do not have the basis for a formal segmentation analysis.

Therefore, most often a complete segmentation analysis is not possible. However, we can identify groups of possible future customers and the uses in which they will be interested. These groups and uses will be a first approach to the future segmentation.

In sum,

When segmentation is still not possible, we will identify groups of future customers and uses that will be the basis of the future customer segmentation

The identification of combinations of possible customers and uses of the products that the technology will make possible is addressed in this chapter, while market prospects are dealt with in the next one. Next, some procedures and recommendations about how to identify the possible customers and uses are presented.

6.2 FACTORS TO CONSIDER

Most probably, at this stage of the technology evaluation, we already have in mind where the technology could be applied. However, it is highly recommended to carry out a systematic analysis of the possibilities. Often, the analysis will uncover interesting new options and new aspects of the possibilities of which we were already aware.

Who the possible customers are depends, to a large extent, on the use of the technology that we are considering. Although the analysis was restricted to a certain area of application of the technology, the specific uses can take very different forms. Different factors can make some uses different from others, in spite of sharing the same basic approach.

Consider, for example, solar cars. We can ask ourselves who the possible customers of this kind of car are. Probably, a single answer would not be correct. In effect, we can take into account some quite different usages. Consider, for instance, the applications of solar energy to the cars that follow:

- Concept solar car from the company Hanergy. The solar panels of this car are able to generate 8 to 10 kW/h from 5 to 6 hours of sunlight, which is enough to drive 50 miles (Turkus 2016). The current conversion rate of its cells is 31.6%, and it is expected to be 38% in 2020 and 42% in 2025, which would make a fully-solar powered car possible (Feijter 2016).
- Stella Lux solar car. This is a concept car designed by Solar Team Eindhoven, a group of students. It is made of lightweight aluminium and carbon fibre and it weighs only 375 kg. It can travel up to 650 km on battery power and up to 1000 km on a sunny day. According to its designers, Stella Lux is a net-positive energy car, which means that it generates more energy than it uses (Lombardo 2015).
- Toyota Prius photo-voltaic roof. It integrates a 280 W solar panel and is included in some of the models of the Prius. Under full sun it could add about four miles to the car's range (Lombardo 2017).

The three approaches are radically different. While the Toyota roof is little more than an aesthetic complement, Hanergy offers limited autonomy and Stella's promised features are astonishing. We would need more information to think about possible customers. However, it seems clear that the fact that someone could be interested in one of the options does not necessarily imply that they would be interested in the others.

The possibilities we will consider will not always be so different. However, there will usually be some different ways to take advantage of the technology application. To analyse these, we can take into account different factors, such as

- Configurations,
- Combinations with other technologies,
- Specific uses and contexts,
- Kinds of customers.

The generation and selection of appropriate factors will make it possible to identify possible customers and uses. This is sometimes a complicated task, as it implies taking into account a significant number of possibilities. Structural methods can be used for developing this task. These are presented next.

6.3 STRUCTURAL METHODS

Structural methods are classical procedures to analyse the prospects of a technology. Morphological analysis and relevance trees are structural analysis methods. These two methodologies are used to analyse in depth the characteristics of a technology and deduce some insights into its future.

Relevance trees

Relevance trees consist in systematically breaking down a problem as a method for finding a solution (Cho & Daim 2013). The relevance tree methodology includes the following steps:

1) Define the business under consideration
2) Develop an initial list of relevant factors
3) Make an array using an initial categorization scheme
4) Fill gaps and identify new factors
5) Assemble initial forecasts and purge array
6) Search for relationships and identify prospective trees
7) Translate to specific threats and opportunities.

The results obtained from this analysis are usually represented by a tree-shaped graph, which gives the name to the method. Figure 19 shows the structure of a relevance tree.

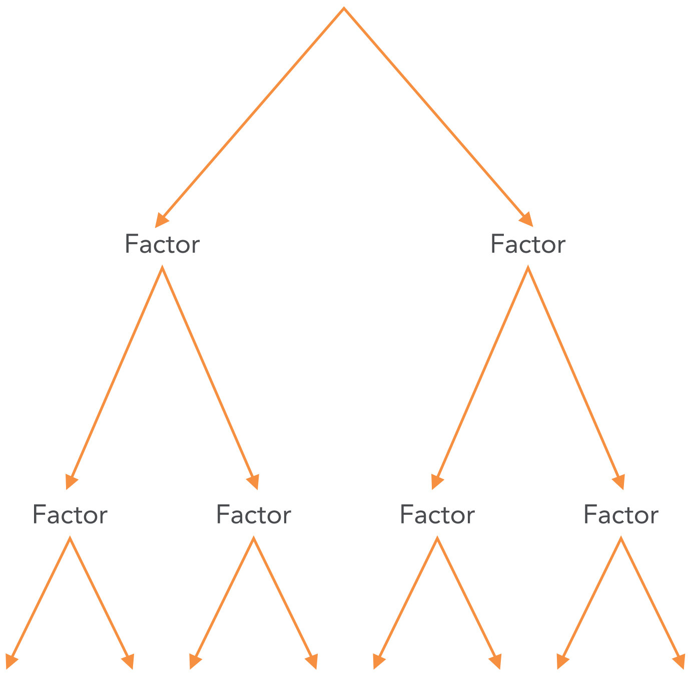


Figure 19. Structure of a relevance tree

The method and the representation of the results of relevance trees resemble mind maps, a very popular tool. Unlike mind maps, relevance trees are intended not only to identify

some factors but also to structure them. The tree shape reflects the categorisation obtained. Figure 20 shows a simple example of a relevance tree showing some options when organising a professional training course.

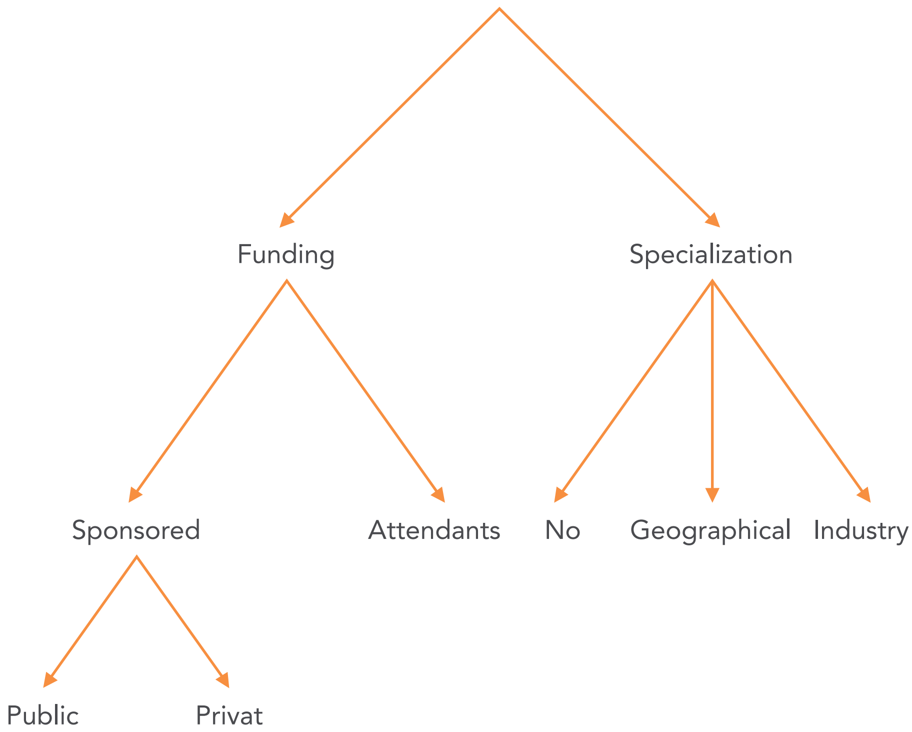


Figure 20. Some options when preparing a professional training course

Morphological analysis

Another structured analysis method to consider is morphological analysis. Morphological analysis is used to check alternative specific options for the future uses of a technology, or, in general, of a certain resource. Future uses determine largely the possibilities of the technology.

Morphological analysis requires knowledge of all possible solutions to a problem in order to find new uses of the technology. The morphological analysis methodology includes the following steps (Ritchey 1998):

1) The problem to be solved is very concisely formulated;
2) All of the parameters that might be of importance for the solution of the given problem are identified and analysed;
3) A morphological box or multidimensional matrix, which contains all of the potential solutions of the given problem, is constructed;

4) All solutions contained in the morphological box are closely scrutinized and evaluated with respect to the purposes that are to be achieved; and
5) The suitable solutions are selected and are practically applied, provided the necessary means are available. This reduction to practice requires, in general, a supplementary morphological study.

The general structure of a morphological analysis is presented in Figure 21.

Factor 1	Factor 2	Factor 3	...
Option 1	**Option 1**	**Option 1**	
Option 2	**Option 2**	**Option 2**	
Option 3		**Option 3**	
...			

Figure 21. Structure of the morphological analysis

An historical case of morphological analysis illustrates the functioning of this method. The Swedish National Defence Research Agency (FOI) applied a morphological analysis to evaluate the future of the Swedish bomb shelters (Ritchey 1998). After the end of the Cold War, the possible uses of these shelters were analysed. This analysis is a good example of how morphological analysis can be applied to take into account the different uses of a technology. A reduced version of the matrix generated is presented in Figure 22. This matrix contains 2,304 possible configurations, while the original 10-dimensional shelter matrix contained more than 500,000 possible configurations.

Geographic priority	Functional priorities	Size and cramming	New construction	Maintanance	General philosophy
Metropoles	All socio-tech. functions	Large, not crammed	With new construction	More frequent maintenance	All get same shelter quality
Cities +50,000	Tech support systems	Large & crammed	Compensation	Current levels	All take same risk
Suburbs and countryside	Humanitarian aims	Small, not crammed	New only for defence build up	No maintanance	Priority: Key personnel
No geo-priority	Residential	Small & crammed			Priority: Needy

Figure 22. Morphological analysis applied to Swedish bomb shelter (Ritchey 1998)

The quality of the results of the structured analysis methods depends on the quality of the information available and the capacity of analysis.

6.4 IDENTIFICATION OF POSSIBLE CUSTOMERS AND USES

Technological opportunities can have very different levels of concretion of how the products finally obtained will turn out. This level of concretion determines to a large extent how to analyse who the possible future customers will be.

Some technological opportunities lead to products that are, in fact, similar to the current ones, but offer some specific advantages. In this case, an analysis of the current market can offer relevant insights into the possible customers and uses. Assume that someone was able to manufacture a non-iron cotton shirt – something that would be more appealing than it might seem for many people. The analysis of the possible customers and uses of this product could take advantage of the information available on the characteristics and preferences of shirt buyers.

On other occasions, the final features of the products that will derive from the development of a technology are not known. When a product has a high degree of novelty, the reaction of the customers is very difficult to foresee. However, we can take advantage of the characteristics of the products to deduce who could be interested in them.

In all cases, a systematic analysis of the different factors influencing the possible customer interest will provide useful insights. To do so, we should identify which are the combinations of factors that are most relevant. The steps to perform this analysis are

- Define the elements that will lead to the most relevant alternatives in terms of configuration, context and kind of customers – relevance trees can help with this.
- Obtain a list of the feasible combinations of configuration, context and kind of customers. This list will be used to analyse the market prospects of the entrepreneurial opportunity – the recommended tool for this is morphological analysis.
- Analyse the combinations obtained by using the information available, including the technical evaluation parameters and the appropriateness map, presented in CHAPTER 4. Based on this, select the combinations describing the circumstances in which the prospect of market success seems clear.
- Analyse further the selected combination. This additional analysis can be developed following the procedure presented in CHAPTER 7.

6.5 EXAMPLES

Morphological analysis: shipping container housing

The possibility of using shipping containers as houses has been analysed because it could offer good advantages in terms of environmental impact, affordability and flexibility. Alternative ways of applying this concept can be identified by using the morphological analysis, as shown in Table 18[1]. The factors involved reflect very different aspects of the decisions to take, such as cost aspects, location, characteristics of the users and some technical alternatives. The number of combinations is 729 and they should be analysed in more detail.

Initial costs	Ease of maintenance	Proximity to an urban centre	Primary source of power	Size of a standard family	Amenities or comforts in a standard housing unit
High cost to set up	Regular maintenance	Less than 20 km	Conventional fossil fuel sources	Small family	Bare minimum
Moderate cost to set up	Periodic maintenance	50 to 70 km away	Mix of conventional and renewable sources	Moderate family	Modest living conditions
Low cost to set up	Low maintenance	More than 70 km away	Renewable sources	Large family	State of the art comforts and amenities

Table 18. Matrix of the morphological analysis of shipping container housing

Morphological analysis: electric vehicle implementation models

The implementation of electric vehicles involves a number of decisions. Morphology analysis has been used to represent and analyse the different alternatives in a remarkable paper (Jun & Muro 2013). In the paper, the different aspects to consider are divided into three blocks, which are vehicle and battery, infrastructure system and system services. The square box that corresponds to the second block, the infrastructure system, is shown in Figure 23.

Infrastructure systems				
Parameters	Alternatives			
Type of power supply	Wired	**Wireless**		Battery exchange
Accessibility	Private	Semi-public		Public
Power connection	1-phase	3-phase	**high V AC**	**high V DC**
Connection type	Undirectional		Bidirectional	
Info flow	**None**	**Unidirectional**		Bidirectional
Info processing	**Day-ahead**	**Intra-day**		Real time

Infrastructure systems				
Parameters	Alternatives			
Operator of power supply	Private	Energy provider	Independent provider	State
Billing type	No fee	Fixed rate		Pay per use
Metering	No metering	At charging station		In vehicle

Figure 23. Parameters and alternatives in the implementation of electric vehicles concerning the infrastructure system (Jun & Muro 2013).

In the box, several parameters and the corresponding alternatives are included. The number of parameters is 9 while the total number of alternatives is 7,776. Some alternatives are selected for further analysis and are marked in grey in the square box.

7 MARKET PROSPECTS

Learning objectives

In this chapter you will learn

- How to address the analysis of the market attractiveness of the combinations of possible customers and uses
- How to consider the influence on the market reaction of eagerness to change, industry structure and regulation, and external impact
- How to obtain useful insights into market prospects.

7.1 INTRODUCTION

After identifying feasible combinations of possible customers and uses, the next stage is to evaluate their future market potential. As detailed in SECTION 6.1, a technology evaluation in the area of entrepreneurship should contain an analysis of market prospects. This analysis has to take into account the products that could be developed, starting from the technology and the application areas under scrutiny. The proposed steps are to

- Consider what is important for customers.
- Consider the influence on the market reaction of eagerness to change, industry structure and regulation, and external impact.
- Consider other information in relation to the market prospects, both already available and obtained for this purpose.

The groups of possible future customers and uses that we have identified as part of the technology evaluation are the basis of the future customer segmentation. Similarly, market prospects can be used to establish market targets.

Besides, market prospects will be useful as the basis for investment decisions as they broadly determine the profit prospects of the opportunity. It is certainly impossible to forecast accurately the sales and profits of the products derived from a technological innovation. Anyway, the people in charge of investment decisions will undoubtedly take into consideration the future sales prospects.

7.2 MARKETABILITY

We might think that the concepts mentioned so far are enough to know about market prospects. To check whether a technological solution has good options to be competitive, we can use the analysis of the technical evaluation parameters and the appropriateness map, presented in CHAPTER 4. Besides, we can identify potential customers and uses by taking advantage of the methods and techniques presented in CHAPTER 6. However, this is not enough.

Effectively, the fact that a product offers a reasonable solution to a certain need of some possible customers is necessary but not enough to get them to buy. Some particular circumstances affect the marketability of a product or a set of products.

Thus, we should take into account that

Some specific market aspects can have strong repercussions on the adoption of a technological solution and have to be addressed when analysing it

Aspects such as eagerness to change, industry structure and regulation, and external impact can have a strong influence on the market reaction. These are addressed next.

Eagerness to change

For customers to adopt a new solution, they have to have some reason. This reason is not always an objective advantage. Illusory qualities are sometimes good strategy. One should not rely on a technology evaluation to define how to attract customers. However, it is possible to detect some characteristics of the product that can facilitate the future commercialisation. Considering how the new products would change the customers' life is a good method to do so.

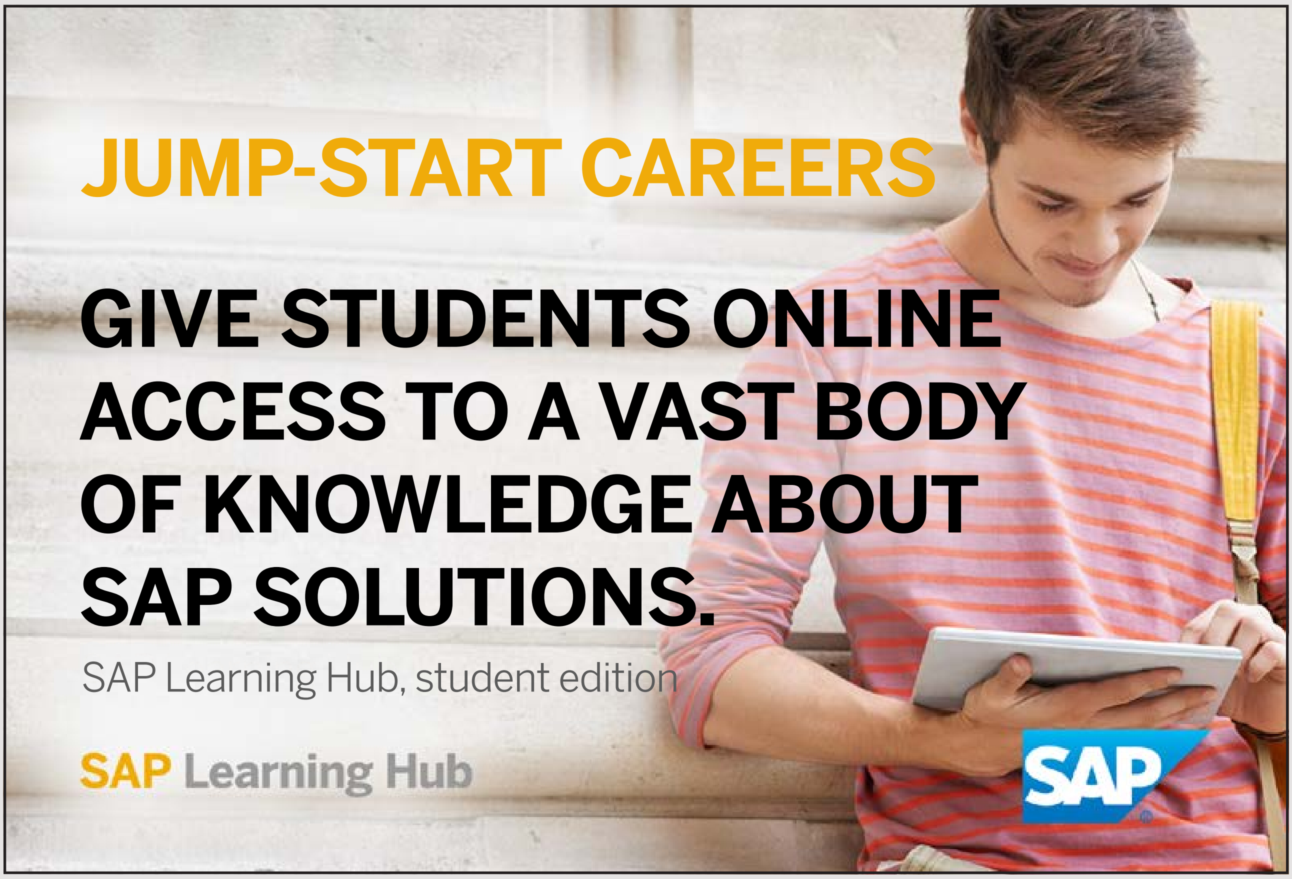
When customers decide to buy a product or service, they change, in some way, their previous experience. Will this change be enough to compensate the cost and effort of obtaining the new product? We can make some conjectures about this by specifying the changes that will occur.

We are considering a technology innovation and a certain area of application. The technology innovation will end in a range of products that will address some needs, more or less explicit, of the customers. How do they address these needs at the current moment? Is it important for them to improve the present situation? Can we expect significant sacrifices on their part to obtain the new products?

The Four Actions Framework and Buyer Utility Map, which are presented in Table 19, are useful frameworks to develop this analysis (Kim & Mauborgne 2004). While the Four Actions Framework proposes considering which elements of the current products will be modified by a new product, the Buyer Utility Map puts the emphasis on identifying the specific aspects and stages of customer experience that a new product is able to improve.

Four Actions Framework	Which of the factors that the industry takes for granted should be eliminated? Which factors should be reduced well below the industry's standard? Which factors should be raised well above the industry's standard? Which factors should be created that the industry has never offered?
Buyer Utility Map	Utility Levers: Customer productivity, Simplicity, Convenience, Risk, Fun and Image and Environmental Friendliness. Stages of the Buyer Experience Cycle: Purchase, Delivery, Use, Supplements, Maintenance and Disposal.

Table 19. Four Actions Framework and Buyer Utility Map (Kim & Mauborgne 2004)



In sum,

Analyse what is important for customers by considering how customers' experience will change from different points of view

Industry structure and regulation

To consider structure and regulation aspects could seem premature when performing a technology evaluation. However, the evaluation could be considered incomplete if these aspects are not addressed. The next steps of the entrepreneurial process, that is to say, the definition of a value proposition and business model and preparation of a business plan, will be clearly influenced by the industry structure and the regulation.

In particular, the influence of market structure on the expectations for a new business initiative is very important. In general terms, a highly concentrated market restricts the opportunities to participate in it, or, at least, to make profits. However, in the case of what are called disruptive technologies, things are not exactly like that.

Disruptive technologies bring to a market a very different value proposition from that previously available (Christensen 1997). Existing companies are often unable to successfully adopt disruptive technologies. Therefore, the current industry structure is not very relevant. It is common for disruptive technologies to disrupt the whole industry and make way for a new set of industry actors. In consequence, a critical question when considering a technological innovation is whether the innovation is disruptive and will be able to disrupt the industry.

Besides, regulation should also be considered. Activities such as transportation, energy and health, among others, are regulated in detail and closely controlled by public authorities. It is common that regulations limit the applicability of new technological solutions that have proved to be advantageous from the technical point of view. In fact, regulation issues are a common source of wrong decisions of entrepreneurs who do not give them sufficient consideration. In other cases, regulations can favour certain kinds of solutions and give chances to the opportunity we are checking.

It may be thought that limitations or advantages due to regulations lack consistency and will tend to disappear after some time. When a new technology provides strong advantages, it is reasonable to think that it will finally prevail. However, when it is not clear what the best alternative is, regulation can be decisive. In any case, regulatory aspects should be considered and mentioned when evaluating a technology.

In short,

Take into account the industrial context and the regulatory framework in which the technology will be implemented

External impact

The implementation of a new technology or the application of an already existing technology for new uses can have social, economic and environmental impacts. Some impacts will be envisioned and considered important even before the product is fully developed. These future impacts can influence the decisions on the adoption of the technology and, therefore, must be taken into account.

In some cases, a proposal is based on an intended external impact. Some technological solutions are conceived to expand the diffusion of a service, reduce costs or improve environmental sustainability, for instance. In these cases, this specific impact will be considered and measured from the beginning. Even in this scenario, it is recommended to analyse globally what the social, economic and environmental impact will be.

It is not expected that a technology evaluation will include a detailed analysis of every possible repercussion of the implementation of that technology. The development of a new activity brings about a number of changes. It is probable that some jobs will be destroyed and others will be created, for example. The carbon footprint will be modified. However, not all these possible consequences will have an influence on the success of the new products proposed. We should focus on the most important repercussions.

In sum,

Consider the external impact aspects that can be influential in the success of the future products based on the new technology

Insights into the market prospects of a technological opportunity can be obtained based on the different analyses presented so far, as described next.

7.3 ANALYSIS OF MARKET PROSPECTS

The market prospects of a technology depend on the features of the products that will be developed based on it. Besides, they also depend on the context in which the products will be marketed. This context includes alternative technologies and any other factor involved. Consequently, this part of the evaluation of a technology has to take into account all the information obtained and the analysis developed. Future sales are, in fact, the final outcome of the entrepreneurial process.

There is no single correct way to review the market prospects of a technology-based entrepreneurial opportunity. Additionally, an accurate forecast seems not be possible at the technology evaluation stage. The final success of the technology will depend to a large extent on the value proposition and business model and business plans that are developed. However, already at this phase, it is expected that we are able to provide some useful insights on market prospects.

The analysis of market prospects should take into account

- A comparison of the technology with other alternatives in the area of application under analysis. This comparison should be based on the evaluation parameters and the appropriateness map, presented in CHAPTER 4, which are critical for the whole analysis.
- The identification of the potential customers and uses, as presented in CHAPTER 6. From this analysis, we will obtain different groups of customers to be considered separately in the rest of the analysis.
- The marketability of the product that will be developed based on the technology. To analyse this, customer preferences, industry structure, regulations, and social, economic and environmental impact, should be taken into account.
- Other available information, including reports from trustworthy organisations and experts' opinions. In particular, the volume of the potential market can be approximated by using data from the present market, public statistics analysis and the opinions of experts.

In sum,

Take advantage of all the information you have to give insights into the market prospects for each group of possible customers and uses

7.4 EXAMPLES

OLED for lighting

During the last two decades, organic light-emitting diodes (OLEDs) have attracted considerable interest owing to their promising applications in flat-panel displays by replacing cathode ray tubes (CRTs) or liquid crystal displays (LCDs) (Geffroy et al. 2006).

A different OLED application to consider is lighting. OLEDs are dramatically different in appearance and lighting performance from light-emitting diodes (LEDs). They are large in surface area, low in luminance, thinner than LEDs, and usually diffuse in appearance (Miller & Leon 2016).

The report "OLED Lighting Products: Capabilities, Challenges, Potential" (Miller & Leon 2016), was prepared for the Office of Energy Efficiency and Renewable Energy, U.S.

Department of Energy. This report analyses OLED for lighting from the point of view of the customers. It takes into account the features of the product, how they compare with the features of LEDs and some practical aspects. This kind of information can be obtained by combining the results of different analyses of the technology and is the basis of a market prospects analysis. Some of the insights provided are presented in Table 20.

• OLED panel efficacies are disappointingly low for architectural applications, restricting their use to decorative elements rather than the principal light sources in a building, because their energy performance is still half or less of the equivalent fluorescent or LED lighting system. • OLED color characteristics are superior to those of early LEDs. With further efforts to improve red saturation and overall gamut, OLEDs could meet color quality needs even for demanding hospitality interior spaces. • One frustration of luminaire manufacturers is that there is only one dedicated OLED driver on the market at the time of this writing, because driver manufacturers do not see a growing potential OLED luminaire market. Instead, manufacturers have had to work with LED drivers, customizing them as best they can to deliver the current and voltages needed, often outside the optimized efficiency range of the driver. Consequently, the driver is a weak point in the system efficacy. • The OLED panels are thin, light, and deliver a unique quality of light. However, the drivers are still relatively large and brick-like. They do not fit gracefully into the OLED luminaires or mounting canopies, so they must be mounted remotely. That poses extra work for the designer and contractor. • Economies of scale are needed to reduce the cost of manufacturing OLED panels, but the costs are currently too high to achieve the widespread adoption, which would incentivize investment in higher-capacity manufacturing. • For full viability of OLED architectural lighting, the systems will need to deliver higher efficacy, better system components, and lower costs. OLEDs are in their infancy compared to LEDs, but the architectural market is taking notice of a lighting product with an entirely different look and function. The potential for applying OLEDs as a luminous and dynamic building material is exciting, and if OLEDs increase in efficacy, longevity, size, and flexibility, they will give designers and engineers a new tool for creative and effective lighting.

Table 20. OLED for lighting from the point of view of the customers (Miller & Leon 2016)

Regarding market prospects, IDTechEx has developed the report "OLED Lighting Opportunities 2017–2027: Forecasts, Technologies, Players" and offers some interesting insights (IDTechEx 2017). Their results include the following:

- OLED lighting is an emerging solid-state lighting technology. It potentially provides a route into the large and growing global lighting market. The lighting market is, however, complex as it is a highly fragmented space thanks to the existence of a broad technology mix and a diversity of customer needs.

- Market segments include residential, office, industrial, outdoor, hospitality, shop and automotive. Each sector attaches a different degree of importance to upfront cost, energy efficiency, lifetime, light intensity, colour warmth and design features. This explains why the technology mix in each sector is different.
- The market will grow to 2.5 billion USD in 2027 (optimistic scenario). The market growth will, however, be very slow until 2019/2020, where the overall sales at panel level will remain below 200 million USD globally.
- Architectural, hospitality and shop segments will be the first to grow as they prize design parameters the most. Automotive is also promising, given the recent announcements by companies like BMW, but lifetime and reliability still need to be improved. Residential, office, and outdoor should follow later once the cost decreases and the lifetimes are prolonged.

Hydrogen energy technologies in stand-alone power systems

The results of the European Commission funded project “Market potential analysis for introduction of hydrogen energy technology in stand-alone power systems” provided a good

example of the analysis of the market prospects of a new technology applied to a certain area of application – hydrogen technologies in stand-alone power systems, in this case.

The market evaluation proposed involves three areas, demand side, supply side and external factors (Zoulias et al. 2006). A summary of the analysis performed is presented in Table 21. A demand forecasting for the Europe market is presented in Table 22, while external factor evaluations for Greece, UK, Spain, Norway and Ireland are shown in Table 23.

Demand side	The users were grouped in three different segments, depending on their current situation with respect to availability of electricity: (A) high cost grid connected users; (B) conventional SAPS users; and (C) non-electrified users. The most promising markets for this segment are the electrified customers who would want to disconnect from the grid for the following reasons: 1) The grid connection is too expensive to maintain and operate for the grid owner and there is no obligation to upgrade the connection and supply the "expensive" customers. 2) A segmentation of costs from the grid owner results in a high cost for these particular customers, rendering SAPS and stand-alone power systems (H-SAPS) an attractive alternative. 3) The customer is not satisfied with the quality of the electricity supplied through the grid. In light of the assessment of Segment A, Segments B and C were identified as the best potential market for the technology.
Supply side	The long-term hydrogen-related market developments must rely on the major, long-term and visionary market drivers. These are the large energy companies with objectives reaching well into the next 2–3 decades, both with regard to commercial achievements and to their responsibilities to society. Companies such as Shell, BP, Norsk Hydro can have a real impact on the marketplace and when these significant actors go public with their visions for the development of a hydrogen economy, the market will listen. Fortunately, there will be some niche markets along the way, which will give sufficient possibilities for profit, hence giving the technology and infrastructure developers the necessary incentives to put their best efforts into their specific role in the market development.

External factors	Many of the input parameters used for traditional market assessments (costs, lifetime, price sensitivity, public awareness, etc.) are far from being available for H-SAPS as of today. Therefore, a specific model for this assessment was developed. The H-SAPS model aims to provide a qualified assessment of the potential H-SAPS market in certain regions in Europe. The external factors are: Energy policy factors: General political climate, Energy mix (considering security of supply, diversification, and environment), Subsidies and Fiscal measures (tax incentives, certificate trading, etc.) and Implementation of the Renewable Energy Sources directive. Other factors: Security and quality of supply (blackouts, natural disasters, terrorist attacks), Population and public perception, Formal procedures in local planning (environmental regulations, local planning), and Grid system and cost issues.

Table 21. Hydrogen energy technologies in stand-alone power systems (H-SAPS).
Market assessment (Zoulias et al. 2006).

	Number of users	Unit power (kW)	Total power (MW)	Annual demand (GWh)
Rural villages, settlements and rural housing	500,000	3	1,500	1,601
Back-up power systems	2,000	5	10	7
Rural tourism establishments	10,000	5	50	37
Rural tourism establishments with strong energy requirements	1,500	30	45	30
Rural farming and ranching	200	40	8	4
Water desalination plants (small)	550	4	2	4
Waste water treatment	450	10	5	10
Large communication stations	150	10	2	13
Total			1621	1706

Table 22. H-SAPS. Demand side. Estimated future potential market in Europe (Zoulias et al. 2006).

	Greece	UK	Spain	Norway	Ireland
General political climate	2	3	3	3	2
Energy mix	2	2	3	2	2
Subsidies and fiscal measures	3	3	3	2	3
Implementation of the renewable energy directive	2	3	3	3	3
Security and quality of supply	2	2	2	3	2
Population and public perception	2	2	2	2	2
Formal procedures in local planning	2	2	2	2	2
Grid system and cost issues	2	2	2	3	2
Total score	17/24	19/24	20/24	20/24	18/24
Total ratio	0.71	0.80	0.83	0.83	0.75

Table 23. H-SAPS. External side. External factor evaluations for Greece, UK, Spain, Norway and Ireland (Institute for Energy Technology 2006)

8 REPORT WRITING

Learning objectives

In this chapter you will learn

- How to define the objectives of a technology evaluation report
- How to select the appropriate contents
- How to write the conclusions.

8.1 INTRODUCTION

After completing the various steps of a technology evaluation, we will have gathered a quite long list of pieces of information, analyses and insights concerning the entrepreneurial opportunity we are considering. Assuming that the steps presented in this book have been followed, we have the following outcomes:

- Obtaining and evaluation of information on the technological basis of the entrepreneurial opportunity and the projects that develop the different aspects of the opportunity.
- Analysis of the level of development of the different projects involved, based on the information available.
- Establishment of the technical evaluation parameters that make it possible to compare the technological solution considered with other options.
- Determining the possible customers and uses corresponding to the one or more application areas of the technology that we are considering.
- Insights into market prospects for each group of possible customers and uses identified.

Each of these analyses includes the applications of several tools of analysis and leads to a number of partial conclusions. Often, the details and conclusions of the analyses performed will have been included in documents. We can use these documents to prepare the report, but it is clear that some additional elaboration will be necessary.

When a technical report is concluded, it is common to prepare a report presenting the work done and the results obtained. This report is so important that there is sometimes confusion between the analysis itself and the report. In fact, it is usual to be asked to prepare a report on something. Naturally, the knowledge of the topic that we have obtained goes beyond the report. This is why we can be asked for details and clarification. However, the report is what will remain from the analysis performed and the main way to communicate the information and results obtained.

The rest of the chapter is intended to address how the information and results we already have should be used to prepare a complete and useful report.

8.2 OBJECTIVES OF THE REPORT

It is necessary to clarify what are and what are not the objectives of the report. The report on the analysis of an entrepreneurial opportunity is not a review of the work done, although some details can be given to contextualize it. Maybe we will be asked to give details on the time spent on the analysis, the resources used or who did each task, for example. It is possible that we ourselves are interested in controlling these aspects. However, this information is not about the technology evaluation, but about our work. In contrast, the final report on a technology is about the technology itself.

Thus,

A technology evaluation report is not intended to give details on the work that its authors did, but on the technology

A technology evaluation is developed for some reason. Naturally, the contents of the report we should prepare will depend on the reason for which the analysis is performed. Assume, for instance, that we are members of a research institute and we are considering focusing the research of the institute on a certain domain. In this case, what the research challenges are in developing the opportunity will be of critical importance.

In contrast, in the case where the analysis is performed as the first step of an entrepreneurial initiative, the business prospects will be critical. The particular circumstances of the possible promoters of the new business and the context in which the activity would be developed will influence the focus of the report.

Sometimes, the reason for developing a technology evaluation is a general interest in this technology. This kind of analysis is usual in universities or public institutions. Business people can also be interested in general information for undisclosed reasons. In all these cases, the information we provide should cover the different aspects involved.

In all cases,

The report on a technology evaluation should focus on the needs and interests that have motivated its development

A technology evaluation report should not be a case in favour of a certain option. The authors of an analysis of an entrepreneurial opportunity are almost never neutral. This is particularly true when it comes to entrepreneurship. The first decision of the entrepreneur is to spend time analysing the viability of an idea. This means that, if the conclusion is that the idea was not as good as it seemed, the time and resources used would not generate any result.

It is often said that, in business, negative experiences are worth gold. Maybe, but what the entrepreneur really needs are incomes. To accept failure is not easy. It can lead to decisions based on the sunk cost, which has been reported to be one of the main sources of wrong decisions. To decide based on the sunk cost means that you go on with an activity because of the resources you already have spent on it, instead of taking into account the future prospects. To be objective, the first challenge is to accept that we could be wrong.

The readers of the report need to take good decisions. They are interested in objective and trustworthy information, reasoning and conclusions. This is especially true when it comes to technical aspects. The passion of an entrepreneur for their project, for instance, is positive and contagious. However, this enthusiasm should not reduce the rigour of the technical analysis.

In consequence,

A technology evaluation report has to maintain rigour and objectivity despite the opinions and interests of its authors

A technical report is neither an opinion nor a verdict. In general, the readers of the report will be diverse. The report could be of interest to specialists in the technology involved, specialists in other related technologies, experts from industry, business people and the public. We have to assume the capacity of analysis of whoever who reads the report and give them enough elements to understand and assess our reasoning.

Naturally, some aspects will be not easily understandable for some readers. We do not control who reads the report and we cannot guarantee that all readers have the appropriate background to have a role in the development of the technology under analysis. However, the report should be fully understandable to readers with a basic knowledge in the area.

In sum,

A technical report should include information and details to make it possible for the reader to understand and verify the reasons and conclusions presented

8.3 CONTENT OF THE REPORT

The structure of a report depends on the specific information to communicate. In any document, the division into sections and subsections is intended to make the reading easier. Therefore, no specific structure for the report is recommended here. The structure should be established by the author after gathering the contents to include.

The first step of the writing of the report is to define the contents to include. The report should include, at least, the following contents.

a) Definition of the scope

The different chapters of the book have dealt with how to develop a technology evaluation in entrepreneurship. The line that separates one entrepreneurial opportunity from others is not always clear. Consider the example of Li-Fi, which was mentioned in SECTION 2.5. What is the technological opportunity, the specific Li-Fi approach or, in general, visible light communication technologies? In addition, what uses have to be considered? Will we take into account a specific use, such as, for instance, machine-to-machine communication, or all the possible uses?

The scope of an analysis depends on external circumstances. Sometimes an analysis is developed because someone has an interest in some specific technological solution or in some concrete application, and decides to perform, or to request to others to perform, the analysis. At other times the scope is limited because there is limited time. In still other cases, we can be asked to cover all possible options. What is clear is that, in the report, we have to define from the beginning the technology or kinds of technologies and the one or more application areas that we are considering.

b) Context

Contextual information is intended to make it understandable why we performed the analysis and why we developed it in a certain way. Although giving this information is not necessary to present the results obtained, it is usually included in any report.

A particular contextual aspect to take into account is the importance and possibilities of the technology, or the group of technologies to which the technology considered belongs. It will often happen that the reader knows well why the technology is important and how it can be used. However, this is not always the case. Even when the reader is aware of what we are speaking about, it is good to clarify where our work starts from.

Thus, we will mention

- The importance of the technology, or the group of the technologies to which it belongs.
- The reason that the use or uses considered are relevant; in other words, why the possibility that some needs that are better addressed by applying the technology solution we are analysing deserve our attention.
- The technological, industrial and economical context in which our analysis takes place or on which, for some reason, we will focus.

- The specific motivations of the development of the analysis that we are going to present.
- In general, why the technology and the application considered are interesting and deserve to be analysed.

c) Specific information on the entrepreneurial opportunity

Just as for the context, we do not know to what extent the readers are aware of the particularities of the technology and the one or more application areas that we are considering. In fact, it would be acceptable to give only the technical specifications and references necessary to identify what we will analyse. However, some of the readers will be grateful if we provide some details, while readers who know the technology will simply skip this part.

Naturally, a technology evaluation report is neither a lesson nor a scientific treatise. A technical evaluation report usually includes the most relevant particularities of the technology and its functioning. Some aspects will not be fully understood by people who do not have the necessary technical background, while the outcomes of the analysis should be comprehensible for anyone.

d) Situation and prospects

After describing the entrepreneurial opportunity, we have to consider what the present stage of development of the technology is, and how it is expected to evolve in the future. When a technology is considered an entrepreneurial opportunity, usually some research groups and companies are already working on its development and improvement. In principle, a technology could still be an entrepreneurial opportunity because of its intrinsic characteristics and even though no-one is working on it. However, it is not common to consider entrepreneurial opportunities based only on ideas or theoretical approaches.

The projects that are developing the technology or some application of the technology in the application area considered should be presented. The information to present includes the objectives of the projects, the current level of development and the foreseeable future development. Naturally, the information available will often be limited and the uncertainty about it should be clearly explained.

How the technology will evolve in the future is also critical. In this book, it is recommended to define technical evaluation parameters (SECTION 4.2) before developing the technology forecasting (CHAPTER 5). The reason is that it is useful to know the parameters to consider before analysing the future evolution of the technology. Effectively, usually the future evolution of a technology solution is traced with some critical parameters. However, when presenting the results, it seems natural to present together the present state and the future evolution.

e) Comparison with other solutions

An analysis of a technology and an application of this technology could omit the comparison of its performance with other technologies. The scientific and technical literature often focuses on specific technical aspects and does not mention at all, or mentions only as a reference, how it compares with others. However, when the analysis is intended to be used to support business decisions, how the technological solution considered compares with others is the most critical result. In fact, customers' decisions will depend on the comparison of alternatives.

As mentioned in CHAPTER 4, it is not common for a technology to surpass all the others in any aspect and context. The report should make clear the results of the comparisons in different circumstances and from different points of view. When the results that we can expect from two different technologies are similar, no clear conclusions can be obtained from them. However, unambiguous results can be a good predictor of which technology will be predominant in the future in a certain context.

How different technologies compare changes over time. In fact, and as mentioned in SECTION 5.3, in the first phase of the life cycle of a new technology its performance is usually low but increases in the next phases. Although it is almost impossible to make accurate predictions on the future performance evolution, reasonable conclusions available about it should be presented and justified.

f) **Possible customers and uses and market prospects**
For the report to be complete, the possible customers and uses identified have to be presented. It is important to detail why certain groups of possible customers and uses are considered promising for the technology. Naturally, these results are uncertain by nature. Since fulfilling the predictions depends on certain hypotheses being finally confirmed, these assumptions have to be clearly presented.

Besides, market prospects also have to be presented. No one will expect accurate predictions in this respect. Future sales are quite unpredictable and the reader will be aware of this. The report should provide some general insights that can help to make decisions or establish plans.

Additionally, the report should present the conclusions obtained. Some recommendations on how to develop the conclusions part are presented in the section that follows.

8.4 WRITING THE CONCLUSIONS

Sometimes, the conclusions of a report could be seen as a summary of the rest of the document. In effect, it is a good idea to recall some of the most critical aspects presented before. A good reason for this is that many readers will start by reading the conclusions. Only if the conclusions are relevant to them will they then check the whole document. To recall some important aspects can also be useful for readers who start reading from the beginning. However, the part of the conclusions that summarizes the rest of the document is only auxiliary.

The essential part of the conclusions is the presentation of the relevant results obtained. Usually these results have already been presented in the previous parts of the report. However, in the other sections the emphasis is on how the results are obtained. In the conclusions, we focus on the importance of the results and their consequences. Besides, the presentation of the main information and results obtained usually leads to some general conclusions.

To summarize,

The conclusions of the report should present the relevant results obtained, their consequences and the general conclusions obtained

Writing the conclusions requires, above all, a deep reflection on what is important for the readers. The focus should be on results that are useful to the reader in order to take decisions in relation to the technology and the area of application under consideration.

Besides, should the analysis developed and details of the results be mentioned in the conclusions? Certainly not all of them. It is quite probable that a good part of the analysis performed has led to results that were already known or that are of little use. From some other analysis, no results may have been obtained. None of this should be included in the conclusions. Even analyses that gave results that were expected should be omitted.

The conclusions should emphasise a small number of results that are relevant and useful. The analysis that led to these results should also be mentioned. If it has not been possible to find out anything about some critical aspect, this also must be explained. In every case,

it has to be emphasized what the results obtained, or the lack of them, imply for the future of the technology and the area of application we are analysing.

In short,

In the conclusions, include only relevant and useful results, why they are important and how you obtained them

It is usual that, after developing an analysis, its authors have opinions and ideas of interest about the object of the analysis. Besides the results that can be sustained and justified, other deductions are doubtful or mere conjectures but may still be of interest to the readers. In the case of the technology evaluation in entrepreneurship, these can include

- Uses of the technology in the area of application considered that now seem improbable but that are not impossible.
- Possible value propositions and business models that could be developed based on the technological solution analysed.
- Possible changes in the market, new consumers' tastes or other factors.
- In general, any long-term prospect.

To include in the conclusions insights that you can only envision, it is necessary that they fulfil two conditions. First, they have to be novelties that would be very important if they were finally confirmed. If they are mentioned despite not being very probable, it is because they could still be critically important. Additionally, the fact that they are not results of the analysis but very uncertain possibilities has to be clearly stated.

In sum,

Mention possible future opportunities and long-term vision if they could be very important for the future and remark on how doubtful they are

9 REFERENCES

Aceytuno, M.-T. & Cáceres, F.R., 2012. On the nature of technological opportunities: concept, origin and evolution. *International Journal of Entrepreneurial Venturing*, 4(2), pp. 168–180.

Alonso-Zarate, J. & Dohler, M., 2017. M2M Communications in 5G. In *5G Mobile Communications*. Cham: Springer International Publishing, pp. 361–379. Available at: http://link.springer.com/10.1007/978-3-319-34208-5_13.

Arnon, S., 2015. *Visible light communication*, Cambridge University Press. Available at: http://www.cambridge.org/catalogue/catalogue.asp?isbn=9781316236666.

ATWOnline, 2017. Airbus and Boeing Average List Prices 2017 | ATWOnline. Available at: http://atwonline.com/data-financials/airbus-and-boeing-average-list-prices-2017 [Accessed November 5, 2017].

Charlton, A., 2016. Super Bowl 2016: Watch Microsoft HoloLens bring NFL match of the future to your living room. *International Business Times*. Available at: http://www.ibtimes.co.uk/super-bowl-50-watch-microsoft-hololens-bring-nfl-match-future-your-living-room-1541663 [Accessed November 5, 2017].

Cho, Y. & Daim, T., 2013. Technology Forecasting Methods. In *Research and Technology Management in the Electricity Industry*. Springer London, pp. 67–112. Available at: http://link.springer.com/10.1007/978-1-4471-5097-8_4 [Accessed March 27, 2017].

Christensen, C.M., 1997. *The Innovator's Dilemma*, Available at: https://www.opac.uni-erlangen.de/webOPACClient/search.do?methodToCall=quickSearch&Kateg=0&Content=2324510&fbt=7955401-2836663.

De Coster, R. & Butler, C., 2005. Assessment of proposals for new technology ventures in the UK: characteristics of university spin-off companies. *Technovation*, 25(5), pp. 535–543. Available at: http://linkinghub.elsevier.com/retrieve/pii/S0166497203001913 [Accessed March 8, 2017].

David Reid, 2017. Supersonic flight promised by 2023 as Boom announces airline orders. *CNBC*. Available at: https://www.cnbc.com/2017/06/20/supersonic-flight-2023-as-boom-announces-airline-orders.html [Accessed November 5, 2017].

Energy Agency, I., 2014. *Technology Roadmap Solar Photovoltaic Energy – 2014 edition*, Available at: https://www.iea.org/publications/freepublications/publication/TechnologyRoadmapSolarPhotovoltaicEnergy_2014edition.pdf [Accessed March 28, 2017].

European Commission, 2014. *EVALSED – The resource for the evaluation of Socio-Economic Development: Sourcebook – Method and techniques – Regional Policy – European Commission*, Available at: http://ec.europa.eu/regional_policy/en/information/publications/evaluations-guidance-documents/2013/evalsed-the-resource-for-the-evaluation-of-socio-economic-development-sourcebook-method-and-techniques [Accessed January 9, 2018].

Feijter, T. De, 2016. Hanergy Launches Solar Powered Cars In China. *Forbes*. Available at: https://www.forbes.com/sites/tychodefeijter/2016/07/04/hanergy-launches-solar-powered-cars-in-china/#13c0b7cf3bb3%0A [Accessed June 15, 2017].

Fleisher, C.S. & Bensoussan, B.E., 2007. *Business and competitive analysis: effective application of new and classic methods*, FT Press. Available at: http://www.loc.gov/catdir/toc/ecip071/2006030892.html.

Fung, M.K., 2004. Technological Opportunity and Productivity of R & D Activities. , (1988), pp. 167–181.

Geffroy, B., le Roy, P. & Prat, C., 2006. Organic light-emitting diode (OLED) technology: Materials, devices and display technologies. *Polymer International*, 55, pp. 572–582.

GreyB, 2016. *LiFi: From Illumination To Communication*, Available at: http://info.greyb.com/hubfs/Downloadable_Reports/LIFI-Landscape-study.pdf?submissionGuid=1a03fceb-c044-41a1-b0c1-af1a6c6722b8 [Accessed March 7, 2017].

Haas, H., 2017. Harald Haas | Speaker | TED.com. Available at: http://www.ted.com/speakers/harald_haas [Accessed March 7, 2017].

Héder, M., 2017. From NASA to EU: the evolution of the TRL scale in Public Sector Innovation. *The Innovation Journal*, 22(2), pp. 1–23.

Hoffman, H.F., 2014. *Engineering and the Capstone Course. Fundamentals for Students and Instructors*, Cham: Springer International Publishing. Available at: http://link.springer.com/10.1007/978-3-319-05897-9_1 [Accessed March 8, 2017].

IATA, German Aerospace Centre & Georgia Tech, 2013. *IATA Technology Roadmap 2013*, Available at: https://www.iata.org/whatwedo/environment/Documents/technology-roadmap-2013.pdf.

IDTechEx, 2017. OLED Lighting Opportunities 2017-2027: Forecasts, Technologies, Players.

IEEE Spectrum, 2017. Mobile World Congress 2017: PureLiFi Debuts New Li-Fi Luminaire and Shares Progress on Commercial Pilots. *IEEE Spectrum*, 54(3).

Innovation Seeds, 2016. Generation of Electricity by the Movement of People and Vehicles on a Designed Pavement Surface. Available at: http://www.innovationseeds.eu/virtual_library/results/generation-of-electricity-by-the-movement-of-people-and-vehicles-on-a-designed-pavement-surface.kl [Accessed December 12, 2012].

Institute for Energy Technology, 2006. *Market Potential Analysis for Introduction of Hydrogen Energy Technology in Stand-Alone Power Systems*.

Jun, M. & Muro, A. Di, 2013. Holistic Methodology to Analyze EV Business Models. *International Journal of Innovation, Management and Technology*, 4(2). Available at: http://www.ijimt.org/index.php?m=content&c=index&a=show&catid=42&id=679.

Kassem, A. et al., 2016. A value tree for identification of evaluation criteria for solar thermal power technologies in developing countries. *Sustainable Energy Technologies and Assessments*, 16, pp. 18–32. Available at: http://www.sciencedirect.com/science/article/pii/S2213138816000217 [Accessed November 5, 2017].

Kim, W.C. & Mauborgne, R., 2004. Blue ocean strategy. *Harvard Business Review*, 82(10), pp. 76–84.

Kotler, P. & Keller, K.L., 2016. *Marketing Management*, Available at: http://search.ebscohost.com/login.aspx?direct=true&db=bth&AN=44033223&site=ehost-live.

Kuhn, M. et al., 2017. Innovative European Launcher Concept SMILE. In *21st AIAA International Space Planes and Hypersonics Technologies Conference*. pp. 1–14. Available at: https://arc.aiaa.org/doi/10.2514/6.2017-2441.

Lee, S.C. & Jung, W.Y., 2016. Analogical understanding of the Ragone plot and a new categorization of energy devices. In *Energy Procedia*.

Liu, X. & White, S., 2001. Comparing innovation systems: a framework and application to China's transitional context. *Research Policy*, 30(7), pp. 1091–1114. Available at: http://linkinghub.elsevier.com/retrieve/pii/S0048733300001323.

Lombardo, T., 2015. Net-Positive Solar EV Goes 600 Miles on a Charge and Carries Four Passengers. *Engineering.com*. Available at: http://www.engineering.com/ElectronicsDesign/ElectronicsDesignArticles/ArticleID/10402/Net-Positive-Solar-EV-Goes-600-Miles-on-a-Charge-and-Carries-Four-Passengers.aspx%0A [Accessed June 15, 2017].

Lombardo, T., 2017. Toyota Prius Photo-Voltaic Roof. *Engineering.com*. Available at: http://www.engineering.com/ElectronicsDesign/ElectronicsDesignArticles/ArticleID/14433/Your-Next-Car-Will-NOT-Be-Solar-Powered.aspx%0A [Accessed June 15, 2016].

Mainali, B. & Silveira, S., 2015. Using a sustainability index to assess energy technologies for rural electrification. *Renewable and Sustainable Energy Reviews*, 41, pp.1351–1365. Available at: http://www.sciencedirect.com/science/article/pii/S1364032114007916 [Accessed November 5, 2017].

Mankins, J.C., 1995. *Technology Readiness Levels. White Paper, April 6.*

Martino, J.P., 1993. *Technological forecasting for decision making*, McGraw-Hill, Inc.

McGrath, R. & MacMillan, I., 1995. Discovery driven planning. *Harvard Business Review*, 73(4), pp. 44–54. Available at: https://hbr.org/1995/07/discovery-driven-planning.

Musk, E., 2013. *Hyperloop alpha, SpaceX/Tesla Motors.*

NJ Miller & FA Leon, 2016. *OLED Lighting Products: Capabilities, Challenges, Potential.*

Osterwalder, A. & Pigneur, Y., 2010. *Business Model Generation – Canvas* Wiley, ed., Available at: http://www.businessmodelgeneration.com/canvas.

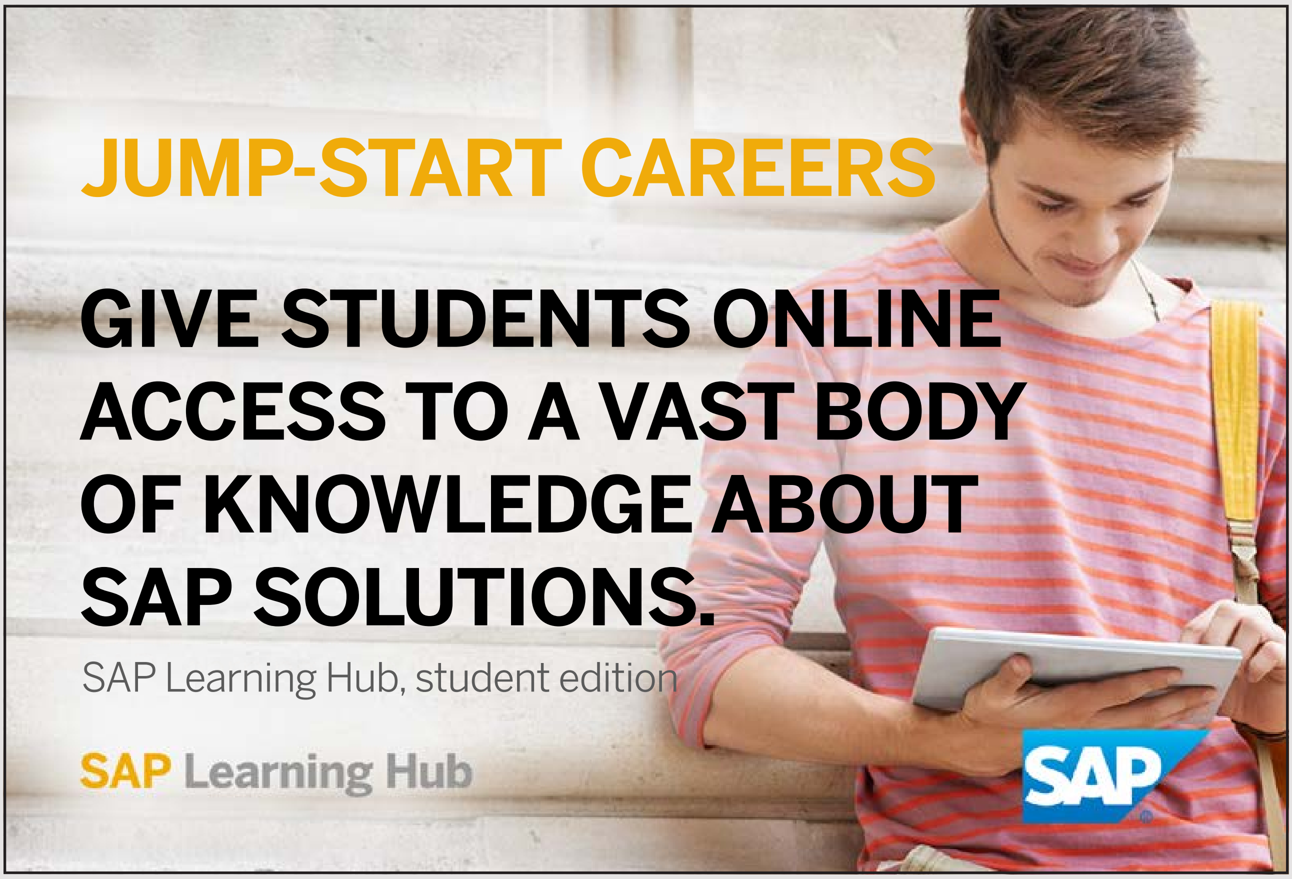
Phaal, R., Farrukh, C.J.P. & Probert, D.R., 2006. Technology management tools: Concept, development and application. *Technovation*, 26(3), pp. 336–344.

Quora, 2016. Which companies are working on LiFi technology and have developed products now? – Quora. *Quora*. Available at: https://www.quora.com/Which-companies-are-working-on-LiFi-technology-and-have-developed-products-now [Accessed March 7, 2017].

Ries, E., 2011. The Lean Startup. *Book*, p.336. Available at: http://theleanstartup.com/book.

Ritchey, T., 1998. Fritz Zwicky, Morphologie and policy analysis. *16th EURO Conference on Operational Analysis, Brussels*, p. 11.

Ross, P.E., 2016. Hyperloop: No pressure. *IEEE Spectrum*, 53(1), pp. 51–54.



Sauser, B. et al., 2006. From TRL to SRL: The Concept of Systems Readiness Levels. *Conference on Systems Engineering Research*. Available at: http://www.boardmansauser.com/downloads/2005SauserRamirezVermaGoveCSER.pdf [Accessed March 8, 2017].

Tablang, K., 2017. Is this $120 Million Supersonic Jet the Future of Commercial Flight? *Forbes*. Available at: https://www.forbes.com/sites/kristintablang/2017/07/21/tom-johnson-cygnus-m3-boom-technology-supersonic-travel/#5a771c2950bc [Accessed November 5, 2017].

Technavio, 2017. *Top 9 Vendors in the Visible Light Communication Market from 2017 to 2021*.

The Times, 2016. PURELIFI raised £7m to bring tech to market. *The Times*.

Tom Johnson Design, 2017. *Cygnus M3 Proposed Specifications*,

Tran, T.A. & Daim, T., 2008. A taxonomic review of methods and tools applied in technology assessment. *Technological Forecasting and Social Change*, 75(9), pp. 1396–1405. Available at: http://dx.doi.org/10.1016/j.techfore.2008.04.004.

Turkus, B., 2016. Hanergy claims solar cars need 5 hours of sun for 50 miles of range. *Autoblog*. Available at: http://www.autoblog.com/2016/07/07/hanergy-claims-solar-cars-need-5-hours-sun-50-mile-range/ [Accessed June 15, 2017].

Uysal, M. et al., 2016. *Optical wireless communications: an emerging technology*, Springer. Available at: http://www.springer.com/gp/book/9783319302003.

Wikipedia, 2017a. Fuel economy in aircraft. Available at: https://en.wikipedia.org/wiki/Fuel_economy_in_aircraft [Accessed November 5, 2017].

Wikipedia, 2017b. Moore's lawtle. Available at: https://en.wikipedia.org/wiki/Moore%27s_law.

Zhang, J. et al., 2016. Towards a visible light network architecture for continuous communication and localization. In *Proceedings of the 3rd Workshop on Visible Light Communication Systems – VLCS '16*. New York, New York, USA: ACM Press, pp. 49–54. Available at: http://dl.acm.org/citation.cfm?doid=2981548.2981556.

Zigler, J. et al., 2017. Comparison of therapies in lumbar degenerative disc disease: a network meta-analysis of randomized controlled trials. *Journal of Comparative Effectiveness Research*.

Zoulias, E.I. et al., 2006. Integration of hydrogen energy technologies in stand-alone power systems analysis of the current potential for applications. *Renewable and Sustainable Energy Reviews*, 10, pp. 432–462.

ENDNOTES

1. Many thanks to the students Victor Blanaru, Diana Ionescu, Siddharth Raghav Murali and Natasha Pillai, who prepared this example.