Trabajo de fin de periodo formativo

Programa de Doctorado: Medio ambiente y minería sostenible

Universidad Politécnica de Cartagena

Desarrollo portuario sostenible:

Modelización del riesgo en inversiones portuarias.

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“Gutta cavat lapidem, non vi, sed saepe cadendo”

Ovidio

In me sunt omnia in corde tuo.

A mi mujer y a mis hijos.

Índice.

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Abreviaturas.

AACE ....Association for the Advancement of Cost Engineering
ARR.. Average Accounting Rate of Return
BCR.. Benefit-Cost Ratio
CAPEX .... CAPital EXpenditues
CAPM ....Capital Asset Pricing Model
CCPM.. Critical Chain Project Management
CEA.. Cost-Effectiveness Analysis
CPM .... Critical Path Method
DCF ....Discounted Cash Flow
EIA .... Environmental Impact Assessment
ESPO ....European Sea Ports Organization
EVM ....Earned Value Management
GERT ....Graphical Evaluation and Review Technique
IRR_E.. Economic Internal Rate of Return
IRR_F..Financial Internal Rate of Return
MCA ....Multi-Criteria Analysis
MIRR ....Modified Internal Rate of Return
NVPf...Financial Net Present Value
NVPe...Economic Net Present Value
OPEX ....OPerational Expenditures
PB .... Payback Period
PERT...Program Evaluation Review Technique
QRA .... Qualitative Risk Assessment
RAMP .... Risk Analysis and Management of Projects
RBS..Risk Breakdown Structure
REI ....Regional Impact Assessment
SDR.. Social Discount Rate
WACC .... Weighted-Average Cost of Capital
WBS ....Work Breakdown Structure

Datos del Doctorando.

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Datos del programa de doctorado.

PROGRAMA DE DOCTORADO	Medio Ambiente y Minería Sostenible	
TÍTULO DEL TFPFD:	Desarrollo portuario sostenible: Modelización del riesgo en inversiones portuarias.	
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Chapter I.**Background and overview.**

1. Introduction.

In recent years the concept of sustainability[1], quality of what is able to be self-maintained at a certain rate or level, according to the Oxford's dictionary, has been spreading wide, gaining force, in all infrastructure areas, ports and harbors in particular.

Focusing on the marine and port fields, the application of sustainable development principles is widely supported in the EU maritime policy, relying on an innovative, competitive and environmentally friendly maritime industry, one of whose objectives should be the application of the concept of sustainable development in the exploitation of marine resources of the seas and oceans, integrating also the improvement of life quality in coastal regions[2]. Thus seeks a sustainable use of oceans and seas, facilitating the sustainable growth of the maritime and coastal regions economy and improving their life quality, reducing levels of air pollution in ports[3].

The General Assembly of the European Sea Ports Organization (ESPO), has drafted several codes to improve the sustainability management within the European port authorities. Among them are the «Environmental Code of Practice»[4] - recommended by ESPO for use to the port authorities, to help develop tools that allow them to manage environmental matters-, the «Code of Practice on the Birds and Habitats Directives»[5] - that, intended for port authorities, port planners and local regulators, is a guide to manage impacts, port development, protection of nature and habitat for birds and other species living in port areas-, the «Good Practice Guide on Port Area Noise Mapping and Management»[6] or the «EcoPorts Port Environmental Review»[7]- that summarizes priorities, measures and actions in the field of environmentally friendly associated ports.

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[1] In 2001 the European Council received from the European Commission *"Communication from the Commission. A Sustainable Europe for a Better World: A European Union Strategy for Sustainable Development" /** [COM/2001/0264 final] (European Commision, 2001). In this communication was raised how sustainability criteria should be integrated within European policies.

[2] Green Paper - Towards a future Maritime Policy for the Union: a European vision for the oceans and seas [COM/2006/275 final] (European Commision, 2006).

[3] Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions. An Integrated Maritime Policy for the European Union. COM (2007) 575 final (European Commision, 2007).

[4] *Vid*: (European Sea Ports Organization, 2003)

[5] *Vid*: (European Sea Ports Organization, 2007)

[6] *Vid*: (NOMEPORTS, 2008). In this document ESPO make the recommendations of NoMEPorts (*Noise Management in European Ports*) project its own.

[7] *Vid*: (European Sea Ports Organization, 2009)

Spanish Port System legislation[8] also determines that the economic management of the ports must be done within a framework of sustainable development which ensures protection and environmental conservation and the proper integration of ports in the cities of their surroundings.

Taking into account that in recent years the investment effort in the Spanish National Port System has been very important, "*from 322 million euros in 1991 to more than 998 million in the year 2008*" (Castillo-Manzano & Fageda, 2011) and actual figures are even higher, 2011 annual accounts closing reflected an investment of 1.15 billion euros (Puertos del Estado, 2012).

On the other hand, the outcomes of a port infrastructure is uncertain (Blok et al., 2000). Because of risk aversion, port projects with a broader spread of results are valued less than projects with less risk.

The social assessment of risk must be expressed in the economic project's net present value, meanwhile the financial assessment of risk must be expressed in the financial project's net present value. Fundamental uncertainties can be brought to the fore by sensitivity analysis and scenario analysis. Since project outcomes become more uncertain the further they lie in the future, it some cases may be useful to limit the time horizon.

Therefore, it seems reasonable to have the necessary tools to analyze investments in order to ensure the sustainability of the Spanish National Port System, these tools will help to evaluate, manage and mitigate risk, but moreover the will help to create the necessary transparency to make Spanish ports more attractive for private investors, obviously these tools can be used to analyze similar situations anywhere.

That is why in this research we will focus on analyzing firstly different existing methods and tools for the economic and financial evaluation of port investment projects.

Secondly we will study which are the most relevant variables within these analyses and statistical models for each one of them will be proposed, based on the analysis of the existing data. In such manner we will obtain all the data needed to confront a Monte Carlo simulation[9] (Metropolis & Ulam, 1949), which will be applied to financial and economic analysis models, to obtain the proba-

[8] *Vid*: (Governement of Spain, 2011).

[9] The expression 'Monte Carlo simulation' appears in 1940, when Von Neumann and Stanislau Ulam, both scientists working on the "Monte Carlo" project, during the Second World War. The project aim was to develop the first atomic bomb before Germany. Many scientists from USA, United Kingdom and Canada, worked together, even among them was Albert Einstein. A reference to the "Monte Carlo simulation" or "Monte Carlo method" was made in the project. This method was used to approximate mathematical expressions, complex and costly to assess accurately. The method is named in reference to the Monte Carlo Casino, being the capital of gambling and Roulette which are the simplest methods of random number generation.

bility distribution of the Net Present Value, both financial (NVP_f) and economic (NVP_e).

Finally we will apply the variables distributions previously defined in the analysis of a real case. In order to check the validity of the results, and try to point out which are the most influencing variables to the final result, we will perform a regression analysis. So far is covered by the present research report, and this would be the starting point for the thesis that would keep on the overall research.

2. Purpose.

This research, that is part of a thesis, has been drafted within the investigation of TEI group "Transport Engineering and Infrastructure" ("Ingeniería e Infraestructura de los Transportes") of the Polytechnic University of Cartagena (Spain). So one of the purposes of the thesis is to consolidate lines of research relating to port infrastructures risk assessment and mitigation, and economic and financial analysis.

The primary objective of this research is to better understand and to improve risk identification and assessment through a better understanding of the variables involved, those that are found more relevant will become the overall objective of the thesis that will develop and adjust statistical distributions to reproduce the behavior of those selected variables, in order to produce a reliable analysis of face model to select investment port projects.

Achieving the previously described primary objective, implies to achieve the following specific objectives:

1. Selection of the most relevant variables in the economic and financial analysis of port investment, through review of the literature.
2. Obtaining the statistical distributions of the selected variables, firstly through literature review, to tackle the problems of the implementation of the economic and financial assessments that include an analysis of risk, through the development of a base case, and try to offer some criteria in the resolution of these problems
3. Develop of a model for economic and financial analysis, including a risk analysis to take into account the statistical distributions of the previously selected variables.
4. Application of the model developed to a real-world example to validate the proposed model.
5. Assess the relevance of each one of the selected variables to the final result of the analysis, by performing a regression analysis.

This document outlines the findings of the tasks performed and highlights the issues of focus for the TEI group of research. These findings also suggest future research by TEI group to address port industry and port authorities risk evaluation issues, methods and procedures to improve the performance of international port projects.

3. Research project methodology.

The research project revolves around the hypothesis that a few of the variables involved in the economic and financial assessment are responsible for a significant part of the risk assumed in these projects, and that those projects going through a systematic risk assessment and management process and associated decision-making steps considering those variables would perform significantly better than projects that do not.

This report outlines initial portion of the investigation including results from the literature review and the results of the regression analysis performed in a practical example, the shaded areas in Figure 1 show the steps included in the present research report. The proposed research methodology to define and test such a hypothesis follows the task flow as shown in Figure 1, and summarized is the following:

1. Perform an extensive literature review including papers regarding project finance, risk management, financial and cost-benefit analysis.
2. Perform an extensive literature review to determine the most relevant variables to economic and financial analysis.
3. Evaluate and develop statistical distributions for the variables selected.
4. Develop an economic and financial model using the statistical models we have opt for.
5. Apply the model to a real case, to sort out the variables and rank them in order of its relevance to the final result.

This research report will cover all previous phases, and a lecture in a national conference was carried out to spread the results obtained. Following steps will be performed later on, within the framework of the thesis that will conclude this piece of research.

6. Perform an extensive literature review regarding the highest ranked variables to the result of the economic and financial analysis.
7. Develop and deploy a questionnaire for industry or government members involved in the definition, managing and development of port projects, which will identify and assess specific issues and values for the chosen variables.
8. Statistical models will be adjusted according to the data obtained.
9. Conduct a series of workshops with industry representatives to gather further input on the results obtained, and if they would be useful to improve risk identification, assessment and mitigation for port projects.
10. Draft of the results and conclusions, the last step to finish the thesis.

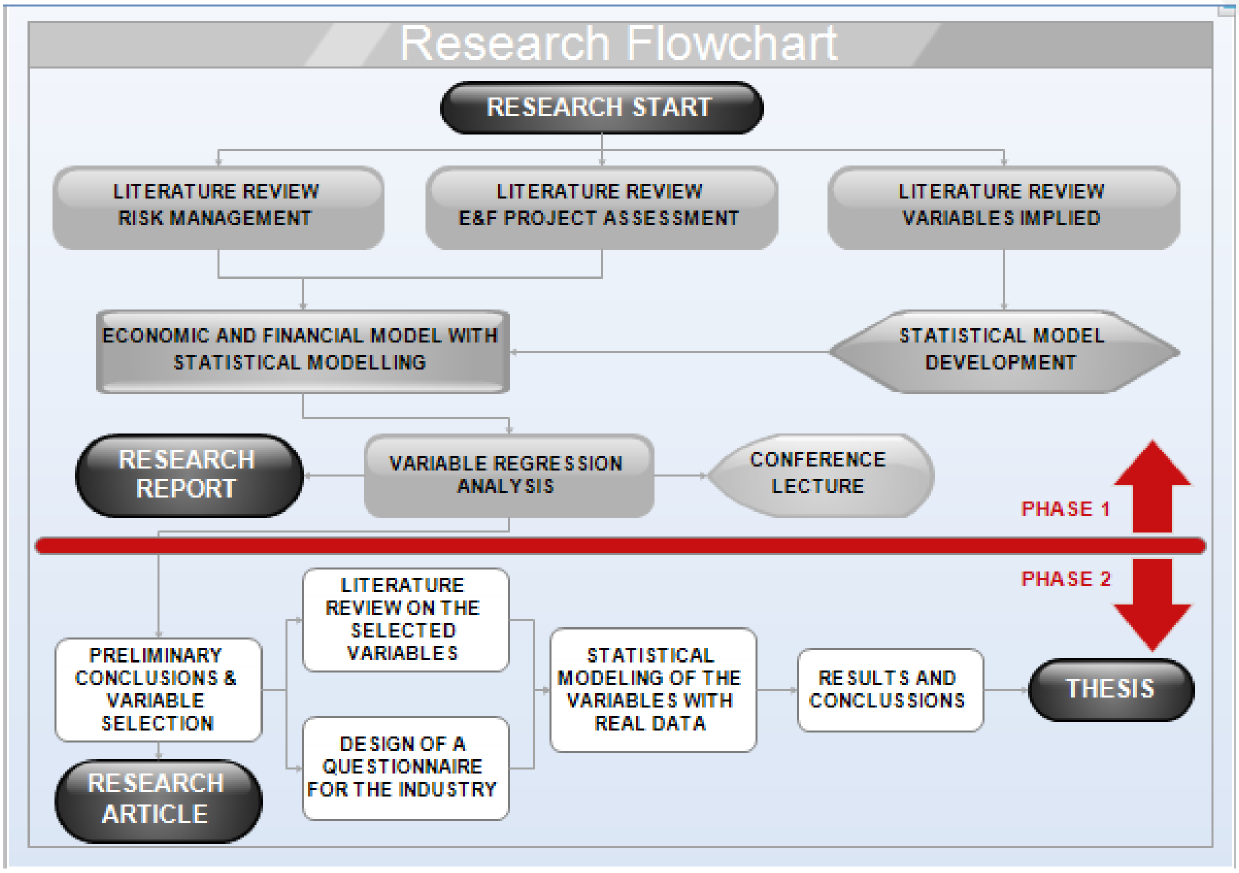

Figure 1. Research flowchart.

4. Summary of the research project.

The present report has been organized in three different chapters.

Chapter one presents an overview of the report and furthermore of the PhD Thesis, and answers the why, how, and where questions of the thesis, regarding the main driving forces that led the author to investigate in this field.

Chapter two sums up the literature review that has been carried out previously to the writing of the report. The literature review is organized in a hierarchical way, going from wider terms to specific ones, focusing step by step on the subject of the thesis.

This order starts with the concept of sustainability of transport infrastructures, which is the main framework for the report. Then we discuss the state of the art of risk management, including a historical review in order to see how the concept has evolved over time, and which are the methodologies and tool currently used.

To finish with the state of the art review, financial and economic appraisals are reviewed, the main concepts, the evolution on methods and tools used to develop these studies and finally some key issues that need a deep understanding, where we should put an especial effort.

Chapter three, is a practical example of an economic and financial appraisal of a port project infrastructure. Chapter is divided in six sections, so the problem and the example can be easily understood. First section is just an overview, a brief introduction of the chapter. In section two the project is defined, both in terms of physical requirements and also demand and possible evolution forecasts.

Sections three and four are dedicated to the economic and financial appraisals, and the main steps and tools that have been used are described. In next section, number five, uncertainty is introduced, and statistical distributions for each one of the most relevant variables are proposed.

To end up chapter three, results for the example are presented, in order of complexity, going from a deterministic analysis to a probabilistic one, including a middle step, which is a sensitivity analysis.

The last step of the report is devoted to sum up the report and highlight the main conclusions that can be extracted from the work that has been done. There is an additional section where possible future investigation fields are outlined, in order to serve a guide for future research.

Chapter II. **State of the art and literature review.**

1. Overview.

An extensive review of sustainability, international project risk assessment, financial and economic analysis of projects, and statistical modeling of the variables involved was conducted during the initial phase of the research effort. In general, on but there is few literature that has focused on the practices, results or development of risk assessment techniques for international projects, and there is an absence of it that has focused specifically in port infrastructures

Much of what exists is specific in nature and can be categorized under the following topics:

- Sustainability in transport infrastructure.
- Risk management
- Financial and economic analysis of transport infrastructure
- Statistical models for variables for analysis

The literature review that follows is structured using the above topics. Attention is given to developing a better understanding of the purpose, structure, and participants involved with port infrastructure projects as well as the practices used to assess and manage risks, and economic and financial appraisal of those projects.

2. Sustainability in transport infrastructures.

2.1 Concept.

Sustainability, is defined as the "*ability to be sustained, without causing problems such as inflation*" or the "*ability to be maintained at a steady level without exhausting natural resources or causing severe ecological damage*" according to Collins Dictionary.

On the other hand, infrastructure is defined as "*the stock of fixed capital equipment in a country, including factories, roads, schools, etc., considered as a determinant of economic growth*" according to the same source.

According to the literature, which shows a general consensus among academics and practitioners, three are the main components encompassed by sustainability; social, economic and environment (Beloff, Lines, & Tanzil, 2005; Carew & Mitchell, 2008; Olewiler, 2006; Spangenberg, Fuad-Luke, & Blincoe, 2010; Tsai & Chang, 2012; Xing, Horner, El-Haram, & Bebbington, 2009). But if we focus on civil engineering or transportation infrastructure projects comes out a fourth component, 'Technical' that some authors use to take into consideration the performance and functional aspects of engineering projects (Ashley, Blackwood, Butler, & Jowitt, 2004; Oltean-Dumbrava, Watts, & Miah, 2013).

2.2 Sustainability and transport infrastructure, difficulties.

Infrastructures are a crucial aspect of sustainable development, therefore of sustainability, because of its connections with areas of primary concern - health, supplies, environmental systems, air and water quality, and wealth-. These links appear clearly on transport infrastructure, because it determines how people can satisfy basic needs, which in turn affects the material and energy they consume in providing for those needs. Infrastructure can either provide for those needs in a sustainable or unsustainable manner.

The term 'sustainability' has spread wide within the infrastructure sector, public and private, and has been adopted by most Governments worldwide (Augenbroe & Pearce, 1999; Curwell, Yates, Howard, Bordass, & Doggart, 1999; European Commision, 2001; Peter S. Brandon, 2010; Rametsteiner, Pülzl, Alkan-Olsson, & Frederiksen, 2011).

Nevertheless, in a first sight, it seems there is a big gap between transport infrastructure and sustainability. In fact, infrastructure alone is rarely of interest in discussions of sustainability, focused mainly on one out of the three[10] aspects quoted before, environment. That may create in some cases "*weaknesses that can lead to inadequacies and contradictions in policy making*" (Lélé, 1991). Moreover, despite being widely used and acknowledged in society, governments and industry, the concept it is still often misunderstood and misinterpreted (Cole, 2006; Lombardi, Rogers, Jefferson, & Hunt, 2008). This may be because definitions of sustainability are numerous, some of them do not cover all the aspects involved, and the spatial and temporal scales in which it is considered are often not made explicit, increasing the difficulty to understand the concept (Oltean-Dumbrava, Watts, & Miah, 2012).

[10] Four in our case, as our research is about transport infrastructure.

Among all these difficulties there is one task that is probably the most important, although the most difficult too (Bell & Morse, 2008). That task is to define the time frame for the aim of achieving sustainability, because a project can have effects on very disparate time scales, and indicators measuring sustainability may differ from one period to another also. Within the infrastructure sector *inter alia*, this can cause much confusion if one does not also identify the appropriate spatial scale one must work within (Ashley et al., 2004; Lélé, 1991). You may think of aspects of a project with local impact (Joao, 2000), like dust or noise emissions, and other that are global, like CO2 reduction for some transport modes using specific infrastructures like ports. An example of different physical and ecological phenomena classified by time and spatial scales is shown in

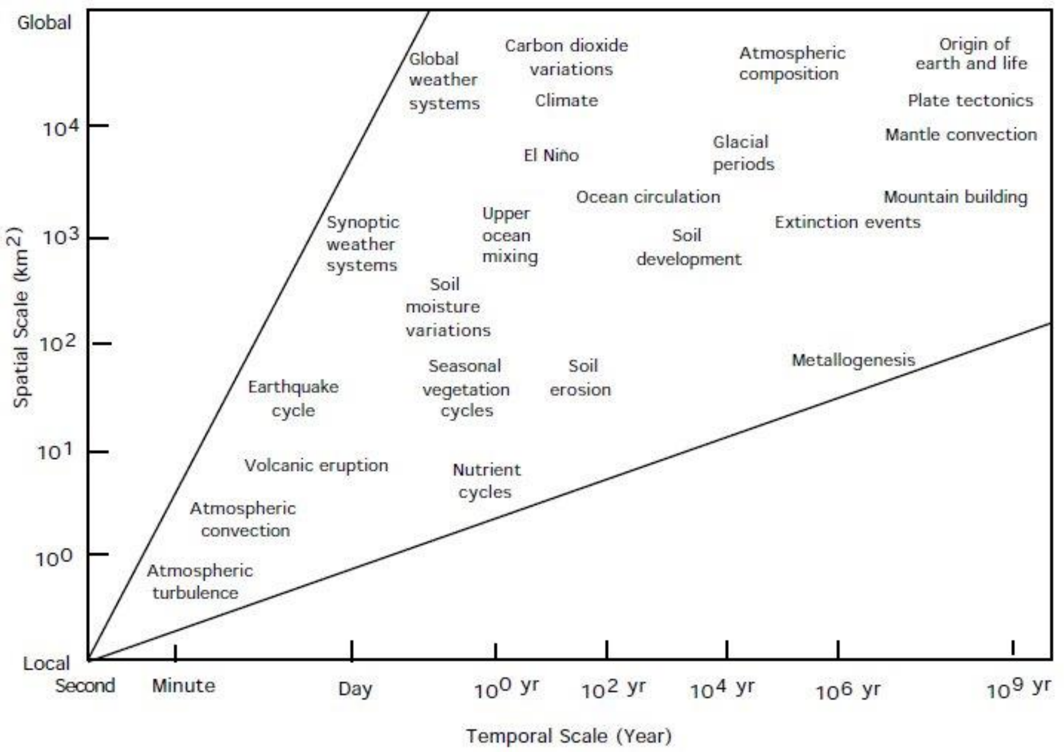

Figure 2. Physical and ecological phenomena and its relation with spatial and temporal scales (Wu 1999)

Figure 2.

3. Risk management.

3.1 Concept

Shall we clarify some concepts before we begin to talk about managing risk? A first step is to make a distinction between risk and uncertainty. Mean-while uncertainty is something that exists in nature *per se*, the state of an event that we are not able to be accurately know or predict, risk is something that one bears, and it is an outcome of uncertainty present in nature, and consequently in all kind of projects or human actions[11].

Moving on, the next step is to define risk. The IEC[12] standard defines risk as: "*The combination of the probability of occurrence of harm and the severity of that harm*", two relevant aspects are pointed out here, firstly risk needs the existence of an uncertain event, hazard, with a known (or not) probability of occurrence. Secondly the occurrence of that event should cause some kind of harm or damage, consequently if the occurrence of an event leads to no damage or harm, no risk is assumed there.

Reviewing specialized literature, we found that within the project risk management field, risk is defined as a chance that an event could have a potential positive or negative effect on a project's overall objective (Project Management Institute, 2012; Rose, 2013). Here we can find out a clear difference between what we said before about risk, we talk about potential effect, instead of hazard, with a positive or negative effect, rather than the negative sense of the previous definition. The difference comes from the two separate facets of absolute risk (Dias Jr. & Ioannou, 1995), and we focused on a different one in each case. In the first case we have defined pure risk, which is involved in situations that present the opportunity for loss but no opportunity for gain, meanwhile speculative risk is a category of risk that, when undertaken, results in an uncertain degree of gain or loss. All speculative risks are made as conscious choices and are not just a result of uncontrollable circumstances, consequently they are uninsurable.

We must separate also two relevant concepts from risk, defined previously:

Cause: Something or someone that produces an effect, result, or condition

Effect: A change that results when something is done or happen

These descriptions have been made to clearly distinguish cause, risk and effect, that will lead us to understand the following risk description: "Due to "*cause/risk driver/hazard*", there is a threat/opportunity (uncertainty) that "*risk*" may occur, which may lead to "*effect*" (AACE International Technical Board, 2012).

When we refer to a Risk Management process, we generally talk about speculative risks. So properly conducted management will increase the probability and impact of positive events, and decrease the impact and likelihood of negative events (Mun, 2010).

[11] For further discussion on this subject *vid*: (Brown & Damery, 2009; Mun, 2010; Nilsen & Aven, 2003; Rowe, 1994)

[12] (International Electrotechnical Commission, 2009)

Considering the above definition we can take a look to risk assessment. Obviously risk assessment has to be an analytical process, which should leads us to evaluate how risky is the project we are analyzing. According to the literature review, risk assessment can be defined as the process of identification of hazards and analysis and evaluation of risks associated with exposure to those hazards. The process is made of three diverse phases (European Medicines Agency, 2006; International Electrotechnical Commission, 2009; Mun, 2010):

1. ***Risk identification***. There is a question that will answer to this phase, "*what can go wrong in the project?"* Events that represent any kind of hazard that can lead to harm should be identified, ideally using information referring to the project systematically. Information can include historical data, theoretical analysis, informed opinions, and the concerns of stakeholders[13]. At the end of this phase we must a have a list of hazards, and its possible consequences (harms). This provides the ground for further steps in the risk management process
2. ***Risk analysis***. An estimation of the risk associated with the identified hazards, and its possible consequent harms, has to be conducted. Here we should answer the following question: *"What is the likelihood (probability) something will go wrong?"* The analysis can be qualitative or quantitative[14], some authors propose intermediate models[15], and in both cases it is a process that will link the likelihood of occurrence and severity of harms:

   $$Risk = f(Severity, likelihood)$$

   In some risk management tools, the ability to detect the harm (detectability) also factors in the estimation of risk (Aneziris, Papazoglou, Konstantinidou, & Nivolianitou, 2013).

   $$Risk = f(Severity, likelihood, detectability)$$

   You may think of a gas spill that can be early detected because of its smell, so even when the event has happened, a spill, it may not have harmful consequences if it is early detected, monitored and mitigated. These also applies for some early detections on parasite infection(Cui, Chen, & Small, 2013)

[13] Some authors (Mun, 2010) stand up for the idea that a previous qualitative risk assessment (QRA) has to carried out, in order to avoid time and money losses evaluating low risk events.

[14] For further discussion on this topic *vid* (Coleman & Marks, 1999; Groen et al., 2006; Norris, Perry, & Simon, 2000)

[15] In the literature you can find examples of semi-quantitative methods (Aven, 2008; Jing, Hao, Han, & Wu, 2009; Moonis, Wilday, & Wardman, 2010)

3. ***Risk evaluation***. The last step compares the identified and analyzed risk against given risk criteria. Risk evaluations consider the strength of evidence for all three of the fundamental questions

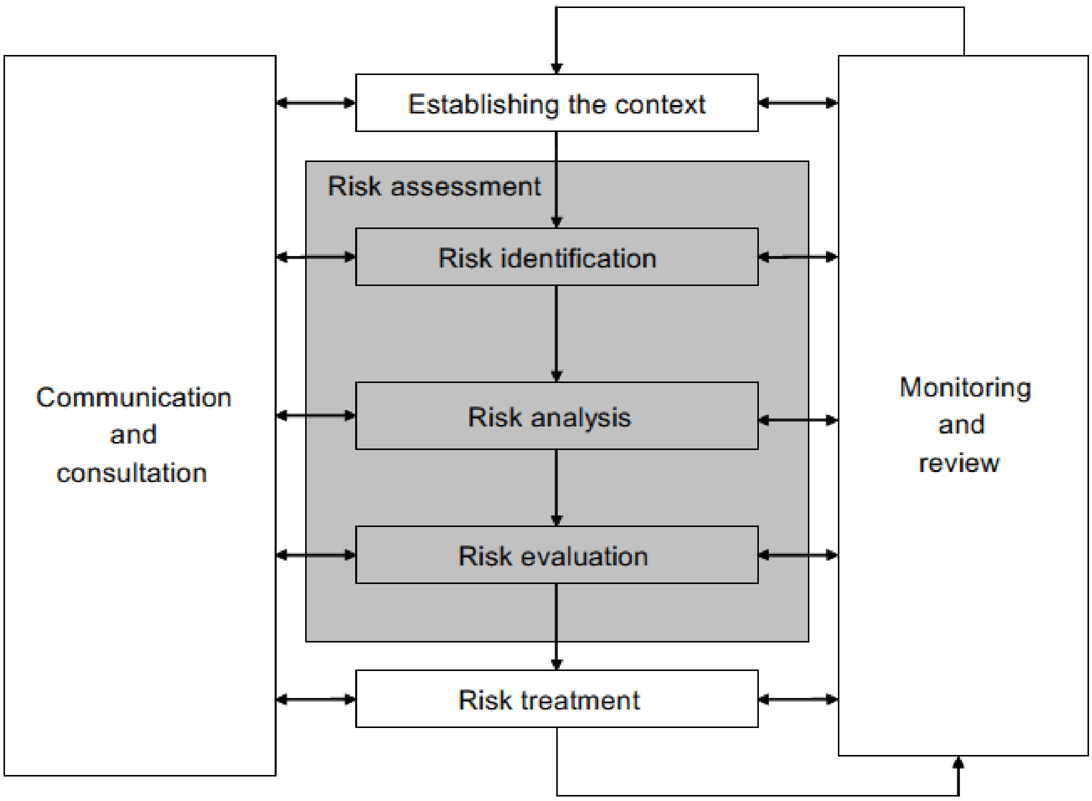

Figure 3. Risk assessment in the risk management process (International Electrotechnical Commission, 2009).

As it can be seen in Figure 3 risk assessment, has a huge relevance within the risk management process, and the overall management result will depend mostly on the way the risk assessment has been carried out.

To complete the definitions, bearing in mind that we have gone upwards from the most concise to the most general term, we should talk about ***risk management.***

Risk management is a systematic process for the evaluation, control, communication and review of risks to the infrastructure project. Some models can be used for risk management, one of them is outlined in Figure 4, used for quality risk management (European Medicines Agency, 2006). Other models might be used, but the general idea is similar to all of them. The emphasis on each component of the framework might differ from case to case but a robust process will incorporate consideration of all the elements at a level of detail that is commensurate with the specific risk.

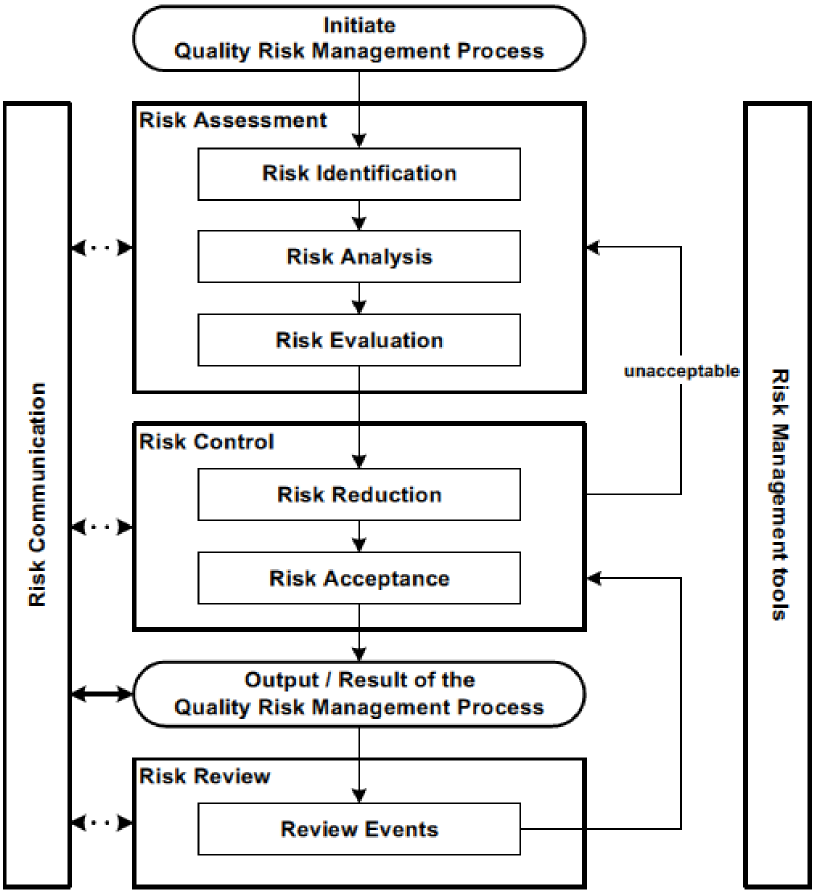

Figure 4. Overview of a typical quality risk management process (European Medicines Agency, 2006)

According to The Project Management Body of Knowledge (Project Management Institute, 2012) Project Risk Management process by following these five steps: (a) plan the risk management process, (b) identify the risks, (c) perform a qualitative and quantitative analysis, (d) plan risk responses (risk mitigation) and (e) control risks. This provides a comprehensive guide to handle the risks of a project is a similar way to the one presented in Figure 3. Risk assessment in the risk management process (International Electrotechnical Commission, 2009).Figure 3.

Whichever project risk management method is used, if properly conducted, will increase the likelihood and impact of positive events, and decrease the impact and likelihood of negative events, and there is a consensus about it among the literature (Raz, Shenhar, & Dvir, 2002; Wylie, Gaedicke, Shahbodaghlou, & Ganjeizadeh, 2014; Zwikael & Sadeh, 2007).

3.2 History

Although humanity has been coexisting with risk since its presence on earth, no studies were carried out until the end of World War II. Academicals studies (Crockford, 1982; Dionne, 2013) date the origin of modern risk management to 1955-1964. The first two academic books were published in 1963 and 1964, covering pure[16] risk management, which excluded corporate financial risk (Dionne, 2013).

The development of new ways of pure risk management, as alternatives to market insurance, emerged during the mid-1950s, when traditional insurance coverage became very costly and incomplete. Several business risks were costly or impossible to insure.

During the 1960s, contingent planning activities[17] were developed, and various risk prevention or self-protection activities were carried out.

The use of derivatives[18] as financial instruments to manage insurable and uninsurable risk began in the 1970s, and developed very quickly during the 1980s, at the same time international regulation of risk began to be developed by financial institutions to protect themselves from unanticipated risks and reduce regulatory capital.

Due to various scandals and bankruptcies resulting from lack or poor risk management[19], the Sarbanes-Oxley regulation was introduced in the United States in 2002, stipulating governance rules for companies (Kuschnik, 2008).

Even though, all these regulations, rules, and risk management methods were create to achieve a better did not prevent the financial crisis that began in 2007. As some author pointed "*Generally speaking, the system of federal monitoring for corporate governance is in itself doubtful*" (Kuschnik, 2008), so maybe those regulations were good and efficient, but rather their application and enforcement, that appear to have, only limited positive effect on corporate governance.

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[16] Usually absolute risk is divided in two different aspects, pure and speculative risks. Pure risk is involved in situations that present the opportunity for loss but no opportunity for gain, and are generally insurable, those risks are related to the loss associated with fortuitous occurrences (e.g., fires, hurricanes, tortuous conduct), so called event risk, hazard risk, or insurance risk, presents no chance of gain, only of loss. Those kind of hazards are covered by traditional property-casualty (P&C) insurance products. On the other hand, speculative risk is a category of risk that, when undertaken, results in an uncertain degree of gain or loss. All speculative risks are made as conscious choices and are not just a result of uncontrollable circumstances, consequently they are uninsurable.

[17] Contingent activities are undertaken to ensure that proper and immediate follow-up steps will be taken by a management and employees if an emergency occurs. Their major objectives are to ensure avoiding or minimizing damage or injury to, or loss of, personnel and property, and continuity of the key operations of the organization.

[18] According to the International Monetary Fund, financial derivatives are financial instruments that are linked to a specific financial instrument or indicator or commodity, and through which specific financial risks can be traded in financial markets in their own right. Transactions in financial derivatives should be treated as separate transactions rather than as integral parts of the value of underlying transactions to which they may be linked. The value of a financial derivative derives from the price of an underlying item, such as an asset or index. Unlike debt instruments, no principal amount is advanced to be repaid and no investment income accrues. Financial derivatives are used for a number of purposes including risk management, hedging, arbitrage between markets, and speculation.

[19] The bill was enacted as a reaction to a number of major corporate and accounting scandals, including those affecting Enron, Tyco International, Adelphia, Peregrine Systems, and WorldCom.

3.3 Project risk management methodology.

3.3.1 *Historical milestones.*

Going a step further, trying to focus on project risk management, particularly transport infrastructure projects, we have reviewed literature regarding this topic, its different approaches, and methods developed to carry out all these tasks.

As project risk management is an important aspect of project management, we should go through both history milestones. This historical review would clarify some current ideas, practices, and techniques used for project risk management. Although project management is as old as early civilizations, project management in the modern sense began in the 1950s. But even in early days some great achievements were made in project management, that led to great and impressive projects surviving as time passes by, e.g. Giza Pyramid, 2580-2560 BC, the Great Wall of China IIth BC, Hanging Gardens of Babylon, 604-562 BC[20].

Focusing on project management, which has been developed in parallel with transport infrastructures (Kozak-Holland, 2011), some milestones have to be pointed out, as they have fostered relevant changes in this field:

1916-1919: Henry Gantt (1861-1919) developed a chart, self-named Gantt chart, which was a kind of scheduling diagram. First ideas where published in *Work, Wages, and Profits* (originally published in 1916) and *Organizing for Work* (originally published in 1919). In those papers proposed some revolutionary ideas, like giving to the foreman each day an “order of work”[21], and coordinating activities to avoid “interferences.” It was a radical idea and an innovation of worldwide importance in the 1920s (Herrmann, 2005). One of its first uses was on the Hoover Dam project started in 1931.

[20] For further information on historical developments vid: (Kozak-Holland, 2011)
[21] An ordered list of jobs to be done that day

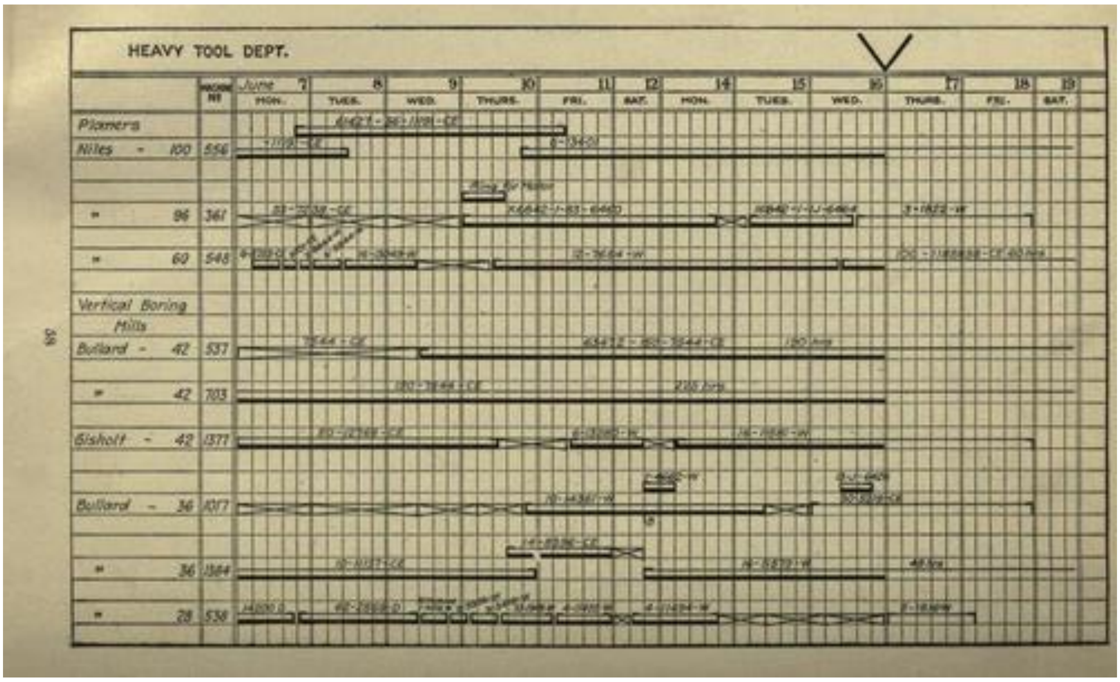

Figure 5. A Gantt Layout[22] Chart (from Clark & Gantt, 1942)

1957: The Critical Path Method (CPM) Invented by the DuPont Corporation. This method was developed to address the challenge of shutting down chemical plants for maintenance and then restarting the plants once the maintenance had been completed. The main issue addressed was to predict project duration by analyzing which sequence of activities has the least amount of scheduling flexibility, the critical path of the project. DuPont saved $1 million in the first year of its implementation (Chapman et al., 2012).

1958: The Program Evaluation Review Technique (PERT) was developed in the late 1950's within the U.S. Navy's Polaris mobile submarine launched ballistic missile project during the cold war. This method analyzes the tasks involved in completing a project, evaluating the time needed to complete each task and identifying the minimum time needed to complete the total project. There are 6 main steps for this method:

1. Identify the specific activities and milestones.
2. Determine the proper sequence of the activities.
3. Construct a network diagram.
4. Estimate the time required for each activity.
5. Determine the critical path.
6. Update the PERT chart as the project progresses.

For the first time in history, a method involving a probabilistic network model of activity precedence relationships was used. The method addressed all uncertainty worth quantification in overall variability terms. (Chapman et al., 2012; Herrmann, 2005).

[22] This layout chart specifies “when jobs are to be begun, by whom, and how long they will take” (Clark & Gantt, 1942)

The method was improved using Markov processes to deal with repetitive tasks, contingency responses within an activity and weather windows, This method was known as GERT (Graphical Evaluation and Review Technique)

1962: Work Breakdown Structure (WBS) Approach

Also in the scope of the Polaris project the WBS was created. WBS is an exhaustive, hierarchical tree structure of tasks and deliverables that need to be carried out to complete a project. WBS remains one of the most common and effective project management tools.

1975. PROMPTII Method Created by Simpact Systems Limited

As computer projects were overrunning on time, and budget, estimated for completion PROMPTII appeared as a solution to set down guidelines for the stage flow of a computer project(Haughey, 2013).

1984. In this year Dr. Eliyahu M. Goldratt wrote his Novel "The Goal" where he first described the “Theory of Constraints (TOC)”

This theory stands that all manageable system are limited in achieving more of its goal by a small number of constraints, and at least one constraint exists. The key point of this method is to identify the constraint and restructure the rest of the organization around it by using Five Focusing Steps (Goldratt, 1992):

1. Identify the system's constraint
2. Exploit the system's constraint
3. Subordinate all other resources to the constraint
4. Elevate the system's constraint
5. Warning! If in the previous steps a constraint has been broken, go back to step 1, but do not allow inertia to cause a system's constraint.

1987: A Guide to the Project Management Body of Knowledge (PMBOK Guide) Published by PMI[23].

First published by the PMI as a white paper in 1987, the PMBOK Guide was an attempt to standardize accepted project management information and practices. (Project Management Institute, 2012).

1989: Earned Value Management (EVM) Leadership Elevated to Undersecretary of Defense for Acquisition.

[23] Project Management Institute was created in 1969, to Promote the Project Management Profession. Since then, the PMI has become best known as the publisher of, 'A Guide to the Project Management Body of Knowledge (PMBOK)' considered one of the most essential tools in the project management profession today.

Although the method has been since the beginning of the 20th century, it came to be widely used as a project management technique in the late 1980s early 1990s.

1997: Critical Chain Project Management (CCPM)

Critical Chain Project Management is based on methods and algorithms drawn from Theory of Constraints (TOC). A Critical Chain project network will keep the resources levelly loaded.

1998: Risk Analysis and Management of Projects (RAMP)

This method uses a project framework to identify and mitigate risk by using the accepted framework of risk identification and project controls by focusing on risks as they occur during the project life cycle. During RAMP assessment analysis is scheduled throughout the life cycle of a project and tends to focus on financial concerns as impacted by project. It is the association of financial issues with project risk that differentiates RAMP from other frameworks (Chapman & Ward, 2007).

RAMP approaches risk on several levels and combined elements from other frameworks to codify four actions that include the launch of a project, a systematic review of uncertainties that affect the project, management of risk, and project termination. (Actuarial Profession & Institution of Civil Engineers, 2005).

2000: Risk Factor Analysis (RFA).

Developed by Los Alamos National Laboratory, RFA is a qualitative method for risk project appraisal, which objective is to understand and identify the underlying factors that will drive the main performance measures for a project. The project analysis follows 6 basic steps (Kindinger & L.Darby, 2000)

1. Define or list task conforming the project.
2. Identify applicable technical risk factors
3. Develop a scale for each risk factor (to rank risk)
4. Rank risk, for each activity and factor
5. Sum results for each activity and factor
6. Document the results and identify potential risks mitigation measures to be evaluated.

2006: "Total Cost Management Framework"

This method is “a systematic approach to managing cost throughout the life cycle of any enterprise, program, facility, project, product or service” (AACE International Technical Board, 2012). It is the first time that a process can be applied for portfolio, and project management.

3.3.2 *Risk management methods*[24].

Apart from methods described up to here, that have driven several and relevant changes within the project management field, some others exist. The most extensive work found in the literature review about this topic presents a comprehensive list of all methods, mixed with some techniques, it and a classification according to three main dimensions: (1) the phase of the risk management process; (2) the phase of the life cycle of a project; (3) the corporate maturity towards risk (Grimaldi, Rafele, & Cagliano, 2012). Table 1 sums up the methods.

Technique	Description
Brainstorming	An effective way to generate lots of ideas on a specific issue and then determine which idea–or ideas–is/are the best possible solution. Ideas about project risk are generated under the leadership of a facilitator.
Cause Consequence Analysis (CCA)	It identifies the set of unwanted effects and goes backwards to trace the causal chain. It is also known as Ishikawa or fishbone diagram and is useful for identifying causes of risks.
Change Analysis (ChA)	It is used to systematically investigate the possible risks and to identify the appropriate risk management strategies and measures in changing situations.
Checklist	It is a detailed aide-memoire for the identification of potential risks. It can be developed based on historical information and knowledge that have been accumulated from previous similar projects.
Decision Tree Analysis	It is usually structured using a decision tree diagram that describes a situation and the implications of each of the available choices and possible scenarios. It incorporates the cost of each available choice, the probabilities of each possible scenario, and the rewards of each logical path.
Delphi	The purpose is to elicit information and judgments from participants to facilitate problem-solving, planning, and decision-making. A facilitator uses a questionnaire to solicit ideas about the important project risks and the experts participate anonymously.
Event and Causal Factor Charting (ECFCh)	It consists of a graphical description of the sequence of events and conditions associated with an accident. The chart provides a logical progression of events.
Event Tree Analysis (ETA)	It is an analysis technique that models the range of possible outcomes of one or a category of initiating events.
Expected Monetary Value (EMV)	The EMV analysis is a statistical concept that calculates the average outcome when the future includes scenarios that may or may not happen.
Expert Judgment	Technique based on the experts' opinion. It is useful for the evaluation of the failure rate and the success chances of the

[24] (Adapted from Grimaldi et al., 2012)

Technique	Description
	overall project.
Fault Tree Analysis (FTA)	An approach that starts from a particular event, known as the top event, in an attempt to identify all the possible event sequences giving rise to it
Failure Mode and Effects Analysis (FMEA)	An analysis technique used in high-risk organizations to identify failure modes in systems/processes and work out response strategies.
Failure Mode and Effects Criticality Analysis (FMECA)	An analysis technique used in high-risk organizations to identify and assess failure modes in systems/processes and work out response strategies.
Fuzzy Logic	Useful approach to address the problems associated with imprecision, uncertainty, and subjectivity of data.
Hazard and Operability (HAZOP)	It is a hazard identification technique that uses a structured and systematic team review of a system or process to identify the possible deviations from normal operations and their causes and consequences. It uses a standard list of guidewords (e.g. "more," "less," "no") combined with process conditions to systematically consider all the possible deviations from the normal conditions. For each deviation, possible causes and consequences are identified as well as whether additional safeguards should be recommended.
Hazard Review (HR)	The Hazard Review, also known as Hazard Survey or Safety Review, is mainly a qualitative review of an activity or system to identify the hazards and to gain qualitative understanding of their significance.
Human Reliability Assessment (HRA)	It is especially used for a detailed evaluation of human operations in procedural tasks. It is a special form of FTA and ETA, designed for modelling and analyzing the range of possible accidents that may happen while performing a procedure.
Incident Reporting (IR)	A structured mode for accident, incident, and near miss signaling collection.
Interviews	The list of risks is produced by interviewing project managers or experts on the applications of the project. The risks are identified and defined and a risk management capability score can be determined from a five-point scale.
Monte Carlo	A type of spreadsheet simulation that randomly and continuously generates values for uncertain variables to simulate a model.
Pareto Analysis (PA)	It is a technique that is used to identify and prioritize the most significant items, for example causes and contributing factors or effects of accidents. This technique employs the Pareto rule (or 80-20 rule), which says that about 80 percent of the effects are generated by about 20 percent of the causes.
Preliminary Hazard Analysis (PHA)	It is used to identify hazards, assess the severity of potential accidents that may happen, and identify measures for reducing or eliminating the risks associated with the hazards.

Technique	Description
Risk Breakdown Matrix (RBM)	An activity and threat matrix where the value of risk associated with each activity and the most frequent overall risks are evaluated.
Risk Breakdown Structure (RBS)	It is a source-oriented grouping of project risks that defines the total risk exposure of a project. Each descending level represents an increasingly detailed definition of sources of risk to the project.
Risk Mapping, Risk Matrix, Probability and Impact Matrix	It is a qualitative technique that can be used to evaluate and prioritize a group of risks which could significantly impact on a project.
Risk Probability and Impact Assessment, Risk Ranking/ Risk Index	It investigates the likelihood that each specific risk will occur and the potential effects on the objectives of a project, such as time, cost, scope, or quality.
Sensitivity analysis	It helps to determine which risks have the most potential impact on a project
Strengths, Weaknesses, Opportunities, and Threats (SWOT)	The SWOT analysis provides a good framework for reviewing strategies, positions and business directions of a company or an idea
SWIFT Analysis	It is a more structured form of the "What-if Analysis" technique and it is used to identify hazards based on brainstorming and checklists.
What-if Analysis	It is a brainstorming technique that uses a systematic, but broad and not very structured, questioning procedures to generate descriptive information.
"5 Whys" Technique	It is a qualitative brainstorming technique that attempts to identify root causes of accidents by asking "why" these events did occur or conditions did exist, in order to help to get to the true causes of problems.

Table 1. Project risk management techniques. (Adapted from Grimaldi et al., 2012)

3.3.3 *Current researchs.*

Once we have gone through the main relevant methods for project risk management, we will focus on what practitioners and academics are discussing nowadays about project risk management of transport infrastructure, and which are the key issues that should be faced in the process. The steps and methods outlined to incorporate risk analysis and mitigation into infrastructure projects have been adapted and tested, by some researchers, to incorporate risk analysis and mitigation into infrastructure projects. For instance, Tummala and Burchett (1999) proposed a risk management process, structured like a quality management process and considering the corresponding project mission, aims and objectives. Olson (2007) proposed that risk should be considered for each function of the management process (i.e., sales, marketing, and technical) to ensure a comprehensive risk analysis.

One key issue of risk management is risk elicitation, consisting of proper risk identification and assessment. About the first stage, risk identification, there are some general recommendations, but none regarding transport infrastructure projects. For example, the PMBOK (Project Management Institute, 2012) to make easier the identification of risks recommends the use of a data flow chart. Another advice is to interview all professionals involved in the management of a project, to help to identify all relevant project risks. AACE International Technical Board 2012 (2012) recommends the use of checklists or a risk breakdown structure (RBS), based generally based on project historical data. Sadeghi (2010) proposed the use of experts during initial risk definition, not to use their information directly, but to define fuzzy variables that can be transformed to apply a Monte Carlo analysis. If we can rely on construction management professionals to define risks, when it comes to account for and mitigate their impacts we should count on specialized expertise.

Kaplan and Mikes (2012) propose a new framework to elicit risk. This new framework is stablished on the basis that risk can be classified in three different categories, and the definition, assessment and mitigation approach has to be diverse for each one. The classification has been made as follows:

1. *Preventable risks*, arising from within an organization, which have always a negative impact and shall be eliminated or mitigated by implementing an integrated corporate culture and compliance model. Those risks are to be monitored and controlled through rules, values, and standard compliance tools.
2. *Strategy risks*, which are taken to achieve superior strategic returns, and should be managed by allocating resources to critical risk events.
3. *External risks*, which are uncontrollable and cannot be avoided, but their effects can be mitigated by envisioning the risks using techniques such as tail-risk assessment, scenario planning, and war-gaming.

Patterson and Neailey (2002) propose a structured database, Risk Register Database System, including a Risk Register, in order to facilitate elicitation, identification and assessment, of risks.

Cretu et al. (2011) propose to tackle the risk management of infrastructure projects from the initial phases of design through construction, moreover he identified three main interviewing methods to conduct risk elicitation in infrastructure projects: (1) one-on-one, (2) large-group, and (3) small-group interviews. Through one-on-one and small-group interviews, it is easier to obtain the true risks within a project as long as the right experts are involved, this method was used to test a new risk assessment methodology (Wylie et al., 2014).

Both Lam, Wang, and Lee (2007) and Cretu et al. (2011) stated that one the big issues during the risk elicitation process is to count on external experts, to be recruited to aid in the elicitation process. Those experts should have experience with similar construction projects and knowledge of project delivery methods.

Once that risks have identified it is time to assess them, another key issue. PMBOK (Project Management Institute, 2012) proposes two approaches, quantitative and qualitative that have already been discussed. Marcelino-Sádaba et al. (Marcelino-Sádaba, Pérez-Ezcurdia, Echeverría Lazcano, & Villanueva, 2014) stated that risk assessment for in Small and Medium Enterprises (SMEs), should be more qualitative than quantitative, so it can be affordable with few resources, but effective trying to objectively prioritize risks according to their potential impact, in order to develop strategies and action plans as necessary.

For big transport infrastructure projects we should focus on the quantitative approach. A mathematical model has to be carried out to evaluate the overall effect on the project. Different methods have been proposed. For instance, Groen et al. (2006) proposed a fault tree structure so that events on it had to be quantified using an extensive set of probabilistic quantification models. Jui-Sheng et al. (2009) focused on a probabilistic simulation, separating unit costs and quantity uncertainty, to develop a distribution of project cost. Tüysüz and Kahraman (2006) analyzed if a fuzzy analytic hierarchy process (AHP) is a suitable and practical way of evaluating project risks based on the heuristic knowledge of experts is used to evaluate the riskiness project. Lee et al. (2009) proposed the use of a Bayesian belief network to manage risk in large engineering projects, concluding that major risks were design change, design manpower, and raw material supply as internal risks, and exchange rate as external risk in both large-scale and medium-sized shipbuilding companies. Peckienea et al. (2013) propose that with the purpose of sharing risks among parties to a construction contract agreement, in such a manner that not of the parties is harmed, cooperative game theory should be used to take into account the needs of all the parties concerned. Dikmen et al. (2008) developed a tool for post-project risk assessment. Sadeghi et al. (2010) used a mixed Fuzzy and Monte Carlo Simulation framework (FMCS), in order to avoid the problems of Monte Carlo simulation when no historical data are available for variable modeling. This framework help us to perform risk assessment in construction considering both fuzzy and probabilistic uncertainty in a problem.

It is clear that several methods, with different levels of complexity, maturity and resources cost are available to analyze the combined effect of different risks. Monte Carlo simulation among all of them is the one that has been widely used because of its relative technical computational simplicity, and power to evaluate an enormous number of risks and cases. Moreover it is possible to have an evaluation of the overall project cost and economic risk (Wylie et al., 2014). Application of the method to different kind of infrastructure projects has been done, e.g. hydropower electric plant (Liu, Wang, & Yin, 2011), electric power plant (Wei et al, 2009), Delhi metro rail (Sarkar, 2011), also the method has been adopted by some Governments to evaluate its infrastructure projects Denmark (Salling & Leleur, 2006), Indonesia National Nuclear Energy Agency (Waskita, Prasetyo, Akbar, & Handoko, 2010)

The last key issue comes after mitigation measures have been taken, (Wylie et al. (2014) concluded that conducting a post-mitigation analysis has relevant potential benefits, as the effects of the mitigation measures can be evaluated. Furthermore a new risk assessment methodology was developed providing added value of risk information that is crucial providing added value of risk information that is crucial and can be utilized to evaluate quantitative effects of project risks.

Nevertheless project risk management is not as widely use in the construction industry as it will be desirable and major infrastructure projects have a history of problems: cost overruns, delays, failed procurement, or unavailability of private financing are common (Beckers et al., 2013). Some barriers have been identified preventing implementation of formal risk management, like lack of knowledge and doubts about the suitability of these techniques, sophisticated nature of techniques compared to project sizes and human/organizational resistance (Azhar, Ginder, & Farooqui, 2008; Serpella, Ferrada, Howard, & Rubio, 2014)

4. Financial and economic analysis of transport infrastructure.

4.1 Concept.

Meanwhile sustainability is a wider concept including economic, financial, ecological, environmental and social dimensions, viability for a project refers to the assessment of whether the project has the capacity to meet the defined objectives, and in addition to generate significant *financial and economic* gains to the stakeholders, both private and public, and to the economy in general. Regarding risk management, viability should be understood as a first step to evaluate transport infrastructure projects, bearing in mind that accounting for risks at early stages of a project will lead to better results. If Risk Management Process (RMP) is applied to a project, not only will costs be more explicitly known, but also profit will be maximized (Ali, 2005). Proper front-end project planning is all about shaping the project's risk profile so it can be managed during execution (Beckers et al., 2013).

Although both types of analysis, economic and financial have the same objective, assess whether a project is viable or not, they approach the problem from two diverse points of view. The concept of financial viability focuses on the adequacy of the returns of a project to the investor, or group of investors or other project participants. On the other hand, economic viability has a wider perspective, measuring the projects effects on the national economy. Obviously financial analysis and economic analysis are complementary, but although they are key subjects to viability, they are not the overriding criteria for approval of all projects. Other analysis can be performed previously to adopt a decision, *inter alia*, Regional Impact Assessment (REI), Environmental Impact Assessment (EIA), Cost-Effectiveness Analysis (CEA), and Multi-Criteria Analysis (MCA). However, economic and financial appraisal are widely used among practitioners, both public and private.

There may be projects which appear to have very high potential for economic gain bit which are very risky in terms of the technical, social and institutional factors; or have negative impacts on the environment. There may be other projects where social and environmental factors are very strong but all the economic gains cannot be easily estimated or valued.

4.2 Methods and tools.

To assess economic and financial viability a wide range of tools and methods can be used. As an example, an issue of Transport Policy (Volume 7, Number 1, 2000) was committed to analyze evaluation methodologies used for transport infrastructure projects worldwide, including public transport and roads.

Meanwhile financial analysis concerns those undertaking a project, economic analysis concerns society in general, focusing on the opportunity cost of diverting resources to the project, e.g. macro orientated efficiency in resource allocation. We will outline key topics to financial and economic appraisal of infrastructure projects.

Resource and cash flow statements, which will show the resources used in the project investment, the resources generated by that investment, the cash flows associated with those resource flows and the cash flows associated with funding the investment.

Discounted cash flow, one major concern about economic and financial appraisal is how to evaluate costs and benefits which occur in the future. Typically investments have a common pattern of costs and benefits, resulting in cost exceeding benefits in early years and the other way round in later years. So we have to account for the fact that the values of benefits or costs in say ten years' time are less than the same values at the present to evaluate whether and by how much overall benefits may exceed overall costs within the life cycle of the project.

Net Present Value (NPV) is the net sum of total discounted benefits (cash inflows) and total discounted costs (cash outflows). This yields a figure showing the excess (or shortfall) of benefits over costs in monetary terms, comparing present value of money today to the present value of money in the future, taking inflation and returns into account. The calculation ca be done for either economic or financial cash flows of a project.

Internal Rate of Return (IRR) IRR is that rate of return percentage, which when used as the discount rate, will cause the sum of discounted future cash inflows to exactly equal the initial cash outflow. If IRR is greater than the rate of return required by investors or society, the investment is financially, or economically attractive.

Benefit-cost ratio (BCR) is an indicator as the NPV of benefits divided by the NPV of costs, and attempts to summarize the overall value for money of a project or proposal. The higher the BCR the better the investment. General rule of thumb is that if the benefit is higher than the cost the project is a good investment.

Sensitivity Analysis[25]. Whenever an economical or financial analysis is performed many variables are involved. For the investor, or interested person, is essential to determine how different values of these independent variables will impact a particular dependent variable, e.g. NVP, IRR, BCR etc., under a given set of assumptions. To get an answer for that question sensitivity analysis is a good way to predict these impacts. By creating a given set of scenarios[26], with different values for each independent variable, we can determine how these changes will impact the target variable.

Average Accounting Rate of Return (ARR) is calculated by finding a capital investment's average EBIT divided by the book value of the average amount invested. The result is expressed as a percentage, providing a quick estimate of a project's worth over its useful life.

Payback Period, (PB) is the time in which the initial cash outflow of an investment is expected to be recovered from the cash inflows generated by the investment. It is one of the simplest, along with ARR, investment appraisal techniques, used for quick calculations and is generally not considered as critical for evaluating whether to invest in a particular situation.

Monte Carlo Simulation, is a method used to propagate uncertainties of the input variables of a model, economic or financial in our case, into uncertainties in model outputs[27] (results). This is made by representing uncertainties by

[25] For a review on the most important methods to perform sensitivity analysis vid: (Hamby, 1994)

[26] So called "what if scenarios", because each of them answers the question to a question like: what if this variable is %% higher or lower?

[27] Kwak (2007) reviewed the applications and uses of Monte Carlo Simulation for project management.

specifying inputs as probability distributions, so that the output result is itself a probability distribution. Benefits of Monte Carlo simulation are obvious using quantified data, allowing project managers to better justify and communicate their arguments when senior management is pushing for unrealistic project expectation.

4.3 Key Issues.

4.3.1 *IRR and NPV.*

Through last 100 years there has been an intense debate on which of one of those measures was the best one to be used as a method for choosing between capital investment projects (Osborne, 2010), this includes transport infrastructure projects.

Even though both have been used to evaluate alternatives in a wide range of projects, there is a gap between academics and financial practitioners. Meanwhile NPV is supported by academics, a tendency that began in middle ’50 with some papers regarding this question (Lorie & Savage, 1955), and it remains unchanged nowadays (Bhattacharyya, 2004; Jensen & Smith, Jr., 1984). This tendency is based on the so-called IRR pitfalls, or deficiencies:

Pitfall 1: Lending or borrowing. The IRR does not distinguish between a lending (investing) or a borrowing (borrow and invest) situation, whereas the NPV clearly points out the negative aspects of the borrowing strategy

Pitfall 2: There could be multiple rates of return. Any change in sign (-,+) in period cash flows produces as many IRR’s as there are changes in the cash flow directions of the investment.

Pitfall 3: Mutually exclusive projects. The IRR may give a conflicting choice relative to the NPV, which focuses more accurately on shareholder value.

Pitfall 4: IRR rule cannot be used when the term structure of interest rates is not flat.

However, and even with these evidences, surveys of corporate managers have consistently shown that managers rank IRR ahead of NPV.

Ryan and Ryan (2002) shown that over 85% of Fortune 1000 companies used NPV over 75% of the time in making investment decisions. Burns & Walker (1997) shown similar results for Fortune 500 companies, also Payne et al. (1999) found results for USA and Canada companies, resulting that in both countries NPV and IRR where the most used techniques, although in Canada NPV was wider used to take decisions than IRR. But these results are not found only in USA, Canada and UK, where most studies are focused. Moreover, things may be changing, Hermes (2007) found that even though among Chinese managers IRR was the most used method, Dutch managers found NPV more useful when it comes to evaluate projects. Other, more simple methods, are still wide used as PB in Cyprus (Lazaridis, 2004), Singapore (Kester & Tsui Kai, 1998) or China (Hermes et al., 2007).

From a mathematical point of view, Osborne (2010), explored the time value of money equation (TVM) to discuss the existence of n solutions, n IRR, to this order n polynomial equation, some of them may be complex. With this approach two of the pitfalls of the IRR are eliminated, opening a new study field for economic research.

Another way of avoiding the pitfalls of IRR, and some deficiencies of the NPV outlined by Kierulff (2008) and Beaves (1988), is the use of the Modified Internal Rate of Return (MIRR). MIRR is a derivative of IRR providing a more accurate percentage measure of financial attractiveness, Kierulff (2008, p. 321) "*describes how MIRR works, and demonstrates how MIRR solves inherent weaknesses in NPV and IRR*".

4.3.2 *Discount rate.*

Estimated future cash flows and the discount rate are the two inputs needed to calculate common discounted cash flow (DCF) used to determine the values previously discussed, NPV and IRR, for both financial and economical assessments. Hence we will split this section in two, one to discuss on the financial discount rate, and another one focused on the economical discount rate.

4.3.2.1 Financial discount rate.

Regarding financial discount rate it is widely accepted to define it as *"the opportunity cost of capital"* (European Commission, 2008, p. 209). Hence the capital has an opportunity cost which is set by the rates of return on alternative uses of that capital. According to IFRS, discount rates shall account for (International Financial Reporting Standards Foundation, 2012):

- The time value of money.
- The risks specific to the asset for which the future cash flow estimates have not been adjusted.

Obviously, different discount rates can make big differences to the outcome of the analysis of projects. Given the importance that the choice of discount rate will have in the financial analysis output, we will outline the approaches to calculate the financial discount rate[28]:

- **Cost of Equity**. Equity shareholders expect to obtain a certain return on their equity investment in a company. From the company's perspective, the equity holders' required rate of return is a cost

[28] For a deeper discount on financial discount rate vid: (Cochrane, 2011; International Financial Reporting Standards Foundation, 2012; Martínez Abascal, 2005)

because if the company does not deliver this expected return, shareholders will simply sell their shares, causing the price to drop. Sharpe (1964) proposed the capital asset pricing model (CAPM) to calculate the cost of equity, becoming the most used formula. So the discount rate shall be chosen to be equal to this equity cost.

- **Weighted-Average Cost of Capital (WACC)** is the average rate of return a project needs to compensate all different parts of its capital structure. This capital structure reflects the overall costs of combined debt and equity capital used to finance a project. The weights are the fraction of each financing source in the project. Although the value of an investment project depends on both its discount rate, which is a measure of risk, survey evidence shows that most firms use only one single discount rate to value all of their projects (Graham & Harvey, 2001), instead of a single rate for each project, what Krüger et al. (2011) named “WACC fallacy”. This fallacy consists of a failure to account for project-specific risk, which damages the selection between heterogeneous projects.
- **Similar projects rate of return**. The rate of return that a company, or an investor, could earn elsewhere on similar projects, in terms of risk and capital structure.
- **Similar finished projects rate of return**. The rate of return that a company, or an investor, have earned on similar finished projects, in terms of risk and capital structure.
- **Company risk aversion.** *“Risk aversion and time preferences create heterogeneity in preferences for project selection with near-term costs and uncertain future benefits. A subjective time discount rate the discounted utility model, describes the problem of decisions over time where utilities at different moments of time. Depending on its capital structure companies may have a higher discount rate, specifically when the firm is controlled by a large, risk-averse shareholder”* (Zhang, 1998).
- **Debt Service.** Talking about project finance in public projects, the opportunity cost embedded in the discount rate is the return that a country can obtain by investing funds, if it did not have to pay debt service today. So any project leading to positive NPV through DCF at sovereign debt rate shall be funded. The discount rate must account for the individual country risks, including those related to non-payment.

4.3.2.2 Economical discount rate.

The choice of a ‘‘correct’’ economic, also called social discount rate (SDR) is one of the main problems when appraising public projects. It has to reflect the social view on the way future benefits of a project are to be valued against present ones. The problems to choose a discount rate are several, Rambaud and Torrecillas (2005) outlined the most relevant: differences between generations to valuate cost and benefits (Kula, 1984), using a single or various discount rates, depending on the beneficiaries, using higher or lower discount rates for projects with relevant effects in the distant future, and so on.

Digging deep into theoretical domain, there are three main approaches, widely accepted (European Commission, 2008):

- In the case the project competes with private projects, the solution can be to use the capital productivity marginal discount rate, or the opportunity cost of capital, that has been discussed in Chapter II.4.3.2.1.
- Another approach is to use social time preference approach, derived from the pure time preference rate and the predicted long-term growth in the economy.
- The most recent approach, especially relevant in the appraisal of very long-term projects or with relevant effects in the long time, is based on the application of variable rates over time.

Apart from those approaches, De Rus (de Rus et al., 2010) proposes a combination of the first two in case the capital for project comes from several origins, an average discount rate shall be calculated regarding the proportions of each capital origin and its discount rate.

Obviously, all these difficulties and different methodologies are reflected in a wide range of discount rates used worldwide. Some governmental agencies have develop different models to calculate SDR in order to appraise public projects, Lake and Ferreira (2002) found differences ranging from 3 to 8% in countries like Japan, USA, UK, Germany and France.

A recent study by Odgaard, Kelly, and Laird (2006) concluded that out of 17 European countries studied, there were a wide range of values used for the discount rate, varying from less than 4% to more than 7%, and they stated that "*the data shows that there are no clear regional differences in the choice of discount rate*".

On a comprehensive work made by the European Commission (2008) the results where similar, and an approach for the STPR was calculated and it is shown in Table 2.

Non CF countries	g	e	p	SDR
Austria	1.9	1.63	1.0	4.1
Denmark	1.9	1.28	1.1	3.5
France	2.0	1.26	0.9	3.4
Italy	1.3	1.79	1.0	3.3
Germany	1.3	1.61	1.0	3.1
Netherlands	1.3	1.44	0.9	2.8
Sweden	2.5	1.20	1.1	4.1
CF countries	**g**	**e**	**p**	**SDR**
Czech Rep.	3.5	1.31	1.1	5.7
Hungary	4.0	1.68	1.4	8.1
Poland	3.8	1.12	1.0	5.3
Slovakia	4.5	1.48	1.0	7.7

Table 2. Indicative social discount rates for selected EU Countries. (European Commission, 2008)

Chapter III. **Modeling risk in port infrastructures. A practical approach.**

1. Overview.

In this chapter, we will analyze which are the specific characteristics of port infrastructure appraisal, highlighting the most relevant issues for projects within this field. This analysis will be done through a practical example of a financial and economic appraisal of a port infrastructure project, a new container port in Cartagena (Spain)[29]. The analysis has been carried out in three different stages:

- A base case.
- Sensitivity analysis of the previous case.
- Risk analysis using Monte Carlo simulation.

A comparison between the three methods is discussed too.

2. Project definition.

2.1 Actual infrastructure.

Nowadays the port of Cartagena has 224’37 Ha of land 13.040 m. of berth line, divided in several uses: commercial, fishing, leisure, and private docks.

The total area of the storage within the port amounts to approximately 578.000 m2.

Figure 6. Port of Cartagena and its two basins.

[29] All data used for this practical example has been obtained from Port Authority of Cartagena’s website: www.apc.es and it is public.

2.2 Actual demand.

In 2011 Port of Cartagena moved 22 million tons, a sharp year-over-year increase, over 18% compared to 2010.

Traffic increase in confirms the growing trend of this port since 1996. Growth has been much faster compared to the Spanish National Port System average. This evolution is shown in Figure 7.

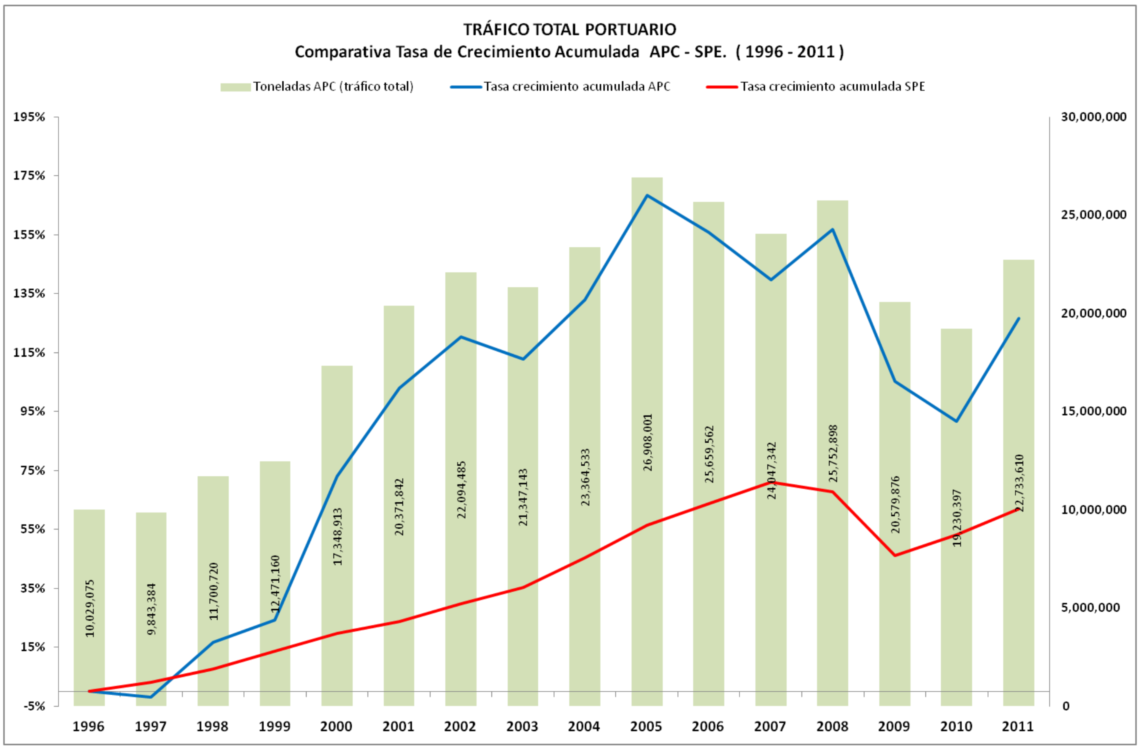

Figure 7. Traffic evolution 1996-2011. P.A Cartagena / Spanish National Port System.

Product mix has varied over time, but liquid bulks remain as the main traffic, which forged the personality of the Port of Cartagena. There is a clear preponderance of crude oil over the rest of the products. This can be seen in Figure 8.

General merchandise is the less relevant traffic, just 5% of the total. The main reason for this is the lack of adequate facilities for this kind of traffic, but also because of its industrial and petrochemical character.

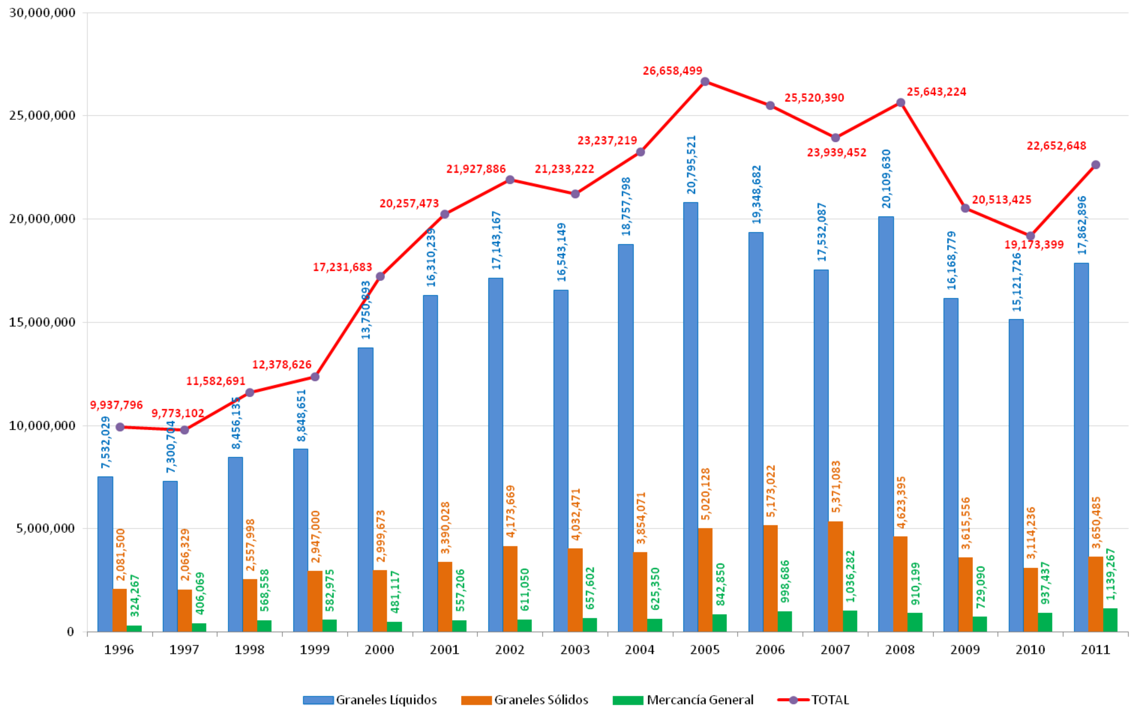

Figure 8. Traffic and product mix evolution.

2.3 Future demand without project.

Traffic evolution if the project would not be develop has been analyzed, this leads to the definition of the base case, which implies do nothing new and maintain the level of investment needed to serve the current activity.

CONCEPT	Demand					
	2012	**2013**	**2014**	**2015**	**2020**	**2025**
LIQUID BULKS	**17.611**	**19.472**	**22.121**	**22.779**	**24.842**	**26.052**
Crude oil	8 800	10.100	12,200	12,600	14,000	14,500
LNG	3.497	3.719	3.937	4.039	4.302	4.584
Refined petroleum products	4.336	4.612	4.882	5.009	5.335	5.684
Other liquid bulks	979	1.041	1.102	1,131	1.205	1.284
SOLID BULKS	**3.385**	**4.270**	**4,345**	**4.430**	**4.835**	**5.206**
For special installation	405	650	665	680	735	806
No special installation	2.980	3,620	3.680	3.750	4.100	4,400
GENERAL CARGO	**1.008**	**1,036**	**1.065**	**1,094**	**1,206**	**1.327**
Conventional general cargo	223	230	237	244	270	305
Containerized cargo	780	802	823	846	931	1,016
Ro-Ro	5	5	5	5	5	5
TOTAL GOODS	**22.004**	**24.778**	**27.531**	**28.304**	**30.883**	**32.585**
FRESH FISH	1	1	1	1	2	2
PROVISIONING	**60**	**61**	**62**	**64**	**70**	**78**

Bunkering	39	40	41	42	46	51
Other	21	21	22	22	24	27
LOCAL TRAFFIC	**0**	**0**	**0**	**0**	**0**	**0**
TOTAL TRAFFIC	**22.066**	**24.841**	**27.595**	**28.369**	**30.955**	**32.664**

Table 3. Forecasts of traffic up to 2025 without project.

We can observe that growth forecasts show a stagnation, vegetative growth, in all oil industry related traffic. This is because by the end of 2015 the refinery will be running at 80-85% of its capacity, and therefore growth will be constricted by refinery's capacity. In the same way, all refined petroleum products and other chemicals storage facilities will also reach capacity by 2020.

2.4 Project infrastructure.

Criteria to define the size, and minimum infrastructure needs for the project, are based on the biggest ship, and the estimated demand to be served at the port.

Attending these criteria, water depth in the port must be between 20 and 55 meters and structural, moreover quay length should be over 1900 meters. A summary of the design ship features is shown in Table 4.

SHIP	MEDIUM container 14.500 TEU´s	CONTAINER Max 18.000 TEU´s
GT	156.907	165.000
Displacement	218.788	230.100
Length L (mm)	397	400
LPP (m)	377	380
B width (m)	56'40	59
Strut T (m)	30'20	32
Depth D (m)	16	14'5
Block coefficient	0'7	0'7

Table 4. Design vessel characteristics.

Regarding the traffic to be served at the port, the minimum physical necessary characteristics are shown in Table 5.

Phase 1:	**·Capacity 2,500,000 TEU´s**
	1.790 meters quay length
	Four 14.500 TEU's ship posts, to be used simultaneously.
	Esplanade for container traffic 80 Ha

Table 5. Minimum physical characteristics for the new port.

With this requirements an alternative appraisal was carried out, resulting in just one viable alternative. The alternative is located near the "Valle de Escombreras", "Sierra de la Fausilla" and "Valle del Gorguel". In particular in "El Gorguel" beach, to the East of Cartagena, nearby Portman Bay, and immediately west of "La Cola del Caballo".

This location, on the shore North of the entrance to the sea of Alboran, would imply that container vessels did not have to deviate from their transoceanic routes.

The proposed solution is achieved with a breakwater approximately 4,500 m, protecting the basin from the swells from the East. This configuration obtains ***3,100 m of quay with terraced Esplanade***.

The width of the basin is 887 m in such a way that it allows the largest ship container ship maneuver.

The esplanade is available is almost 150 Ha, this surface is intended for temporary hoarding of goods.

2.5 Future demand, if project is developed.

The last study carried out by the port Authority of Cartagena up to now, was made in 2011, we have used the results of this study for our analysis. The study designed three scenarios, pessimistic, neutral and optimistic, that in terms of risks can be seen as low, mid and high risk situations. The expected demand, without capacity restrictions is shown in Figure 9 reflecting the actual potential traffic to be attracted by the new infrastructure.

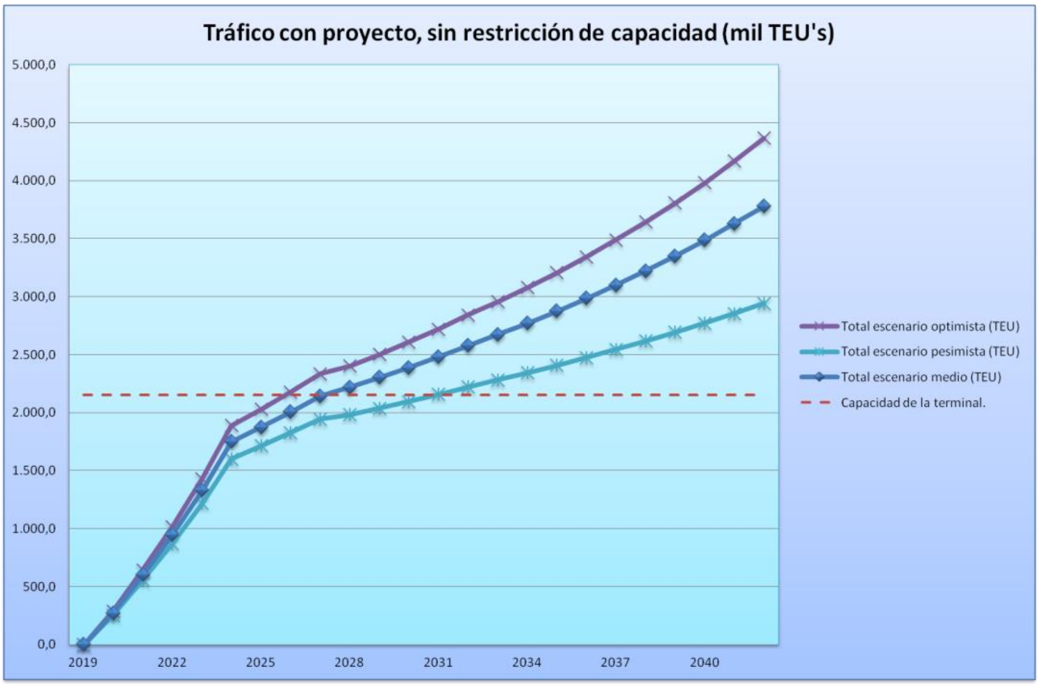

Figure 9. Predicted demand for the three scenarios, without capacity restriction.

Bearing in mind the maximum operational[30] (80% occupancy) capacity that can be held by the new infrastructure we realize that the new port is designed to cover the needs in the medium term on the mid-risk scenario, as shown in Figure 10.

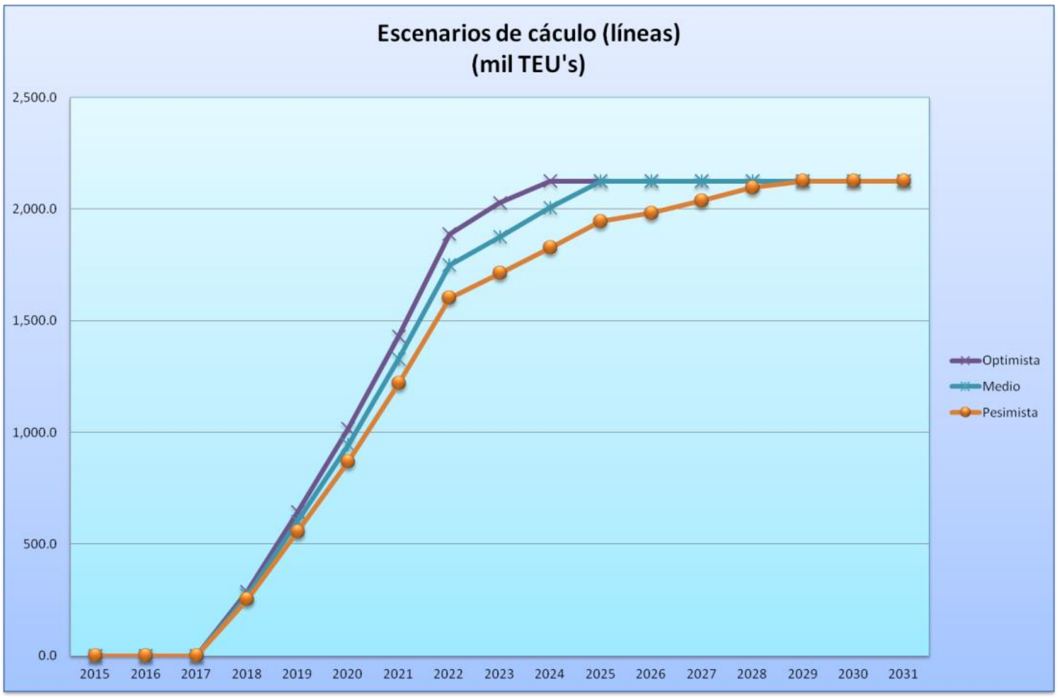

Figure 10. Predicted demand for the three scenarios, with capacity restriction

Demand was calculated according to three main kinds of traffic, as reflected in Figure 11, to ease CBA analysis from the point of view of the surpluses obtained each of them:

- New transshipment traffic, not existing previously.
- Previously existing Import/Export traffic.
- Deviated Import/Export traffic, from other ports.

[30] It is commonly accepted that the operational capacity it is reached at 80% of the maximum theoretical occupancy.

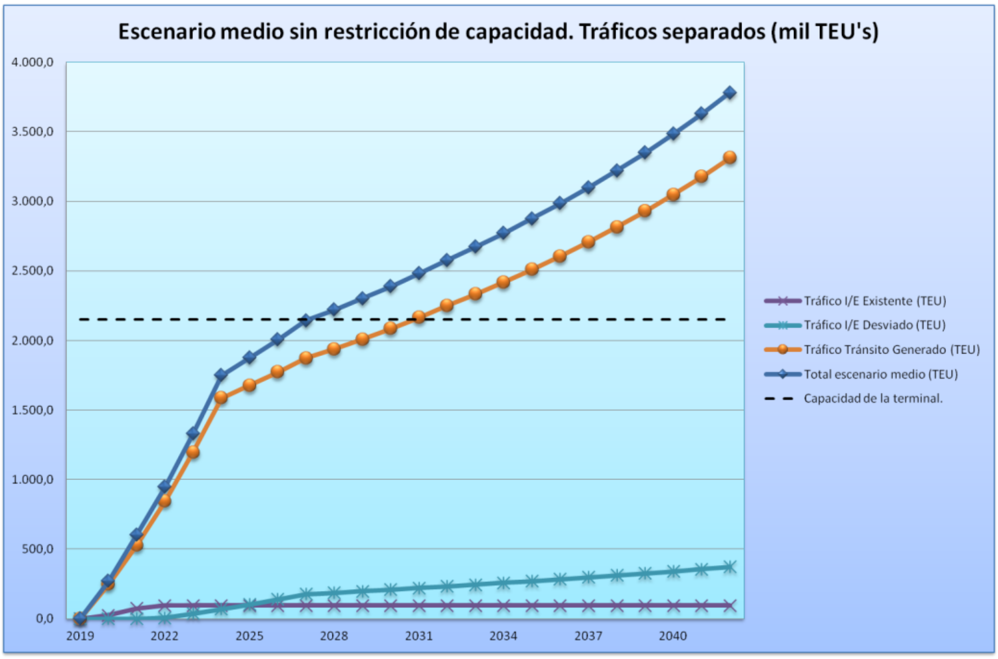

Figure 11. Total demand divided by type.

3. Financial analysis.

In this section we describe the most relevant inputs to financial analysis, justifying the origin of data. These data are used in the **"BASE case".** On variables on which there is more uncertainty, we will apply the statistical distributions described in section *Variables and uncertainty.* Figure 12. Financial analysis scheme shows the scheme of the financial model.

Results of base case financial analysis are graphically shown in Annex I.,

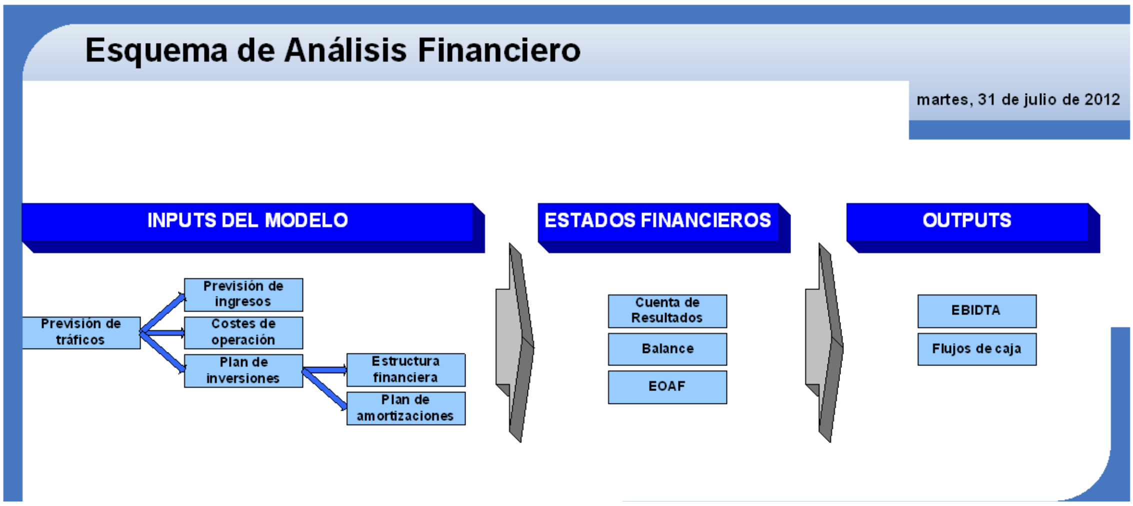

Figure 12. Financial analysis scheme

with a series of charts summarizing the evaluation model.

Some assumptions made for the study must be highlighted:

- Investment is being only assessed from the point of view of the port authority.

- All calculations have been made in current euro, with an inflation of 2%.
- Year basis for the calculation is 2013 when works are commissioned, therefore inputs will be referred to 2013 euros.
- Data from the preliminary version of the Port Authority Master Plan (2009) have been used as a starting point. Only traffic data, updated in 2011, as well as data on the infrastructure costs have been modified.
- We have considered that 85 hectares of 125 total to be constructed will be given in concession for container terminal.
- Period for assessment is 35 years after the finishing of the works, corresponding to the maximum period of a possible concession (Governement of Spain, 2011). By doing so, those facilities whose repayment period is greater than these 35 years will have a residual value that will be assessed in the analysis.
- General data, obtained from a similar container port have been used.

Datos generales del tráfico		
Descripcción	Valor	Unidades
Porcentaje de contenedores llenos estimados en la nueva terminal	70%	%
Porcentaje de contenedores vacíos estimados en la nueva terminal	30%	%
Porcentaje de contenedores de 20 pies estimados en la nueva terminal	50%	%
Porcentaje de contenedores de 40 pies estimados en la nueva terminal	50%	%

Table 6. General data.

3.1 Investment, CAPEX.

A preliminary investment evaluation study was developed Berenguer Ingenieros (2006). This study has been used as starting point to calculate the total investments (CAPEX). The initial study data has been corrected with the new size and needs emerging from the study of traffic update (Spim & Royal Haskoning, 2011). All investment figures are shown in Table 7.

Estudio APC 2010 (Base Escombreras)			
Elemento	Medición	Precio unitario	Licitación
Dique + Contradique	4,400	50,000.00 €	220,000,000.00 €
Muelles	2,050	60,000.00 €	123,000,000.00 €
Movimiento de tierras (m2 relleno)	1,222,000	110.00 €	134,420,000.00 €
Pavimentación	1,222,000	120.00 €	146,640,000.00 €
Edificios, instalaciones y adecuación			73,000,000.00 €
Total			697,060,000.00 €
Accesos (se añadirán a la partida de instalaciones)			50,000,000.00 €

Table 7. Investments.

With this basis, an adjustment was made based on the Port Authority of Cartagena know-how, which is materialized in a prices database. Once this adjustment was made, the actual data *proposed initial budget increased by almost 15%*.

Regarding the same database, it should be noted that a difference between investment prices and tender prices was found. The difference varies usually between a 15% and 20%, up to 40% in some cases, of the initial investment that appears to be always higher than the final tender price. This will be considered when modelling of the distribution of the corresponding variable. All prices were updated to 2013.

On the one hand, a part of the investment will be held by the dealer. The forecast is that it will held the costs of paving works, as well as 5% of the rest of the port infrastructure. We should also indicate that, just as a practical exercise, we assumed that works would be contracted in the year 2013, and execution would begin in the year 2014.

In order to be methodologically correct[31] the investment of the land accesses to the new port have been added to the total investment. Accesses budget has been obtained from the study carried out by TYPSA (2008), all prices have been updated to 2013 prices. The prices that are listed in the following table are flows of the year 2013.

Table 8 shows the main figures used to calculate investment. Expected period of execution of the works is 6 years and the total investment by the port authority is 573 million euros (2013 euros).

Datos para cálculo de inversión

Descripcción	Valor	Unidades
Año en el que se contrata la inversión (comienza a pagarse al año siguiente)	2,013	Año
Inversión total en infraestructuras	697,060	mil €
Inversión total a realizar por la Autoridad Portuaria	572,899	mil €
Inversión a realizar por la Autoridad Portuaria en diques	209,000	mil €
Inversión a realizar por la Autoridad Portuaria en muelles	116,850	mil €
Inversión a realizar por la Autoridad Portuaria en rellenos	127,699	mil €
Inversión a realizar por la Autoridad Portuaria en pavimentación	0	mil €
Inversión a realizar por la Autoridad Portuaria en instalaciones y accesos	119,350	mil €
Inversión a realizar por la Autoridad Portuaria en mobiliario	75	mil €
Inversión a realizar por la Autoridad Portuaria en sistemas informáticos	100	mil €
Porcentaje de la inversión a realizar por le inversor privado (aparte de pavimentación)	5%	%
Plazo de ejecución de las obras	6	años

Table 8. Investments plan.

Table 9 is also based in Port's know-how, an investment calendar was designed according to the data included in the Port's Master Plan.

[31] Otherwise we will not be evaluating a complete project(de Rus et al., 2010; European Commission, 2008), leading to a positive bias in the final results.

Ritmo de ejecución previsto de las obras.		
Descripción	**Valor**	**Unidades**
Porcentaje ecjecución obras 2014	9.00%	%
Porcentaje ecjecución obras 2015	10.00%	%
Porcentaje ecjecución obras 2016	11.00%	%
Porcentaje ecjecución obras 2017	30.00%	%
Porcentaje ecjecución obras 2018	30.00%	%
Porcentaje ecjecución obras 2019	10.00%	%

Table 9. Investments rates.

3.2 Incomes.

Revenues have been calculated according to Spanish law (Governement of Spain, 2011). The dealer has to pay two different taxes, occupation and activity, and the ship-owner must pay for vessel and merchandise taxes. Aids to navigation tax has not been included in as an income, because it is a general income for the Port Authority, not related with a single port.

To calculate future revenues, maximum legal bonuses have been applied, and correction factor has been valued as 1. Activity and occupancy taxes have been rated an 0'30 € per movement and 7€/m2/year respectively, both figures similar to those in similar projects in Spanish ports, like, Cartagena, Algeciras, Barcelona, and so on. All rates are updated annually with inflation, but the rate of occupation that is updated annually with 75% of the previous year consumer prices index according to Spanish law (Governement of Spain, 2011).

Table 10 shows the most relevant data used to calculate incomes.

Datos para cálculo de ingresos		
Descripción	**Valor**	**Unidades**
Bonificación de la T3	20%	%
Bonificación de la T1	30%	%
Coeficiente corrector de la tasa a la mercancía	1	
Coeficiente corrector de la tasa al buque	1	
Estimación de la tasa de actividad.	0,3	€/TEU
Tasa a la mercancía. Cuota íntegra para contenedores 20 pies llenos	31	€/Mov
Tasa a la mercancía. Cuota íntegra para contenedores 20 pies vacios	2,79	€/Mov
Tasa de ocupación. Cuota anual estimada.	7	€/m2
Superficie concesionada para la terminal de contenedores	850	mil m2
Coeficiente para modificar la T-3 en el caso de tránsito marítimo	25%	%
Tamaño (GT) del buque medio que operara en el puerto	350	x100 GT
Operación media (carga+descarga) del buque que atraque en el puerto.	1800	TEU
Tiempo medio de estancia del buque	15	horas
Cuantía básica de la Tasa al buque (B)	1,5	€/100 GT/hora

Table 10. Data to calculate incomes.

3.3 Operational expenses, OPEX.

To evaluate OPEX, management and maintenance costs have been estimated, as a percentage of the total inversion cost and are summarized in Table 11. All percentages have been obtained from the current analytical accounting of the port authority.

15 new direct jobs are created by the port authority, which are the staff expenses. Staff expenses have been valued equal current staff of the port authority. These costs are updated since the first year of application of these costs. Staff costs represent an annual cost exceeding 700 thousand euros.

Management expenses have been forecasted at 10.000 € per year, and maintenance at 0'5% of the investment costs, both of them are updated with inflation. Finally, taxes have been estimated regarding legal considerations, and it has evaluated in some 450 thousand euros per year.

Datos para cálculo de gastos

Descripcción	Valor	Unidades
Nuevos puestos de trabajo fijos creados por la APC durante la explotación de la nueva terminal	15	uds
Coste medio por trabajador en la APC	40	mil €/trabajador
Porcentaje sobre ingresos de gastos anuales de gestión corriente	0,05%	%
Porcentaje de sobre la inversión inicial para gastos anuales de mantenimiento	0,23%	%
Porcentaje de aportación sobre ingresos a Puertos del Estado (no se incluye navegación marítima)	4%	%
Porcentaje de aportación sobre ingresos a Tributos	1,50%	%
Porcentaje de Impuestos sobre beneficios	4%	%

Table 11. Data to calculate OPEX.

3.4 Amortization.

To calculate the amortization plan international accounting regulations[32] have been taken into account, as well as regulated life values, terminal values, which have been commonly accepted values. Depreciation has been considered to be linear.

In the model used to evaluate the project some assumptions were made regarding replacement:

- Furniture will be replaced every 10 years.
- Computer systems will be replaced every five years.
- An investment of 10% of the initial investment will be made 17 years before the commissioning of the terminal, which corresponds to half of the life service of the quays.
- All this investments are valuate at current prices of the corresponding years.

To finish with the amortization plan, to account for terminal values, which have been estimated at 10% higher than the residual book value to take into account the intermediate inversions made to improve the infrastructure.

Table 12 shows data used to calculate depreciation and the consequent amortization plan.

[32] The International Accounting Standards Board (IASB) is an independent, private-sector body that develops and approves International Financial Reporting Standards (IFRSs), which have been used to develop the amortization plan of this example. The IASB operates under the oversight of the IFRS Foundation. The IASB was formed in 2001 to replace the International Accounting Standards Committee.

Datos para cálculo de amortizaciones		
Descripcción	**Valor**	**Unidades**
Valor actualizado de las obras de los diques (parte ejecutada APC)	225.959	mil €
Valor actualizado de las obras de los muelles (parte ejecutada APC)	126.332	mil €
Valor actualizado de las obras de los pavimentos (parte ejecutada APC)	0	mil €
Valor actualizado de las obras de los instalación (parte ejecutada APC)	121.737	mil €
Valor actualizado de los sistemas informáticos (parte ejecutada APC)	75	mil €
Valor actualizado del mobiliario (parte ejecutada APC)	100	mil €
Vida útil para el cálculo de la amortización de los diques	50,00	años
Vida útil para el cálculo de la amortización de los muelles	30,00	años
Vida útil para el cálculo de la amortización del pavimento	15,00	años
Vida útil para el cálculo de la amortización de las instalaciones	17,00	años
Vida útil para el cálculo de la amortización de los equipos informáticos	5,00	años
Vida útil para el cálculo de la amortización del mobiliario	10,00	años

Table 12. Data used to calculate depreciation & amortization plan.

3.5 Financial plan.

For the financial plan of the two sources of funds, apart from cash flow generated by the new terminal, have been used.

The first will be senior debt (EIB credit or similar), with a rate of interest of 3'4%[33], for the base case, and a maximum repayment period of 25 years. This debt is returned, and therefore interests are accrued, from the first moment that the credit is available. The credit will be available in three yearly consecutive provisions starting from 2017, and grace periods are supposed to be given to each one of the credit provisions. Finally, to take into account the goodness of the financial plan proposed, the accumulated working capital will be used as an output variable, obtaining its statistical distribution to check its probability of being less than 0.

The second source of funds will be the surplus, variations in the cash-flow at the end of each year, generated in all the other quays and ports depending on the same Port Authority. In the next two tables the two origins of funds planned to deal with the construction of the new facility are broken down.

[33] Similar interest rates have been applied to similar inversions in the Kingdom of Spain by the European Investment Bank, e.g. 2'9% in a loan obtained to finance Port of Gijon's expansion.

Datos para cálculo de financiación y actualización			
Descripcción	Variable (Calculo Excel)	Valor	Unidades
Tasa de actualización (Inflación estimada durante el proyecto si es 0% --> Euros corrientes)	Inflación	2,00%	%
Fondo de maniobra generado por las otras dos dársenas	FM APC	22000	mil €
Importe del crédito 1	Credito 1	220000	mil €
Periodo de carencia del crédito 1	Carencia 1	5	Años
Tasa de financiación 1	Tasa financiacion 1	3,3%	%
Plazo del crédito a partir del periodo de carencia	Plazo credito 1	20	Años
Año concesión crédito 1	Año conc crédito 1	2017	Año
Importe del crédito 2	Credito 2	130000	mil €
Periodo de carencia del crédito 2	Carencia 2	4	Años
Tasa de financiación 2	Tasa financiacion 2	3,3%	%
Plazo del crédito a partir del periodo de carencia	Plazo credito 2	20	Años
Año concesión crédito 2	Año conc crédito 2	2018	Año
Importe del crédito 3	Credito 3	35000	mil €
Periodo de carencia del crédito 3	Carencia 3	3	Años
Tasa de financiación 3	Tasa financiacion 3	3,3%	%
Plazo del crédito a partir del periodo de carencia	Plazo credito 3	20	Años
Año concesión crédito 3	Año conc crédito 3	2019	Año

Table 13. Financial plan. Senior debt.

As shown in Table 13 grace periods, interest only payments, where the of 5, 4 and 3 years respectively, have been considered. So capital of the three loans begins to be returned at the same time, when the new port works are completed. Moreover, in any case the total 25 years period since the first provision of the credit is exceed.

Table 14 shows the contributions of the port authority own capital, which will be the second source of project funds, as discussed previously.

Datos para cálculo de financiación y actualización		
Descripcción	Valor	Unidades
Tasa de actualización (Inflación estimada durante el proyecto si es 0% --> Euros constantes)	2.00%	%
Fondo de maniobra generado por las otras dos dársenas	22000	mil €
Aportación APC 2013	115000	mil €
Aportación APC 2014	26400	mil €
Aportación APC 2015	26400	mil €
Aportación APC 2016	26400	mil €
Aportación APC 2017	26400	mil €
Aportación APC 2018	25834	mil €
Aportación APC 2019	25281	mil €
Aportación APC 2020	24127	mil €
Aportación APC 2021	25239	mil €
Aportación APC 2022	25732	mil €
Aportación APC 2023	26149	mil €
Aportación APC 2024	26498	mil €
Aportación APC 2025	22000	mil €
Aportación APC 2026	22000	mil €
Aportación APC 2027	22000	mil €
Aportación APC 2028	22000	mil €
Aportación APC 2029	22000	mil €
Aportación APC 2030	22000	mil €
Aportación APC 2031	22000	mil €

Table 14. Financial plan. PA of Cartagena capital contributions.

3.6 Period of evaluation.

The assessment for the financial and economic analysis are the same, which will coincide with the maximum period permitted by law, which is 35 years[34]. This period excludes the time required for the construction of the infrastructure that will be six years.

3.7 Discount rate.

In Chapter II we have discussed which possibilities we have to choose a discount rate. We use this rate to discount the cash flows of the project, once taxes and financial expenses, and get the NPV.

We will review the different choices we discussed in Chapter II, evaluating them for this example, and finally decided which one is the one that best fit our example.

- **Cost of Equity**. In our example there is just one shareholder, the Spanish Government, whose profitability is 2'5%, thus it is legally fined[35]. Here it should be noted that, in fact, the legislation provided corrective coefficients to the rates in those cases in which the benefit is greater than the 2'5%.
- **Weighted-Average Cost of Capital (WACC).** Taking into account the approach of the project financial plan we would get a WACC around 3'25%. But we do not discount FCF, we have also included cost of external finance and taxes to deduct them from the FCF. So it makes no sense to use WACC for this project.
- **Similar projects rate of return**. In the case of the port authority, and given the uniqueness of the project we are evaluating, no similar projects can be carried out, so it has no sense to apply this criterion to assess the discount rate.
- **Similar finished projects rate of return**. . In this case we would have to talk about values between 2'5 - 2'8% that are the returns of the last projects carried out.
- **Company risk aversion.** It is an approach with a very high degree of subjectivity and therefore we must reject it in this project.
- **Debt Service.** In our case, we could use the cost of the 10 years bonus, 6% in the current situation, discounting inflation of 2 - 2'5% would lead to a discount rate between the 3'5% and 4%. It should be noted that as in the case of the WACC this formulation is expected to deduct FCF and not project flows as we do.

Once reviewed different possibilities raised and taking into account the comments done in each of them, we will use the cost of equity, because it is the

[34] Although the maximum period for a port concession used to be 35 years (Governement of Spain, 2011), and this has been used in this example, in 2014 a new law was enforced, changing the maximum period to 50 years. With this premise it is easy to understand that the results shown here will not be accurate today, but still valid if understood as a methodological exercise.

[35] Legal profitability for ports is 2'5% as stated by Law (Governement of Spain, 2011)

closest to the project legal framework, and the only one that we can use in our case, where we are discounting project flows.

4. Cost-benefit analysis.

Before raising the socio-economic analysis in this example we will remember its definition, quoting:

"The ***cost-benefit analysis*** is an analysis technique that allows the economic evaluation of projects expressing their benefits and costs in a common unit, which incorporates time preference of individuals in society with respect to the goods and services in a broad sense"

As it has been remarked previously, it is clear that the use of this type of analysis presents certain difficulties. The main difficulties are, firstly, the uncertainty of the data in the medium and long term, which can lead to significant bias in the results obtained. To mitigate these effects we use a probabilistic approach to perform the analysis. Secondly we found the difficulty of rating the intensity of preferences of individuals through a monetary equivalent, and similar problems described in Chapter II.

Implementation of a new transport project unbalances the forces in a market or markets affected thereof. Therefore the objective of the analysis cost benefit is to measure changes in social welfare leading to the new market equilibrium.

To analyze this changes, within the scope of this project, we have chosen the **change in the social surplus** point of view. All these surplus changes will be produced by changes in the market balances distorted by the construction of a new infrastructure. We choose this approach because it will allow us to find out who wins and who loses with a project, identifying which stakeholders will benefit or harm with the new project. In such manner we obtain, in addition to the result of the analysis, a kind of "social map" reflecting the acceptance or rejection of the project.

Using this approach payments or transfers between agents are relevant, because they determine the final size of the income perceived by each one.

4.1 Identifying the costs and benefits.

Bearing in mind indications given by De Rus et al. (2010) we will consider the surpluses of major producers and major consumers, as outlined below:

Main producers.

- Port Authority’s surplus variation (Producer surplus)
- Terminal concessionaire’s surplus variation (Producer surplus).
- Shipping companies and other producers’ surplus variation (Producer surplus).

Main consumers.

- Existing traffic's surplus variation (Consumer surplus)
- Diverted traffic's surplus variation (Consumer surplus). This traffic will be import-export with origin or destination at any point in Spain and that if the project is not developed will exit without the project out by other ports.
- Diverted traffic's surplus variation (Consumer surplus).
- Generated traffic's surplus variation (Consumer surplus).
- Variation in the surplus from the consumer (E.C.) for generated traffic. This will be new transit traffic that without the project would not be moved at any national port.
- Rest of society's surplus variation (environmental impacts).
- Indirect effects.

Investment. Investment is just a cost assumed by the producer of the infrastructure, Port Authority in this example, but given its unique character and its great importance in the calculation of the CBA it is treated separately.

4.2 Discount rate.

To evaluate the surplus of each of the agents implied, to ease the calculation, we will use a constant rate discount throughout the period of analysis. Discount rate will be the social marginal rate of time preference, since we are talking about a public project in which there can be no private competition, therefore we could not use the marginal productivity of capital rate. The value used for this project will be 5%[36].

4.3 Inputs: assumptions for CBA.

In next sections, we describe the criteria and assumptions used to calculate producers and consumers' surpluses, as discussed earlier.

4.3.1 *Investment.*

Investment amount has been discussed earlier, in the financial analysis chapter. Though some differences can be found when we are talking about CBA.

Firstly we will correct the investment figure to take into account the cost of the investment opportunity. We will use the following corrections:

It is assumed that 30 per cent of the amount of the investment corresponds to the cost of labor[37].

[36] Value proposed by European Commission (European Commission, 2008)

[37] According to Royal Decree 365/1970 which approves the picture of general type formulas for revision of prices of contracts of works of the State and autonomous bodies. This is the estimate of the weight of the labor force in construction with large volume of concrete.

The corresponding investment figure for the labor force is corrected by using the formula proposed by de Bo et al (2011). This formula is calculated on the basis of current unemployment in the region, long term unemployment, income per capita and the percentage of rural employment (*rurality*). A correction factor of 84 percent was calculated with this formula, and consequently it will be applied.

Although road and rail accesses are not part of the project, and they will not be included in the financial analysis, we have decided to include their cost in the CBA, otherwise we add a positive bias that could lead us to overestimate IRR_S and NPV_S

4.3.2 *Port Authority's surplus variation.*

This variation will be given by the following formula:

$$\Delta EP = (p_t^1 q_t^1 - p_t^0 q_t^0) - (C_t^1 - C_t^0),$$

Where:

- p^1 : price if project is developed.
- p^0 : price if project is not developed.
- q^1 : traffic if project is developed and capacity constraint exists.
- q^0 : existing or without project and capacity-constrained traffic.
- C^1 : costs if project is developed.
- C^0 : costs if project is developed.

To facilitate the understanding of the calculation we have split into three basic sections the increase in income between the current situation, without project, and the raised with project:

- **Lost revenues when the current terminal ceases to operate**. If terminal reaches its capacity in 2015, as foreseen, revenues generated for this not attended traffic will be lost. The revenues are obtained by multiplying capacity in TEU by the current terminal cost per TEU, which is higher than that in the new terminal, since in the current terminal surface occupancy rates are higher, and bonuses by volume are not applied as they will be for the new terminal. Cost per TEU has been calculated on a yearly basis.
- **Import-Export traffic revenues**. They are calculated with the planned rates for the new terminal, updated on an annual basis. This section includes incomes from both containers from the old terminal which will use the new one, and moreover we add new import-export traffic diverted from other terminals.
- **Transit traffic revenues**. This will be new, generated, traffic because it previously did not exist.

On the other hand the new infrastructure will add an additional cost, which already has been discussed in the financial analysis section.

4.3.3 *Terminal concessionaire's surplus variation*

At this point we assume the difference between the discount rate required for this project and the calculated IRR means that there is a profit above the opportunity cost of capital (understood as the expected return on an investment that is waived for investing in a similar project). This difference was calculated in the viability study of the terminal, and it was 3% (IRR was 11% and the minimum discount rate was 8%).

4.3.4 *Shipping companies and other producers' surplus variation.*

In this section we assume, deduced from international transport offer, that the majority of the traffic of transit, and thus of this project, is operated by large international companies.

Under this assumption we have decide not to take into account their surplus as producers, since in no case they affect Spanish society.

On the other hand, we consider that private companies providing port services, as stevedores, tugboats enterprises, pilots... operate in competitive markets, so their producer surplus is zero. We assume here that they cover their opportunity costs.

4.3.5 *Existing traffic's surplus variation.*

For the diverted traffic (fully import-export) from the old terminal there is a **decrease in the generalized price they pay**, savings in time by the use of modern facilities and with higher capacity. This **decrease in the generalized price they pay** is their surplus variation:

$$(g^0 - g^1) \times (q^0) = (vt^0 - vt^1)\, q^0\, x.$$

To calculate time savings for the traffic that currently uses the port of Cartagena we assume that the new terminal will feature more modern equipment for loading and unloading, with greater capacity, moreover, the number of cranes per berth will be 4, instead of one per berth at the current terminal.

New, deeper, draft will allow the entrance of larger ships. These ships can perform in a single operation the same movements that are performed with four ships in the current terminal. The use of a semi-automated yard will also save time in land operations.

We have assumed savings average 20 hours, but the values adopted for the statistical distribution of this variable (saving time) are later discussed in the corresponding section.

Finally, we assume that final price for the consumer remains the same.

4.3.6 *Diverted traffic's surplus variation*

Diverted traffic previously entering by other Spanish ports (without making any distinction between the Region of Murcia or not, since this distinction would not contribute to clarify anything) with origin or destination Spain, e.g. all import-export traffic (q1 q0), has a surplus because the difference between consumer's value of transport which we can assess as:

1/2 (q1-q0) x (g1 + g0)

While generalized price consumers are really paying for it:

(q1 q0) x (g1)

Therefore this surplus would be:

1/2 (q1 q0) x (g0-g1)

Time savings have to be evaluated on the basis of the complete logistic chain (origin - destination), because the new infrastructure allows to modify the full paths. Assessment of time savings are based in the demand forecast for the new terminal (Spim & Royal Haskoning, 2011)

For traffic diverted from other terminals, we could divide time savings in two parts, the main savings that occur when considering the total supply chain, reducing the number of kilometers traveled by truck, and the secondary which accounts for additional time savings passing through the new port instead to use other Spanish terminals.

In the same way if the cargo is diverted from a little saturated terminal we can have a surcharge because of time difference to pass through the terminal (although the overall result of the complete logistic chain source target is still best to use the new terminal).

4.3.7 *Generated traffic's surplus variation*

All generated traffic is transit, so we adopt a rather conservative stance. We should consider no surplus from the consumer's point of view, since this is a traffic that could be done in another country, or not be done at all, depending on the routes planning and shipping companies load plans.

In addition a large part of transit containers may have origin and final destination outside of Spain, in addition to being their owners foreign. So evaluating this surplus would increase fictitiously the benefit of the infrastructure.

If we wanted to take this surplus into account we should carry out a detailed study about what percentage of containers in transit may or may not have origin or destination Spain and then calculate corresponding surpluses of these containers.

4.3.8 *Rest of society's surplus variation*

Here we analyze possible effects, on natural resources and the improvement of welfare in the rest of society, the project would have. In our example we do not have information that allow us to know the environmental impact of the project. On the other hand, construction of this infrastructure would release an important space occupied by the current terminal and that would be part of the port city area, but we don't have either sufficient criteria to assess which would be the effects or the social assessment of the recovery of these land for the city.

We have decided that, in order to be able to assess this surplus, the included cost of environmental measures allows us to alleviate, at least economically, the possible adverse effects that may have the Master Plan on the environment. Therefore we consider this surplus as 0.

4.3.9 *Indirect effects.*

Investment in infrastructure and the possible existence of indirect, additional, or synergic economic effects are usually linked to public debate when it comes to justify projects of questionable profitability. However, literature review regarding this topic is contradictory both in sign and magnitude, and the results are hardly extrapolated between projects.

5. Variables and uncertainty.

In this section we are going to describe how uncertainty has been assessed, and how it has been used to modify the case base described in previous chapters. Main relevant input variables have been chosen to be described as statistical functions. We describe and justify the statistical distribution that has been adopted for each one of the input variables.

5.1 Demand

As discussed previously, traffic was described by three future scenarios of possible evolution. This evolution has have been adapted to the rhythm of the works described above leading to start operations in the new port by 2020.

Reviewing Figure 13 we can clearly see three well differentiated trends, the first one when operations begin, with greater growths. Then a second phase of traffic stabilization where growths are much more moderate and the last one when the maximum capacity of the terminal is reached.

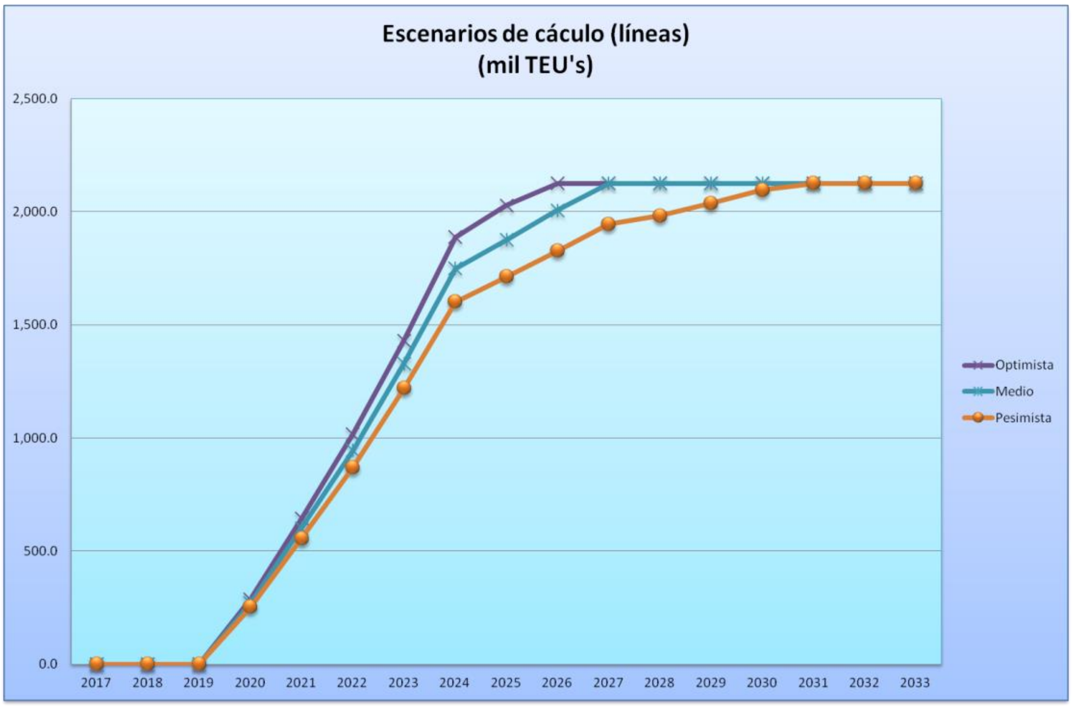

Figure 13. Traffic evolution in the base case. (Spim & Royal Haskoning, 2011)

Also looking at Figure 14 where Import-Export and transit traffic are detailed, we can better distinguish these trends.

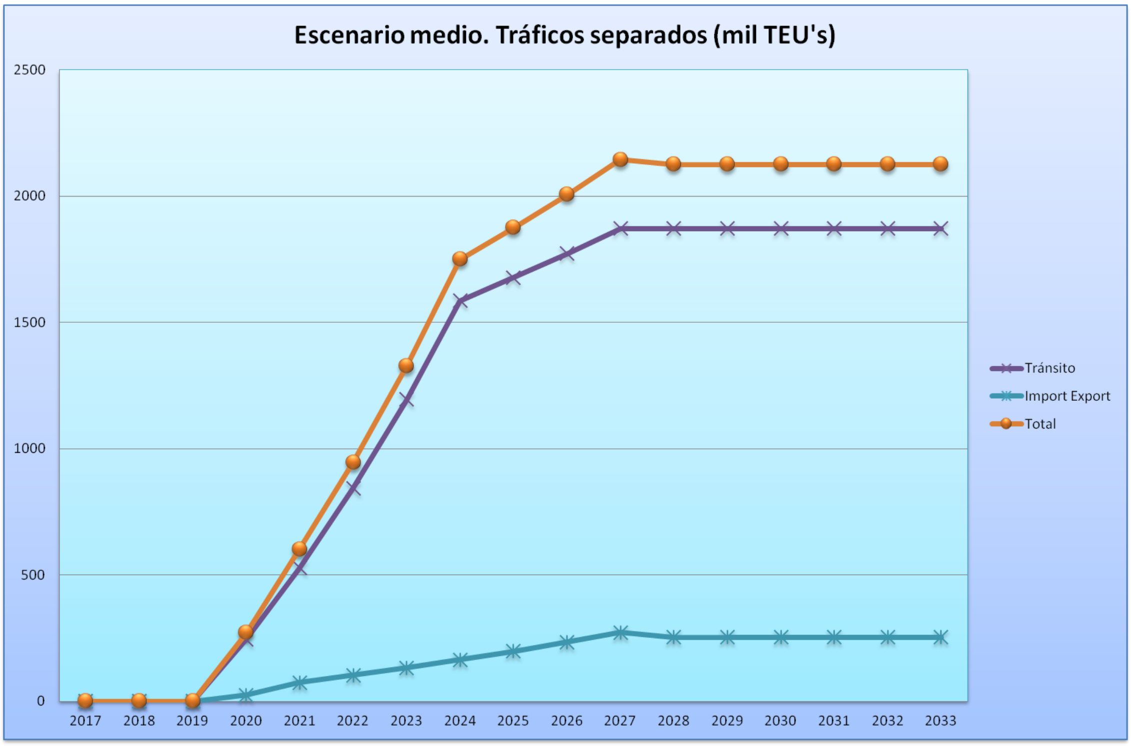

Figure 14. Graph of the average calculation, separate traffic scenario.

In order to statistically model the demand, we have decided to make the following assumptions:

1. Separate each traffic in 3 stages: Initial growth, that will last 5 years for transshipment and 8 years for Import/Export, view Figure 14. Secondary growth beginning just after the first stage, and during until capacity is reached. And a final stage, where traffic volumes vary +-1% around capacity.
2. For the first and second stages, and based on the existing demand studies, we adjusted a distribution for the traffic growth. The adjustment was made among 20 different statistical distributions[38]. And the distribution adopted for each case is the one that has the greater p-value. In any case, all the distributions selected have a p-value resulting from the test greater than 0'92.
3. Finally, when maximum capacity of the installation has already reached does not seem reasonable that trades stay stable. We have proposed a uniform distribution, where the maximum traffic varies 1% up and down of the total traffic. Whereupon we will have years operating at 99% capacity and others at 101%.

Here's a table summary with the results of the settings of each of the variables that have been raised and set with the designated procedure.

[38] Statistical adjustment of growth distribution has been carried out with freeware, GNU, PSPP, statistical processing of data, which allows fine-tuning best function with different statistical distributions, up to a total of 20, among which the most common, uniform, triangular, are normal, lognormal, gamma, Chi-squared, weibull...

Distribución de los incrementos de tráfico de Import/Export

Descripcción	Distribución	Valor medio	Desviación std	Unidades
Crecimiento hasta el año 8 desde la puesta en funcionamiento	Normal	34	8	Mil TEU
Crecimiento a partir del 8 año de funcionamiento	Normal	11	3	Mil TEU
Oscilaciones cuando se alcance el pleno rendimiento	Uniforme	-5	5	Mil TEU

Distribución de los incrementos de tráfico de Tránsito

Descripcción	Distribución	Valor medio	Desviación std	Unidades
Crecimiento hasta el año 5 desde la puesta en funcionamiento	Normal	316	57	Mil TEU
Crecimiento a partir del 5 año de funcionamiento	Normal	58	35	Mil TEU
Oscilaciones cuando se alcance el pleno rendimiento	Uniforme	-20	15	Mil TEU

Figure 15. Least squares adjustment results.

Distributions of traffic growth have been described, now going one step further we have found traffic distributions evolution curves. To do so, a Monte Carlo analysis was made with these distributions, to calculate the possible evolution of the growth in traffic. 10000 simulations where made to describe the functions of traffic distribution.

Figure 16 illustrates 5%, 10%, 50%, 90 and 95% percentiles, which give us an idea of what the traffic distribution looks like.

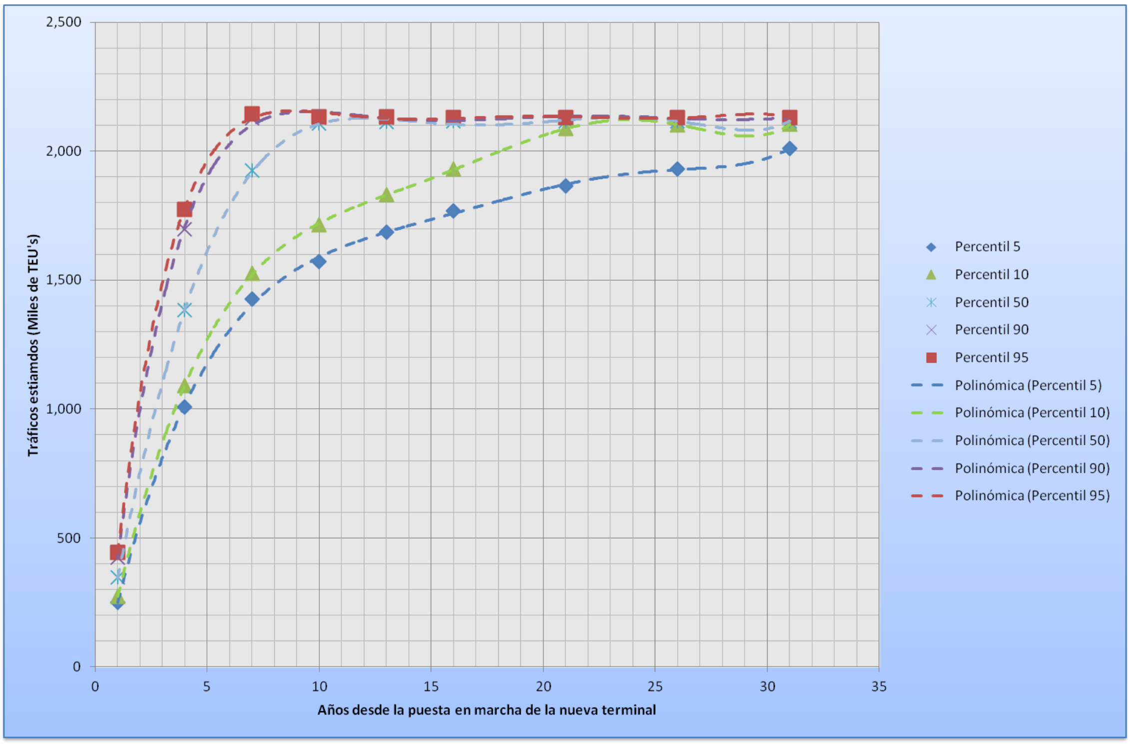

Figure 16. Traffic statistical distribution.

5.2 Investment

The most relevant amount of money of the project is CAPEX, investment. Our starting point is the study made by Berenguer Ingenieros (2006) to estimate the total cost of the project. As discussed before, this figure has been corrected according to the Port Authority experience in similar works, what leaded to an increase in estimated investment. This correction has supposed an increase of almost 20% on the original investment, so the values used to define the ***Base case*** should be very similar to reality.

To account for uncertainty we have taken into account two issues:

- Call for tenders made by the Port Authority have bids lowering tender prices from 15% to 20%.
- None of the contracts regarding similar works carried out by the Port Authority have an increase on the contract.

With these issues we could conclude that the final cost of the infrastructure will be between 15% and 20% below the estimated values. Assuming these lowering in the call for tenders can be a positive bias that could lead to underestimate risk. So we have decided to adopt a more conservative position, with an even distribution deeming a maximum cost 4% superior to the original and only 10% lower. This variable is introduced as a corrective factor for investment.

Distribución de los costes de la infraestructura				
Descripcción	Distribución	Valor máximo	Valor Mínimo	Unidades
Costes de la infraestructura	Uniforme	104,00%	90,00%	Porcentaje

Table 15. Investment corrective factor distribution.

An additional corrective factor will be included to modify the investment figure. Regarding that the alternative adopted in the Master Plan is close to an environmentally protected area, the project might need additional protecting measures than those already provided on the project. These measures, in the absence of a better valuation, have been estimated as an additional cost between one and three per cent of the total value of the investment, with an even distribution. This variable is also introduced as a corrective factor for investment.

Distribución de los costes de las medidas preventivas, correctoras y compensatorias				
Descripcción	Distribución	Valor máximo	Valor Mínimo	Unidades
Coste de las medidas medioambientales como % del Coste de infraestructura	Uniforme	103,00%	101,00%	Porcentaje

Table 16. Additional environmental measures, as a percentage of the initial inversion.

5.3 Operating costs.

To account for management and maintenance costs, operating costs, and without any theoretical nor practical information, OPEX have been estimated as a percentage of the initial inversion. To describe uncertainty we have defined an even distribution, deeming from 5% up and 10% down from the estimated OPEX.

Distribución de los costes de gestión y mantenimiento				
Descripcción	Distribución	Valor máximo	Valor Mínimo	Unidades
Costes de gestión y mantenimiento	Uniforme	105,00%	90,00%	Porcentaje

Table 17. OPEX corrective factor distribution.

5.4 Profit over cost of opportunity for the terminal operator.

As described previously, the difference between the discount rate (8%) required for this project and the calculated IRR (11%) means that there is a profit above the opportunity cost of capital.

So, it seems reasonable to model this surplus with an even distribution between 1 and 3% (percentage of the revenue per TEU to the concessionaire of the terminal, which is also calculated in the same reference). We obtain this surplus by multiplying this unit extra income by the total traffic that moves through the terminal.

Variación del beneficio por encima del coste de oportunidad para la terminal de contenedores				
Descripcción	Distribución	Valor máximo	Valor Mínimo	Unidades
Beneficio de la terminal de contenedores por encima del coste de oportunidad	Uniforme	30,00%	15,00%	%

Table 18. Profit over cost of opportunity for the terminal operator distribution.

5.5 Time savings from the use of the new terminal to the existing.

Traffic currently coming through the port of Cartagena will reduce significantly its waiting period. These reductions come from equipment for loading and unloading improvements, modern cranes, with greater capacity, and also the number of cranes by berth will be 4, instead of the current crane per berth.

Moreover, deeper new draft will allow the entrance of larger ships able to perform in a single operation as many movements as those performed by four ships in the current terminal. By using a semi-automated land equipment will also save of time in land operations. All this will result in a minimum time saving of 10 hours, only accounting for time saved in dockage and moorage for the larger vessels, which could reach up to 30 hours taking into account the rest of the factors. Having no more data to carry out a distribution, we will assume an even distribution of the time saved.

Ahorro esperado de tiempo de la nueva terminal respecto a la existente				
Descripcción	Distribución	Valor máximo	Valor Mínimo	Unidades
Ahorro de tiempo en la nueva terminal con respecto a la existente	Uniforme	30,00	10,00	Horas

Table 19. Time savings from the current terminal statistical distribution.

5.6 Time savings from the use of the new terminal to other Spanish terminals.

For traffic diverted from other terminals, main time savings occur when considering the whole supply chain. Using the new port will, in some cases, reduce the number of kilometers traveled by truck. However we will bear in mind that there could be an additional time saving by passing through the new port compared to other Spanish terminals. Consequently if cargo deviates to a saturated terminal can have a time surcharge at passing through the terminal (although the target, overall result of the whole logistic chain, is still best to use the new terminal).

Provided that we do not have data enough to make a more accurate assessment, we have assumed that these time differences will be included between 1'5 hours of time saving and 1 of time overrun. The new terminal must be generally more efficient than those that exist simply by technological issues.

Ahorro esperado de tiempo de la nueva terminal respecto a otras existentes en España				
Descripcción	Distribución	Valor máximo	Valor Mínimo	Unidades
Diferencia de tiempo en la nueva terminal con respecto otras en España	Uniforme	1,50	-1,00	Horas

Table 20.Time savings from the current terminal statistical distribution.

5.7 Debt interest rate.

The interest rate on the debt has been set in a 3'4% for the ***base case*.** This rate is higher than interest rates used by the European Investment Bank in similar inversions for others port authorities. However, it seems reasonable to also consider possible variations in the interest rate, therefore we have proposed the following uniform distribution:

Distribución de la tasa de interés				
Descripcción	Distribución	Valor máximo	Valor Mínimo	Unidades
Costes de gestión y mantenimiento	Uniforme	3.75%	2.75%	Porcentaje

Table 21. Interest rate statistical distribution.

6. Results.

Before deepening into figures to present the results, we will do a brief review of the approach used to perform this analysis. Our starting point was an infrastructure proposed by the Port Authority of Cartagena to comply with its Master Plan (2009).

Firstly we reviewed the current situation of the port of Cartagena and its possible evolution, to create an alternative"0" line, ***do nothing or do minimum***. Afterwards we have finally raised financial and economic appraisal of the infrastructure. For financial analysis we have used three different techniques, deterministic, sensitivity analysis, and finally a probabilistic analysis, increasing complexity step by step, to compare the benefits of each of the types of analysis. We also have made an economic analysis from the same perspective.

Now we present the results of both financial and economic analysis, regarding each one of the techniques used, some graphics that made results easier to understand can be found in in Annex I.

6.1 Financial analysis.

6.1.1 *Base case*

Once the model has been developed and run, including income statement, balance sheet, statement of source and application of funds, cash flow statement, we can calculate the most relevant outputs:

- Cash flow NPV. Cash flow was calculated and then financial costs and taxes were deduced, and the discounted to 2013. This value is above the 15 million euros (2013 euros).
- IRR: We have also calculated IRR, the rate of return that makes the NPV equal to zero.
- Minimum value of working balance. As discussed previously, we have highlighted this parameter to verify the goodness of the proposed financing Plan.

Results for the Base Case are summed up in Table 22.

Principales resultados del estudio de viabilidad financiera

Valores económico financieros (miles de €)	Importes
Inversiones APC (euros constantes)	584.356,98 €
Inversiones APC (euros corrientes)	660.717,61 €
Coste de las medidas Medioambientales soportado por la APC (euros constantes)	596.044,12 €
Coste de las medidas Medioambientales soportado por la APC (euros corrientes)	673.931,96 €
Ingresos tasas portuarias (euros corrientes)	1.275.832,81 €
Ingresos tasas portuarias (euros constantes)	753.096,88 €
Aportaciones APC (euros corrientes)	553.460,00 €
Deuda L/P (euros corrientes)	395.000,00 €

Valores de la rentabilidad del proyecto (antes del pago de la deuda)	Valores
Tasa de retorno para el proyecto	2,50%
VAN de la inversión realizada (1)	598.435,21 €
VAN de los flujos de caja operativo (2)	531.176,63 €
VAN de valor residual de la inversión (3)	118.416,76 €
VAN flujo de caja libre (incluyendo valor residual) -(1)+(3)+(4)	51.158,17 €

Valores de la rentabilidad para la APC (después del pago de la deuda)	Valores
TIR para la APC	2,65%
Tasa de retorno para la APC	2,50%
VAN de la inversión realizada (1)	598.435,21 €
VAN de los flujos de caja operativo (2)	531.176,63 €
VAN de valor residual de la inversión (3)	118.416,76 €
VAN de la deuda neta (ingresos de los créditos menos las devoluciones de los mismos) (4)	109.340,09 €
VAN de los intereses de la deuda (5)	144.808,32 €
VAN flujo de caja libre para la APC (incluyendo valor residual) -(1)+(2)+(3)+(4)-(5)	15.689,94 €

Table 22. Results for the Base Case.

Financial analysis, regarding only the Base Case, shows that ***the project is financially viable***; with an IRR of the 2' 65%, higher than the profitability required to draft the 2'5%, and NPV of ***15'5 million euros***.

6.1.2 *Sensitivity analysis.*

A sensitivity analysis was carried out, i.e. an analysis of the what if...?, where we analyzed the result of the output variable, NPV, IRR…, if one input variable changed in one percent point remaining the others unmodified. We obtained relations between the variations of the input variables and the output variable.

We will present the output of this analysis using a Web graph and tornado one. Both graphs show similar information from a different perspective. Web graph shows how the different variables affect the result of the output variable, in terms of deviation from the base case. The tornado chart shows which variable variations have higher incidence in the output variable result.

The results will be presented in the following order: NPV, IRR and Minimum value of working balance.

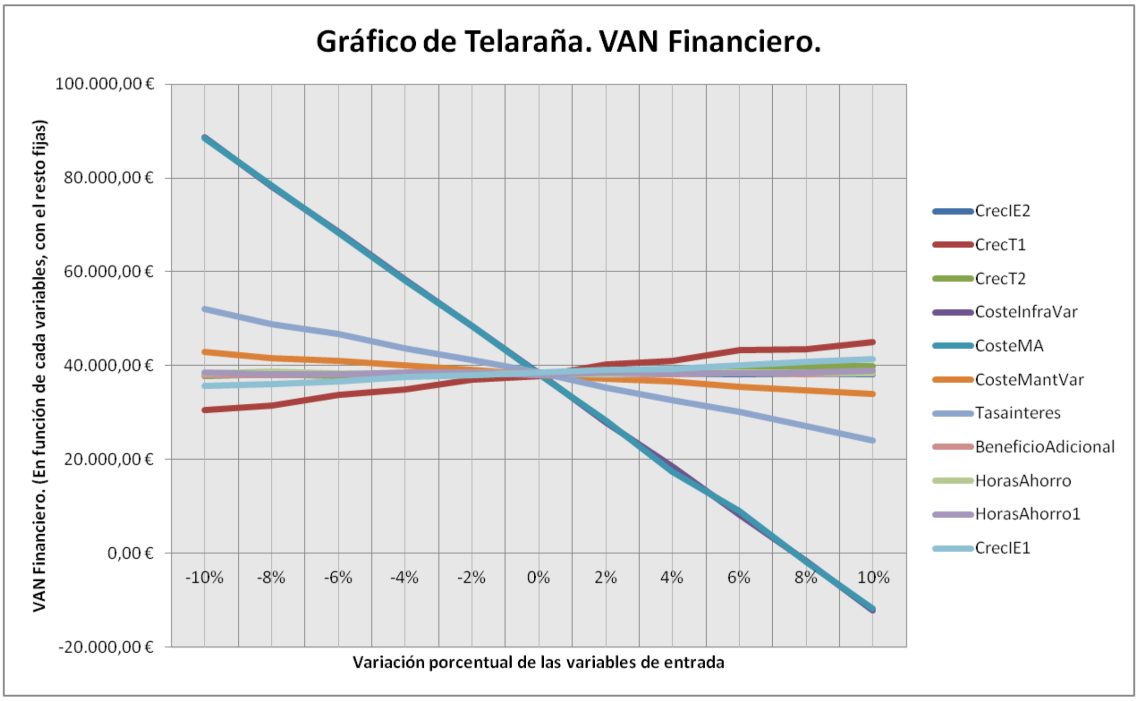

Figure 17. NPV sensitivity analysis. Web graph.

We should be careful in this kind of analysis because all variables vary in the same percentage order, but some of the values are not real, e.g. investment can vary from 1 to 10% but it is less feasible that discount rate varies from 1 to 10%, this would not happen in the probabilistic analysis.

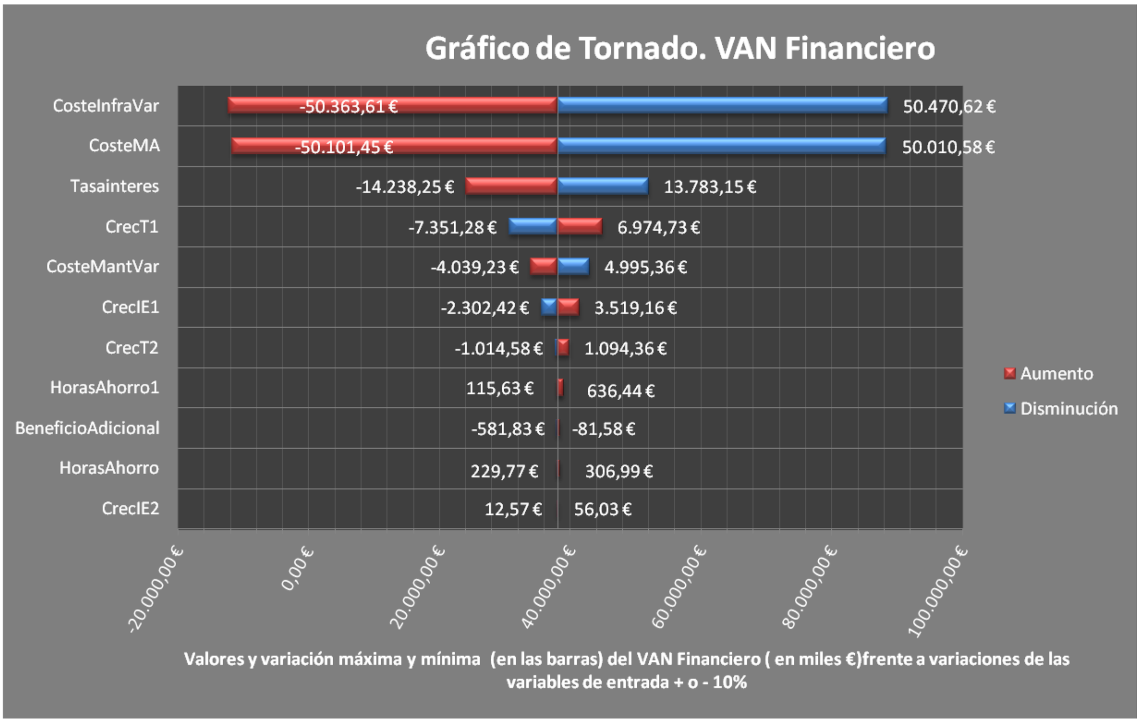

Figure 18. NPV Sensitivity analysis. Tornado graph.

In this graph we see the maximum and minimum variations on the output variable that may cause the variation of each one of the input variables. We have analyzed variations ± 10% in each of the input variables, such variations in the case of the cost of infrastructure have an influence of roughly ±50 million €. This type of graph corresponds to the correlation analysis we have done in the probabilistic approach.

Now we shows results for IRR.

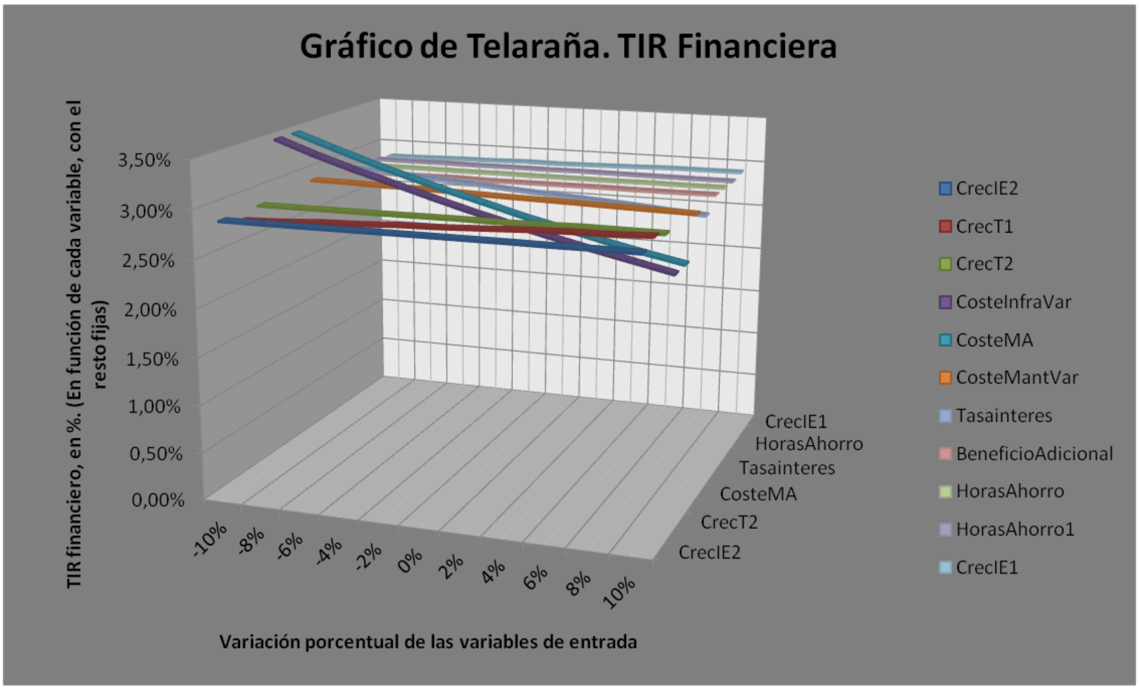

Figure 19. IRR Sensitivity analysis. Web graph.

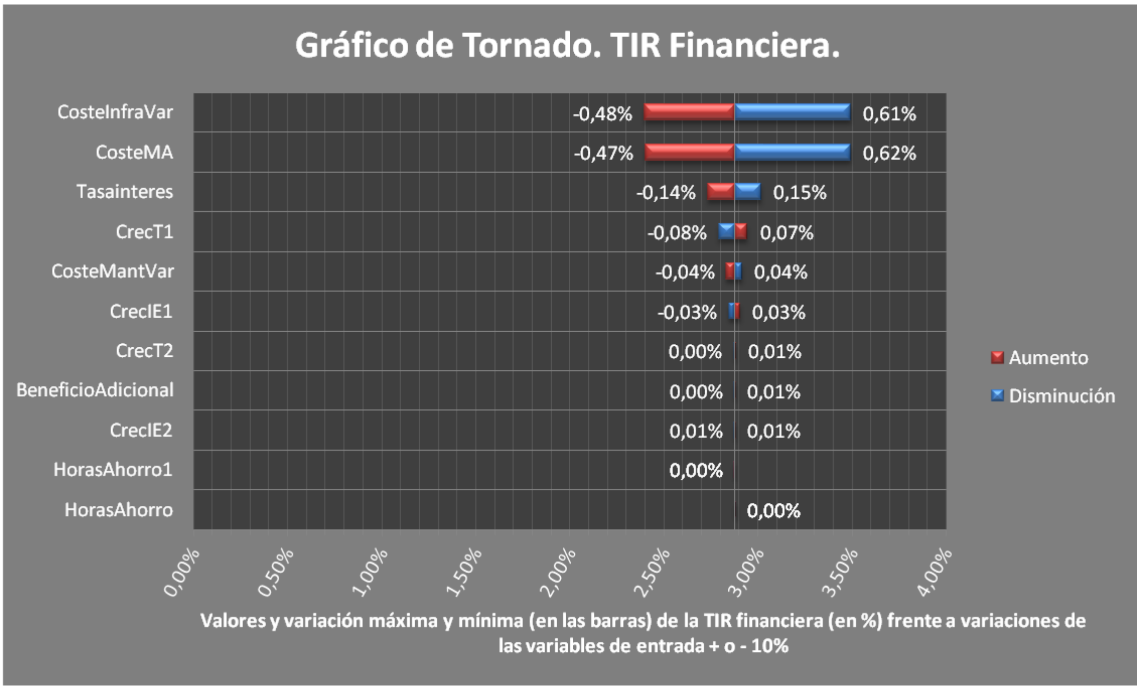

Figure 20. IRR Sensitivity analysis. Tornado Graph.

Variations in the case of the cost of infrastructure have influence of more +0’61% or -0’48%, from the IRR calculated in the Base Case.

We end up this section with the results of the Minimum value of working balance.

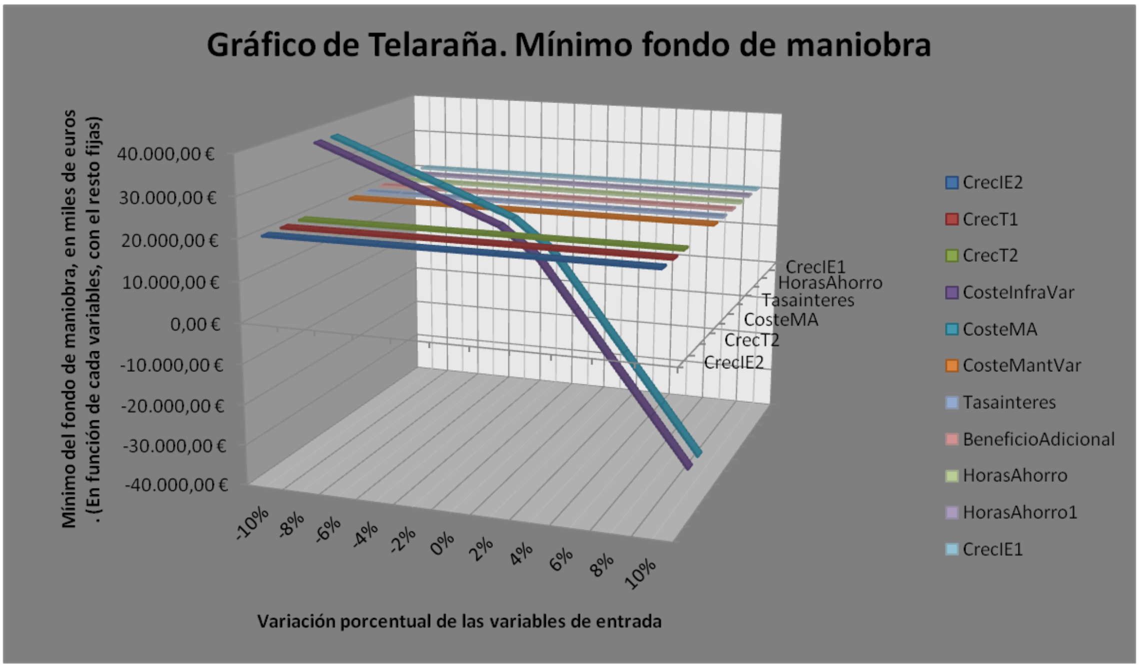

Figure 21. Minimum value of working balance. Web graph.

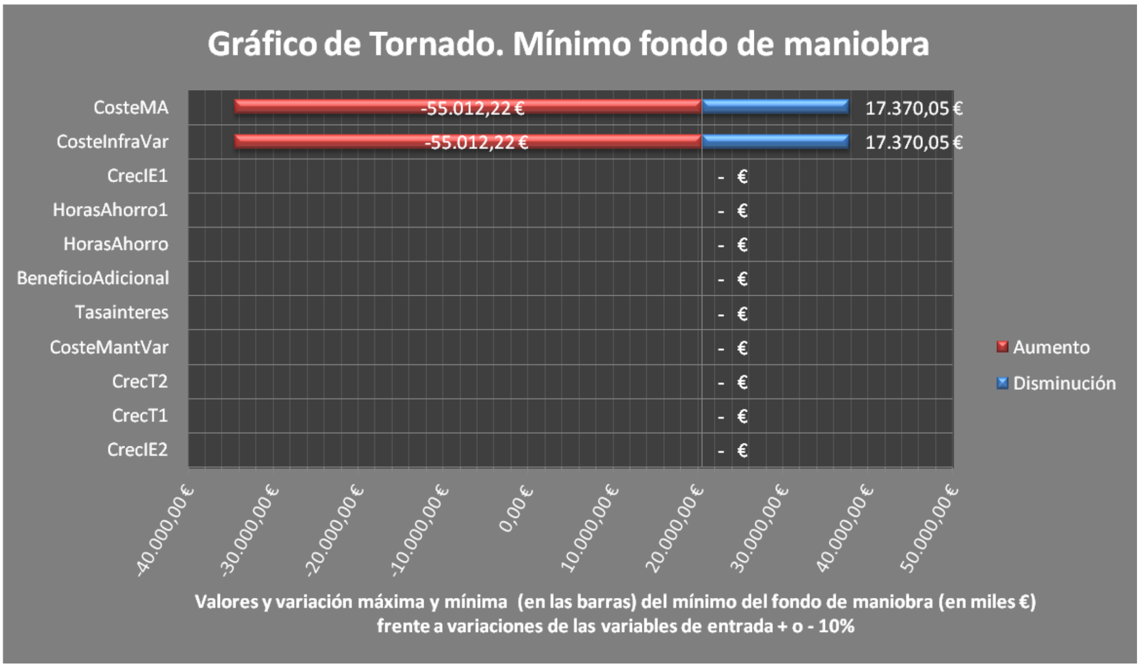

Figure 22. Minimum value of working balance. Tornado graph.

Variation in the case of the cost of infrastructure have influence of more than 17 million euros or less 55 million euros. On the other hand it is significant that other variables values do not have any influence on the minimum value of working balance, ***which tells us that this minimum value will be given during the period of construction, and before beginning the credit payback***.

6.1.3 *Risk analysis.*

The method of simulation Monte Carlo, which consists in evaluating a model several times, usually thousands, by assigning random values (taking into account a statistical distribution function that previously has to be defined for each input variable) to describe statistically the output. In our example we decided to evaluate the model 10000 times, to obtain distributions of each of the output variables. This will allow us to obtain the same number of values for each of the output variables, so we can get the output variable histogram and define its probability distribution which allows us to assign a probability of occurrence. In the same way, each of the values for an output variable will have a probability of success or failure when we take decisions on the basis of the study.

For the implementation of this model a specific simulation software that works as a supplement to Microsoft Excel has been used.

Net present value.

We have evaluated NPV of project cash flow for the port authority, once deducted from FCF all financial costs, so that the figure that we obtain goes directly to the of benefits account of the port authority or may become a part of the reserves.

The histogram that is obtained from the simulation is:

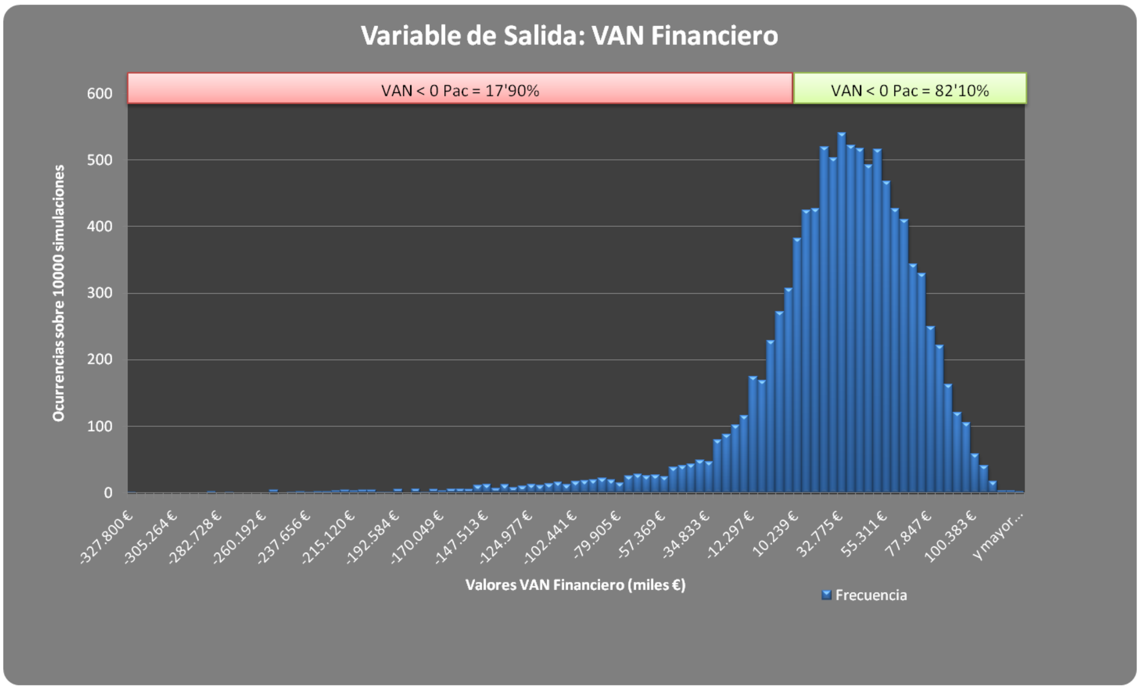

Figure 23. NPV Statistical Analysis. Histogram.

As shown in the histogram there are nearly 85% of the values of the NPV that are positive, which is giving us the first headline, “there is a 85% probability for NPV to be positive in this project”. From the opposite point of view, acceptable risk for this project for Port Authority has to be at least 15%, because there is a 15% chance for NPV to be negative in this project, and therefore would not be financially profitable for the port authority.

Now we can see the cumulative probability function:

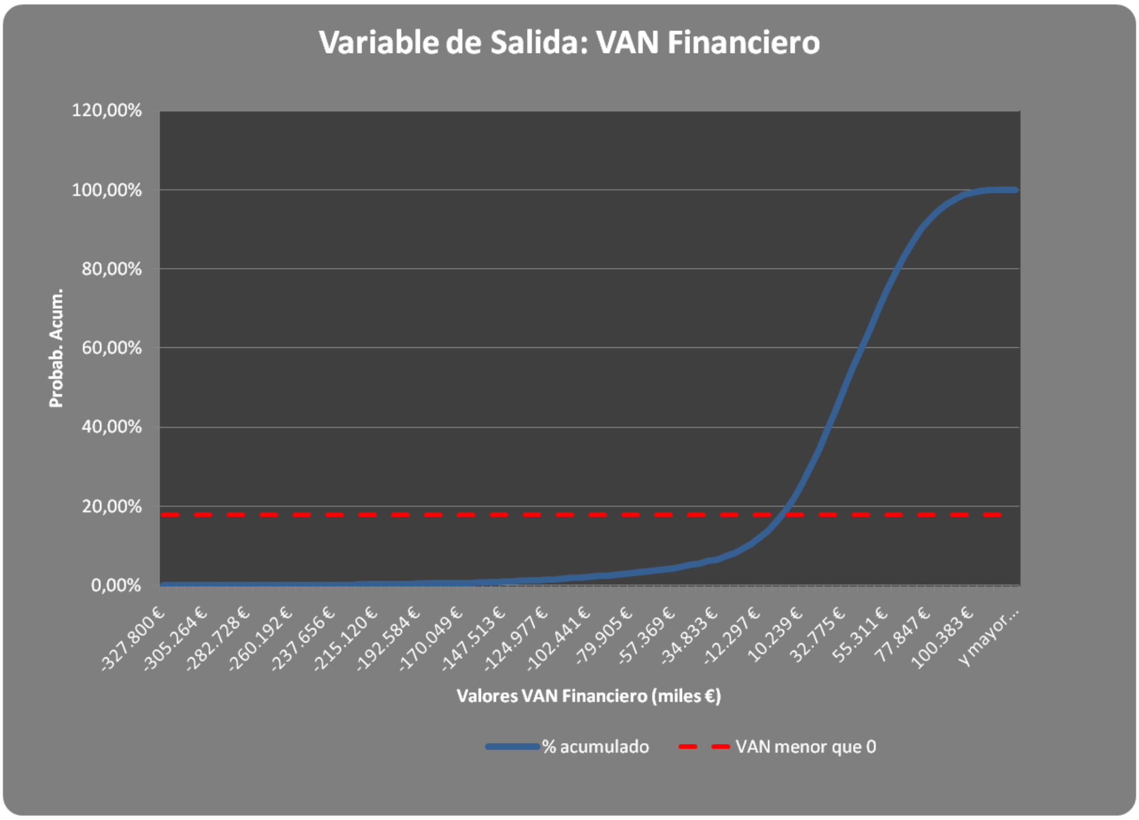

Figure 24. NPV Statistical Analysis. Cumulative probability function.

Once variable probability function has been described graphically, we present figures for the most relevant statistics:

Estadísticas de la Simulación	
Nro. Iteraciones	10000
Mínimo	- 327.800,27 €
Promedio	27.175,61 €
Máximo	122.919,00 €
Mediana	32.842,17 €
Varianza	1.988.753.736,42 €
Desvío Estándar	44.595,45 €
Rango	450.719,26 €
Curtosis	6,801
Coef. de Asimetría	-1,895
Coef. de Variación	1,641

Figure 25. NPV Statistical Analysis. Statistics.

Now we will analyze the influence that each of the input variables defined has on the values of the NPV. We will use two approaches:

Regression analysis. We compare the different input values (independent variable) against the output values (dependent variable) obtained from the simulation. Then a regression analysis is carried out, the slope of the line of regression or beta coefficient is calculated. The absolute values are ordered from highest to lowest (which shows the incidence of each input variable) setting a tornado chart.

For example the following chart shows that variable "Rate of interest" has a beta coefficient of regression equal to - 44'87. This means that an increase of one unit, in the case of this interest rate would mean an increase of 1%, the variable input causes a decrease of 44'87 million euros in the output variable (VAN), so if the interest rate goes from 3 to 4% increasing by 1% NPV would suffer a decline of 44'87 million.

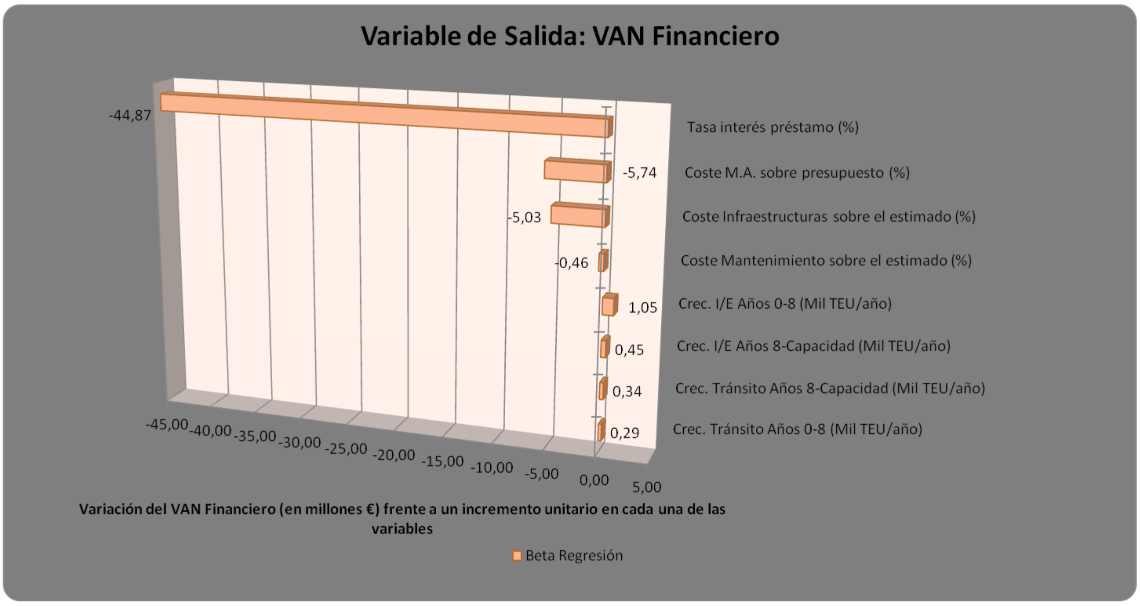

Figure 26. NPV. Regression analysis.

Correlation analysis. In this approach we calculate the correlation coefficient[39] between each input variable and the selected output variable. The correlation coefficient indicates how output variables move respect a variation on the input variable. This coefficient can take values from - 1 to 1. A value 1 indicates that the input variable and the output variable move “together” in the same way, i.e. when one grows by 5%, the other one also grows at the same percentage. A value equal to - 1 indicates that the two variables move exactly in the opposite way. There is no correlation (value equal to 0) when it is not possible to establish a pattern of movement, or relationship, between both variables.

[39] In order to measure dependence between two quantities we have used the Pearson product-moment correlation coefficient, or "Pearson's correlation coefficient", commonly called simply "the correlation coefficient". It is obtained by dividing the covariance of the two variables by the product of their standard deviations.

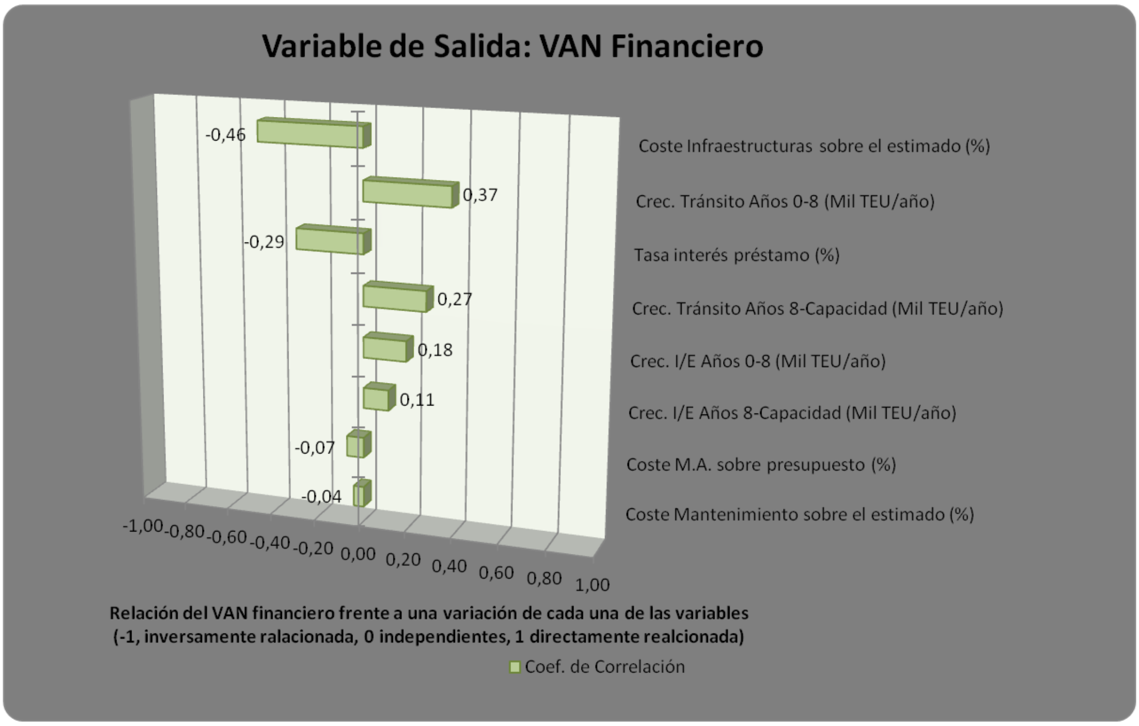

Figure 27. NPV. Correlation analysis.

It is clear from Figure 27. NPV. Correlation analysis.that the NPV_F depends directly on traffic growth rates, both transit and Import/Export, and in the two growth stages defined in the corresponding section, this seems quite logical. NPV_F is more sensitive to transit traffic growth of during the first five years, so during commissioning of the new terminal, special attention may be paid to this traffic, consequently marketing efforts should focus on capture traffic in that market.

On the other side, we can deduce that NPV_F depends inversely on infrastructure costs, interest rate of bank debt, and to a lesser extent the cost of environmental measures and maintenance costs. We can deduce also that the NPV_F is very sensitive to variations on infrastructure cost, so it will be fundamental to pay special attention when it comes to developing the project.

*Internal rate of return IRR***.**

With this variable we can see which would be the greatest profitability that we could require for our project, obviously associated with a probability value. But we can also have a glimpse on what would be the probability that the project was profitable in the event that we decide to apply a lower rate, having previously covered the financial costs of the project.

The histogram obtained from the simulation is:

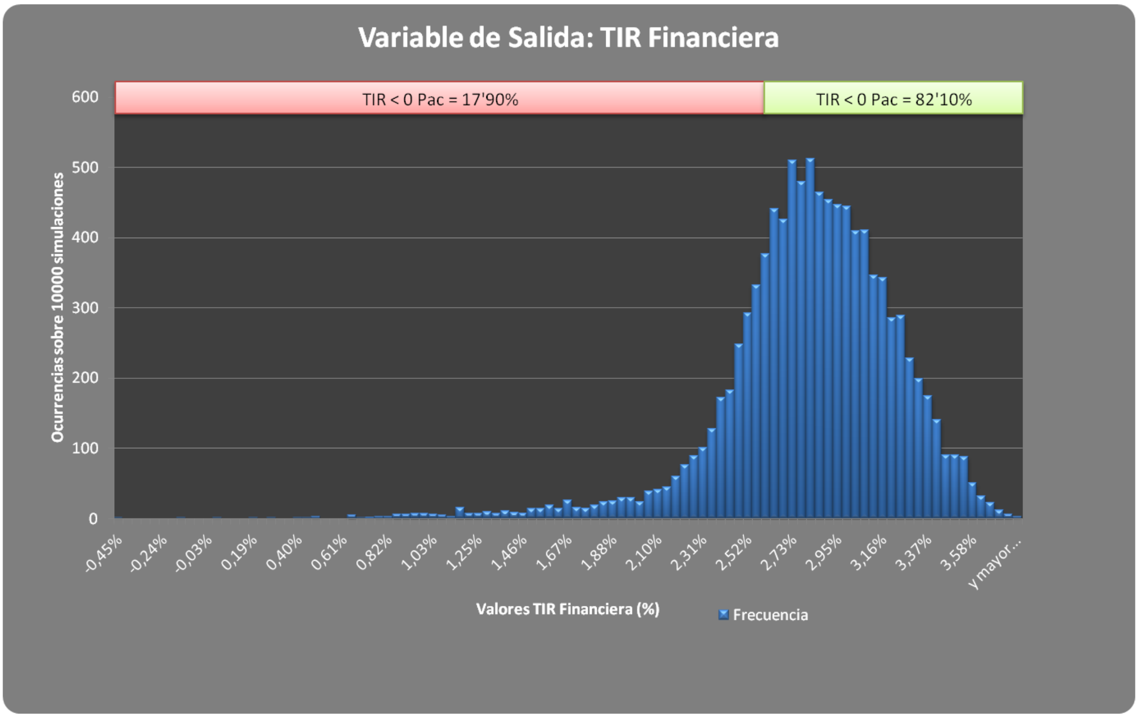

Figure 28.IRR. Regression analysis.

Below we can see the cumulative probability function:

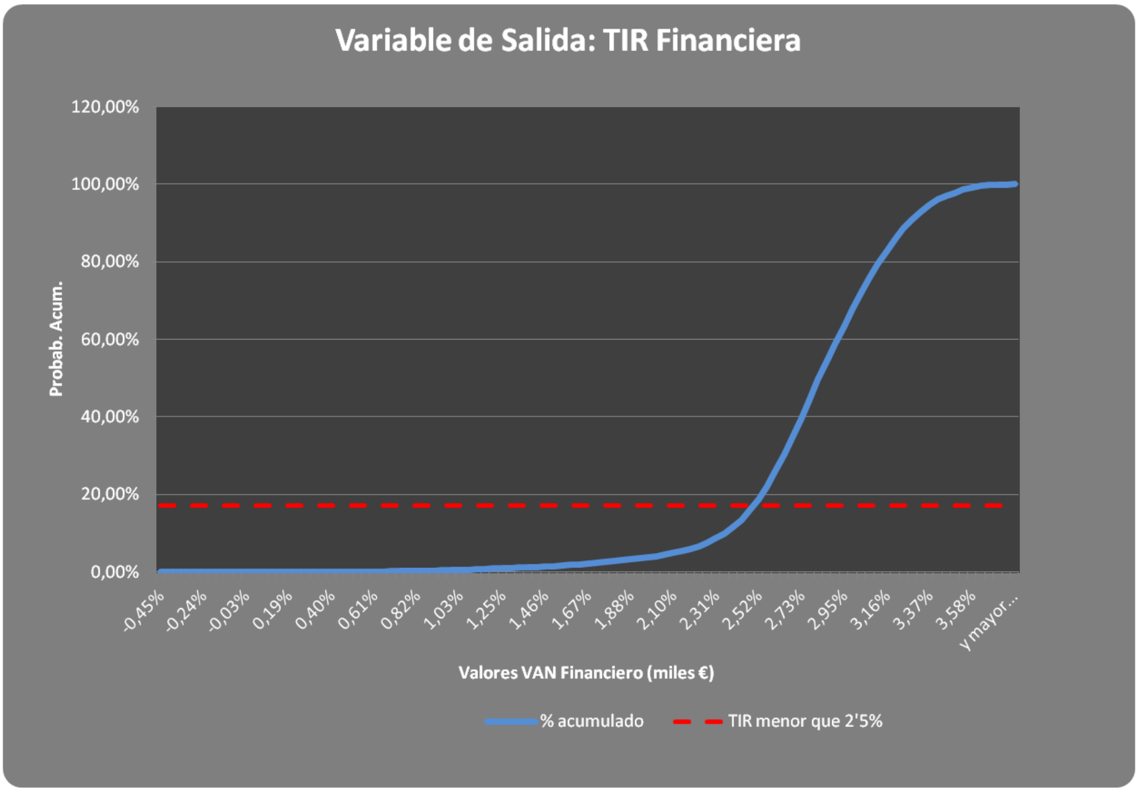

Figure 29.IRR Statistical Analysis. Cumulative probability function.

Once variable probability function has been described graphically, we present figures for the most relevant statistics:

Estadísticas de la Simulación	
Nro. Iteraciones	10000
Mínimo	-0,45%
Promedio	2,80%
Máximo	3,80%
Mediana	2,82%
Varianza	0,00%
Desvío Estándar	0,42%
Rango	4,25%
Curtosis	4,399
Coef. de Asimetría	-1,322
Coef. de Variación	0,150

Table 23. IRR Statistical Analysis. Statistics

Now we will analyze the influence that each of the input variables defined has on the values of the IRR. We will use the same two approaches used for NPV: *Regression analysis*

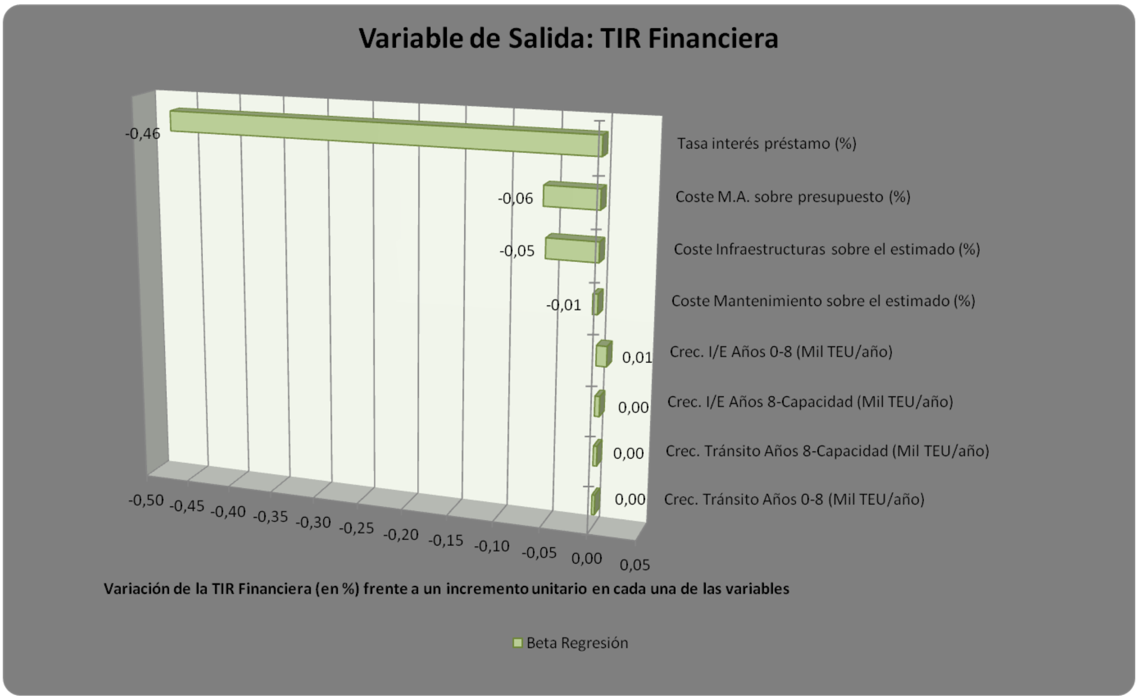

Figure 30. IRR. Regression analysis.

Correlation analysis.

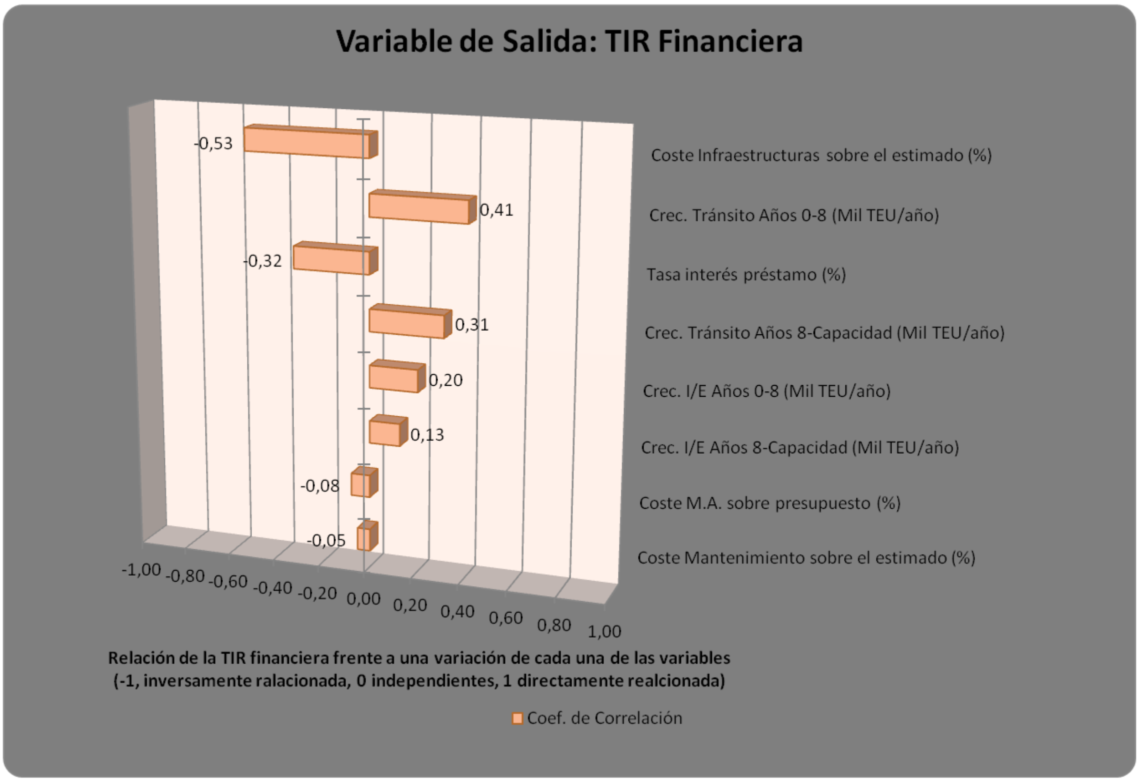

Figure 31.IRR. Correlation analysis.

Previous illustration suggests that IRR_F depends directly of the traffic growth rate, both transit and Import/Export, in the two growth stages defined in the corresponding section, this seems quite logical, in the same way as NPV_F. The traffic growth influences more the outcome of the IRR_F is traffic growth during the first five years, during the commissioning of the terminal, consequently marketing efforts should focus on capture traffic in that market.

In a parallel way, the same than $NPV_{F,}$ IRR_F depends inversely on infrastructure costs, interest rate of bank debt, and to a lesser extent the cost of environmental measures and maintenance costs. We can deduce also that the IRR_F is very sensitive to variations on infrastructure cost, so it will be fundamental to pay special attention when it comes to developing the project.

Minimum value of working balance.

Previously we have already discussed the inclusion of this output variable to verify the goodness of the financial plan used for this simulation. Therefore we directly describe statistically this variable.

Histogram obtained from the simulation is:

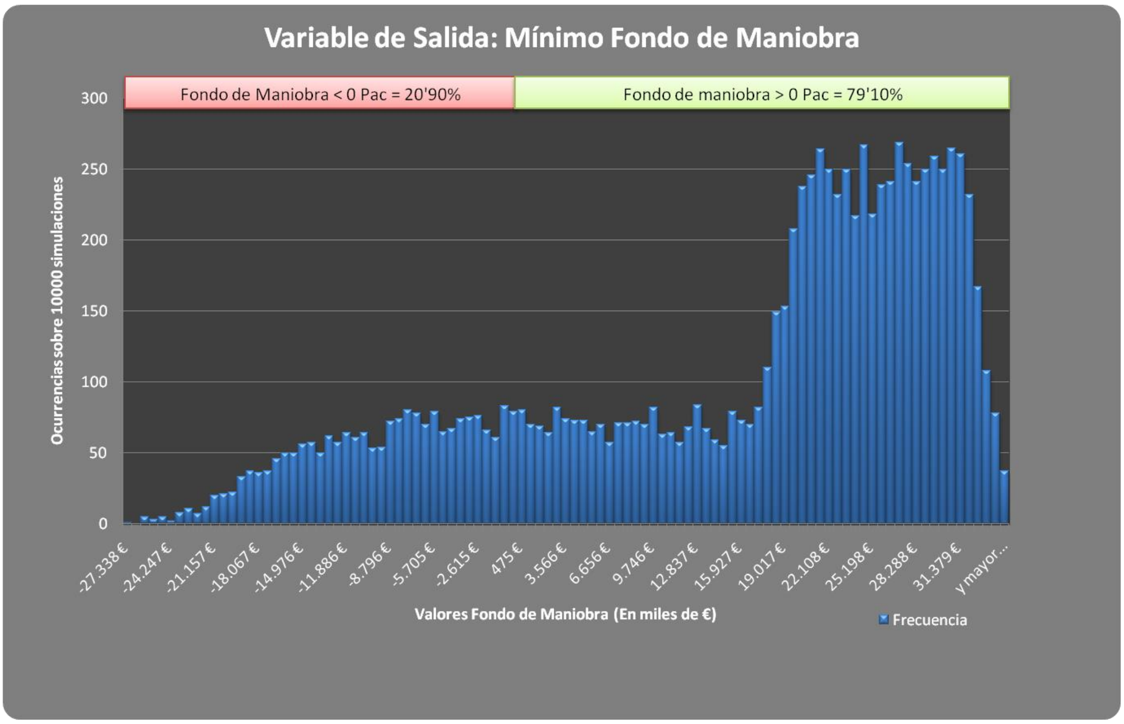

Figure 32. Minimum value of working balance. Statistical Analysis. Histogram.

As deducted from Figure 32, there is a probability of 79% working remains above 0. It also should be noted that this probability is similar to IRR_F and NVP_F being be positive, therefore being both dependent variables, for same financing plan already set, we can conclude that in the vast majority of cases in which IRR_F and NVP_F are positive the working capital also will remain above 0. So the financial plan proposed for the ***Base case*** is also valid for the calculation used in the simulation model.

Below we can see the cumulative probability function:

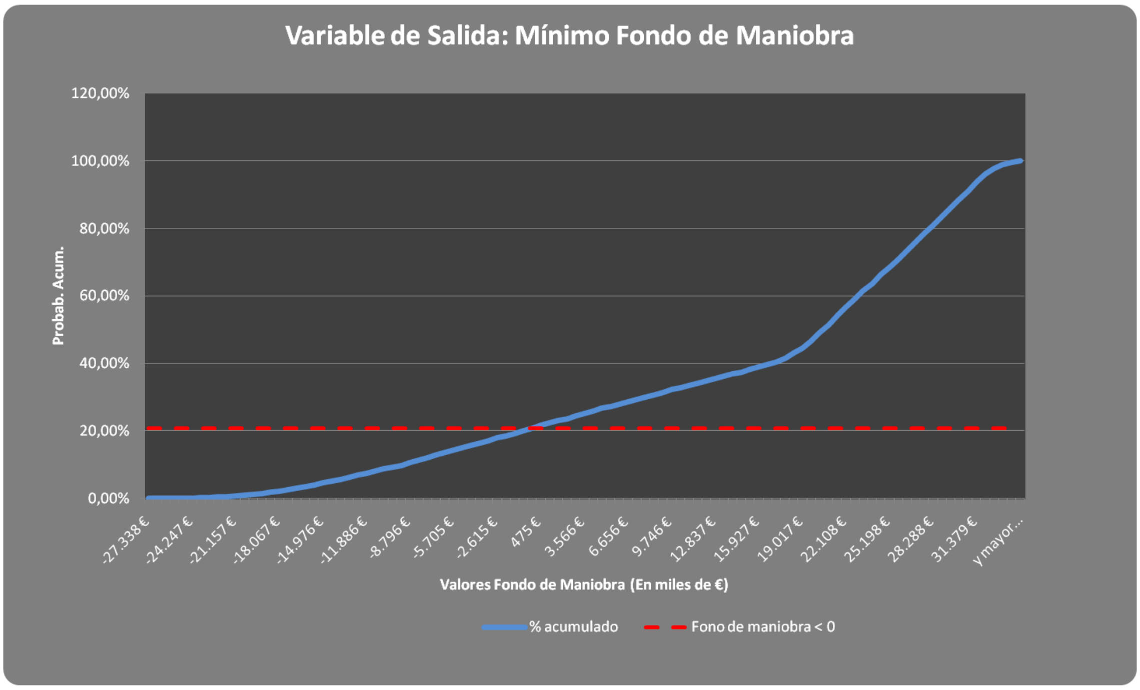

Figure 33. Minimum value of working balance. Statistical Analysis. Cumulative distribution function.

Once variable probability function has been described graphically, we present figures for the most relevant statistics:

Estadísticas de la Simulación	
Nro. Iteraciones	10000
Mínimo	- 27.337,80 €
Promedio	14.860,84 €
Máximo	34.469,18 €
Mediana	20.481,79 €
Varianza	225.957.759,63 €
Desvío Estándar	15.031,89 €
Rango	61.806,99 €
Curtosis	-0,5731
Coef. de Asimetría	-0,8004
Coef. de Variación	1,0115

Figure 34. Minimum value of working balance. Statistical Analysis. Statistics

Now we will analyze the influence that each of the input variables defined has on the values of the Minimum value of working balance. We will use the same two approaches used for NPV and IRR:

Regression analysis

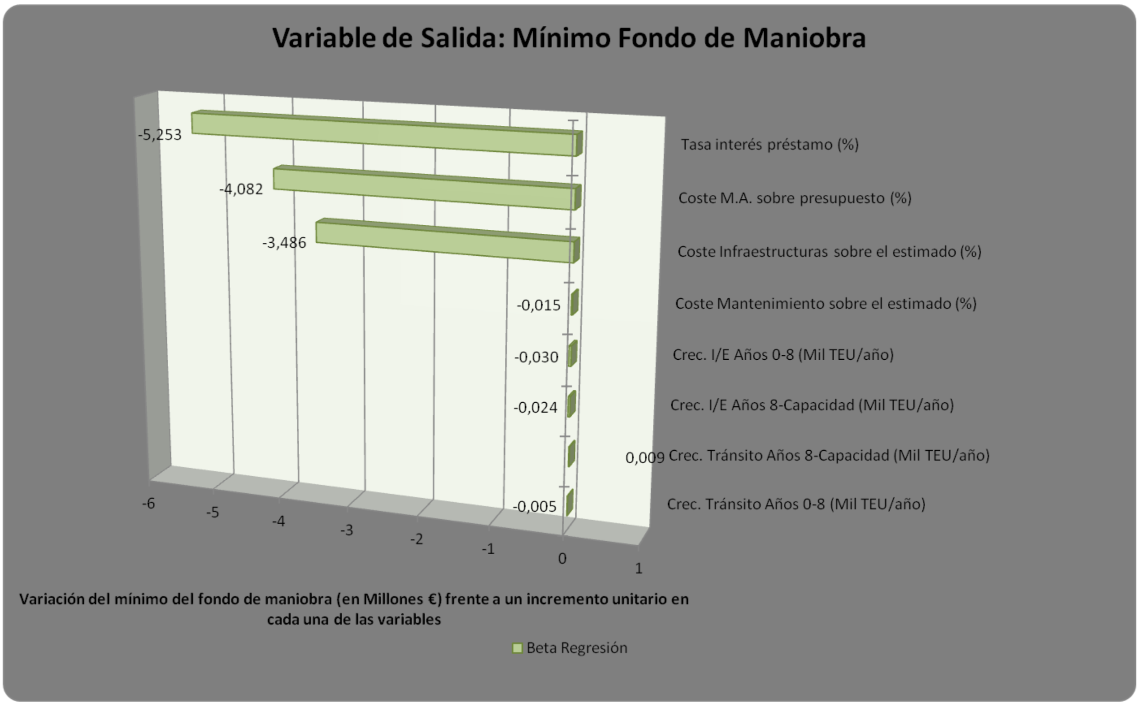

Figure 35. Minimum value of working balance. Regression analysis.

Correlation analysis.

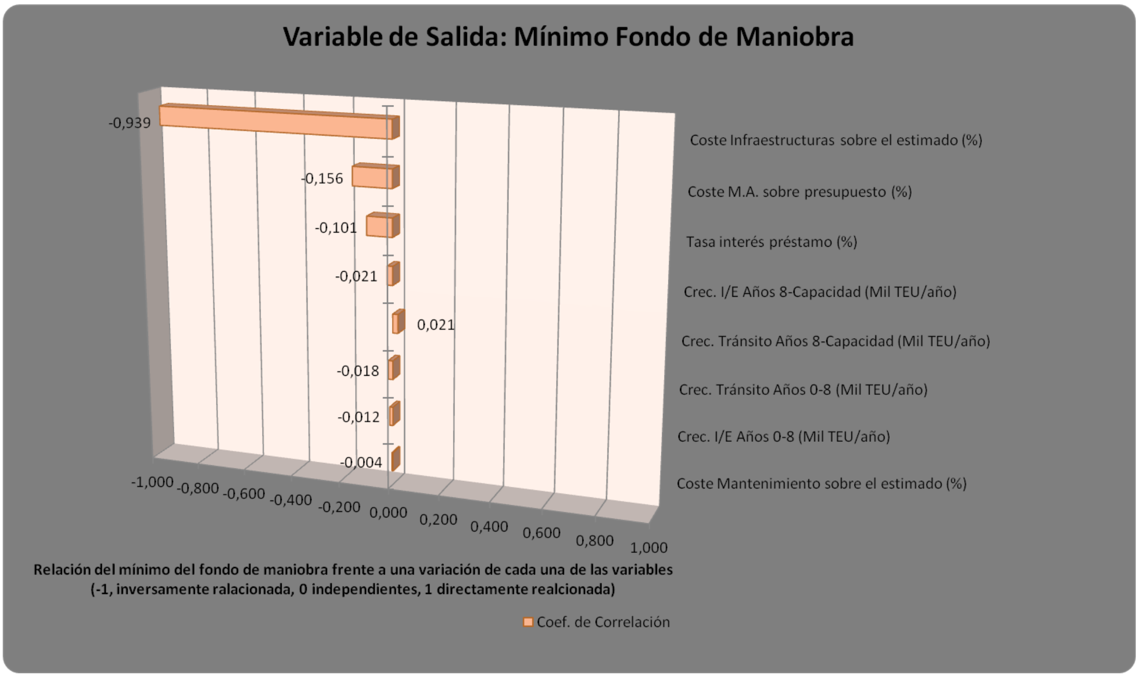

Figure 36. Minimum value of working balance. Correlation analysis.

Figure 36 suggests that the Minimum value of working balance does not depend on directly any variables.

On the other side is deduced that minimum value of working balance depends inversely on infrastructure costs, environmental costs, interest rate of bank debt, and to a lesser extent of maintenance costs of the both transit and Import/Export traffic growth rates, in the two growth stages defined in the corresponding section.

6.2 Economic analysis.

6.2.1 *Base case*

Once the model has been developed and run, including income statement, balance sheet, statement of source and application of funds, cash flow statement, we can calculate the most relevant outputs:

- Cash flow NPV. Cash flow was calculated and then financial costs and taxes were deduced, and the discounted to 2013. This value is above the 15 million euros (2013 euros).
- IRR: We have also calculated IRR, the rate of return that makes the NPV equal to zero.
- Minimum value of working balance. As discussed previously, we have highlighted this parameter to verify the goodness of the proposed financing Plan.

Results for the Base Case are summed up in Table 22

6.2.2 *Sensitivity analysis.*

Following the previous work already made for the financial appraisal, a sensitivity analysis was carried out, i.e. an analysis of the what if...?, where we analyzed the result of the output variable, NPV_S, IRRS, if one input variable changed in one percent point remaining the others unmodified. We obtained relations between the variations of the input variables and the output variable.

We will present the output of this analysis using again a Web graph and tornado one.

The results will be presented in the following order: NPV, IRR.

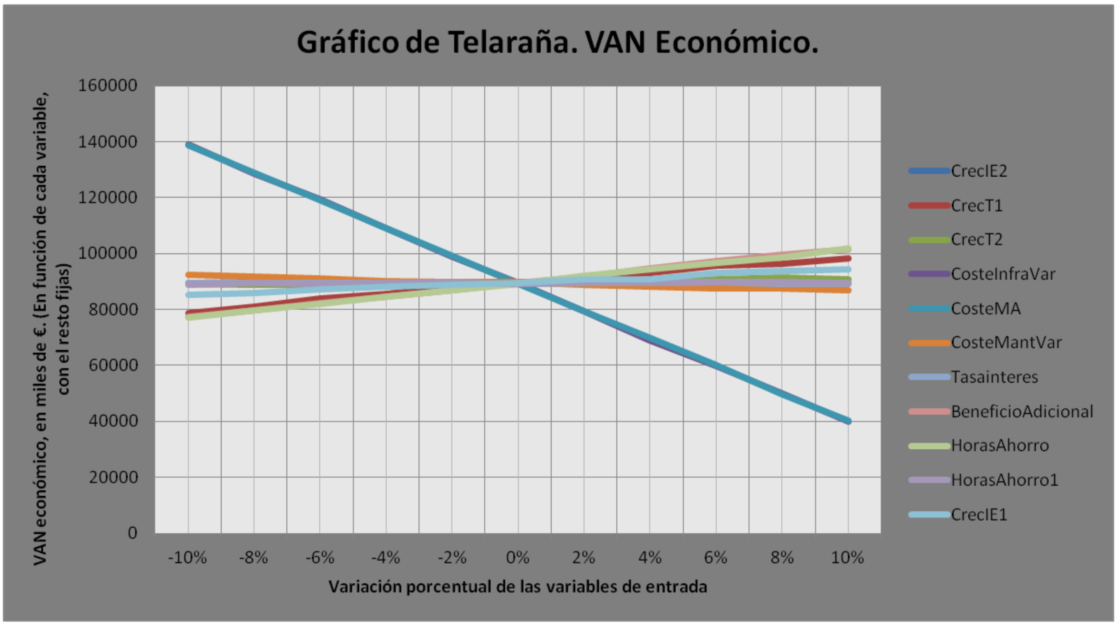

Figure 37. NPVS sensitivity analysis. Web graph.

Figure 37 shows us that we should be careful in this kind of analysis because all variables vary in the same percentage order, but some of the values are not real, e.g. investment can vary from 1 to 10% but it is less feasible that discount rate varies from 1 to 10%, this would not happen in the probabilistic analysis.

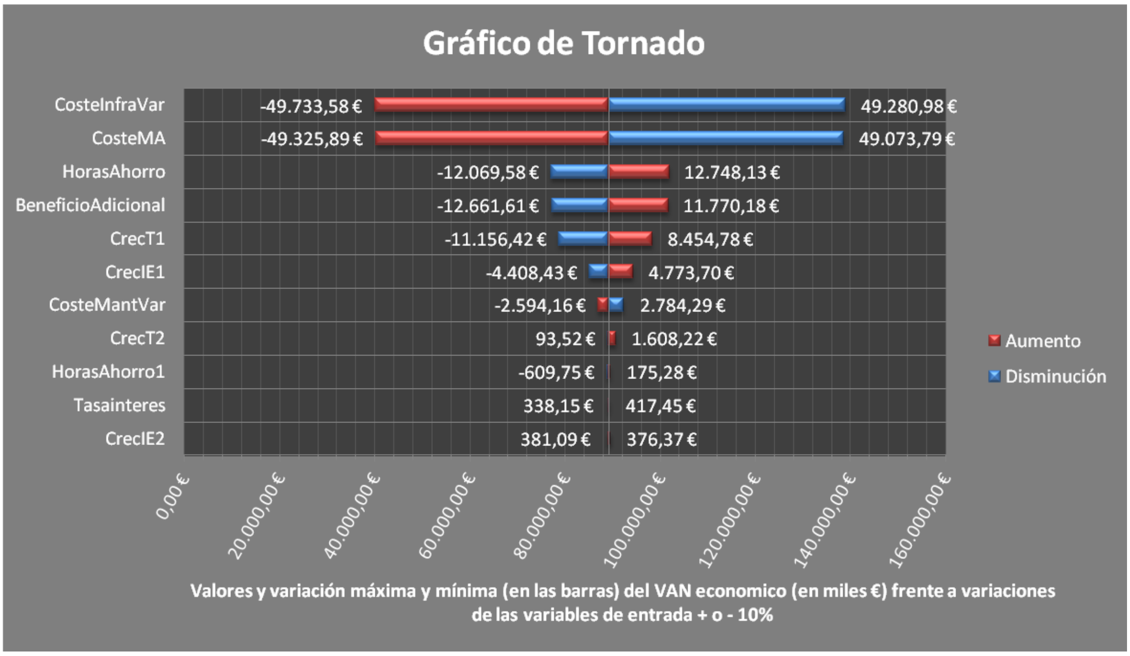

Figure 38. NPVS Sensitivity analysis. Tornado graph.

In Figure 38 we see the maximum and minimum variations on the output variable that may cause the variation of each one of the input variables. We have analyzed variations ± 10% in each of the input variables, such variations in the case of the cost of infrastructure have an influence of roughly ±50 million €. This type of graph corresponds to the correlation analysis we have done in the probabilistic approach.

Now we shows results for IRR_S.

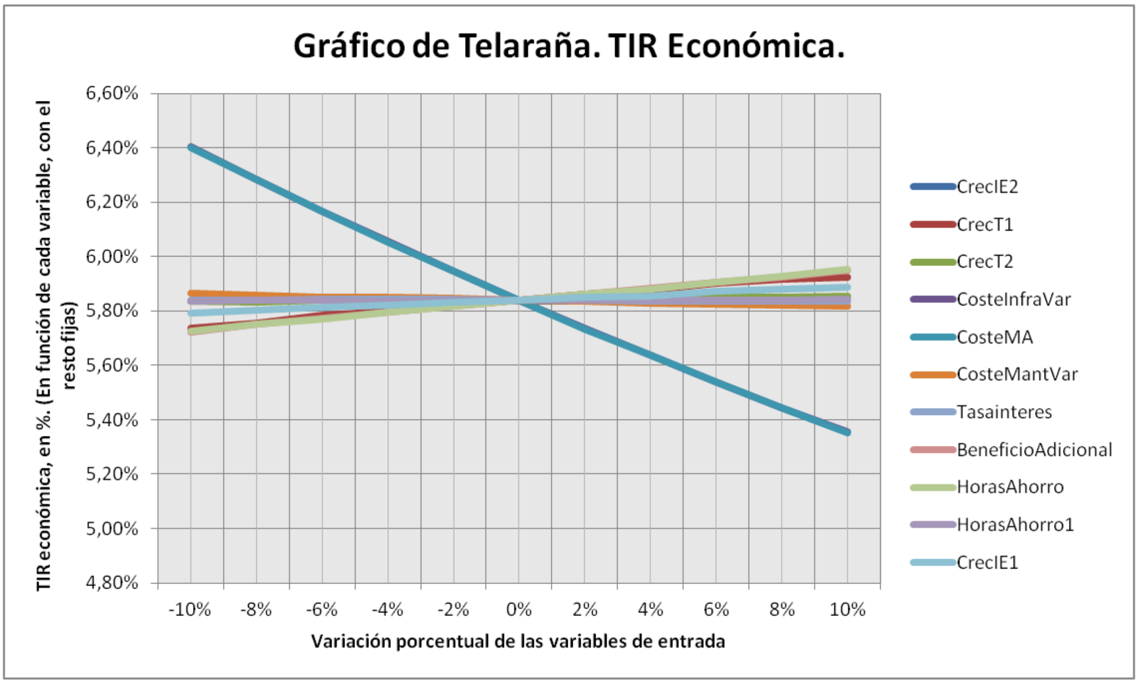

Figure 39.IRRS sensitivity analysis. Web graph.

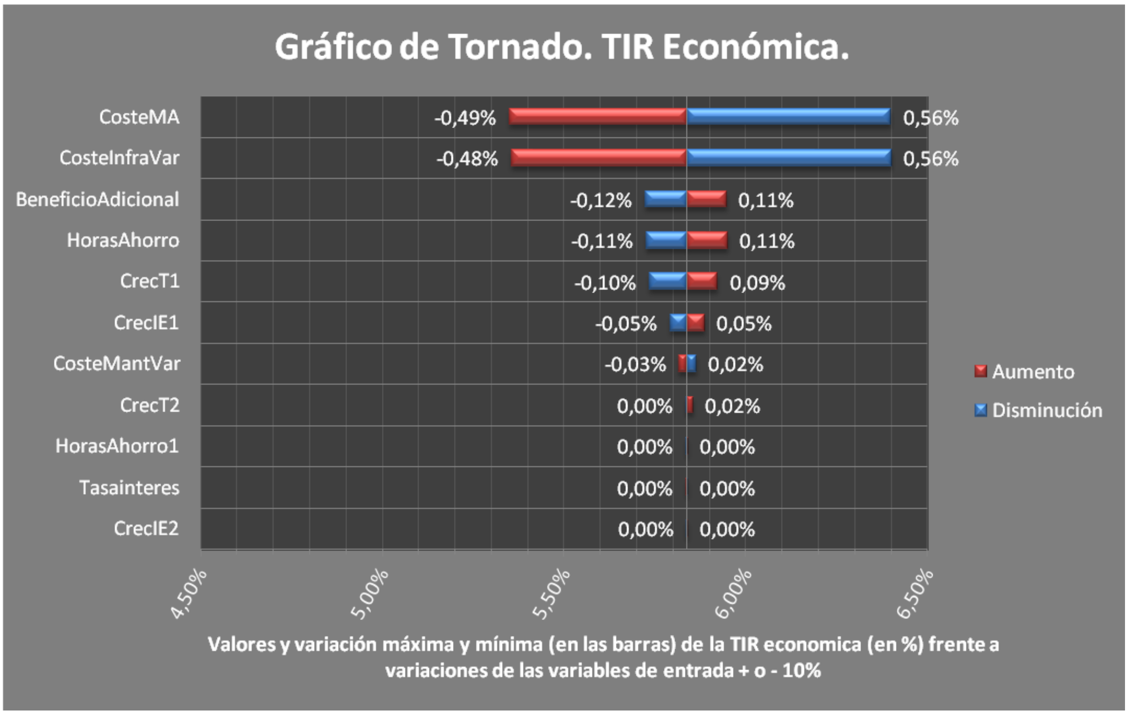

Figure 40. IRRS Sensitivity analysis. Tornado Graph.

Variations in the case of the infrastructure and environmental costs have influence of more +0'56% or -0'48%, from the IRR_S calculated in the Base Case.

6.2.3 *Risk analysis.*

The method of simulation Monte Carlo will be used again, so we do not explain it again.

For the implementation of this model a specific simulation software that works as a supplement to Microsoft Excel has been used.

Net present value.

NPV_S was modeled by aggregating different surpluses in each of the actors involved, as mentioned in to the corresponding section.

The histogram that is obtained from the simulation is:

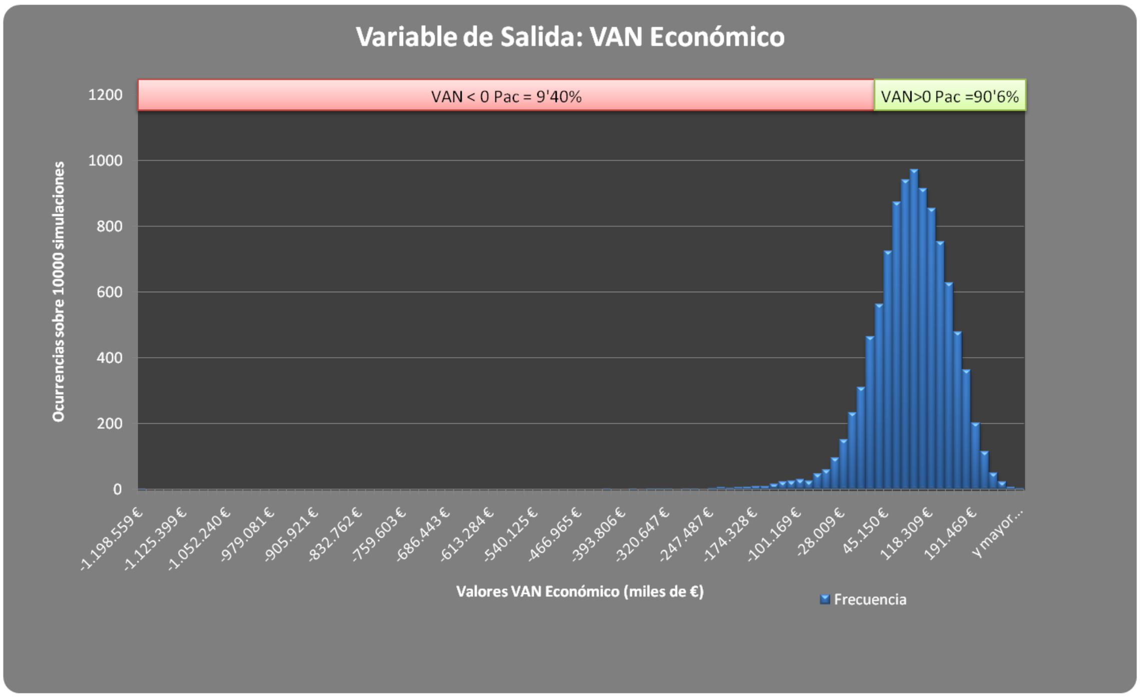

Figure 41. NPVS Statistical Analysis. Histogram

As shown in the histogram there are over 90% of the values of the NPV_S that are positive, which is giving us the first headline, "there is a 90% probability for NPV_S to be positive in this project". From the opposite point of view, acceptable risk for this project for society has to be at least 10%, because there is a 10% chance for NPV to be negative in this project, and therefore would not be financially profitable for society.

Now we can see the cumulative probability function:

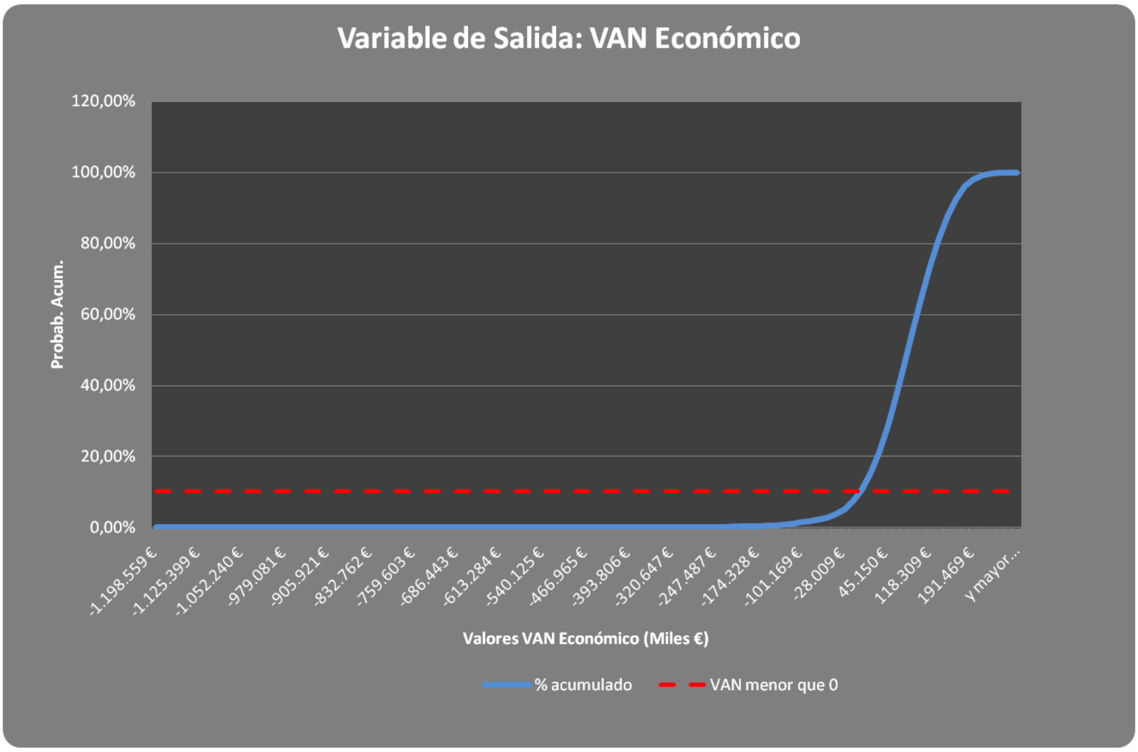

Figure 42. NPVS Statistical Analysis. Cumulative probability function.

Once variable probability function has been described graphically, we present figures for the most relevant statistics:

Estadísticas de la Simulación	
Nro. Iteraciones	10000
Mínimo	- 1.198.558,59 €
Promedio	76.049,71 €
Máximo	264.628,03 €
Mediana	79.919,05 €
Varianza	4.425.336.100,24 €
Desvío Estándar	66.523,20 €
Rango	1.463.186,62 €
Curtosis	15,937
Coef. de Asimetría	-1,533
Coef. de Variación	0,875

Figure 43. NPVS Statistical Analysis. Statistics.

Now we will analyze the influence that each of the input variables defined have on the values of the NPV_S. We will use two approaches:

Regression analysis.

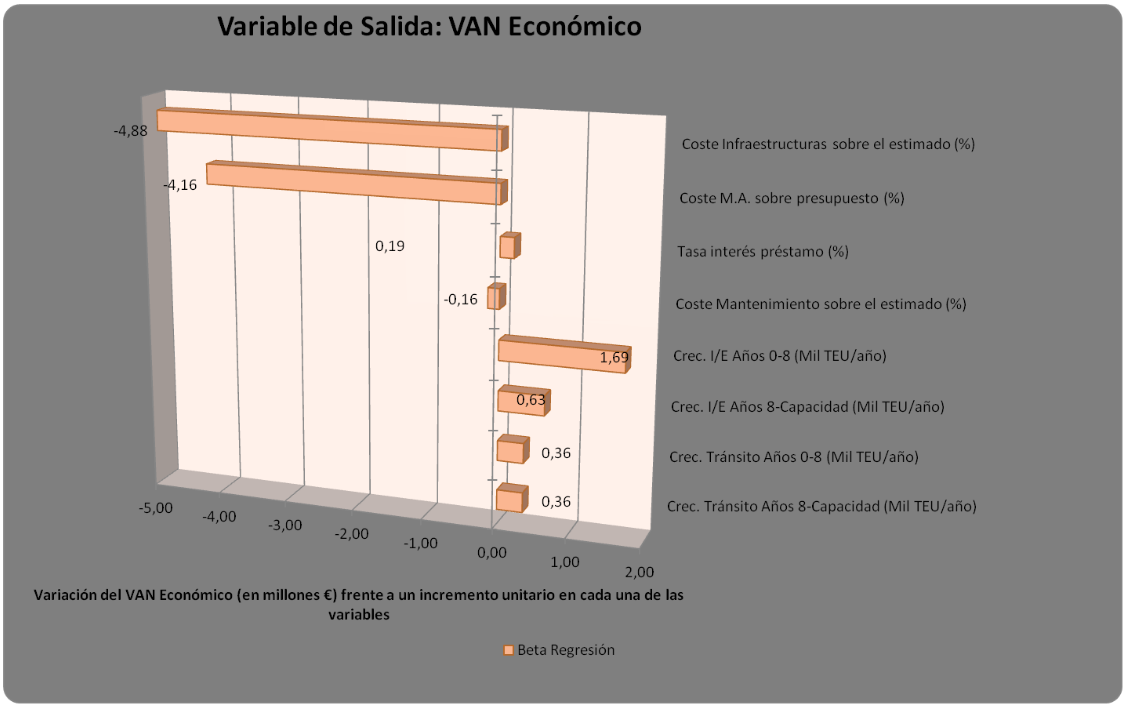

Figure 44. NPVS. Regression analysis.

Correlation analysis.

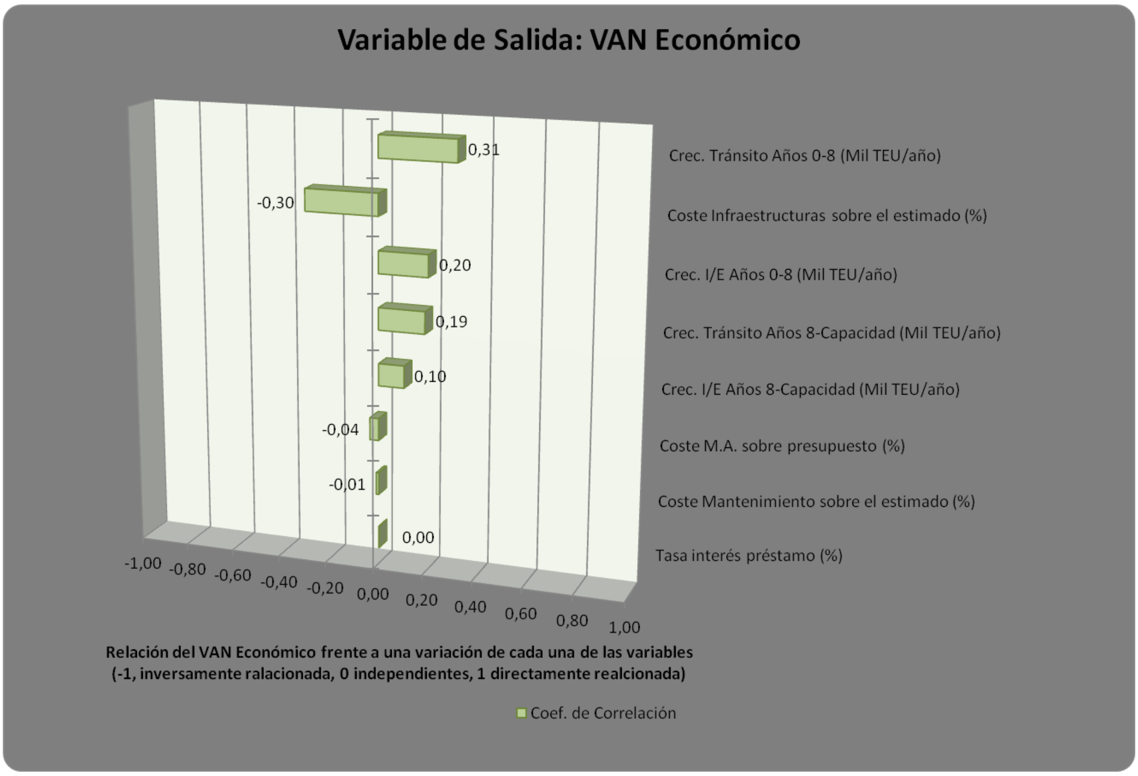

Figure 45. NPVS. Correlation analysis.

It is clear from Figure 45 that the NPV_S depends directly on traffic growth rates, both transit and Import/Export, and in the two growth stages defined in Project definition. Section. NPV_S is more sensitive to transit traffic growth of during the first five years, so during commissioning of the new terminal, special attention may be paid to this traffic, consequently marketing efforts should focus on capture traffic in that market.

On the other side, we can deduce that NPV_S depends inversely on infrastructure costs, interest rate of bank debt, and to a lesser extent the cost of environmental measures and maintenance costs. We can deduce also that the NPV_S is very sensitive to variations on infrastructure cost, so it will be fundamental to pay special attention when it comes to developing the project.

As expected, NPV_S does not depend of bank interest rate, since it has no influence the funding scheme in the social result.

Internal rate of return.

With this variable we can see which would be the greatest profitability that society requires for our project, obviously associated with a probability value. But we can also have a glimpse on what would be the probability that the project was socially profitable in the event that we decide to apply a lower rate, having previously covered the financial costs of the project.

The histogram obtained from the simulation is:

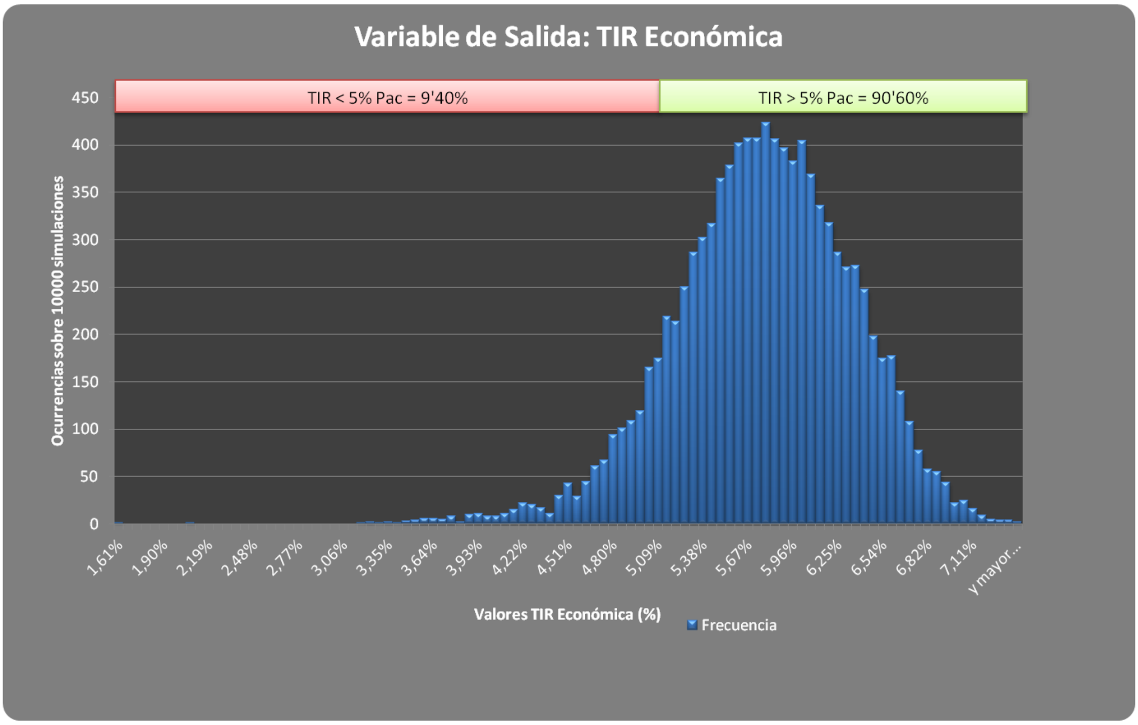

Figure 46. IRRS Statistical Analysis. Histogram

Now we can see the cumulative probability function:

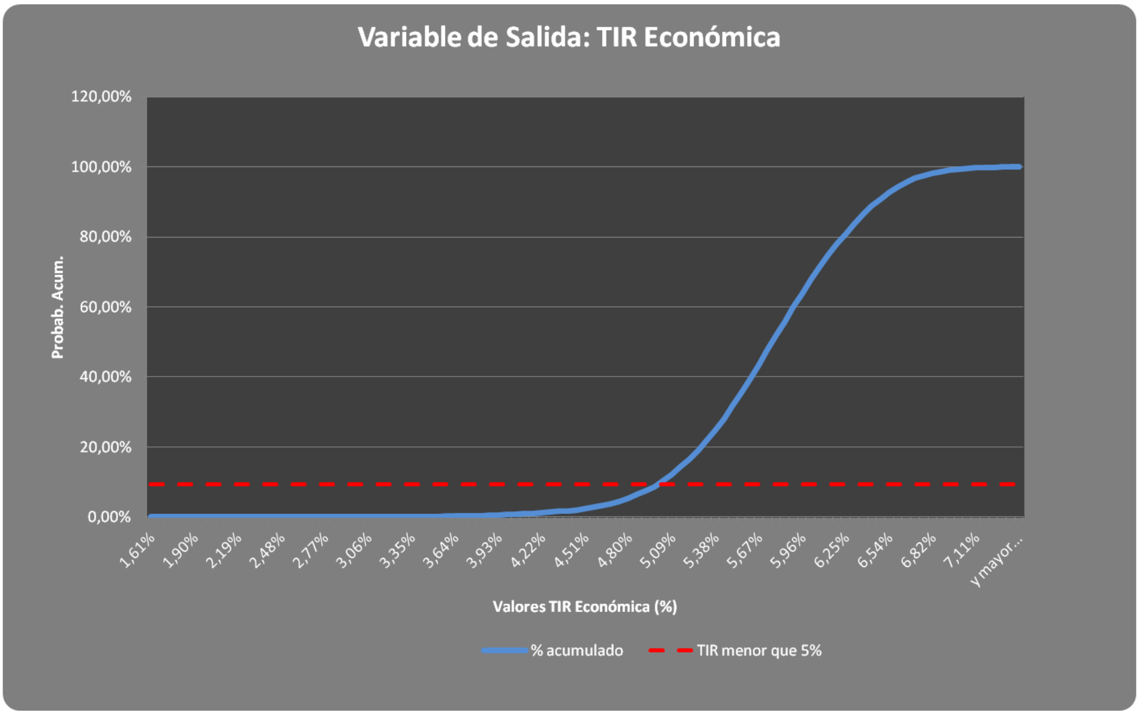

Figure 48. IRRS cumulative probability function.

Once variable probability function has been described graphically, we present figures for the most relevant statistics:

Estadísticas de la Simulación	
Nro. Iteraciones	10000
Mínimo	1,61%
Promedio	5,74%
Máximo	7,40%
Mediana	5,75%
Varianza	0,00%
Desvío Estándar	0,58%
Rango	5,79%
Curtosis	0,972
Coef. de Asimetría	-0,476
Coef. de Variación	0,101

Table 23. Statistics of probability of economic IRRS function.

Now we will analyze the influence that each of the input variables defined have on the values of the IRR_S. We will use the same two approaches:

Regression analysis.

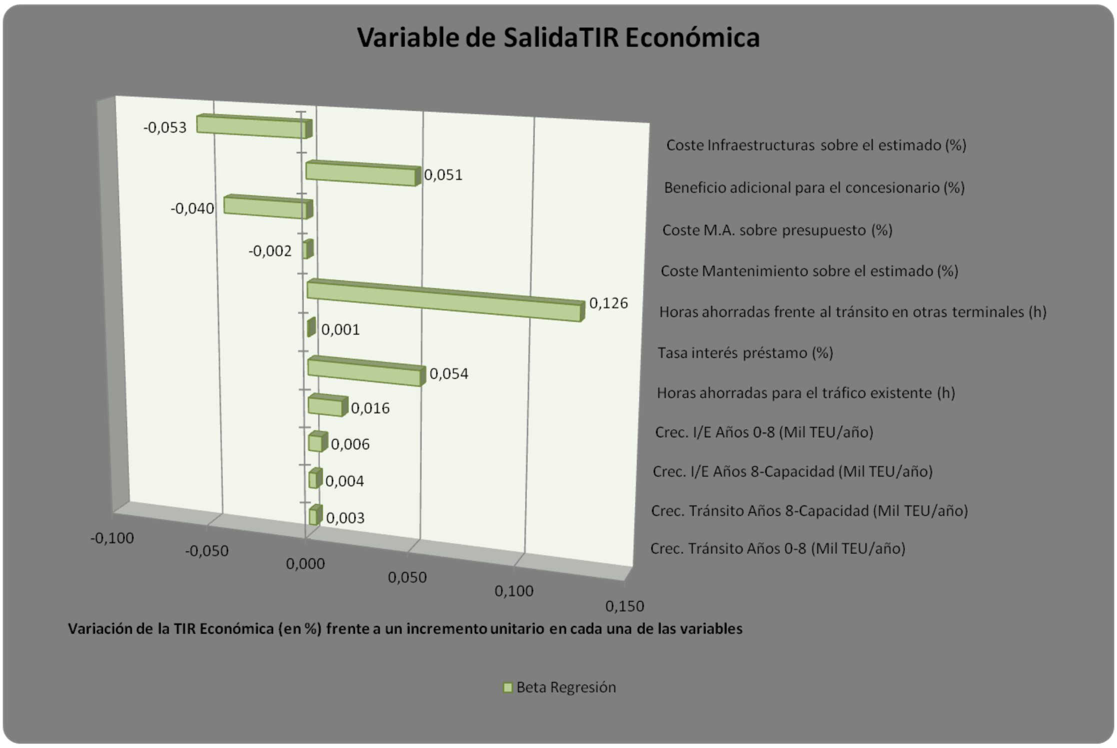

Figure 47. IRRS. Regression analysis.

We can see as in the case of the economic IRR_S depends largely on the outcome of operator, concessionaire of the terminal, which will bring an important added value to society.

Correlation analysis**.**

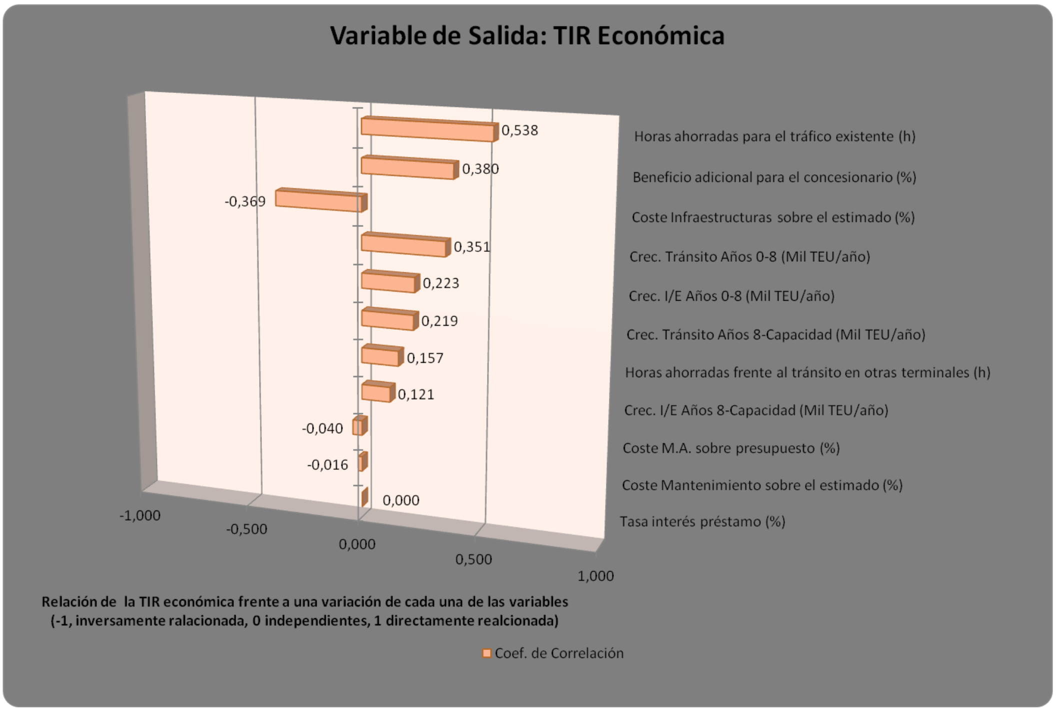

Figure 48. IRRS. Correlation analysis.

Figure 48 suggests that IRR_S depends directly on the time savings for consumers of the existing terminal, the additional benefit for the new terminal concessionaire, rates of traffic growth, both transit and Import/Export, in the two growth stages defined in the corresponding section, this seems quite logical.

On the other side we see that IRR_S is inversely dependent on the costs of infrastructure, and to a lesser extent the cost of environmental measures and maintenance costs. We can also see that the IRR_S is strongly influenced by the cost of the infrastructures which will be fundamental to this section note when it comes to putting up the Master Plan. As in the case of $VAN_{S,}$ IRR_S does not depend on the interest rate of bank debt.

6.3 Discussion.

If we analyze in detail the results of both appraisals we can see that in the case of the economic analysis, there is a ***probability greater than 90% that the project is profitable for the society, TIR_S> 5% VAN_S > 0*** .In the case of the ***NPV_F and IRR_F this probability is somewhat lower and reaches 83%***. Both probabilities of success are high, although they imply ***the existence of a likelihood of failure that might be excessive depending on the risk assessment that an external evaluator could carry out***.

It is at this point where we also use probabilistic analysis to assess how and to what extent the input variables are related to the outputs obtained.

As we could imagine, and as shown in the corresponding sections, ***the probability distributions of the NPV_F and the NPV_S are non-identical***, even though the input variables are the same for both cases. In fact we have a higher probability for the project to be viable for society than for the port authority. This will be an important aspect to take into account when it comes to decision-making.

Probabilistic analysis and further results can also offer valuable information, which in this case we could use to consider measures that help us to improve these results, or to understand what would be the reluctance from the point of view of an external project evaluator.

Analyzing the regression analysis of each of the variables should highlight:

- Both ***NPV_F and the NPV_S have a very significant dependence on protect cost.*** *An increase of costs exceeding 5% of the expected maximum (which already was a 104%) would make the project unviable*. From the point of view of the developer, efforts would have to be focused in order to improve the performance of the project. This could be done in one of these two ways:

  - ***Project review*** to optimize the design, using an appropriate solution that would allow us to cope with the expected growth in a satisfactory manner but minimizing unproductive areas.

- ***Project phased implementation*** allowing us to moderate investment, and to adapt the infrastructure provision to existing demand (within the low elasticity offers allows us to).

\- Other variable which can modify the results in a relevant way is the ***banking interest rate***. *An increase of 1% on the project maximum interest rate (up to 4'75%) making the viability of the project difficult*. From the point of view of the external evaluator it may raise doubts as how to obtain such a high amount of funding. Moreover, regarding this variable, and approaching Master Plan's financial analysis, we could also take some measures that would help us improve the NPV_F *and the* NPV_S :

- First of all we could try to ***reduce the need for funding*** by delaying start of the works. With this delay the working capital of the port authority would continue to increase and could cope with the construction with a less need for debt.
- Secondly, works could have ***extended deadlines***, leading to less annual investment effort and more working capital generated by the port authority, which would lead to a reduction in the financial costs.
- Finally, ***phasing investment*** might provide a common solution to the previous section, and it would allow us to reduce the investment effort and the need for external capital, and therefore also reduce financial expenditure.
- Finally we have to point out that there is also a significant correlation between the social outcome and the result of the concessionaire. So deepening in this field through a much more detailed study that would allow us to corroborate the additional margins to the opportunity cost of capital for the dealer.

Talking about financial analysis we should highlight the importance of I/E traffic to the incomes, whose influence is very relevant when obtaining NPV. A *decline in I/E traffic growth during the first 8 years below 14.000 TEUs would make the project unfeasible*. However the importance of the growth from year eighth after terminal commissioning is less relevant, in fact reduced by half. On the other hand, talking about *transit traffic, first eight years become crucial, and if the growth in these years is less than 240000 TEUS's / year the project would have also serious viability problems*. These two aspects also give us a clue about the importance of the concessionaire having a shareholder who has capacity to attract traffic of this type (could be a shipping company or a global terminal operator).

In the calculation of the NPV_S, there are a couple of aspects that are also notable. There is a clear influence on the consumer's surplus of the time savings when using the new terminal. These time savings are approaches made with the aggregated data available, so a new investigation field that would be interesting, is to construct a disaggregated database that would allow us the detailed assessmenttime savings for each of the cases raised, existing, devious and generated.

We should also indicate that the consumer's surplus from the of transit traffic generated is not taken into account and this is another aspect where the present study could be improved through the use of more reliable data on ownership of containers, its origin and destination and the time savings that would entail making transshipment at the new terminal.

It should be noted finally that we have not assessed with detail the environmental aspect of the project, since performing studies that allow us to know impacts of the implementation of the project are not still done. Obviously the lack of data and difficulty in terms of evaluation of possible preventive, corrective or compensatory measures are a handicap.

In any case it has been assumed when calculating models an additional environmental cost for the project varying between one and three percent to cover the possible environmental measures, from an economic point of view allows us to justify that surplus for natural resources is considered to be null since we compensate environmental costs through the different measures proposed in the Master Plan, and the additional cost in this project.

Conclusions.

We must now look back and review which the objectives of the present project were. In such manner we can check that in the conclusions we have given compliance to them.

Our first, and main, goal was to deal with the problems of risk identification and assessment through a better understanding of the variables involved, particularly we have focus on port investment, and its economic and financial assessments including risk analysis. We have developed a base case, and try to offer some criteria in the resolution of these problems. During the development of the economic and financial assessments we have found the problems, mainly related to the secondary objectives proposed, which we describe and comment below:

- ***Optimistic demand forecasts***. This is related to a secondary objective, about selecting the most relevant variables in the economic and financial analysis, because demand appears to be one of the key variables when evaluating port investments.
  Managers when drafting demand forecasts for plans have very detailed but somewhat optimistic forecasts. A common reference point in the majority of cases is the use of an intermediate case for all economic and financial calculations without taking into account the increase in uncertainty in the long term. All this leads to a unique solution, which may be optimistic, as we have seen the ***Case Base*** using a deterministic model. For example in our case, NPV for the financial analysis was positive, but when we performed a probabilistic approach a probability close to 17% was estimated for NPV being negative. In the same sense we can talk about economic analysis, although in the event we are concerned we have found a lower percentage, close to 10%, of which the NPV could be negative. Therefore when carrying out this type of analysis ***a statistical forecast of traffic approach is recommended*.**
- ***Determination of the input variables and its distributions***. It is complex to consider which input variables use for the probabilistic analysis, and even more complex to determine their probability distribution, given the lack of information. What seems reasonable is try to model these variables having more influence on the calculation and those which risk level is higher. After the analysis we have done in this project, the following variables are the most relevant:
  - ***Cost of infrastructures.*** It must take into account the real costs, in our case we have increased 15% initial forecasts in the Master Plan. Data from similar projects should be used if possible, and finally take into account possible deviations, of at least one 4% of the total investments.

- ***Cost of the environmental preventive, corrective and compensatory measures if any.*** This is another relevant aspect to take into account, since in some cases the amount of environmental measures can reduce or even eliminate the economic and financial viability of the project. Therefore it is important to include the cost of these measures in the analysis, trying to obtain a target value, but even in the case that is not possible, it may be interesting to do a simulation with a predicted value for environmental measures between 1 and 5% of the total value of the infrastructures, to be able to check their effects.
- ***Interest rate.*** We must study the possible sources of funding and the interests of them, finally should take into account possible variations in interest rates in the event of variable rate loans, this should not be included in the case of fixed rate loans.
- ***Operation and maintenance costs OPEX***. When we are talking about transport infrastructures they are not as relevant at the time of evaluation, but also should have be taken into account, and its modelling is recommended because in some cases it may be relevant.

- ***Financial models***. Setting up a funding model is a problematic aspect, since its automatic programming as a statistic variable is certainly complex, because funding deadlines, amounts, and interest rates should be adapted to the results of other input variables, such as infrastructure costs, and output variables as minimum of working balance. The proposal made in this project is to validate the expected financial plan, in terms of deadlines, dates of request for credits, amount and qualifying periods, to meet the requirements of ***case base.*** And later on, in the statistical analysis, define interest rate of the credit as a statistical input variable, and an output variable to control the goodness of the financial plan raised previously. We have used the minimum value of working balance.
- ***Time saving estimates***. This aspect is very important in determining the economic benefit of the project, but normally there is not enough disaggregated information to assess time consumed in the initial situation, as well as subsequent operation of the new facilities. The problem of restrictions on capacity and quality of service, measured in timeout should be added.
- ***Delay analysis and waiting time during operation and its effects on the outcome of the terminal***. It must be borne in mind that the complexity to statistically describe functions to model the average times standby depending on the characteristics of demand and level of operation of the infrastructure. Capacity, operation and delays in the case of a container terminal are determined by the lim-

iting value present in any of the four subsystems in which the terminal can be divide in.

Once analyzed the results it has been shown that the use of probabilistic, bootstrap, models in the economic and financial analysis of projects provides us with much more information, apart from a number of advantages over the other two models analyzed, deterministic and sensitivity analysis. We will now review the most important advantages:

Obtaining statistical output variable distributions. By using bootstrap methods, we can obtain the statistical distributions of output variables. This is an important source of information that will allow us to assess more effectively the risks which are assumed, much more than with a deterministic model offering us a single figure, as we have seen in the ***base case***. This amount of information allows us to define and assess risks, a key issue for decision-making.

Obtaining regressions between variables. Regression analysis between the input and output variables, enable us to know what is the influence of each one of the variables, this improves the issues raised in a sensitivity analysis, since in the probabilistic only is taken into account the raised values of the input variables, while in a sensitivity analysis, we propose percentage increases in the input variables that can lead us to values whose probability of occurrence is either 0 or close to 0.

Further research.

At the very beginning of this report the following steps that were to be covered in further research were anticipated, in order to finish the Ph.D. Thesis of the author. Those steps were:

- Perform an extensive literature review regarding the highest ranked variables to the result of the economic and financial analysis.
- Develop and deploy a questionnaire for industry or government members involved in the definition, managing and development of port projects, which will identify and assess specific issues and values for the chosen variables.
- Statistical models will be adjusted according to the data obtained.

Once the report has been finished, and a wide literature review has been done, we can make a fine tuning of the following steps, and investigation fields that could be explored.

Obviously a deeper literature review has to be done, but focusing on specific variables that have been highlighted in the conclusions, especially on demand forecast.

There are also two fields that can provide us with future research lines. First one is container traffic evolution, including aspects like correlation with GDP, containerization index, terminal attractiveness.

Another interesting field, also related with container traffic is capacity assessment of terminals, because traditionally capacity is measured in TEU's/year, but there are some daily or weekly capacities that might be more restrictive, in terms of level of service and delays.

Finally, deepening on statistical models specifically designed to accommodate to real variables distributions is an interesting field.

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Annex I.

1. **Yearly incomes.**

Valores anuales de los ingresos en plena explotación (2030) (miles de € corientes)	Importes € 2030	€ ctes 2020	€ ctes 2012
Total Tasa actividad (mil €)	870,21 €	713,87 €	609,28 €
Tasa de ocupación (7'00 €/m2) (mil €)	7.550,46 €	6.194,01 €	5.286,53 €
Total Tasa a la Mercancía I/E	8.585,43 €	7.043,04 €	6.011,17 €
Total Tasa a la Mercancía Tránsito	2.527,77 €	2.073,65 €	1.769,84 €
Total Tasa al Buque (mil €)	10.153,40 €	8.329,32 €	7.109,00 €
Ingresos totales (euros corrientes)	29.687,27 €	24.353,90 €	20.785,82 €

2. **Yearly incomes per unit.**

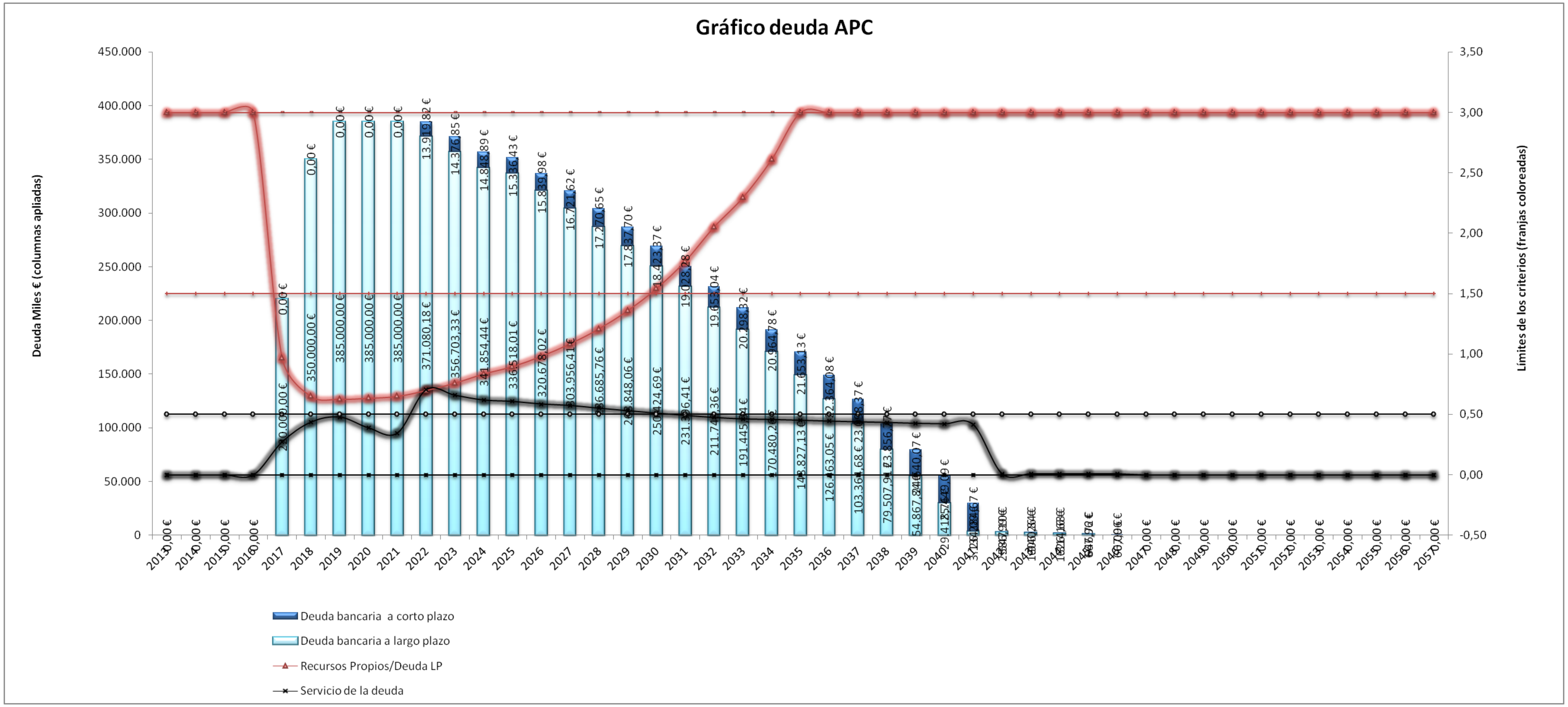
Valores de los ingresos medios por TEU en plena explotación (2030) (€ corrientes)	€ corrientes 2030	€ ctes 2020	€ ctes 2012
Ingresos Tasa Ocupación (TEU)	3,57 €	2,93 €	2,50 €
Ingresos Tasa Actividad (TEU)	0,41 €	0,34 €	0,29 €
Ingresos Tasa mercancía + Tasa Buque (TEU)	10,06 €	8,26 €	7,05 €
Ingresos totales (TEU)	**14,05 €**	**11,53 €**	**9,84 €**
Ingresos Tasa Ocupación (TEU I/E)	3,57 €	2,93 €	2,50 €
Ingresos Tasa Actividad (TEU I/E)	0,41 €	0,34 €	0,29 €
Ingresos Tasa mercancía + Tasa Buque (TEU I/E)	33,67 €	27,62 €	23,57 €
Ingresos totales (TEU I/E)	**37,65 €**	**30,89 €**	**26,36 €**
Ingresos Tasa Ocupación (TEU Tránsito)	3,57 €	2,93 €	2,50 €
Ingresos Tasa Actividad (TEU Tránsito)	0,41 €	0,34 €	0,29 €
Ingresos Tasa mercancía + Tasa Buque (TEU Tránsito)	5,05 €	4,15 €	3,54 €
Ingresos totales (TEU Tránsito)	**9,04 €**	**7,42 €**	**6,33 €**

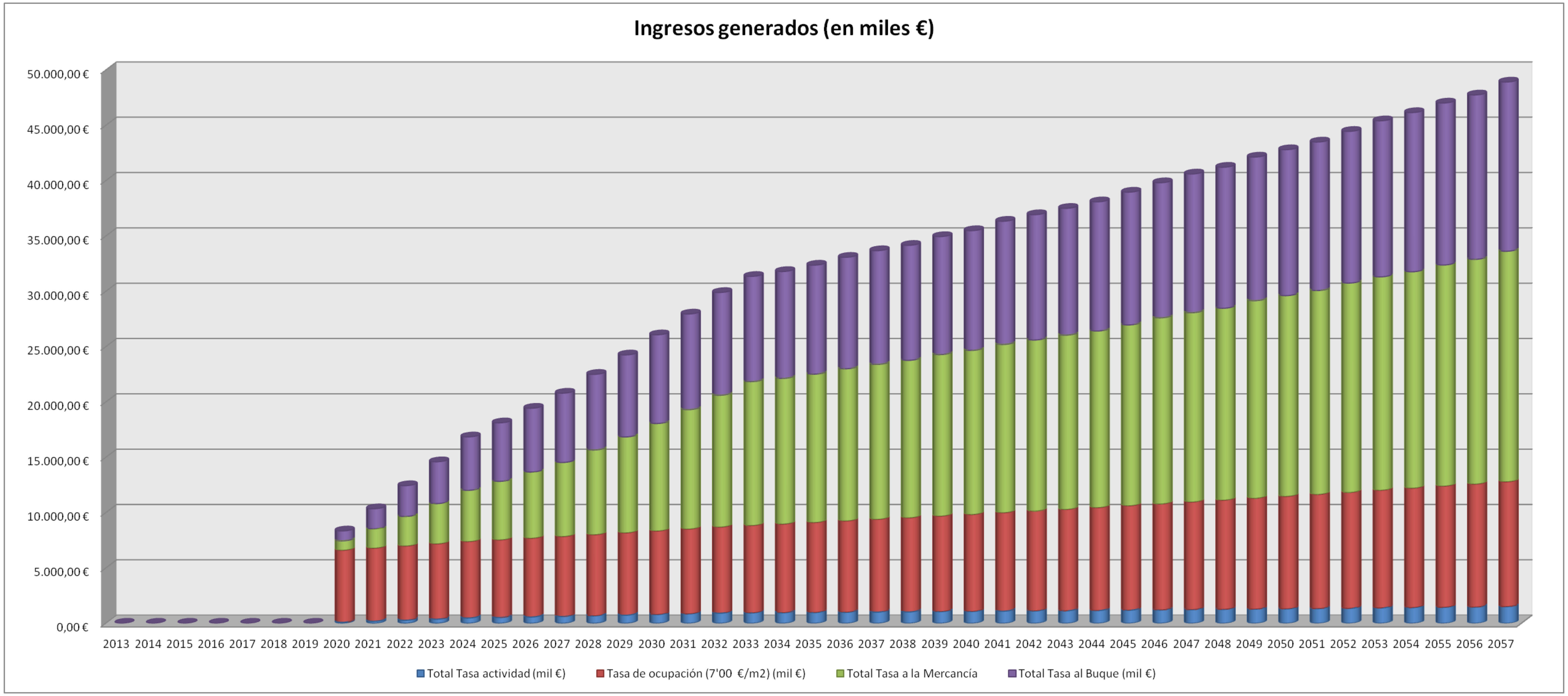
3. **Income statement.**

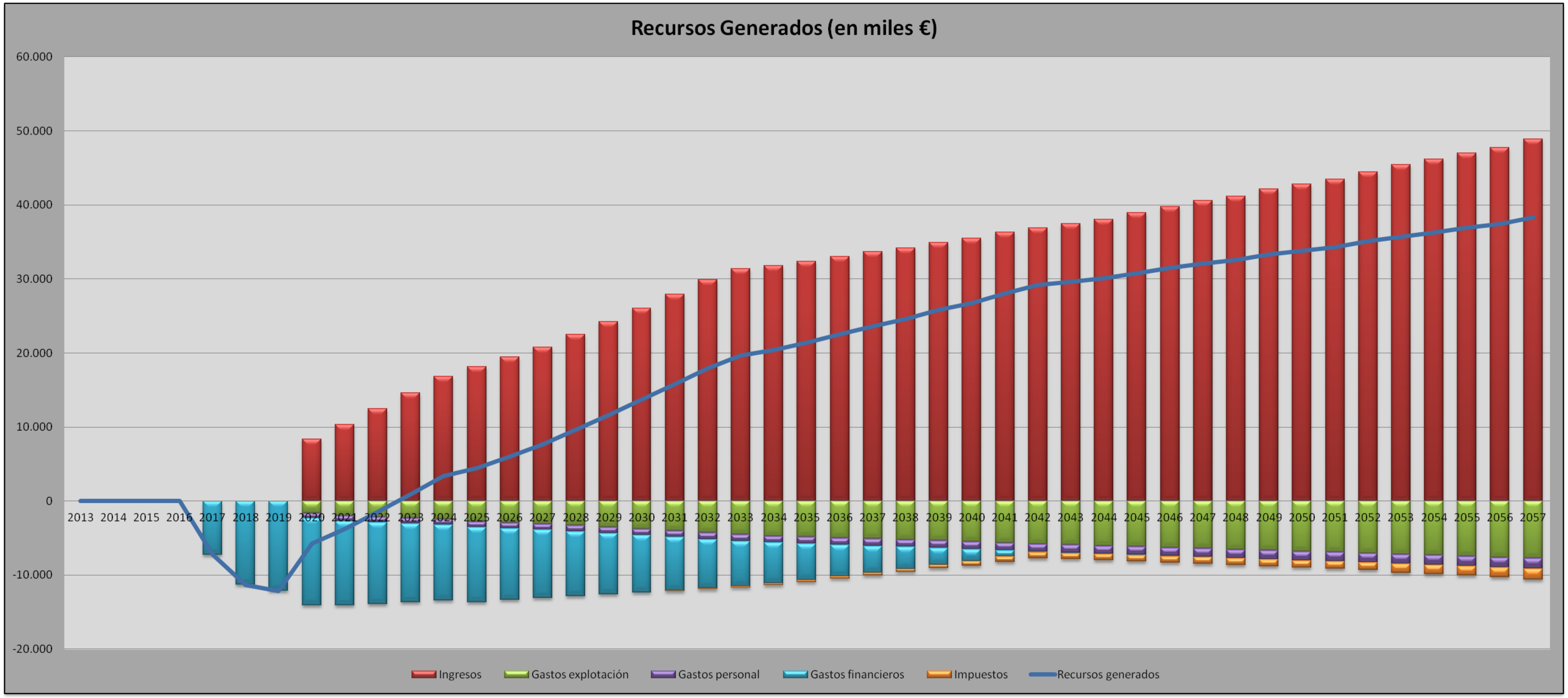
Pérdidas y ganancias en una año tipo en plena explotación (2030) (miles € corrientes)	Importes € 2030	€ ctes 2020	€ ctes 2012
1. Importe neto de la cifra de negocios	**29.687**	**24.354**	**20.786**
A. Tasas portuarias	**29.687**	**24.354**	**20.786**
a) Tasa de ocupación	7.550	6.194	5.287
b) Tasas de utilización	21.267	17.446	14.890
1. Tasa del buque (T1)	*10.153*	*8.329*	*7.109*
4. Tasa de la mercancía (T3)	*11.113*	*9.117*	*7.781*
c) Tasa de actividad	870	714	609
B. Otros ingresos de negocio	-	-	-
3. Trabajos realizados por la empresa para su activo	-	-	-
5. Otros ingresos de explotación	-	-	-
6. Gastos de personal	**(824)**	**(676)**	**(577)**
7. Otros gastos de explotación	**(4.464)**	**(3.662)**	**(3.125)**
a) Servicios exteriores	(1.966)	(1.613)	(1.377)
1. Reparaciones y conservación (excluido Marpol)	*(1.966)*	*(1.613)*	*(1.377)*
a. Reparaciones y conservación (excluido Marpol)	*(1.966)*	*(1.613)*	*(1.377)*
b) Tributos	(594)	(487)	(416)
d) Otros gastos de gestión corriente	(15)	(12)	(10)
e) Aportación a Puertos del Estado art. 19.1.b) RDL 2/2011	(1.114)	(914)	(780)
f) Fondo de Compensación Interportuario aportado	(775)	(635)	(542)
8. Amortizaciones del inmovilizado	**(15.607)**	**(12.803)**	**(10.927)**
9. Imputación de subvenciones de inmovilizado no financiero y otras	-	-	-
10. Excesos de provisiones	-	-	-
11. Deterioro y resultado por enajenaciones del inmovilizado	-	-	-
Otros resultados	-	-	-
A.1. RESULTADO DE EXPLOTACIÓN (1+3+5+6+7+8+9+10+11)	**8.793**	**7.213**	**6.156**
	-	-	-
12. Ingresos financieros	-	-	-
13. Gastos financieros	**(7.501)**	**(6.153)**	**(5.252)**
a) Por deudas con terceros	(7.501)	(6.153)	(5.252)
14. Variación de valor razonable en instrumentos financieros	-	-	-
16. Deterioro y resultado por enajenaciones de instrumentos financieros	-	-	-
A.2. RESULTADO FINANCIERO (12+13+14+16)	**(7.501)**	**(6.153)**	**(5.252)**
	-	-	-
A.3. RESULTADO ANTES DE IMPUESTOS (A.1+A.2)	**1.292**	**1.060**	**905**
17. Impuesto sobre beneficios	**(65)**	**(53)**	**(45)**
A.4. RESULTADO DEL EJERCICIO (A.3+17)	**1.227**	**1.007**	**859**
	-	-	-
EBIDTA (A.1.-8)	**24.400**	**20.016**	**17.084**

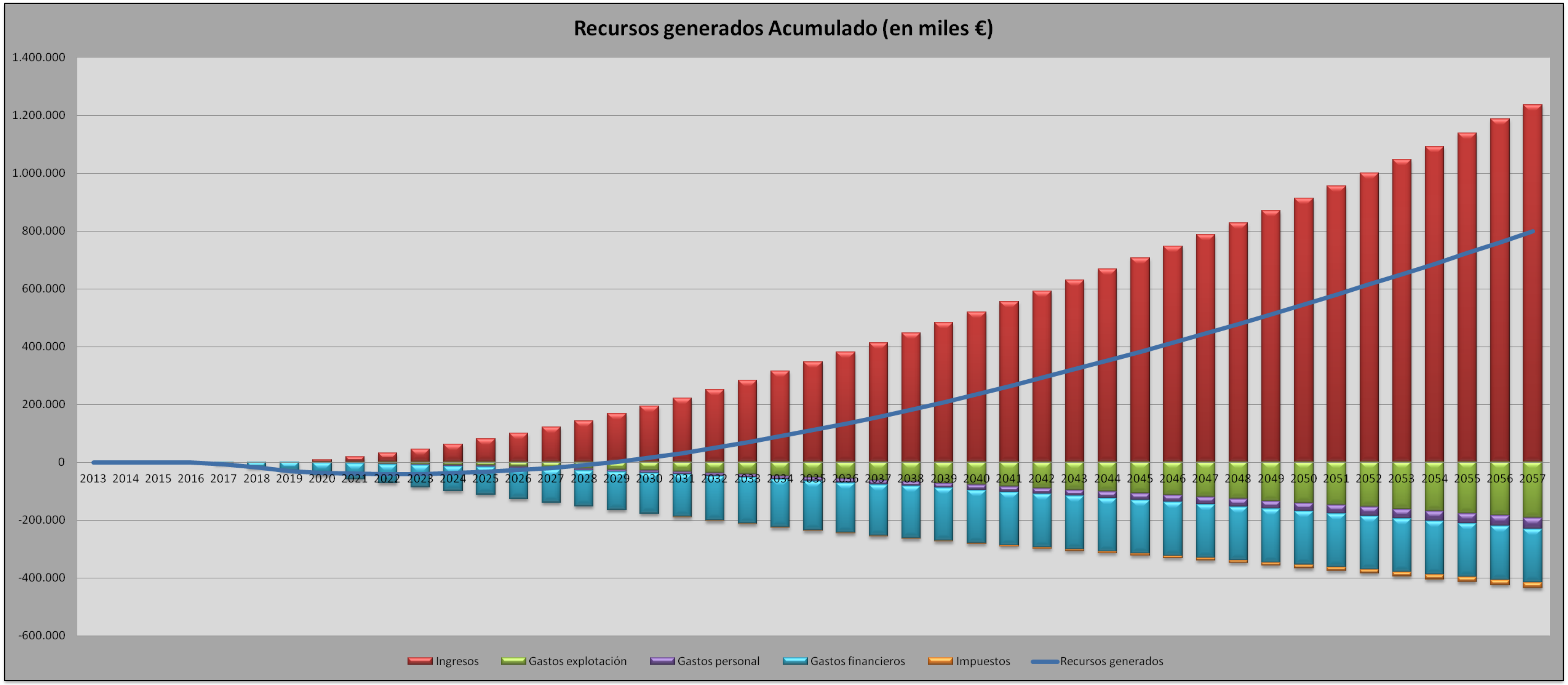
Tabla 1. Cuenta de pérdidas y ganancias de un año tipo.

4. Graphic output.

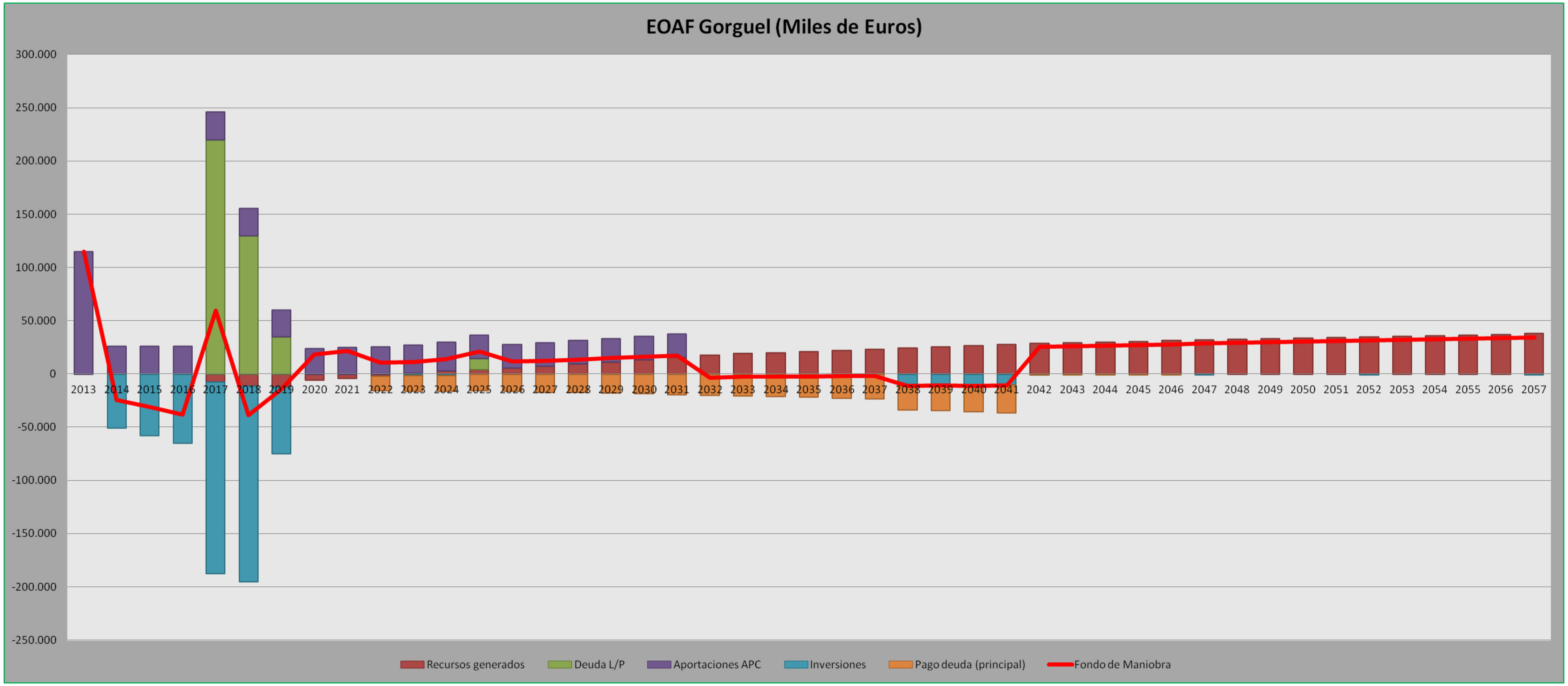


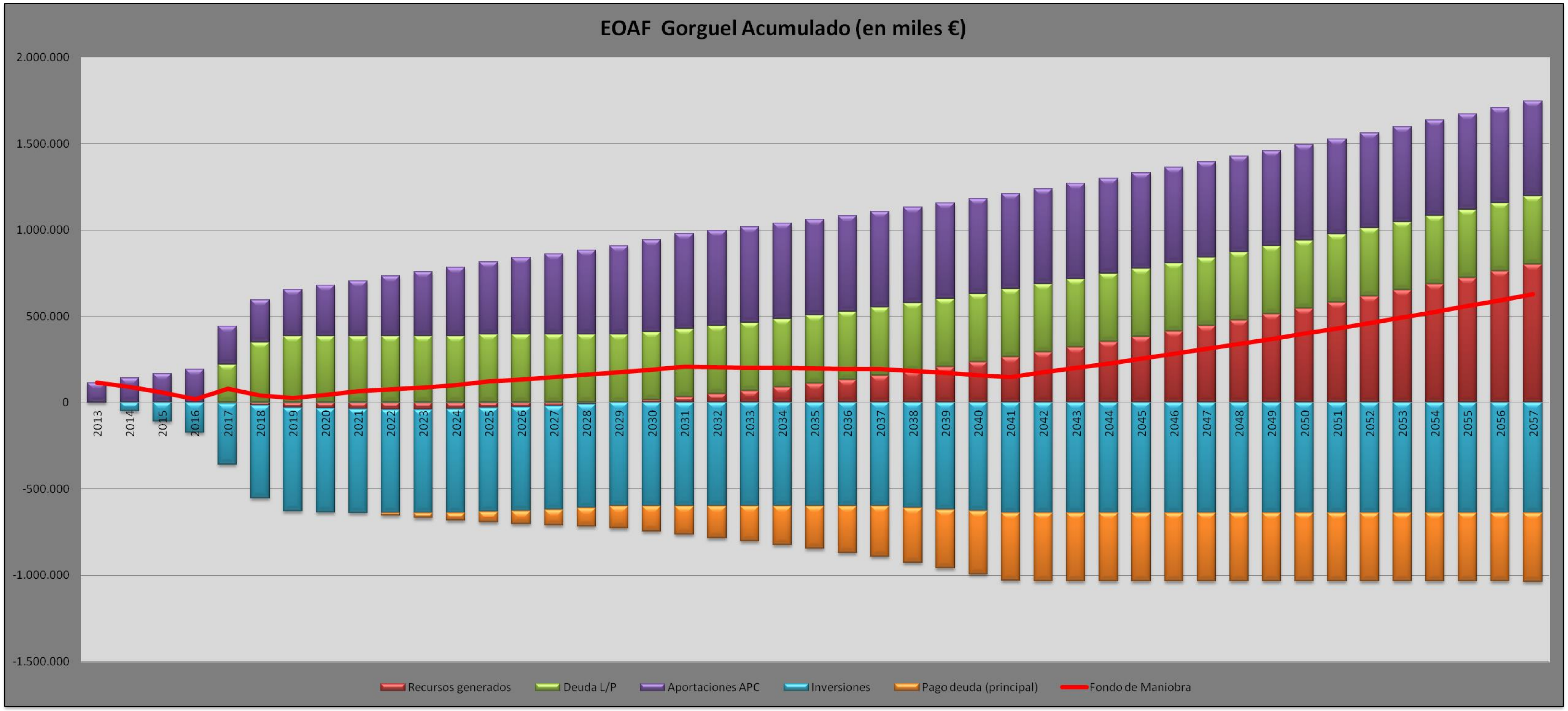

Ingresos generados (en miles €)
50.000,00 €
45.000,00 €
40.000,00 €
35.000,00 €
30.000,00 €
25.000,00 €
20.000,00 €
15.000,00 €
10.000,00 €
5.000,00 €
0,00 €
2013 2014 2015 2016 2017 2018 2019 2020 2021 2022 2023 2024 2025 2026 2027 2028 2029 2030 2031 2032 2033 2034 2035 2036 2037 2038 2039 2040 2041 2042 2043 2044 2045 2046 2047 2048 2049 2050 2051 2052 2053 2054 2055 2056 2057
Total Tasa actividad (mil €)
Tasa de ocupación (7'00 €/m2) (mil €)
Total Tasa a la Mercancía
Total Tasa al Buque (mil €)


Recursos Generados (en miles €)
60.000
50.000
40.000
30.000
20.000
10.000
0
-10.000
-20.000
2013 2014 2015 2016 2017 2018 2019 2020 2021 2022 2023 2024 2025 2026 2027 2028 2029 2030 2031 2032 2033 2034 2035 2036 2037 2038 2039 2040 2041 2042 2043 2044 2045 2046 2047 2048 2049 2050 2051 2052 2053 2054 2055 2056 2057
Ingresos
Gastos explotación
Gastos personal
Gastos financieros
Impuestos
Recursos generados



Recursos generados Acumulado (en miles €)
1.400.000
1.200.000
1.000.000
800.000
600.000
400.000
200.000
0
-200.000
-400.000
-600.000
2013 2014 2015 2016 2017 2018 2019 2020 2021 2022 2023 2024 2025 2026 2027 2028 2029 2030 2031 2032 2033 2034 2035 2036 2037 2038 2039 2040 2041 2042 2043 2044 2045 2046 2047 2048 2049 2050 2051 2052 2053 2054 2055 2056 2057
Ingresos
Gastos explotación
Gastos personal
Gastos financieros
Impuestos
Recursos generados


EOAF Gorguel (Miles de Euros)
300.000
250.000
200.000
150.000
100.000
50.000
0
-50.000
-100.000
-150.000
-200.000
-250.000
2013 2014 2015 2016 2017 2018 2019 2020 2021 2022 2023 2024 2025 2026 2027 2028 2029 2030 2031 2032 2033 2034 2035 2036 2037 2038 2039 2040 2041 2042 2043 2044 2045 2046 2047 2048 2049 2050 2051 2052 2053 2054 2055 2056 2057
Recursos generados
Deuda L/P
Aportaciones APC
Inversiones
Pago deuda (principal)
Fondo de Maniobra


EOAF Gorguel Acumulado (en miles €)
2.000.000
1.500.000
1.000.000
500.000
0
-500.000
-1.000.000
-1.500.000
2013
2014
2015
2016
2017
2018
2019
2020
2021
2022
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2051
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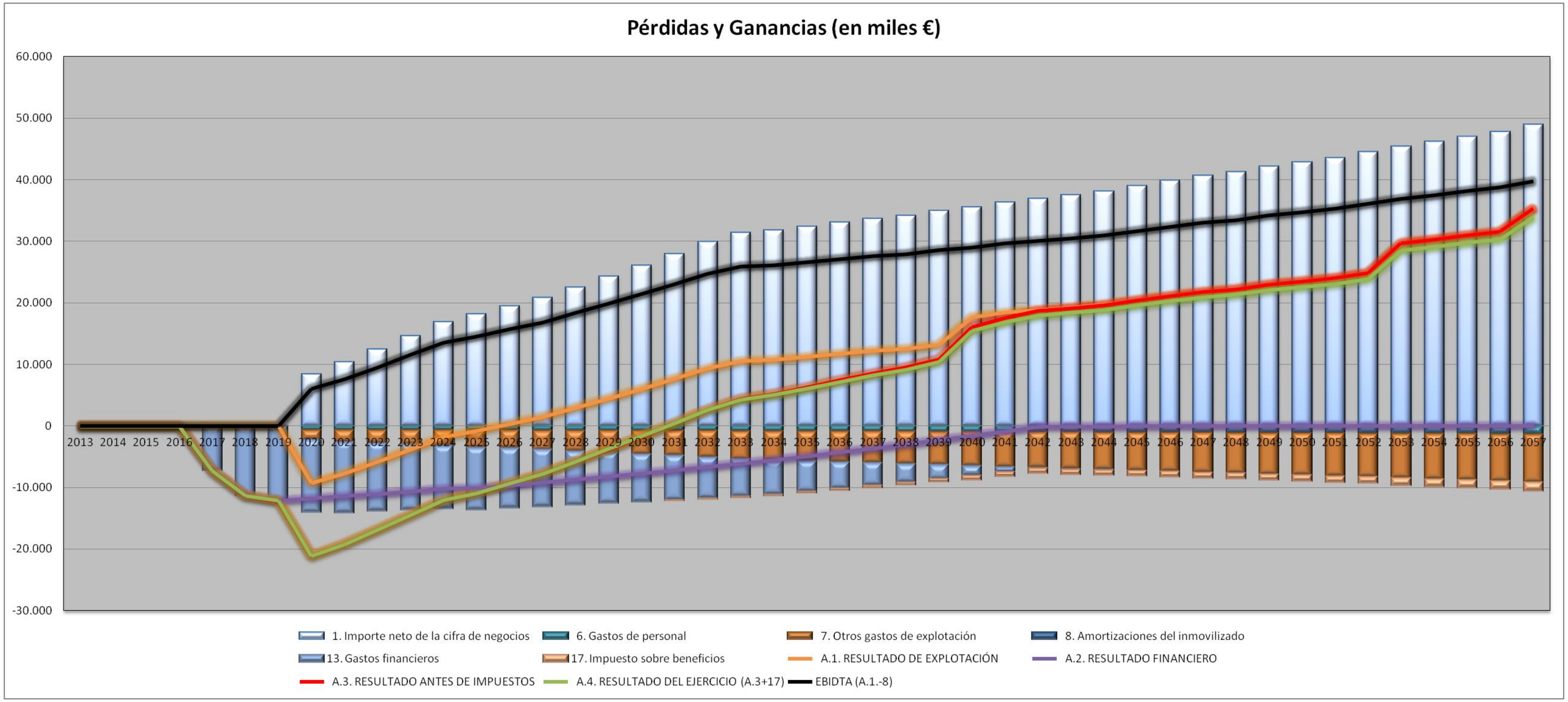
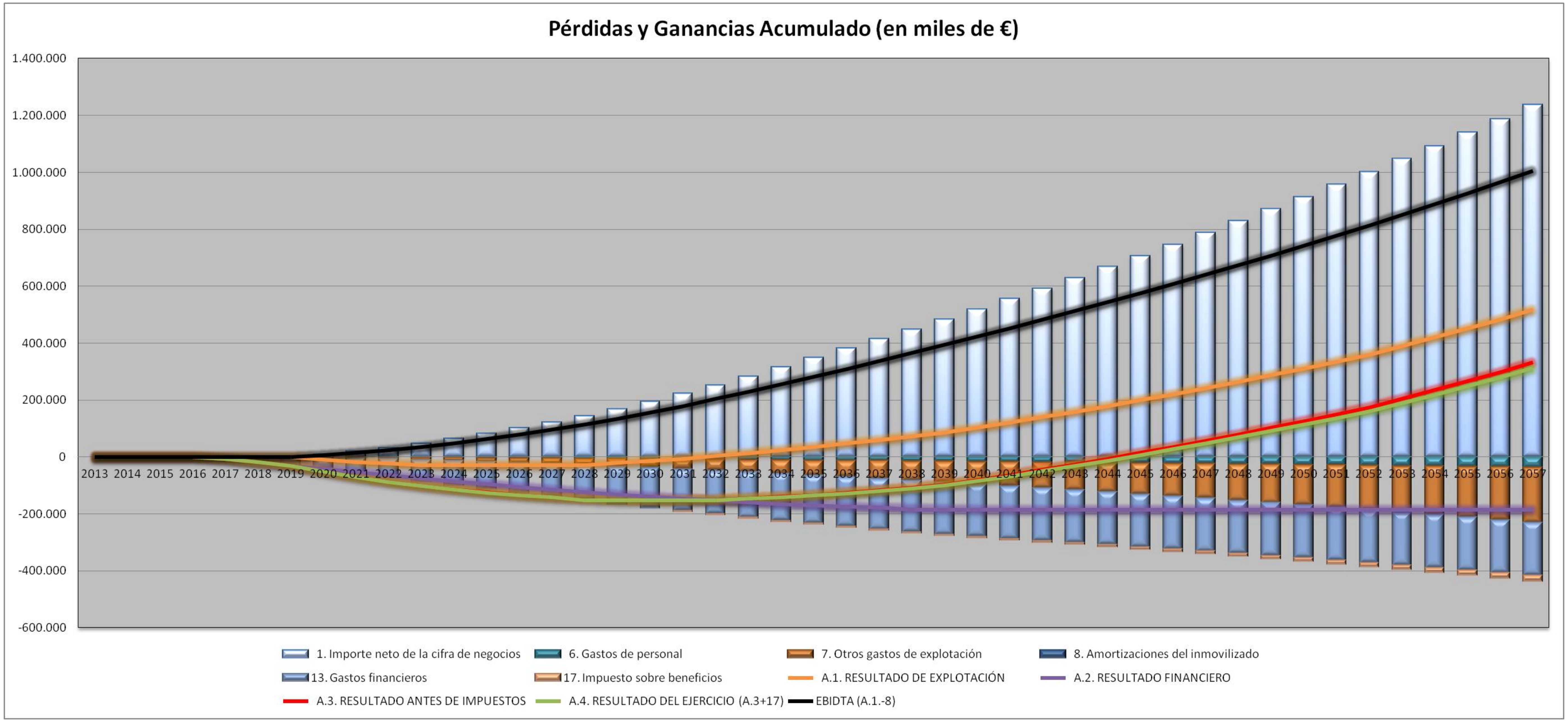
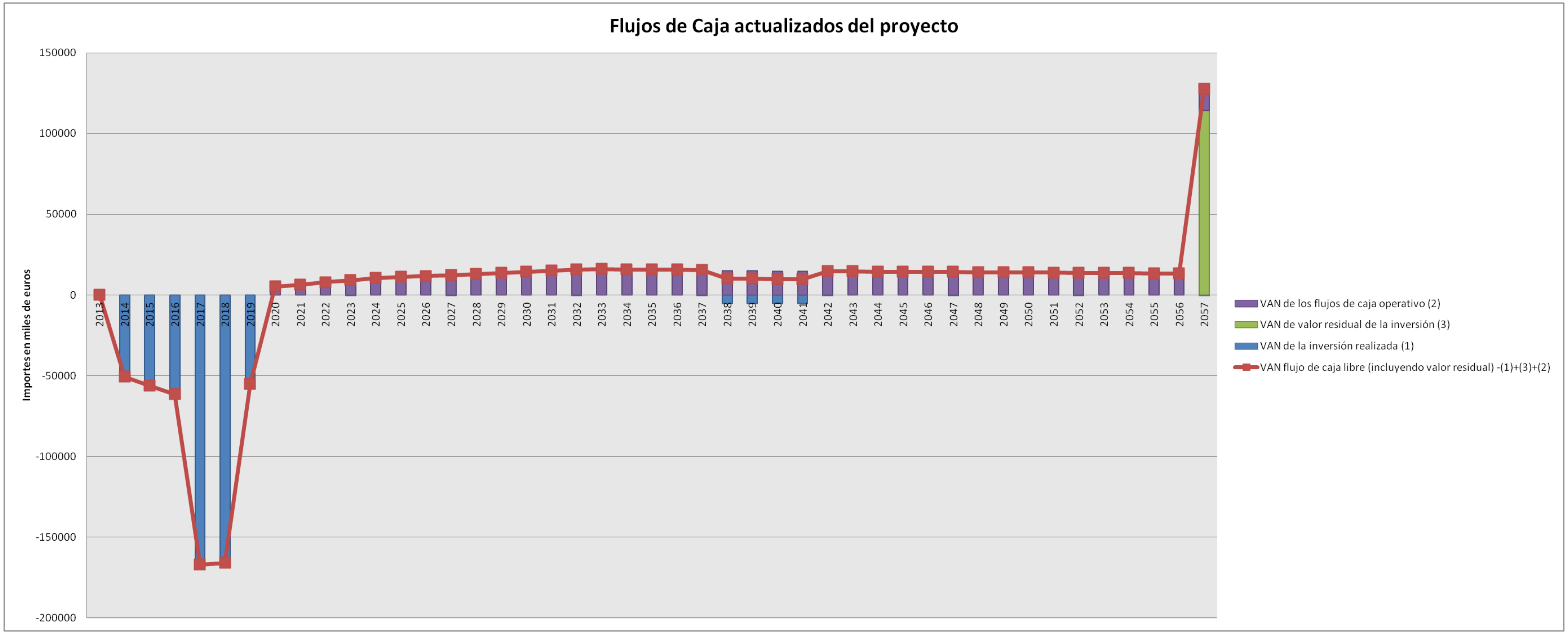
2053
2054
2055
2056
2057
Recursos generados
Deuda L/P
Aportaciones APC
Inversiones
Pago deuda (principal)
Fondo de Maniobra


Pérdidas y Ganancias (en miles €)
60.000
50.000
40.000
30.000
20.000
10.000
0
-10.000
-20.000
-30.000
2013 2014 2015 2016 2017 2018 2019 2020 2021 2022 2023 2024 2025 2026 2027 2028 2029 2030 2031 2032 2033 2034 2035 2036 2037 2038 2039 2040 2041 2042 2043 2044 2045 2046 2047 2048 2049 2050 2051 2052 2053 2054 2055 2056 2057
1. Importe neto de la cifra de negocios
6. Gastos de personal
7. Otros gastos de explotación
8. Amortizaciones del inmovilizado
13. Gastos financieros
17. Impuesto sobre beneficios
A.1. RESULTADO DE EXPLOTACIÓN
A.2. RESULTADO FINANCIERO
A.3. RESULTADO ANTES DE IMPUESTOS
A.4. RESULTADO DEL EJERCICIO (A.3+17)
EBIDTA (A.1.-8)



Pérdidas y Ganancias Acumulado (en miles de €)
1.400.000
1.200.000
1.000.000
800.000
600.000
400.000
200.000
0
-200.000
-400.000
-600.000
2013 2014 2015 2016 2017 2018 2019 2020 2021 2022 2023 2024 2025 2026 2027 2028 2029 2030 2031 2032 2033 2034 2035 2036 2037 2038 2039 2040 2041 2042 2043 2044 2045 2046 2047 2048 2049 2050 2051 2052 2053 2054 2055 2056 2057
1. Importe neto de la cifra de negocios
6. Gastos de personal
7. Otros gastos de explotación
8. Amortizaciones del inmovilizado
13. Gastos financieros
17. Impuesto sobre beneficios
A.1. RESULTADO DE EXPLOTACIÓN
A.2. RESULTADO FINANCIERO
A.3. RESULTADO ANTES DE IMPUESTOS
A.4. RESULTADO DEL EJERCICIO (A.3+17)
EBIDTA (A.1.-8)


Flujos de Caja actualizados del proyecto
150000
100000
50000
0
-50000
-100000
-150000
-200000
Importes en miles de euros
2013
2014
2015
2016
2017
2018
2019
2020
2021
2022
2023
2024
2025
2026
2027
2028
2029
2030
2031
2032
2033
2034
2035
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2040
2041
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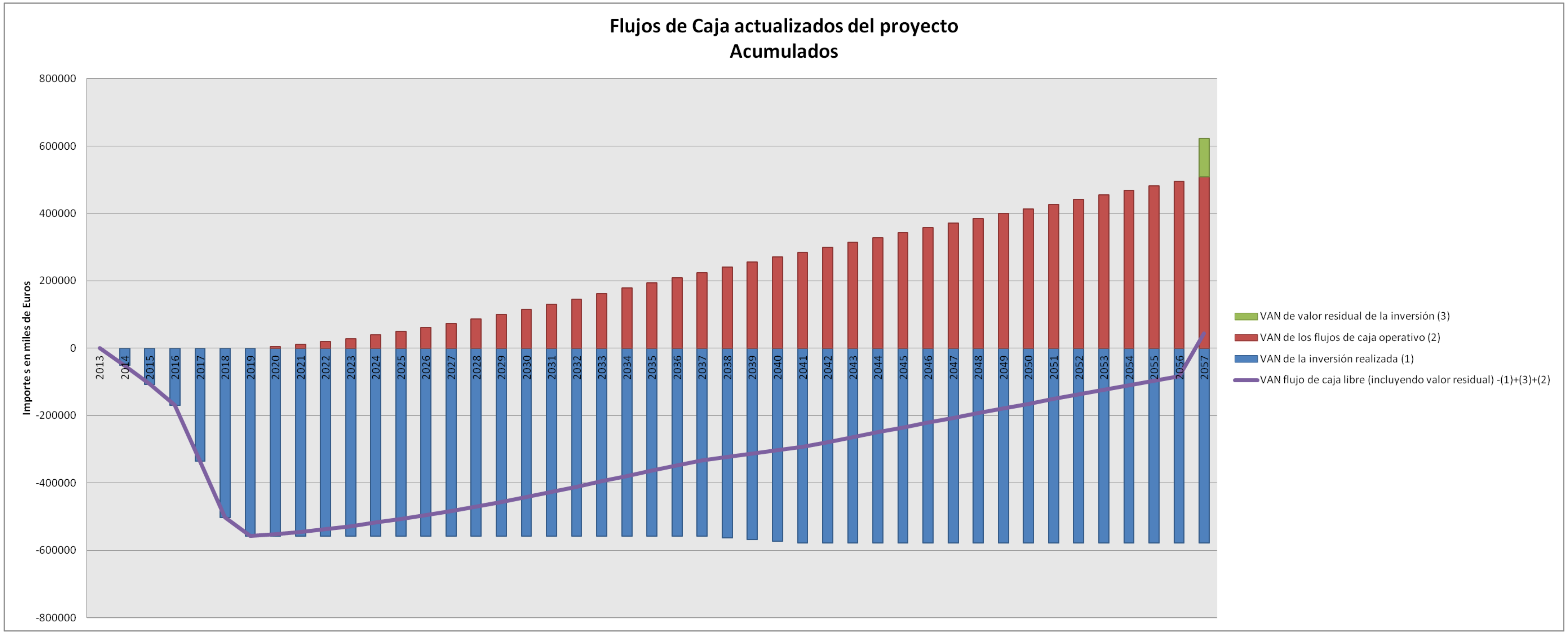
2046
2047
2048
2049
2050
2051
2052
2053
2054
2055
2056
2057
VAN de los flujos de caja operativo (2)
VAN de valor residual de la inversión (3)
VAN de la inversión realizada (1)
VAN flujo de caja libre (incluyendo valor residual) -(1)+(3)+(2)


Flujos de Caja actualizados del proyecto
Acumulados
Importe s en miles de Euros
800000
600000
400000
200000
0
-200000
-400000
-600000
-800000
2013
2014
2015
2016
2017
2018
2019
2020
2021
2022
2023
2024
2025
2026
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2030
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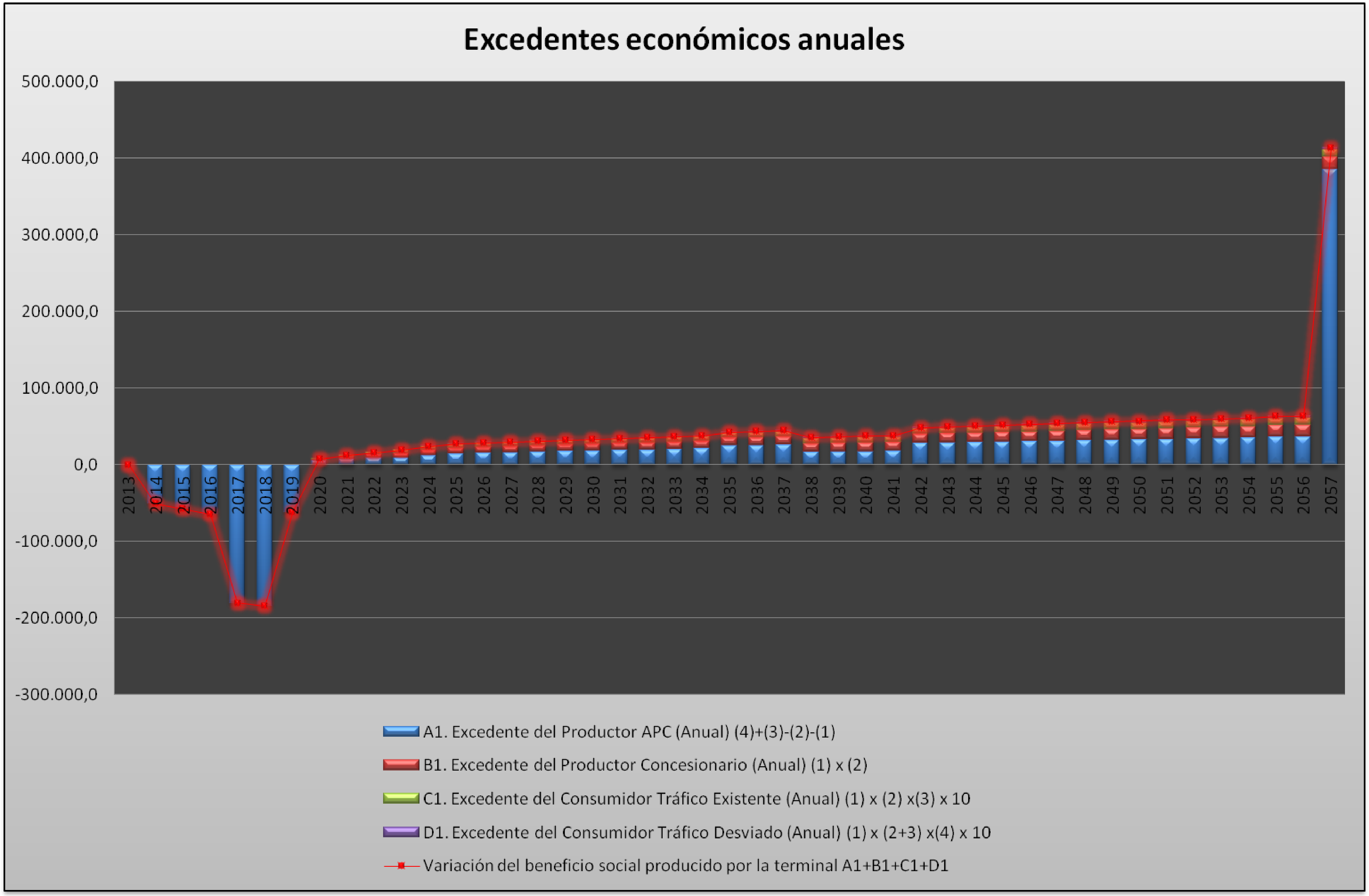
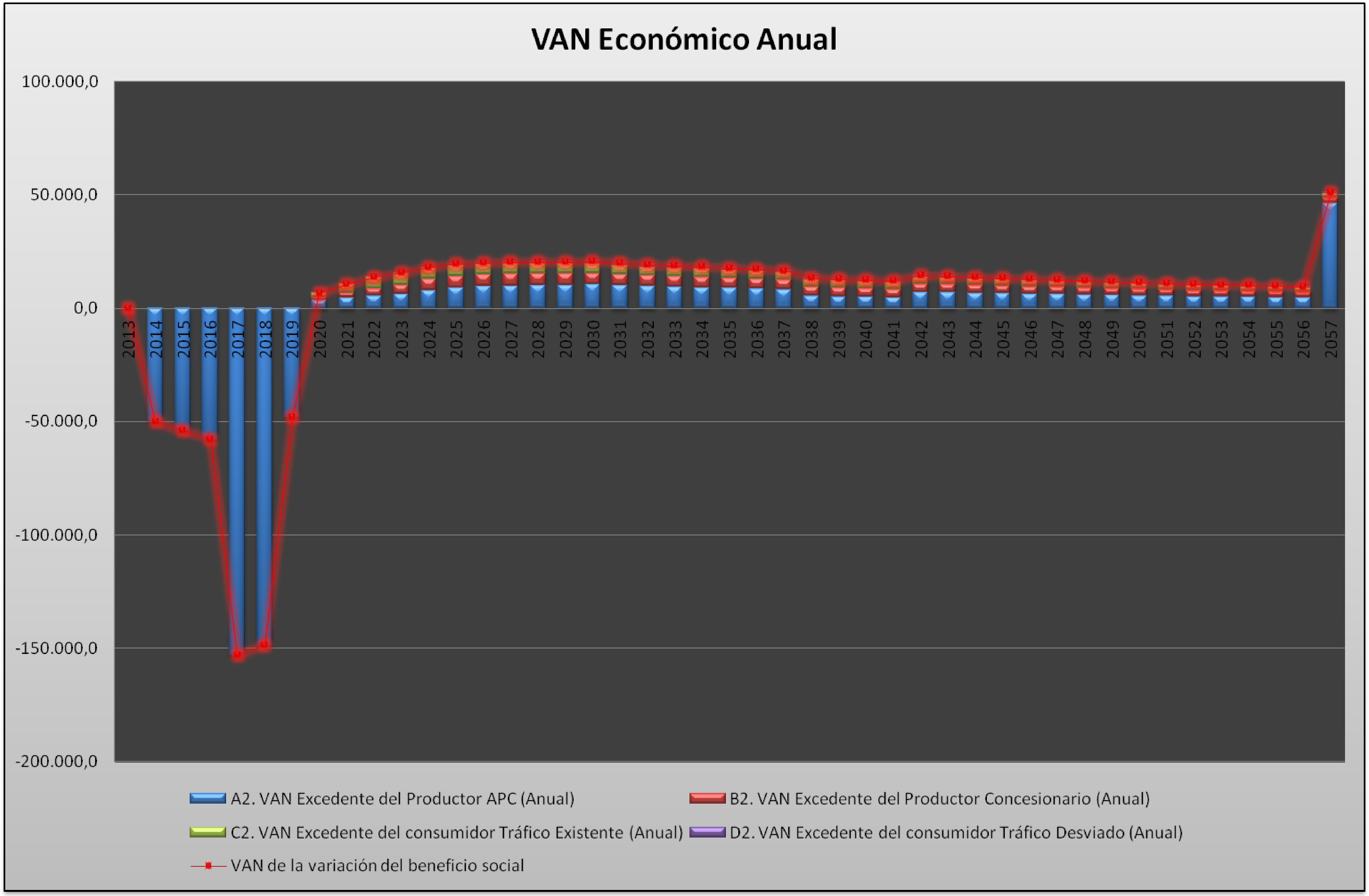
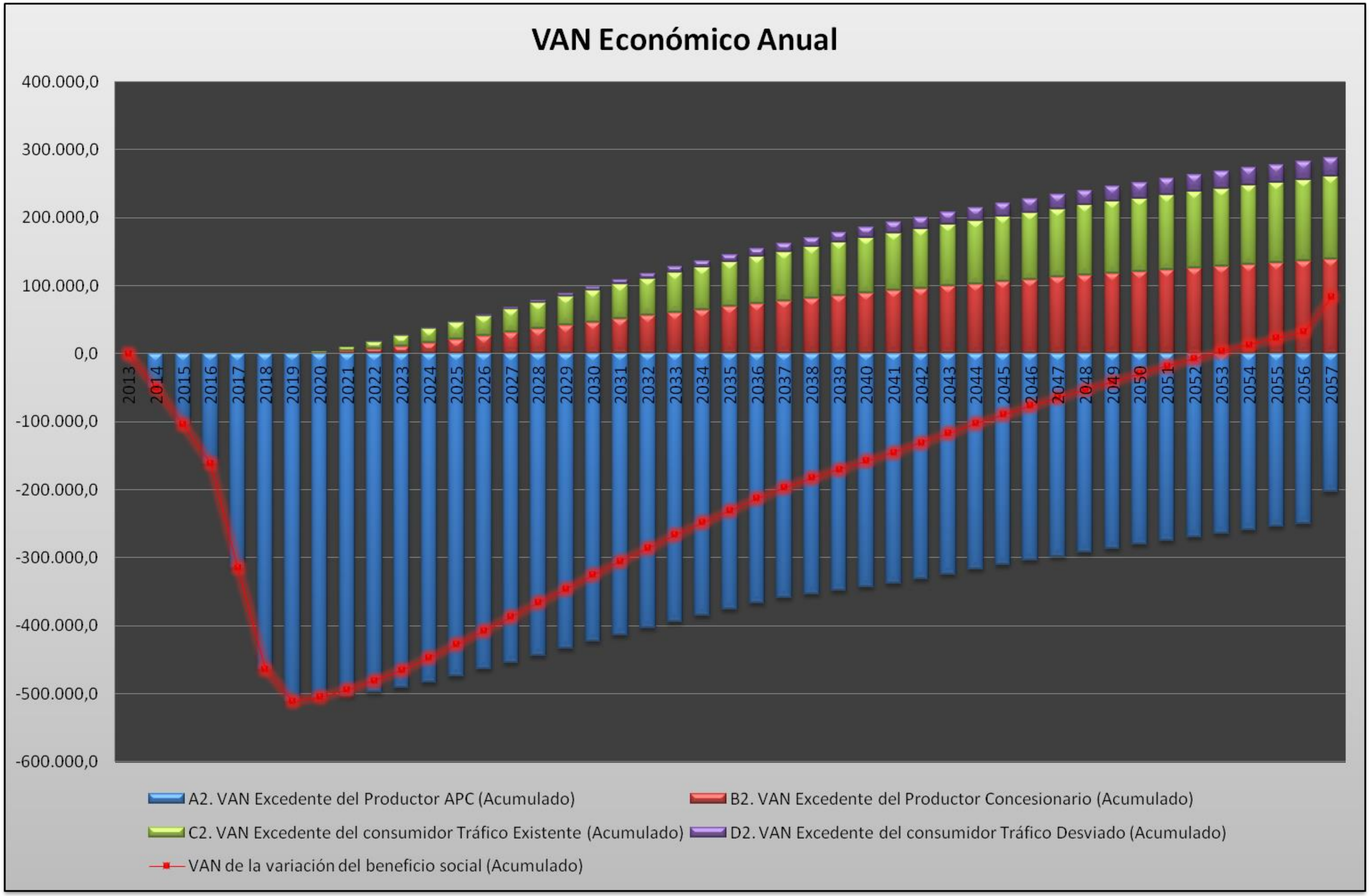
2050
2051
2052
2053
2054
2055
2056
2057
VAN de valor residual de la inversión (3)
VAN de los flujos de caja operativo (2)
VAN de la inversión realizada (1)
VAN flujo de caja libre (incluyendo valor residual) -(1)+(3)+(2)

Annex II. Economic analysis Case Base Graphic output.


Excedentes económicos anuales
500.000,0
400.000,0
300.000,0
200.000,0
100.000,0
0,0
-100.000,0
-200.000,0
-300.000,0
2013 2014 2015 2016 2017 2018 2019 2020 2021 2022 2023 2024 2025 2026 2027 2028 2029 2030 2031 2032 2033 2034 2035 2036 2037 2038 2039 2040 2041 2042 2043 2044 2045 2046 2047 2048 2049 2050 2051 2052 2053 2054 2055 2056 2057
A1. Excedente del Productor APC (Anual) (4)+(3)-(2)-(1)
B1. Excedente del Productor Concesionario (Anual) (1) x (2)
C1. Excedente del Consumidor Tráfico Existente (Anual) (1) x (2) x(3) x 10
D1. Excedente del Consumidor Tráfico Desviado (Anual) (1) x (2+3) x(4) x 10
Variación del beneficio social producido por la terminal A1+B1+C1+D1


VAN Económico Anual
100.000,0
50.000,0
0,0
-50.000,0
-100.000,0
-150.000,0
-200.000,0
2013 2014 2015 2016 2017 2018 2019 2020 2021 2022 2023 2024 2025 2026 2027 2028 2029 2030 2031 2032 2033 2034 2035 2036 2037 2038 2039 2040 2041 2042 2043 2044 2045 2046 2047 2048 2049 2050 2051 2052 2053 2054 2055 2056 2057
A2. VAN Excedente del Productor APC (Anual)
B2. VAN Excedente del Productor Concesionario (Anual)
C2. VAN Excedente del consumidor Tráfico Existente (Anual)
D2. VAN Excedente del consumidor Tráfico Desviado (Anual)
VAN de la variación del beneficio social


VAN Económico Anual
400.000,0
300.000,0
200.000,0
100.000,0
0,0
-100.000,0
-200.000,0
-300.000,0
-400.000,0
-500.000,0
-600.000,0
2013
2014
2015
2016
2017
2018
2019
2020
2021
2022
2023
2024
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2047
2048
2049
2050
2051
2052
2053
2054
2055
2056
2057
A2. VAN Excedente del Productor APC (Acumulado)
B2. VAN Excedente del Productor Concesionario (Acumulado)
C2. VAN Excedente del consumidor Tráfico Existente (Acumulado)
D2. VAN Excedente del consumidor Tráfico Desviado (Acumulado)
VAN de la variación del beneficio social (Acumulado)