sustainability

MDPI

Article

Decision-Making for Risk Management in Sustainable Renewable Energy Facilities: A Case Study in the Dominican Republic

Guido C. Guerrero-Liquet [1,†], Juan Miguel Sánchez-Lozano [2,†], María Socorro García-Cascales [1,*,†], María Teresa Lamata [3,†] and José Luis Verdegay [3]

1 Departamento Electrónica Tecnología de Computadoras y Proyectos, Universidad Politécnica de Cartagena, 30202 Cartagena, Spain; gcgl0@alu.upct.es
2 Centro Universitario de la Defensa de San Javier, Academia General del Aire, Universidad Politécnica de Cartagena, 30720 San Javier, Spain; juanmi.sanchez@cud.upct.es
3 Departamento de Ciencias de la Computación e Inteligencia Artificial, Universidad de Granada, 18014 Granada, Spain; mtl@decsai.ugr.es (M.T.L.); verdegay@ugr.es (J.L.V.)
* Correspondence: socorro.garcia@upct.es; Tel.: +34-968-326574; Fax: +34-968-326400
† These authors contributed equally to this work.

Academic Editor: Marc A. Rosen
Received: 23 December 2015; Accepted: 4 May 2016; Published: 7 May 2016

Abstract: Today, Renewable Energy Sources (RES) are a key pillar to achieving sustainable development, which is the main reason why energy projects are being carried out not only in developed countries but also in many emerging countries. Since the technical and financial risk remains a major barrier to financing renewable energy projects, several mechanisms are available to reduce risks on investment into clean energy projects. This paper discusses risk management tools in solar photovoltaic facilities based on the guide to the Project Management (PMBOK Guide). To do this, a combination of different decision-making methodologies will be carried out. These methodologies enable to not only extract the knowledge by experts but also to know the causes and effects that help to make the best decision. In order to do so, techniques to seek information (Delphi and Checklist) as well as diagram techniques such as cause and effect diagrams or Strengths Weaknesses Opportunities and Threats (SWOT) are applied. The categorization and prioritization of risks will be carried out through the Analytic Hierarchy Process (AHP). Finally, a sensitivity analysis will allow for providing consistency to the obtained results. A real case in the Dominican Republic will also be presented as case study.

Keywords: risk management; renewable energies; multicriteria decision-making; analytic hierarchy process; Delphi

---

1. Introduction

The sustainable development of energy systems is increasingly important for politicians and decision makers' worldwide. The main objectives of the overall policies of states often include economic growth, energy security and mitigating the effects of climate change [1]. Use of sustainable energy means not only providing enough energy for current and future energy needs, but also the protection of the environment and the integrity of ecosystems [2]. Therefore, the sustainability of future energy systems is an important prerequisite for development. Nevertheless, a sustainable energy system by itself does not guarantee sustainable development; technical and financial factors must always be taken into account.

Today, renewable energy sources (RES) are a key pillar to achieving sustainable development. They have great potential to meet part of the global energy demand and offer sustainable solutions to long-term wealth creation, employment and new business opportunities. The vision is the creation of a sustainable local business environment for renewable energy investments. Many projects in peripheral areas have served as a basis for implementing a sustainable development strategy [3,4]. They have been contributing to sustainable development and the specific approach to climate challenges. However, renewable energy facilities require a solid infrastructure to generate and distribute energy resources. This requires proper planning and management in construction, as well as compliance with environmental and social concerns in order to meet sustainable building guidelines [5]. The development of these infrastructures requires great efforts by researchers, designers, financiers, owners, customers and builders to attempt to cause the least possible risk. Investment in such projects is usually quite high, so energy companies and investors should avoid making poor decisions. In addition, as a result of the continuing rapid changes in climatic conditions of the planet, helping potential investors and the different administrations to assess, mitigate and insure risks, will generate a significant business opportunity for services managing such risks. It is, therefore, of great interest to have in-depth knowledge regarding the technological, social, and environmental constraints that may arise, and the necessary investments, and the economic and political interests that may appear.

In Latin America, the need to invest heavily to develop energy infrastructures in order to meet regional energy objectives [5] is a priority. Caribbean states adjacent to the Dominican Republic (DR) are showing interest in the development of a regional sustainable energy policy and measures that can help protect member states from volatile oil markets, promoting the use of their own resources [6]. Furthermore, in the Conference of the Parties to the United Nations Framework Convention on Climate Change (UNFCCC) held in Copenhagen (2009) and Cancun (2010), the advanced economies committed to providing developing countries US $30 billion in financial and technical aid for climate change adaptation and mitigation for 2012, and US $100 billion annually by 2020.

In 2013 DR spent $4.4 billion on oil imports; equivalent to 7.3% of gross domestic product (GDP) [7]. In 2015, fossil fuels prevail in DR electricity sector (Figure 1): oil (46.27%), natural gas (25.92%) and coal (14.03%), represented 86% of electricity generation in the country [8]. Only 10% of electricity generation was produced from renewable sources, particularly hydropower (6.26%) and wind energy (1.90%).

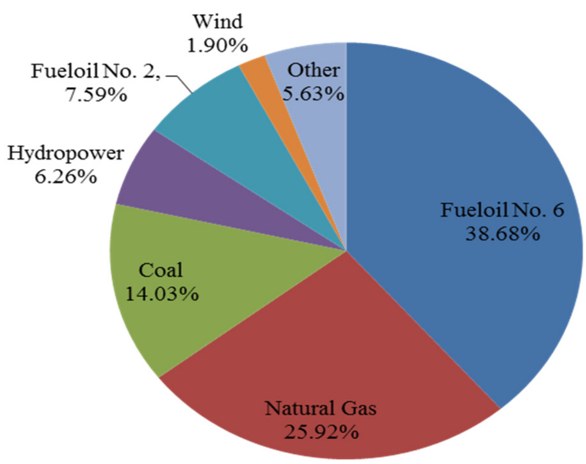

Figure 1. Annual electricity generation by fuel type in DR, 2015.

Today, DR has developed a legislative framework, applying the law 57-07 [9] on incentives to develop renewable energy sources and their special schemes which encourages the implementation of technologies available to harness the potential of renewable resources. The country has established the general principles of a public fund to sustainable energy by Law 112-00 [10] (the law on hydrocarbons). This law describes the creation of "a special fund the differential tax on fossil fuels in order to finance projects of great national interest to promote alternative or renewable energy and energy savings". The fund is designed to be funded through allocations of 5% of the revenue generated through the application of taxes collected. In contrast to direct project loans or fiscal support through a feed-in tariff, loan guarantees allow the government to support projects with no initial capital outlay [7]. However, actual implementation of the fund has not been made. The fund would pay for the premium FIT and support development of renewable energy in low-income areas through a capital grant that would cover up to 75% of the cost of labor and installation of renewable energy projects on a small scale, as stipulated in the law 57-07 [11]. In DR both public and private financing for energy efficiency and renewable energy investments exists. Along with private financial actors, national public funding plays a key role in the development and deployment of renewable energy [7]. For project developers, identifying attractive loan packages, funds and other funding sources is an important factor in determining the financial viability of making investments. To date, private financing has proved insufficient to allow widespread investment in sustainable energy. Dominican project developers often lack enough equity to invest in renewable energy projects and have little access to financial instruments such as soft loans, credits or grants [7]. To date they have invested US $644 million in this sector, with solar and wind technologies being those that have the most established investment, with percentages of 53.7% and 40.5%, respectively [12].

The major investment in solar energy is because this country has high and constant sunlight throughout the year. An estimated 86 square kilometers of photovoltaic solar panels could meet the total energy production of the country, claiming that solar energy will be the cheapest energy source by 2020 if the country is able to benefit from experience and economies of scale [7].

However, in order to further promote the implementation of solar technology, the difficulties posed by specific barriers that currently restrict access to finance in the sector must be resolved [7]. One of the country's regional energy objectives is to reduce the risk associated with investment in RES projects. Thus, it is possible for investors to know the risks of an investment and can optimize the project design. In order to help the decision-makers (investors, local and regional governments, *etc.*) to evaluate and prioritize the potential risks of such facilities, it is advisable to use tools and techniques of decision support. These are vital as they allow risks that could prevent the solar energy system from being profitable to be identified, thus strategies could be set during construction and subsequent commissioning, providing funding prospects facing the investment.

There are methods for project management solution that address risks, including the PMBOK guide which is one of the best known [13]. According to this guide one can take different techniques to identify risks among which are: brainstorming, Delphi, interviews, causal analysis, diagram of cause and effect, flow diagrams of systems, influence diagrams and SWOT which are applied in the stages of collection of information, diagramming techniques and expert judgment [13].

Therefore, in this paper different tools and techniques for identifying risks to a real case study developed in DR were analyzed. The parking lot of a building for administrative purposes intended to cover part of their energy demand through the implementation of a photovoltaic installation has been selected. In this research the complexity of decision-making in the energy sector, where there are multiple sustainability criteria, is shown. The sustainability criteria that this study takes into account are those determined by the banking institutions, which require DR risk analysis to make loans in pursuit of sustainable development. These criteria are of limited scope and these financial institutions have neither the experience nor sufficient government support to establish more demanding sustainability. This study addresses the need for advanced tools in managing risks by identifying problems that occur in the solar photovoltaic plants. Specifically, this paper discusses risk management tools in solar photovoltaic facilities based on the PMBOK Guide through the combination of different decision-making methodologies. These methodologies enable to not only extract the knowledge by experts but also to know the causes and effects that help to make the best decision. In order to do that, techniques to seek information (Delphi and Checklist) as well as diagram techniques such as causes and effects diagrams or Strengths, Weaknesses, Opportunities, and Threats (SWOT) are applied. The categorization and prioritization of risks will be carried out through the Analytic Hierarchy Process (AHP). Finally, a sensitivity analysis will allow to provide consistency to the obtained results.

This paper is organized as follows: in Section 2 the current state of risk management in renewable energy and its relationship with decision making is presented, Section 3 briefly defines the model used to identify risks. The actual conditions of the case study in DR and collecting documentation are described in Section 4. Section 5 is where the methodology is applied to the case study providing results. Finally, Section 6 reflects both the conclusions of the study conducted as well as discussion to resolve potential mitigations.

2. Literature Review: Risk Management and Decision Making in RES

Risk management is a process that takes place during all phases of the project life. In it, through a sequence of activities including assessment, development strategies and mitigating risks, uncertainties concerning a threat are handled. The analytical approach is based on models of financing projects through three different dimensions: analysis of contracts and institutional relations; estimates and financial modeling; or risk assessment allocation [14].

The analysis of risk assessment combines the techniques of financial risk management of the project and semi-structured interviews to identify the main perceived risks in the different phases of the project interviews. The risk management of the project includes not only the processes related to conducting work planning, identification, analysis and response of the risks, but also the monitoring and control of the project. The objectives of risk management are to increase the probability and impact of positive events and decrease the probability and impact of negative events for the project [13]. Since the risks exist from the moment a project is conceived, there should be a conscious choice of risks to identify and pursue effective management during the life of the project.

From an energy standpoint, a comprehensive risk assessment across a wide range of technologies should consider a set of risk indicators covering different aspects and perspectives [13]. The literature shows that previous studies have taken place in European countries, which classify risks for different categories of renewable energy facilities [15]. A description of the different types of risks faced by producers in the deregulated electricity markets is presented in [16]. These authors suggest three main areas of risk.

- *Price risk*: it reflects the uncertainty of fuel, CO_2 and electricity prices that affect the cost and revenue generators.
- *Technical risk:* it indicates the uncertainty of the costs of investment, operation, maintenance and decommissioning.
- *Financial risks*: including credit, interest rate and contractual risks; this group is also considered the risk that regulation uncertainty caused by possible legislative changes poses.

The determinants of systematic risk for renewable energy companies is an interesting topic to discuss, the importance of which will increase in the coming years driven by energy insecurity and climate change [17]. Financial risks can be mitigated by government policies; for example, fixed feed-in tariffs guaranteed over the amortization period of the plant limit income risks, and can allow plant operators to access credits in more advantageous conditions than in the case of more risky investments. More directly, governments can offer cheap credits via public banks. Regulatory risk directly affects the financial risks; this type of risk has therefore been included in the financial risks. Technical risks can at least be reduced by publicly funded R&D and demonstration projects, and learning spillovers generated as an effect of deployment support may also contribute to reduce risks for individual actors. However, the private sector must also make efforts to mitigate the prevailing technical and financial risks not with other risks. For this reason, our study focuses solely on the technical and financial risks since these encompass the problems that occur in a system of renewable energy. To mitigate technical and financial risks it is necessary to resort to more rigorous and larger evaluation.

Increased demand for renewable energy has generated a corresponding increase in funding and investment in the sector. The success of the investment and funding in this sector requires a good understanding of the tradeoffs between risk and return. The risk is reflected in capital that companies have to pay to finance their projects. The funds can be obtained through the capital markets in the form of debt. The cost of capital shows the expected returns by investors in supplying capital to finance a project performance and be competitive with the returns of alternative investments with the same risk profile [16]. For these reasons, policy makers should pay special attention to how policies affect the risk of supporting renewable energy projects. However, the balance between risk and return in the sector of renewable energies is precarious. Renewable energy companies are often more sensitive to any technical or financial problem, therefore, it is necessary to have a good knowledge of the risk factors [17].

Many aspects must be analyzed from a holistic and systematic view to reduce the risks affecting the profitability of a photovoltaic installation. The literature shows that there are several types of risks that are of great interest to those considering investing in developing countries. These include the technical and financial risks. As an example, [18] can be mentioned, in which important implications for political action are provided. They identify risk areas where urgent action is for the national and international political community in order to encourage investment in generation capacity of renewable energy. This study highlights the importance of identifying those policies and programs to reduce risks, or to help stakeholders manage risks through innovative financing schemes, such as public-private partnerships. They also showed that the actors were more concerned with the risks associated with investment in renewable energy capacity than any other.

In the field of renewable energy, risk management is a key issue to achieving the goals of global sustainability. Therefore, in recent years risk management has started being studied in this area. Different methodologies can be found in the literature on the topics of sustainability and renewable energies. Some of them are scenario planning, which seek to address and put limits on the uncertainty [19]. A recent study [20] conducted a comparative analysis of energy management of financial risk between countries of the European Union and Turkey; later [17] modeled the risks in renewable technology companies. After 2014, [21] analyzed the economic risk in decentralized renewable energy infrastructure by Monte Carlo simulations and recently, [22] analyzed the solar potential in emerging markets. Typical methods of environmental assessment and environmental impact assessment, risk assessment and life cycle assessment are generally conducted to assist decision making [19]. Implementations of decision-making in risk management in renewable energy are presented in recent studies such as: [23] at work, apply analytical processing network ANP for selecting solar photovoltaic (PV) projects. Another scientific work is quoted: [24] which use experts to evaluate qualitative features, AHP is used to calculate the priorities and a case study is examined to select a photovoltaic solar plant. Sample models in risk identification can also cite [25] that manage the risk of satisfaction/customer dissatisfaction looking for its causes with an Ishikawa diagram. Delphi applications in risk management can be found in studies such as: [26]. This paper describes some of the recent approaches to discount the environment and applies them to the economic evaluation of a plant for desalination of irrigation return and [27] is a risk analysis based on Delphi that identifies and assesses the potential impact and the likelihood of future events, which could evolve in the hazards. These examples are shown in greater detail (Table 1).

Table 1. Visual comparison based on distributed papers of past research.

Author	Year	Nationality	Technique and Application	Title of Paper	Criteria	Project Type	Ref.
Sadorsky, P.	2012	Canada, Toronto	Monte Carlo Simulation	Modeling renewable energy company risk	Risk of renewable energy companies	Solar, wind, battery storage or fuel cells hydrogen	[17]
Komendantova, N. *et al.*	2012	Austria	Research Questions	Perception of risks in renewable energy projects: The case of concentrated solar power in North Africa	Stakeholder perceptions of risk	Concentrated solar power	[18]
Mardani, A. *et al.*	2015	Malaysia	MCDM	Sustainable and Renewable Energy: An Overview of the Application of Multiple Criteria Decision Making Techniques and Approaches	Sustainable and renewable energy	-	[19]
Sudi, A. *et al.*	2011	Istanbul, Turkey	Learning-by-doing	Financial risk management in renewable energy sector: Comparative analysis between the European Union and Turkey	Financial Risk Management	Solar, wind, hydrogen and geothermal	[20]
Arnold, U. and Yildiz, O.	2014	Berlin, Germany	Monte Carlo Simulation	Economic risk analysis of decentralized renewable energy infrastructures e A Monte Carlo Simulation approach	Risk analysis	Bio-energy plant	[21]
Frisari, G.; Stadelmann, M.	2015	Venice, Italy	Simulation and sensitivity analysis	De-risking concentrated solar power in emerging markets: The role of policies and international finance institutions	Risk analysis financial	Concentrated solar power	[22]
Aragones-Beltran, P. *et al.*	2010	Valencia, Spain	ANP/AHP	An ANP-based approach for the selection of photovoltaic solar power plant investment projects	Risk identification	PV Solar	[23]
Lee, A.H.I. *et al.*	2015	Chung Hua, Taiwan	Fuzzy AHP	An Integrated Decision-Making Model for the Location of a PV Solar Plant	Select the most appropriate site	PV Solar	[24]
González, J.B.C.	2010	Matanzas, Cuba	Ishikawa diagram	Evaluation and analysis of improved export authorization service log cultural goods killings	Assessment, analysis of the improvement	-	[25]
Almansa, C. and Martinez-Paz, J.M.	2010	Navarra, Spain	Monte Carlo Simulation	What weight should be assigned to future environmental impacts? A probabilistic cost benefit analysis using recent advances on discounting	Evaluate the financial profitability and risks	Water desalination plant	[26]
Markmann, C. *et al.*	2012	Wiesbaden, Germany	Delphi	A Delphi-based risk analysis: Identifying and assessing future challenges for supply chain security in a multi-stakeholder environment	Identification and quantification of risks	Supply chain security	[27]

3. Methodology

The risk identification aims to provide information on the specific risk in question and must respond to the need for different types of users involved in the processes of decision making [28]. The PMBOK guide [13] set out the steps that must be met to identify risks in a project. These steps are the foundation of the proposed model. The novel contribution to the model proposed by the PMBOK guide made by this research is to add trial multicriteria decision making, specifically the AHP, to the technical evaluation stage. The methodology described in (Figure 2) shows the model that has been used for the identification of risks after performing planning risk management that takes a thorough review of the documentation. The steps for identifying risks are [13]: the collection of information, analysis of the checklist, the scenario analysis, diagramming techniques and expert judgment by applying innovative tools and techniques to explain hereinafter.

The starting point will be to develop the risk list using proven methodologies and tools such as Delphi methodology [13]. Sometimes it is not easy to relate the causes of different risks of any problem, it is appropriate to apply layout techniques such as Ishikawa diagrams [25] or SWOT [13]. Furthermore, since it is usual that a number of risks intervene, use should be made of known multi-criteria decision methodologies such as AHP [29] in order to prioritize and thus evaluate its importance.

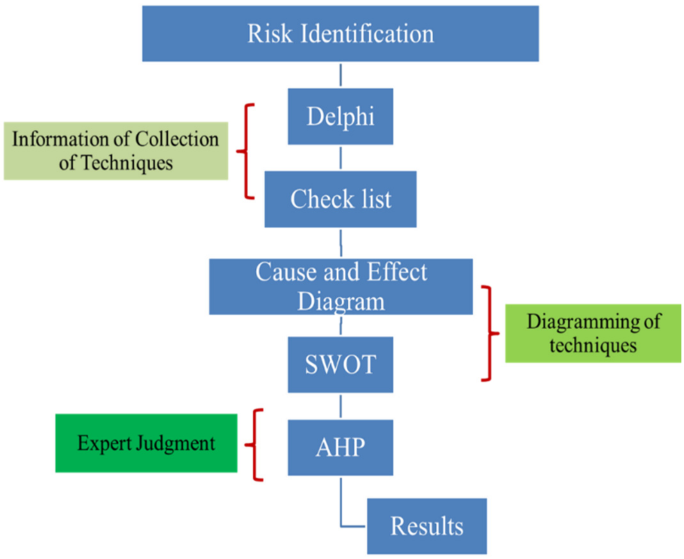

Figure 2. Technical scheme of the methodology.

3.1. Techniques of Collecting Information

The first step is to make a structured documentation review. To do this a widespread technique is the Delphi methodology. This consists of a questionnaire to a group of experts with a second questionnaire based on the results of the first to achieve a consensus among experts [30]. Project experts should participate in this technique anonymously and independently, they cannot interact with each other. The decision-maker uses a questionnaire to solicit ideas about the important project risks. Other techniques used in the stage of collecting information are brainstorming, interviews and causal analysis [13]. However, unlike these the Delphi technique helps reduce bias in the data and prevents any person from exercising inappropriate influence on the outcome [30].

After the structured review of the information, it should be reviewed and check verification techniques used, a simple example of such tools is the Checklist technique, which is used to make sure that systematic checks do not omit anything important. Checklist is applied as a second-round questionnaire used to secure and verify the previous possible step to analyze the results. For this, an orderly sequence that allows, through a quick glance, to verify that the expected result is plotted. Ultimately, it serves as a record to keep track of what occurred and may be revised as often as necessary [13]. It therefore allows revising any inaccuracy or inconsistency in the course of exploring the validity of the scenarios applied in the project.

3.2. Diagramming of Techniques

In order to connect any problem presented graphically with the primary and secondary causes of the case study layout, techniques of cause and effect are usually employed. These techniques are known for their simplicity and visualization: an Ishikawa or Fishbone diagram [25] is a technique to identify possible causes that affect a project. It allows a detailed and easy viewing of different causes for that particular problem. This diagram is not a tool to solve a problem, but to explain its reasons; a required first step if you seek to correct such issues. To increase the spectrum of identified risks it is advisable to make an analysis of the strengths, opportunities, weaknesses, and threats SOWT [13]. This technique begins by identifying the strengths and weaknesses of design, focusing on project organization. Its analysis identifies any opportunity and threat [31]. In addition, it also examines the extent to which the strengths offset threats and opportunities that can be used to overcome weaknesses. There are other diagramming techniques often used at this stage, such as the influence diagram and the flowchart [32] but combining the cause and effect diagram with SWOT clearly explains the causes of risks [13].

3.3. Assessment Techniques Expert Judgment. Analytic Hierarchy Process (AHP)

In the model, the decision-making that serves as a key tool to obtain the weight of each criterion has been used; in this case it is the weight of each identified risk. Among the possible methods known for their simplicity and robustness the AHP [29] method developed by Saaty (1980) stands out. The problem is modeled through a hierarchical structure, using scales of importance based on preference of one element over another (Table 2). As a result it provides coefficients of importance [33].

Table 2. Saaty's preferences in the pair-wise comparison process [29].

Verbal Judgments of Preferences between Criterion *i* and Criterion *j*	Numerical Rating
C_i and C_j is equally important to	1
C_i is slightly more important than C_j	3
C_i is strongly more important than C_j	5
C_i is very strongly more important than C_j	7
C_i is extremely more important than C_j	9
Intermediate values	2,4,6,8

The AHP method proposes a way to sort analytical thinking, which includes three basic principles: the principle of building hierarchies, the principle of priority and the principle of logical consistency. To obtain the assessment and establishment of priorities between criteria you have to capture the preferences of the decision maker through the construction of paired matrices, determined by the n (n − 1)/2 comparisons needed. In our case, the objective is to obtain a vector of weights that determines the relative importance of each criterion. When the decision maker is asked to set priorities by a paired comparison to determine the relative weights of the criteria, what it does is build a matrix R (Figure 3), which, given the r_{ij} entry that represents the relative importance of C_i about C_j, verified that the importance of C_j about C_i is $1/r_{ij}$.

$$R = \begin{pmatrix} 1 & r_{12} & \cdots & r_{1n} \\ r_{21} & 1 & \cdots & r_{2n} \\ \cdots & \cdots & \cdots & \cdots \\ r_{n1} & r_{n2} & \cdots & 1 \end{pmatrix} \boxed{r_{ij} \cdot r_{ji} = 1}$$

Figure 3. Matrix binary comparison.

For reciprocal arrays, it is true that the maximum autovalue λ_{max} is a positive real number and that there is associated an eigenvector, whose components are also positive. One of the problems that can appear in AHP is inconsistency, this will be defined (Consistency Ratio, CR) [29]:

$$CR = \frac{CI}{RI}$$

where *CI* is the Consistency Index:

$$CI = \frac{\lambda_{max} - n}{n - 1}$$

The *RI* is the Random Consistency Index, defined as the medium random consistency index obtained by simulation [34,35] (Table 3).

Table 3. Random index for different matrix orders [34,35].

	1–2	3	4	5	6	7	8	9	10
RI	0.00	0.5247	0.8816	1.1086	1.2479	1.3417	1.4057	1.4499	1.4854

To end the AHP method a sensitivity analysis is performed in which it can be seen that the results are clear, strong and consistent. The method provides an efficient means to deal with complex decision-making and enables better, easier and more efficiently to identify the selection criteria. The AHP strength is its ability to capture both subjective and objective measures of assessment, providing a useful process to check the consistency of the evaluation [29,35].

Sensitivity analysis is performed to see how it changes the order of importance of the risks by increasing or decreasing the importance of the criteria. This analysis can be done with an application built for AHP, the Expert Choice 2000 [36]; the application offers four graphics modes of sensitivity analysis: dynamic, gradient, performance and two-dimensional analysis [37]. The analysis with Expert Choice identifies the impact of changes in the importance of the criteria [37].

4. Study Case

4.1. Planning Risk Assessment of RES in DR

The system of electricity supply in DR has one of the highest distribution losses indices in the world, close to 38% in 2010. According to the US State Department [38], the factors responsible for these heavy losses include ceiling prices for electricity, power outages, inadequate investment in capacity increases and limited regulatory capacity [11].

Law 57-07 [9] of renewable energy set by DR in 2007 opens the door to commercial financing in this sector through incentives such as feed-in tariffs or tax exemptions [11]. With the law large renewable energy projects were installed in DR obtaining incentives and benefits, and harnessing the island's potential of renewable energy resources in wind, sun, biomass, and water. This legislative framework has led to increased investor confidence and creates a favorable environment for planning this type of investment [7].

Currently the Dominican banking sector still lacks the consciousness required to finance renewable energy. As indicated above, barriers still exist including the perception of investment risk. Therefore, the lack of appropriate risk equalization instruments prevents sustainable growth. Risk reduction mechanisms are becoming more conventional over time for financing initiatives and funds. For projects to be developed, the difficulty representing specific barriers that currently restrict access to financing in the sector should be solved [7]. However, some banks are willing to contribute to the sustainable development of the country venturing on these technologies through special credit lines for projects of sustainable energy efficiency and taking important steps to reduce the risks. An example to mention is the Dominican mortgage bank (BHD) which requires a risk analysis with the technical, environmental and financial aspects to any user who wants to use credits for this type of energy services, applying for financing projects sustainability criteria defined in Figure 4. BHD is one of the few commercial banks that offer a credit line for renewable energy, energy efficiency and clean energy production in the country. With the support of the International Finance Corporation (IFC) it provides loans at low interest rates (approximately 5.5%) medium-term developer's small and medium projects, with 80% of the costs of financing available for investment. The bank is responsible for most aspects of the lending process, including marketing, valuation and credit approval [7].

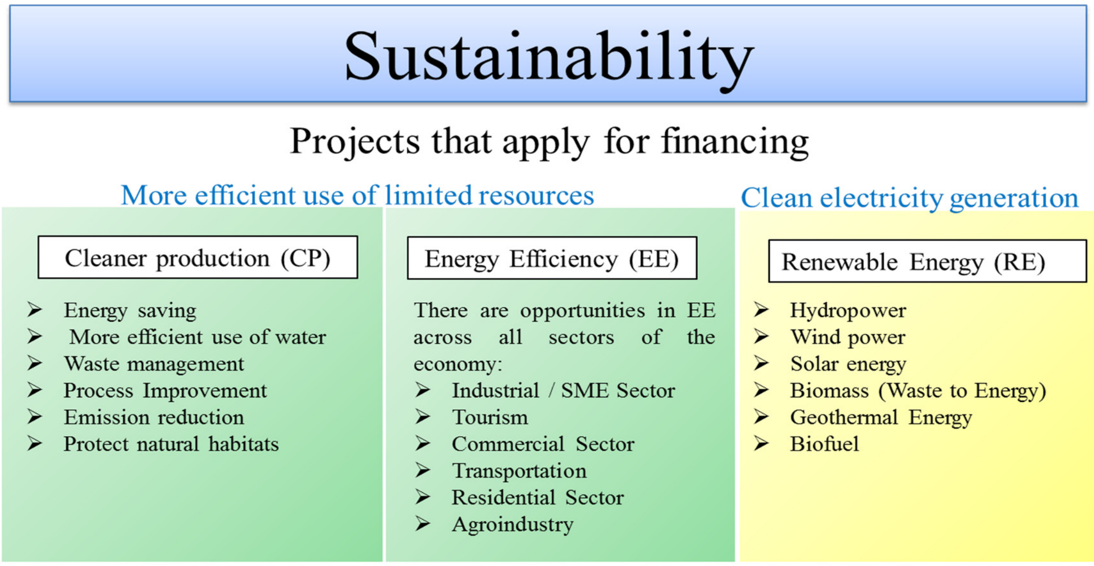

Figure 4. Defining sustainability of the Dominican Mortgage Bank BHD and Financial International IFC.

4.2. Collection of Documents

An energy service company which heads the design and installation of the photovoltaic plant was used to demonstrate the applicability of the risk identification model designed and detailed below. This solar installation is located in the parking area of a building used for administrative purposes in order to cover part of their electricity demand through it. In the first stage of risk management the analysis plan defining the structure of project implementation will be developed. This plan will include a review of: methodology, project documents, roles and responsibilities, budget, calendar, files from previous projects, estimates, scope of the project, and the risk category.

For this risk structure, the plan is developed taking into account two categories: technical risks and financial risks. The technical risk will be defined based on the design of the installation, technology used, production and demand of electricity. Financial risks are chosen based on the investment, cost estimates, funding and project subsidies. The breakdown of the categorization of risk experts facilitates the identification process and ensures the effectiveness and quality of the collection of documentation. The project documentation comes from the energy service company commissioned to design and build the facility. This information has been compiled in Figure 5 as a set of project objectives, the sizing and design of the plant, in addition to customer consumption data and economic analysis. The design of this facility has been made with the PVsyst program [39]; which performs all dimensioning calculations and their components. Economic analysis has been recreated in a spreadsheet. The information serves for experts to know all the details of the project and through these to identify and assess risks.

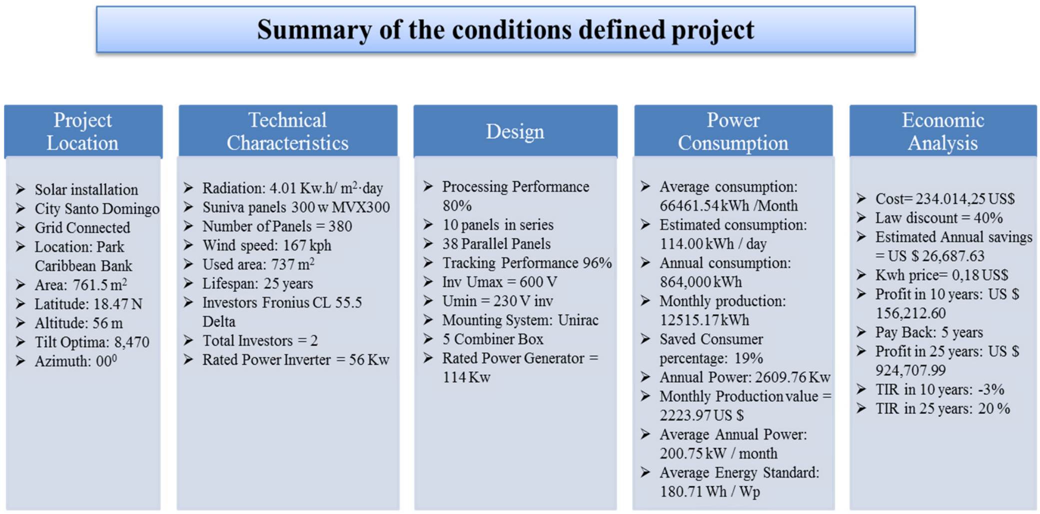

Figure 5. Collection of documents.

5. Analysis and Results

5.1. Collection and Analysis of Information from the Experts

The extraction of knowledge was carried out, based on a group of five experts with proven ability. From the structured review of files from previous projects, design documents and information gathered, the project experts were commissioned to identify and compare risks in order to achieve greater consistency in the results. The expert interviews were conducted via e-mail after making sure that they will review the information obtained regarding the project. Experts were selected at random from a database of researchers from the area of renewable energy with experience in photovoltaic projects in the Caribbean and DR. All had post-graduate degrees in the area of renewable energies. For experts to find project risks more easily after reviewing the documentation they were given a questionnaire that consisted of two phases. A first questionnaire with open questions was performed using the Delphi technique. A number of risks were obtained and with these initial responses a second technique was prepared, combining the questionnaire of the Delphi technique with a Checklist. Selected points on the Checklist are the risks which experts agreed with in the first round of the questionnaire. In this second phase, the experts classified the risks that had previously been indicated according to the effects of profitability and probability of occurrence. The questionnaire the experts responded is shown in Figure 6.

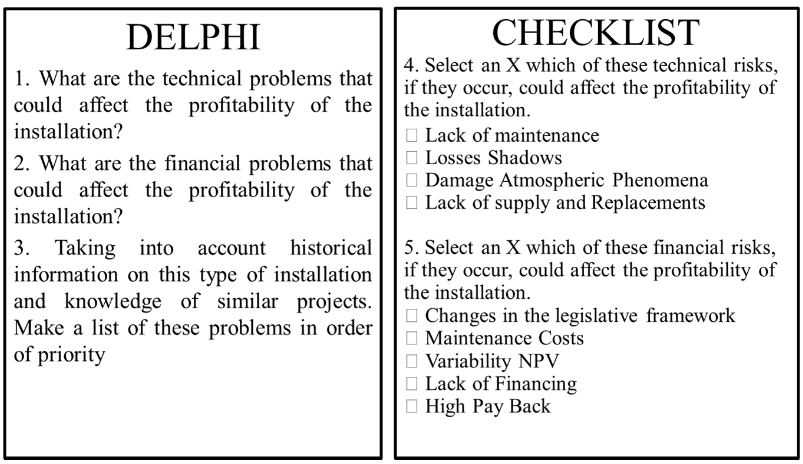

Figure 6. Questionnaire method Delphi-Checklist.

At this stage, the experts assessed the study case in order to create a list where the level of consensus is reflected. This questionnaire allows experts to identify risks to the system via the Delphi technique (questions 1 and 2). Subsequently, a connection was made between the risks marked with the Checklist and the list of identified problems (questions 3, 4 and 5), which reflects the consensus reached by the experts. This procedure is not complicated and generates a final report on file at the registry of the risks of continuing evaluation. The risks identified by experts include:

R1. *High Pay Back*: Long time it takes to recover the initial outlay invested in the production process.
R2. *Shadows losses:* Losses of solar radiation by photovoltaic installations to shadows.
R3. *Maintenance Costs:* Total price to pay for cleaning dirt from the solar panels over the lifetime of the installation.
R4. *Atmospheric Phenomena damage:* Earthquakes, hurricanes, storms *etc.*, which may cause damage to the facility.
R5. *Variability NPV:* It is the route as a percentage of the project's profitability. The net present value or net present value of an investment is an indicator of net absolute return provided by the project. It measures the baseline and the benefit provided in absolute terms, after discounting the initial investment.
R6. *Lack of Maintenance:* Effects caused by not cleaning the dust and dirt of a facility over its lifetime.
R7. *Changes in the legislative framework:* Different changes that may arise on current legislation and rules governing aids applied to this type of investment.
R8. *Lack of replacements and supplies:* Replacement of any component or structure which prevents the efficiency during the life of the installation.
R9. *Lack of Financing:* no bank loans or funding to support the project investment.

R2, R4, R6 and R8 are within the category of technical risks and the remaining risks are financial risks.

5.2. Scenario Analysis

Once you have carried out the collection of documentation and identification of risks you can precede with the next stage. This consisted of an analysis of assumptions and identifies the causes of occurrence. To validate the exploration of this stage as indicated in the risk identification model, experts identified project assumptions as inaccurate, unstable, inconsistent or incomplete depending on the characteristics of their nature. Each identified risk was so defined taking into account a set of hypotheses, which could occur once the validity of the following list of assumptions had been explored.

(1) Possibility of appearance of shadows due to construction of buildings in the vicinity.
(2) Change in the power sector legislation on renewable energy in terms of its connection to the network, grants and subsidies.
(3) Possibilities of developing hurricane or other adverse weather events in the Caribbean area which can damage the installation.
(4) Possible errors in the economic outlook since the repayment of the facility is closely linked to the level of funding and some economic indicators have not been taken into account in the design.
(5) Maintenance costs of the installation and repair of parts or elements thereof, damaged over time.

Table 4. Classification of risks according to the nature of the assumption.

Risk Classification According to the Nature of the Assumptions				
Character	**Incomplete**	**Incoherent**	**Unstable**	**Inaccurate**
Technical	Supply and Replacements	Maintenance	Atmospheric phenomena	Shadows losses
Financial	Maintenance costs and Variability NPV	Legislative Framework	Lack of Financing	High Pay Back

Reviewing the responses of experts from the Checklist and the information provided in relation to cases it was possible to classify the risks identified according to the nature of the assumption (Table 4).

5.3. Application to Diagramming Techniques

5.3.1. Cause and Effect Diagram

With the cause and effect diagram (Figure 7) problems were connected with their main and secondary causes in order to facilitate the organization of the relationship. As shown in Figure 7 the main causes in this case are the technical and financial problems in the installation. Secondary causes selected correspond to the risks identified by experts, considering that the study case presents a single and main effect, which is the lack of profitability of the project. The diagram improved the quality of the opinion gathering the different reasons and causes for the occurrence of different factors. This served as a guide for subsequent corrective actions that were performed.

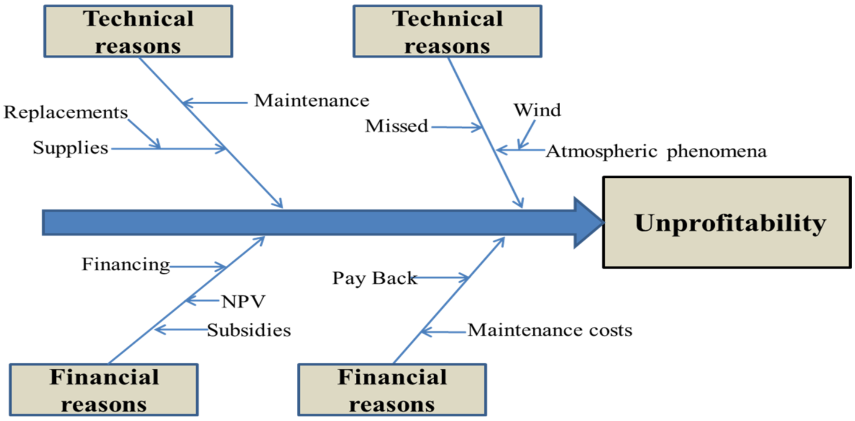

Figure 7. Cause and effect diagram.

5.3.2. SWOT Diagram

Subsequently a SWOT diagram was built which is able to detect issues such as weaknesses, threats, strengths and opportunities of the project to increase the reflection of the risks identified. The most consistent expert was commissioned to prepare this analysis (Figure 8) from the phase of polls in the stage of gathering information. He examined these qualities on the basis of the causes of the risks of cause and effect diagram.

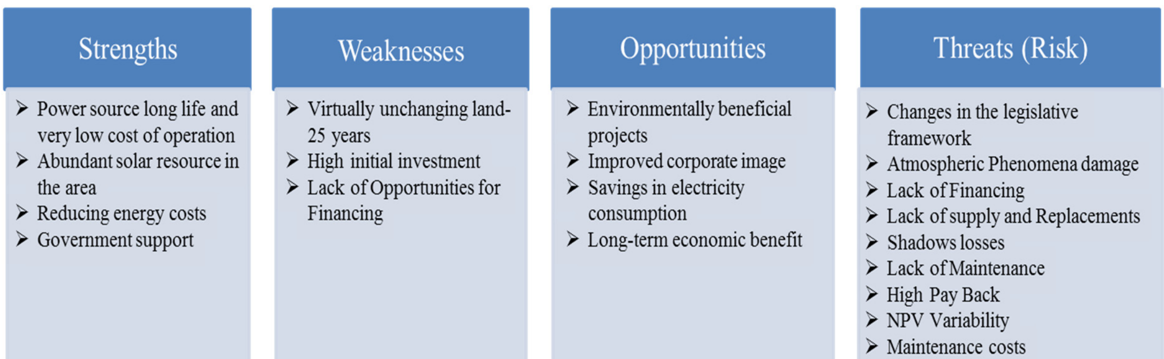

Figure 8. SWOT analysis of the project based on the opinion of expert.

5.4. Expert Judgment Assessment

To apply the AHP methodology described above in order to assess the significance of the risks as being technical or financial, the questionnaire described in Figure 9 was prepared, where 1 means equal importance with regard to the criteria evaluated. The values on the left mean greater importance with respect to another and criteria on the right mean minor regarding one criterion over another.

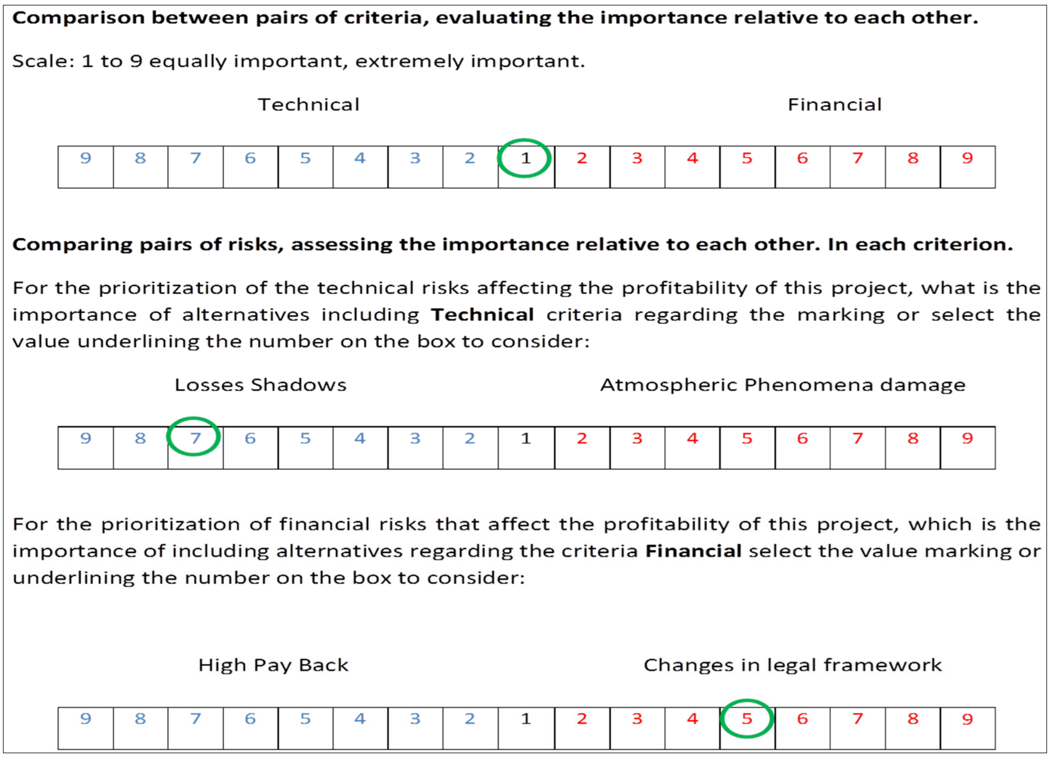

Figure 9. Synthesis of AHP questionnaire.

The questionnaire provided a number of outcomes that were modeled in a spreadsheet measuring the consistency of the expert for the importance of the risks. The consistency obtained for the matrix of technical risks is 0.08 and that obtained for the array of financial risks is 0.06. After applying the AHP methodology the weight or coefficient importance of each risk (Table 5) was obtained, which also allows to check that the technical and financial risks affecting the photovoltaic solar installation are equal.

Table 5. Coefficient of importance of risks.

AHP	
Technical Risk	**Weight**
R2: Shadows losses	0.640
R4: Atmospheric Phenomena damage	0.063
R6: Lack of Maintenance	0.235
R8: Lack of supply and Replacements	0.063
Financial Risks	**Weight**
R1: High Pay Back	0.068
R3: Maintenance costs	0.069
R5: NPV Variability	0.138
R7: Changes in the legislative framework	0.508
R9: Lack of Financing	0.217

5.5. Sensitivity Analysis

Finally, to see the variations in the relative importance of risk over time a sensitivity analysis was performed using Expert Choice [36]. This analysis allowed us to verify the results of the final decision through dynamic graphics mode (Figure 10). The same values of importance of AHP are obtained with Expert Choice (Table 5). From these values, varying sensitivity analysis is done to compare and check the consistency of these results.

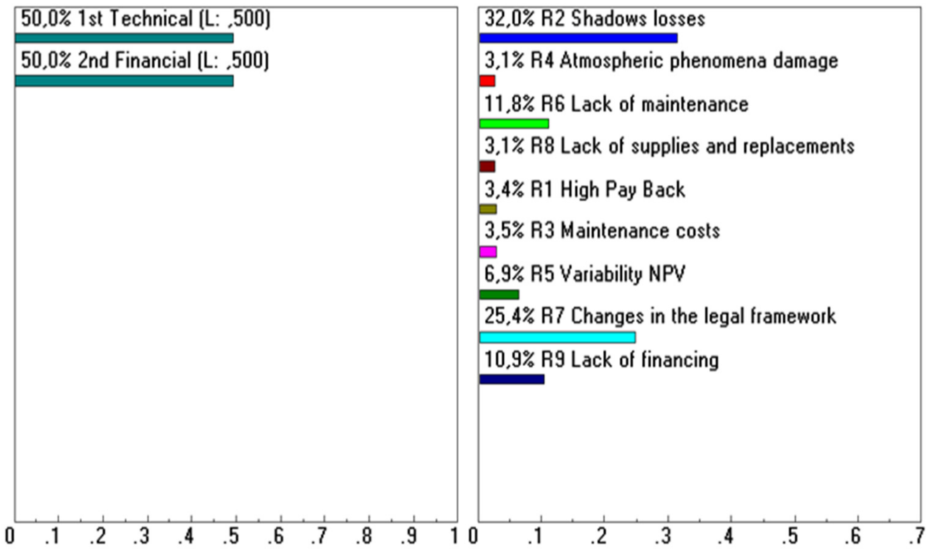

Figure 10. Results of dynamic sensitivity analysis of the risks, the importance of technical criteria 50%, importance of financial criteria 50%.

For comparison, performance sensitivity analysis was used. This study compared the results when the matrix of criteria (type of risk) has been varied and the matrices of the sub-criteria (technical and financial risks) have remained unchanged.

It is clear in Figure 11 that insofar as the technical and financial criteria vary with a proportion that increases to 70% and decreases to 30%, the two risks with the highest score keep their order of importance among the top three places. Specifically they are one sub-criterion belonging to the category of technical risks (R2 shadows losses) and another of the financial type (R7 changes in the legislative framework).

Table 6. Comparative of sensitivity analysis with Expert Choice.

Results of the Sensitivity Analysis with Dynamic Expert Choice					
AHP	**Technical/ Financial**	**Technical/ Financial**	**Technical/ Financial**	**Technical/ Financial**	**Technical/ Financial**
Percentage change criteria	**75%/25%**	**70%/30%**	**50%/50%**	**30%/70%**	**25%/75%**
R2: Shadows losses	48.00%	44.70%	32.00%	19.20%	16.00%
R4: Atmospheric Phenomena damage	4.70%	4.40%	3.10%	1.90%	1.60%
R6: Lack of Maintenance	17.60%	16.40%	11.80%	7.10%	5.90%
R8: Lack of supply and Replacements	4.70%	4.40%	3.10%	1.90%	1.60%
R1: High Pay Back	1.70%	2.00%	3.40%	4.70%	5.10%
R3: Maintenance costs	1.70%	2.10%	3.50%	4.80%	5.20%
R5: NPV Variability	3.40%	4.10%	6.90%	9.60%	10.30%
R7: Changes in the legislative framework	12.70%	15.30%	25.40%	35.50%	38.10%
R9: Lack of Financing	5.40%	6.50%	10.90%	15.20%	16.30%

All risks have been evaluated in a different order to find significant variations. Other risks coefficients of notable importance are R6 (Lack of maintenance) and risk R9 (Lack of financing). Finally, there would be a risk group whose weights have values very close to each other (R1, R3, R4 and R8). The results are shown in Table 6.

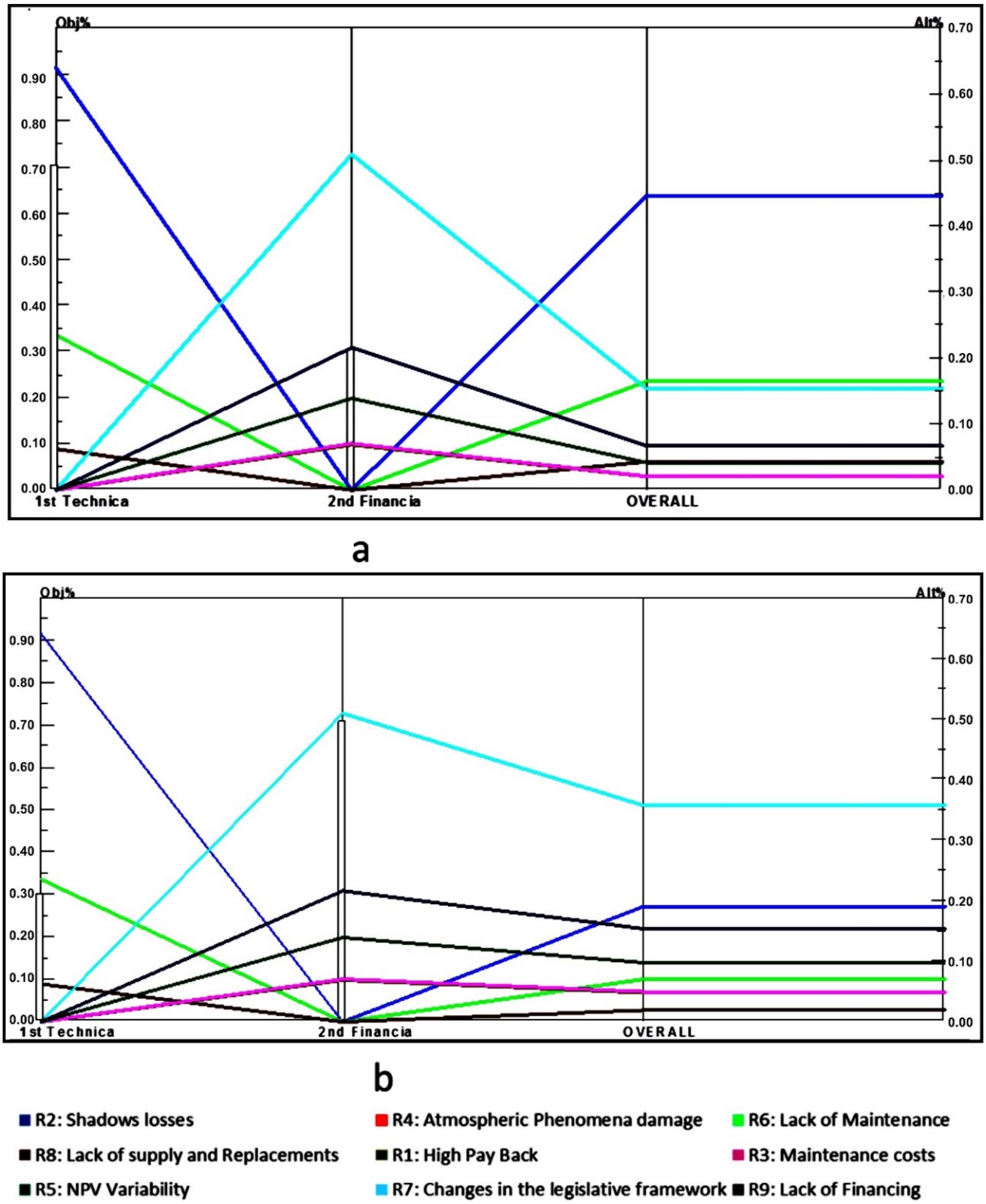

Figure 11. (**a**) importance of technical criteria 70%, importance of financial criterion 30%; (**b**) importance of technical criteria 30%, and importance of financial criterion 70%.

Table 6 presents the values of the different variations that have been made in the study to compare the data obtained with each risk through the importance of the criteria. These results are checked graphically in Figure 12, which represents the evolution of risk on the basis of the different variations of the criteria simultaneously. The abscissa axis represents variations analyzed and the ordinate axis represents the final weight of risk (Table 6).

Table 6 and Figure 12 show that the two risks (R2 losses shadows) and (R7 changes in the legislative framework) continue to maintain an order of overriding importance throughout the numerical variation made through sensitivity analysis with Expert Choice. This analysis allowed us to verify the consistency of the results obtained with AHP. Therefore, a model for identifying risks with robust and consistent results is obtained.

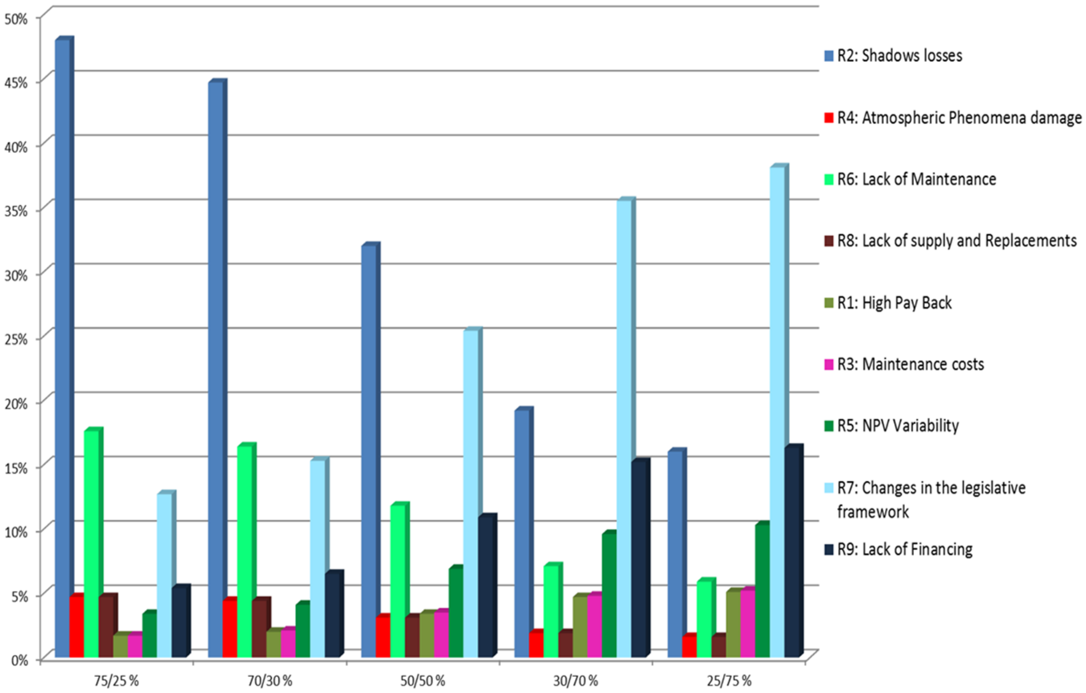

Figure 12. Frequencies histogram.

5.6. Discussion

It is logical that one of the major risks is (R7 changes in the legislative framework) and DR currently features a new legal system that has introduced some changes with regard to the investment allowance. Currently the law 57-07 [9] governing renewable energy sources is under renovation. It is also important to note that the risk of lack of financing kept its order of importance among the third or fourth. DR today, as mentioned above, has very few entities and financial institutions that are dedicated to providing support and money to these projects due to the lack of confidence that the current market for renewable energies offers. Regarding the major technical risks, they highlight the typical problems anticipated in all world famous photovoltaic systems. It is advisable to achieve mitigation and controls of these risks to implement routine solutions that feature the global scope.

Comparing previous studies in this paper we note that studies such as [17] estimating the risks identified different risk factors. Instead this study identifies risks directly through experts based on technical and financial criteria, which allows collecting experiences from previous projects. Other studies [20] examined the instruments of financial risk management of renewable energy by learning practices without taking into account technical factors that affect the profitability of the facility. Studies such as [18] used interviews with experts to identify the perception of the risks affecting renewable energy projects but did not use multicriteria decision making analysis. A study that if you apply a multicriteria decision making process analytical method uses the network (ANP) to select the best photovoltaic project to invest in based on risk minimization identifying risks iteratively [23]. However, this study does not use any recognized fundamental guide such as PMBOK [13] to also apply sensitivity analysis to identify risks [36]; or a coefficient of importance of each risk is obtained. Using AHP allows you to check the consistency of assessment and help those responsible for managing the project to make the best decision. This study focuses on applying the model for risk identification; however there are studies [21] that focus on economic risk analysis in renewable energy infrastructure. These studies [22] propose models for risk analysis covering the entire life cycle of renewable energy projects using Monte Carlo simulation and sensitivity analysis for the likelihood of occurrence.

This model is necessary in the critical phase of evaluation of such facilities; its application is also recommended in risk management to develop photovoltaic systems similar to DR emerging countries in need of investment in renewable technologies. If this process of risk identification recommends applying it to a real case it is possible to control and mitigate possible occurrences thus providing guarantees prior to the profitability of this type of project.

6. Conclusions

In this paper, method multicriteria decision making combined with different methodologies to identify and analyze risks has been applied. The problems affecting profitability in a renewable energy plant in the DR are determined, obtaining a base model for managing the technical and financial risks. The model allows a solid and clear multi-criteria decision analysis, which shows the best way to select the risks. The model also provides the largest project's general manager peace of mind when making final decisions.

Applying risk management tools proposed by the guide to the Project Management (PMBOK Guide) in photovoltaic solar installations, the impact of technical and financial problems on profitability and investment of these projects was verified. Previous results that have been obtained to identify risks in such projects have focused solely on the application techniques to seek information (Delphi and Checklist) or diagramming techniques (Ishikawa diagram and SWOT). However, this study also focuses on improving the evaluation process of applying methods of decision making, specifically AHP judgment.

The risks considered in greater order of importance were changes in the legislative framework and losses shadows. With the sensitivity analysis performed, the consistency of the results was verified, providing robust and reliable model risk identification. However, the uncertainties identified in these facilities should be subjected to further analysis to know the probability of their occurrence and provide immediate answers to each of these risks.

It is important to account for possible mitigation financing conditions contained in the project environment. There should be clear provisions for maintenance, technical calculations and accurate data of legislative stability of the territory. Finally, the application of this model in projects in developing countries recommends the need to invest in renewable technologies as an opportunity for a transition to an energy system that is both economically and environmentally sustainable. In order to further expand this work, further studies should be carried out using other techniques and instruments of decision, taking into account important factors to compare the process effectively.

Acknowledgments: This work is partially supported by projects TIN2014-55024-P from the Spanish Ministry of Science and Innovation and P11-TIC-8001 from Junta de Andalucía (including FEDER funds), SENECA Foundation 19882-GERM-15 and a doctoral scholarship from the Ministry of Higher Education from Dominican Republic (MESCYT) with the contract number 1065-2015, respectively. The authors are grateful to the reviewers of this paper for the suggestions that have been made to the original version, which have significantly improved the final version.

Author Contributions: Guido C. Guerrero-Liquet has collected, processed and interpreted data, and has written the manuscript. Juan Miguel Sánchez-Lozano, María Socorro García-Cascales and María Teresa Lamata assisted in data interpretation, manuscript evaluation, and editing. José Luis Verdegay supervised the development of the work and assisted in data interpretation.

Conflicts of Interest: The authors declare no conflict of interest.

Acronyms

PMBOK	Project Management Body of Knowledge
SWOT	Strengths Weaknesses Opportunities and Threats
AHP	Analytic Hierarchy Process
RES	Renewable Energy Sources
DR	Dominican Republic
UNFCCC	United Nations Framework Convention on Climate Change
GDP	Gross Domestic Product
ANP	Analytical Processing Network
PV	Photovoltaic Solar
MCDM	Multicriteria Decision-Making
BHD	Dominican Mortgage Bank
IFC	International Finance Corporation
R	Risk
NPV	Net Present Value

References

1. Santoyo-Castelazo, E.; Azapagic, A. Sustainability assessment of energy systems: Integrating environmental, economic and social aspects. *J. Clean. Prod.* **2014**, *80*, 119–138. [CrossRef]
2. Oksay, S.; Emre, I. A new energy paradigm for Turkey: A political risk-inclusive cost analysis for sustainable energy. *Energy Policy* **2011**, *39*, 2386–2395. [CrossRef]
3. Magnoni, S.; Bassi, A.M. Creating Synergies from Renewable Energy Investments, a Community Success Story from Lolland, Denmark. *Sustainability* **2009**, *2*, 1151–1169. [CrossRef]
4. Ramos, J.S.; Ramos, H.M. Sustainable application of renewable sources in water pumping systems: Optimized energy system configuration. *Energy Policy* **2009**, *37*, 633–643. [CrossRef]
5. Pietrosemoli, L.; Monroy, C.R. The impact of sustainable construction and knowledge management on sustainability goals. A review of the Venezuelan renewable energy sector. *Renew. Sustain. Energy Rev.* **2013**, *27*, 683–691. [CrossRef]
6. Shirley, R.; Kammena, D. Renewable energy sector development in the Caribbean: Current trends and lessons from history. *Energy Policy* **2013**, *57*, 244–252. [CrossRef]
7. Ochs, A.; Konold, M.; Matthew Lucky, S.; Musolino, E.; Ahmed, A.; Weber, M. *Harnessing Energy Resources Sustainable of the Dominican Republic*; Worldwatch Institute: Washington, DC, USA, 2015.
8. Agency for the National Interconnected Electric System Dominican Republic (OC). Annual Report 2015 OC. Available online: http://www.oc.org.do/INFORMES/Administrativos/InformeAnual.aspx (accessed on 24 February 2016).
9. National Energy Commission. *Incentives on Development of Renewable Sources of Energy and its Special Regimes*; Decree Law 202-08 Regulation 57-07; National Energy Commission: Santo Domingo, Dominican Republic, 2012. Available online: http://www.cne.gov.do/app/do/marco_leyes.aspx (accessed on 24 February 2016).
10. Secretary of State for Industry and Commerce. *Hydrocarbons Law*; Decree Law 112-00; Ministry of Industry and Trade: Santo Domingo, Dominican Republic, 2001.
11. Spanish Institute for Foreign Trade; ICEX. *The Renewable Energy Market in Dominican Republic. Market Studies*; Economic and Commercial Office of the Embassy of Spain in Santo Domingo: Santo Domingo, Dominican Republic, 2012.
12. Bloomberg New Energy Finance (BNEF), Frankfurt School. *Program of the United Nations Environment Ambient (PNUMA)*; Global Trends in Renewable Energy Investment; Collaborating Centre for Climate & Sustainable Energy Finance: Frankfurt, Germany, 2014.
13. Project Management Institute. Managing Project Risk. In *A Guide to the Project Management for (PMBOKGuide)*, 5th ed.; Global Standard; Project Management Institute: Newtown Square, PA, USA, 2010; pp. 234–266.
14. Burgherr, P.; Hirschberg, S. Comparative risk assessment of severe accidents in the energy sector. *Energy Policy* **2014**, *74*, S45–S56. [CrossRef]

15. Klessmann, C.; Nabe, C.; Burges, K. Pros and cons of exposing renewables to electricity market risks—A comparison of the market integration approaches in Germany, Spain, and the UK. *Energy Policy* **2008**, *36*, 3646–3661. [CrossRef]
16. Debyani, G.; Shukla, P.R.; Garg, A.; Venkata Ramana, P. Renewable energy technologies for the Indian power sector: Mitigation potential and operational strategies. *Renew. Sustain. Energy Rev.* **2002**, *6*, 481–512.
17. Sadorsky, P. Modeling renewable energy company risk. *Energy Policy* **2012**, *40*, 39–48. [CrossRef]
18. Komendantova, N.; Patt, A.; Barras, L.; Battaglini, A. Perception of risks in renewable energy projects: The case of concentrated solar power in North Africa. *Energy Policy* **2012**, *40*, 103–109. [CrossRef]
19. Mardani, A.; Jusoh, A.; Kazimieras Zavadskas, E.; Cavallaro, F.; Khalifah, Z. Sustainable and Renewable Energy: An Overview of the Application of Multiple Criteria Decision Making Techniques and Approaches. *Sustainability* **2015**, *7*, 13947–13984. [CrossRef]
20. Sudi, A.; Erhan, A.; Güngör, T. Financial risk management in renewable energy sector: Comparative analysis between the European Union and Turkey. *Procedia Soc. Behav. Sci.* **2011**, *24*, 935–945.
21. Arnold, U.; Yildiz, O. Economic risk analysis of decentralized renewable energy infrastructures e A Monte Carlo Simulation approach. *Renew. Energy* **2014**, *77*, 227–239. [CrossRef]
22. Frisari, G.; Stadelmann, M. De-risking concentrated solar power in emerging markets: The role of policies and international finance institutions. *Energy Policy* **2015**, *82*, 12–22. [CrossRef]
23. Aragones-Beltran, P.; Chaparro-Gonzalez, F.; Pastor-Ferrando, J.; Rodriguez-Pozo, F. An ANP-based approach for the selection of photovoltaic solar power plant investment projects. *Renew. Sustain. Energy Rev.* **2010**, *14*, 249–264. [CrossRef]
24. Lee, A.H.I.; Kang, Y.; Lin, C.Y.; Shen, K.C. An Integrated Decision-Making Model for the Location of a PV Solar Plant. *Sustainability* **2015**, *7*, 13522–13541. [CrossRef]
25. González, J.B.C. Evaluation and analysis of improved export authorization service log cultural goods killings. *Adv. Sci.* **2010**, *13*, 1–15.
26. Almansa, C.; Martinez-Paz, J.M. What weight should be assigned to future environmental impacts? A probabilistic cost benefit analysis using recent advances on discounting. *Sci. Total Environ.* **2011**, *409*, 1305–1314. [CrossRef] [PubMed]
27. Markmann, C.; Darkow, I.; von der Gracht, H. A delphi-based risk analysis: Identifying and assessing future challenges for supply chain security in a multi-stakeholder environment. *Technol. Forecast. Soc. Change* **2012**, *80*, 1815–1883. [CrossRef]
28. Colli, A.; Vetere Arellano, A.L.; Kirchsteiger, C.; Ale, B.J.M. Risk characterization indicators for risk comparison in the energy sector. *Saf. Sci.* **2009**, *47*, 59–77. [CrossRef]
29. Saaty, T.L. *The Analytic Hierarchy Process*; McGraw Hill: New York, NY, USA, 1980.
30. Mulhall, R.A.; Bryson, J.R. Energy price risk and the sustainability of demand side supply chains. *Appl. Energy* **2014**, *123*, 327–334. [CrossRef]
31. Reinsberger, K.; Brudermann, T.; Hatzl, S.; Fleiß, E.; Posch, A. Photovoltaic diffusion from the bottom-up: Analytical investigation of critical factors. *Appl. Energy* **2015**, *159*, 178–187. [CrossRef]
32. Hook, D.; Gustafsson, P.; Nordstrom, L.; Johnson, P. An enterprise architecture based method enabling quantified analysis of it support system's impact on maintenance management. In Proceedings of the Portland International Conference on Management of Engineering & Technology, Portland, OR, USA, 2–6 August 2009; pp. 3176–3189.
33. Arancibia, S.; Contreras, E.; Mella, S.; Torres, P.; Villalba, I. *Multi-criteria Evaluation: Application to the Development of Sports Infrastructure*; University of Chile, Ministry of Planning and Cooperation, MIDEPLAN: Santiago de Chile, Chile, 2003; Available online: https://www.academia.edu/1067942/Evaluaci%C3%B3n_Multicriterio_aplicaci%C3%B3n_para_la_formulaci%C3%B3n_de_proyectos_de_infraestructura_deportiva (accessed on 24 February 2016).
34. Alonso, J.A.; Lamata, M.T. Estimation of the Random Index in the Analytic Hierarchy Process. In Proceedings of the Information Processing and Management of Uncertainty in Knowledge-Based Systems, (IPMU'04), Perugia, Italy, 4–9 July 2004; Volume 1, pp. 317–322. Available online: http://ipmu2004.dipmat.unipg.it/ (accessed on 14 October 2015).
35. Alonso, J.A.; Lamata, M.T. Consistency in the analytic hierarchy process a new approach. *Int. J. Uncertain. Fuzziness Knowl. Based Syst.* **2006**, *14*, 445–459. [CrossRef]

36. Expert Choice. Product Brief. Available online: http://www.expertchoice.com/ (accessed on 14 October 2015).
37. García-Cascales, M.S.; Lamata, M.T. Selection of a cleaning system for engine maintenance based on the analytic hierarchy process. *Comput. Ind. Eng.* **2009**, *56*, 1442–1451. [CrossRef]
38. U.S. Department of State. Background Note: Dominican Republic. Available online: www.state.gov/r/pa/ei/bgn/35639.htm (accessed on 24 February 2016).
39. PVsyst Photovoltaic Software. Available online: http://www.pvsyst.com (accessed on 2 October 2015).