

# SELECTION OF SOCIALLY RESPONSIBLE INVESTMENT PORTFOLIOS USING THE RESTRICTIONS METHOD AND A MULTIPLE CRITERIA ANALYTIC HIERARCHY PROCESS TECHNIQUE

LADY M. BERNARD-SUÁREZ<sup>1</sup>

✉ NÉSTOR RAÚL ORTIZ-PIMIENTO<sup>2</sup>

JUAN BENJAMÍN DUARTE-DUARTE<sup>3</sup>

## ABSTRACT

This paper presents a procedure to support investors' decision-making process to select a portfolio that meets their economic and corporate social responsibility (CSR) expectations. Profitability and risk criteria were considered as economic measures, which, when addressed using the restrictions method, provide a series of efficient portfolios that were used as alternatives to apply the multiple criteria analytical hierarchy process (AHP) technique. This technique makes it possible to select the portfolio that meets criteria related to corporate governance, employee relations, the environment, and community relations as CSR measures.

The procedure was applied to select investment portfolios from the Colombian stock market. The study found that the portfolio that best met the CSR criteria proposed in this paper was also the one with minimum risk.

**KEYWORDS:** Investment portfolios, Markowitz, Multiobjective, Multi criteria, Corporate Social Responsibility.

## SELECCIÓN DE PORTAFOLIOS DE INVERSIÓN SOCIALMENTE RESPONSABLES USANDO EL MÉTODO DE LAS RESTRICCIONES Y LA TÉCNICA MULTICRITERIO PROCESO ANALÍTICO JERÁRQUICO

## RESUMEN

En este artículo se presenta un procedimiento que permite apoyar el proceso de decisión de los inversionistas al seleccionar un portafolio que cumpla con sus expectativas económicas y con aquellas relacionadas con Responsabilidad Social Empresarial (RSE). Para ello, se consideran criterios de rentabilidad y riesgo como medidas económicas que,

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<sup>1</sup> Industrial engineer. Universidad Industrial de Santander. Bucaramanga, Colombia.

<sup>2</sup> Magister in Systems Engineering, Universidad Industrial de Santander. Bucaramanga, Colombia.

<sup>3</sup> Doctor in company finances. Universidad Industrial de Santander. Bucaramanga, Colombia.



*Correspondence author:* Ortiz-Pimiento, N.R. (Néstor Raúl). Universidad Industrial de Santander. Cra 27 calle 9. Bucaramanga, Colombia. / Tel.: (571) 6344000.  
Email: nortiz@uis.edu.co

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abordadas desde el método de las restricciones, dan como resultado una serie de portafolios eficientes que se emplean como alternativas para la aplicación de la técnica multicriterio AHP (sigla en inglés), la cual permite establecer el portafolio que cumple con criterios de gobierno corporativo, relaciones con colaboradores, medio ambiente y relaciones con la comunidad como medidas de RSE.

El procedimiento se aplica en la selección de portafolios de inversión para acciones del mercado bursátil colombiano, dando como resultado que el portafolio que mejor cumple con los criterios establecidos en este artículo para RSE también es el de mínimo riesgo.

**PALABRAS CLAVE:** portafolios de inversión, Markowitz, multiobjetivo, multicriterio, Responsabilidad Social Empresarial (RSE).

## SELEÇÃO DE CARTEIRAS DE INVESTIMENTO SOCIALMENTE RESPONSÁVEIS, UTILIZANDO O MÉTODO DE RESTRIÇÕES E A TÉCNICA DE MULTICRITÉRIO PROCESSO ANALÍTICO JERARQUICO

### RESUMO

Este artigo descreve um procedimento que permite a apoiar o processo de tomada de decisão dos investidores para selecionar um portfólio que atenda às expectativas econômicas e as relacionadas com a Responsabilidade Social Empresarial (RSE). Para isso, consideramos critérios de risco e retorno como medidas econômicas, que tomadas desde o método das restrições, dão como resultado uma série de carteiras eficientes que são utilizados como alternativas para a implementação do multi-criterio AHP (sigla em inglês) que permite estabelecer o portfólio que atende aos padrões do governo corporativo, relações com funcionários, meio ambiente e relações com a comunidade como medidas de RSE.

O procedimento é aplicado na seleção de carteiras de investimento para ações do mercado colombiano, dando como resultado que a carteira que melhor atenda os critérios estabelecidos no presente artigo para RSE também é o do risco mínimo.

**PALAVRAS-CHAVE:** carteiras de investimento, Markowitz, multi-objetivo, multi-criterio, a Responsabilidade Social Empresarial (RSE).

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### 1. INTRODUCTION

Every day, the capital market becomes more and more important for a country's economic development since it has become an alternative method for financing companies and governments, as well as being an investment alternative. However, given the possibility of finding various securities options, it becomes difficult to establish which type of stock is the best to invest in and the amount of money to be invested. Therefore, the scientific literature has presented different models, most of them quantita-

ive, to make this kind of decision and mathematically represent reality. The quantitative methods used include the "mean-variance" model proposed by Markowitz, which has become the basis of portfolio theory and has given rise to other models that search for an optimal, or at least feasible, solution to the problem of selecting investment portfolios.

Likewise, the issue of corporate social responsibility (CSR) has taken on special importance in the financial sphere. For some investors, knowing that the companies in which they invest their money have a commitment to society and the environment

could be gratifying since their investments will indirectly contribute to sustainable development in the country. However, mathematically modeling these company characteristics in the process of investment portfolio decision-making is complex given that they are mainly qualitative. Despite the complexity of mathematical modeling, some authors have established multiple criteria techniques to incorporate several qualitative considerations into different processes in order to find a solution that is a better fit for the decision-maker's needs.

In order to address the problem of investment portfolio selection involving the CSR perspective, this article proposes a procedure that consists of two phases: the first is based on the restrictions method and supports the analysis of quantitative measures of profitability and risk, and the second is the analytical hierarchy process (AHP), which supports the decision-making process by evaluating characteristics related to CSR, such as corporate governance, employee relations, the environment, and community relations.

## 2. LITERATURE REVIEW

The origin of the vast majority of portfolio selection models is that of Harry Markowitz, presented partially in 1952 and more completely in 1959. It is also called "mean-variance" and has become the basis of modern portfolio theory, as well as contributing to multiple developments and derivations that provide a conceptual framework for finding an optimal, or at least feasible, solution to the problem of investment portfolio selection.

The model presented by Markowitz is founded on the following hypotheses (Franco, Avendaño & Barbutín, 2011):

- The performance of any security or portfolio is considered to be a random variable for which the investor estimates a probability distribution for the period of study. The expected value of the random variable is used to quantify the investment's performance.

- Variance or standard deviation are used to measure dispersion as a measurement of risk of random variable profitability. This measurement must be made individually for each asset and the entire portfolio.

- The investor's rational behavior leads him or her to prefer the composition of a portfolio that represents the greatest profitability for a determined level of risk, or the minimum risk for a determined level of profitability.

- Selecting diversified elements (whose characteristics differ) allows for balancing the losses and gains that come with different securities.

Based on the above suppositions, a multi-objective mathematical programming problem is established in order to maximize performance and minimize risk, which will, to a certain degree, satisfy the investor's preferences. Since each investor will have different preferences regarding performance or risk, we cannot talk about exact preferences. However, all choices that are made should be on the efficient frontier, which is defined as the set of efficient portfolios such that, for given performance levels, there are no other portfolios with lesser risk and equal or greater performance; or, for various levels of risk, that there are no portfolios with greater performance and equal or lesser risk (Minutti, 2010).

With the definition of the efficient frontier, the investor will be able to establish the most convenient portfolio according to his or her preferences and attitude toward risk. The Markowitz model therefore consists of two main stages: first, determining the set of efficient portfolios, and then choosing from this set the portfolio that best meets the investor's expectations.

However, the Markowitz model has been limited in practice due to the method's mathematical complexity. First, since it is a parametric quadratic program, the resolution algorithm is complex. In addition, the number of estimations of expected profitabilities, variances, and co-variances to be made is very high. Likewise, some authors have considered

other characteristics of the model to be relevant, such as: that it supposes perfect divisibility of the selected securities, that the entire available capital will be invested, that it is not possible to go into debt in order to increase the investment, and that it does not provide a tool so that the investor can value his or her attitude to risk and derive the utility function, which is necessary for choosing the optimal portfolio (Mendizabal, Miera & Zubia, 2002). Finally, it has been considered that the use of historical parameters as estimators for expected parameters introduces significant biases that provide portfolios centered on few securities and which are not very attractive for investors.

However, in order to contemplate several of these characteristics, some authors have proposed including restrictions to the original model that are related with transactions costs and limit the maximum percentage of the budget that can be allocated to each bond (Mendizabal, Miera & Zubia, 2002). Others, like Black & Litterman, propose a model based on Bayesian methods to value investors' attitude toward risk (Franco, Avendaño & Barbutín, 2011).

In general, the main contribution of the Markowitz model for selecting an optimal portfolio in accordance with the investor's objectives lies in its usefulness to pick up on the fundamental aspects that should guide a rational investor in choosing the makeup of his or her portfolio. This process begins with verifying the nature of each asset individually and ends with the final decision about the optimal portfolio.

Subsequent to this model, various alternative models have been proposed, including linear, non-linear, deterministic, and stochastic models, as well as models that use other paradigms such as maximizing expected gain subject to a certain level of risk or even optimizing a parameterized combination of earnings and risk (Fernández, 2008). These include studies performed by Branke, et al. (2009) and Subbu, et al. (2005), where the frontier of efficient portfolios is also determined.

In addition, the problem has been solved through what are called evolutionary algorithms that are based on heuristics and meta-heuristics such as genetic algorithms, tabu search, and simulated annealing. In these multi-objective proposals, risk and performance are not always calculated as is proposed in the Markowitz model, and in some others, restrictions such as sale price are used (Zavala, et al. 2009).

Likewise, we can highlight the fact that multi-objective techniques have also addressed, though not widely, the issue of socially responsible investment. One of these is the study by Charnes & Cooper (1961) related to goal programming that considers the investor's preferences reflected, on the one hand, in setting acceptable levels of profitability, risk, and corporate social responsibility, and, on the other, in ordering the objective functions according to their relative importance for the investor, thereby establishing a system of exclusive priorities and even considerations within each priority level, if necessary (Antomil, Cañal & Rodríguez, 2008). In order to make this technique applicable, indices have been established to measure the social responsibility of an investment portfolio. However, there are very few related studies. According to Bilbao et al. (2009), these studies include those of Basso & Funari (2003), Barrachini (2004), Barnett & Salomon (2006), and Kempf & Osthoff (2008).

Likewise, some authors have proposed different multiple criteria models for selecting portfolios which consider criteria related to wealth management, financial management, performance measures, portfolio management, stock evaluation, credit risk, etc. or other references for socially responsible investments that consider social, environmental, and/or ethical characteristics.

The study by Hallerbach et al. completed in 2004 is one of the few in which multi-criteria techniques are applied to the selection of socially responsible fund portfolios (Antomil, Cañal & Rodríguez, 2008).

Likewise, various multiple criteria methods can be found today based on multi-objective programming, over-classification relationships, the ELECTRE and PROMETHEE methods, valuing utility functions, and expert systems (decision rule models), which allow for the portfolio selection in light of various criteria like those mentioned above (Fontalvo, Morelos & Vergara, 2012). Multiple criteria techniques proposed for the problem of investment portfolio selection include UTASTAR and AHP.

Despite the extensive literature on the topic of investment portfolio selection and optimization, some investors have not found tools that adjust to their particular interests regarding their choice of portfolios. This is the case of investors whose concern for CSR-related issues has increased in recent years. Therefore, the methodological proposal made in this article, which is based on simultaneously including quantitative and qualitative techniques, aims to build a procedure that supports the decisions of socially responsible investors in their search for a portfolio that can meet their expectations.

### 3. METHODOLOGY

We propose a process for investment portfolio selection that, in addition to the traditional measures of profitability and risk, also considers issues of corporate social responsibility. To do so, the following activities are established:

#### 3.1. Phase 1: Multi-objective optimizations

The flowchart presented in **Figure 1** relates the activities carried out in the first phase of the process which are associated with multi-objective optimization.

#### 3.2. Phase 2: Multiple criteria optimization

Once the efficient frontier has been built, the investor, in accordance with his or her risk profile (low, medium, or high), establishes the number of alter-

natives or portfolios that he or she will later analyze using the multiple criteria AHP technique and considering CSR criteria such as corporate governance, employee relations, the environment, and community relations.

In order to apply the AHP technique, the degree of CSR commitment is established for each of the securities issuers selected for the portfolio. This process includes the following steps:

A. For each, sustainability reports or memoirs are reviewed, as well as initiatives that the securities issuers have begun regarding the CSR criteria defined.

B. Based on these initiatives, a checklist is created with a set number of factors that can support the companies' commitment to the aforementioned criteria.

C. For each criterion, a maximum number of factors is established, and the existence of supporting initiatives is then checked. If there are initiatives, the checklist is marked with a 1; if not, it is marked with a 0.

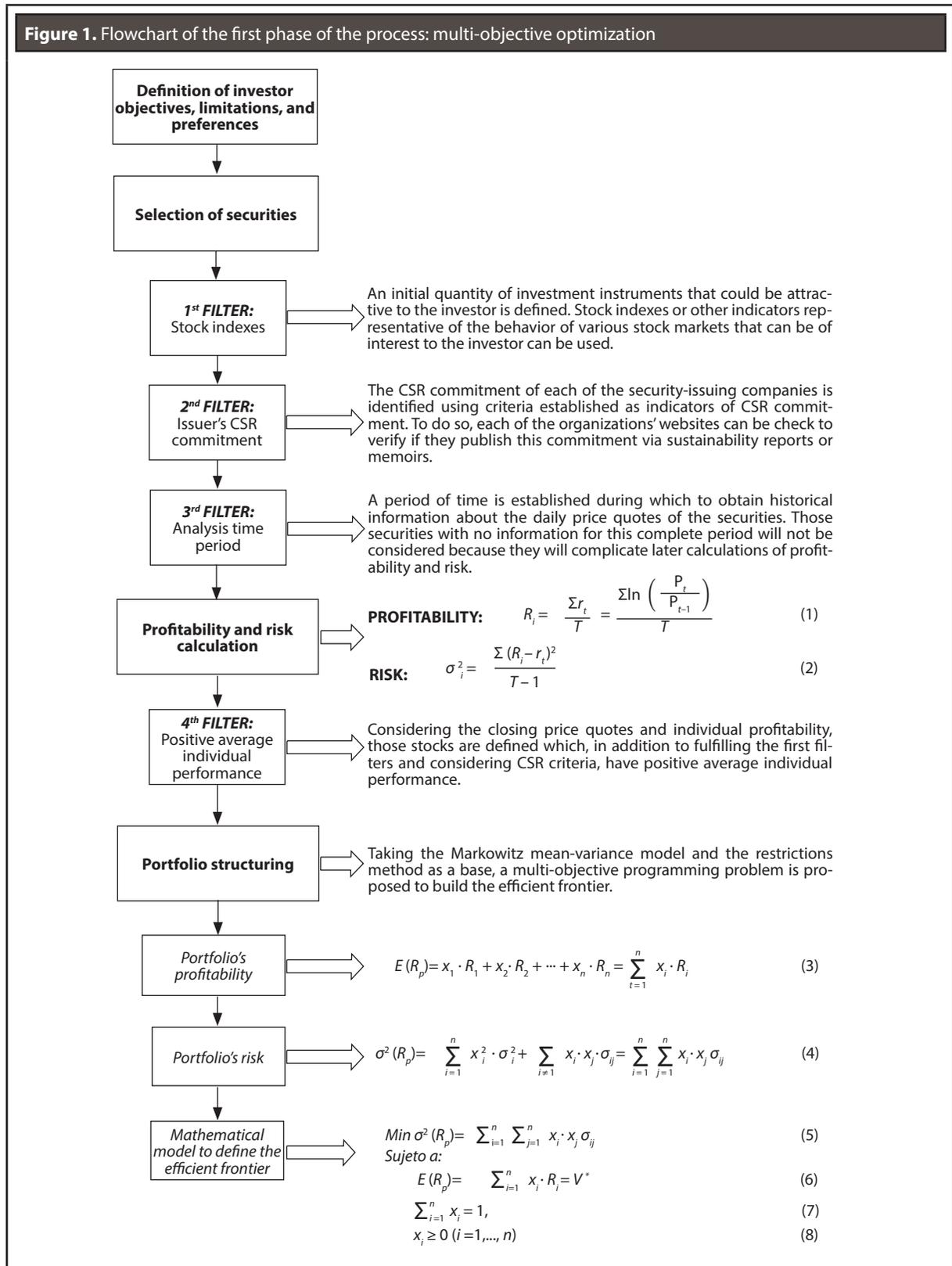
D. The cells marked with a 1 are added up for each company and each criterion to establish a score, as shown in **Table 1**.

E. The scores of the companies in the portfolio are averaged for each criterion, and the fulfillment percentage of the average is established with respect to the maximum score.

F. In order to establish the level of importance among criteria, the differences in their fulfillment percentages are considered, as well as the paired fundamental scale defined by Saaty. To do so, a 4x4 matrix is developed, as shown in **Table 2**.

G. If the fulfillment percentage for criterion 1 (corporate governance) is greater than the fulfillment percentage for criterion 2 (employee relations), criterion 1 is considered to be more important, and so on for the remaining criteria. Depending on the magnitude of the difference, the paired fundamental scale is established considering the following in **Table 3**.

**Figure 1.** Flowchart of the first phase of the process: multi-objective optimization



**TABLE 1.** SCORE FOR EACH COMPANY FOR EACH CRITERION

<i>Companies</i>	<i>Corporate governance</i>	<i>Employee relations</i>	<i>Environment</i>	<i>Community relations</i>
Company 1				
Company 2				
⋮				
Company n				
Average score				
Maximum				
% fulfillment				

**TABLE 2.** DIFFERENCES BETWEEN FULFILLMENT PERCENTAGES OF CSR CRITERIA

	<i>Corporate governance</i>	<i>Employee relations</i>	<i>Environment</i>	<i>Community relations</i>
Corporate governance				
Employee relations				
Environment				
Community relations				

**TABLE 3.** RELATIVE IMPORTANCE ACCORDING TO DIFFERENCES BETWEEN FULFILLMENT PERCENTAGES AND SAATY PAIRED FUNDAMENTAL SCALE

<i>Interval</i>	<i>Value</i>
[0 – 11.11 %)	1
[11.11 % - 22.22 %)	2
[22.22 % - 33.33 %)	3
[33.33 % - 44.44 %)	4
[44.44 % - 55.55 %)	5
[55.55 % - 66.66 %)	6
[66.66 % - 77.77 %)	7
[77.77 % - 88.88 %)	8
[88.88 % - 99.99 %]	9

H. Considering the score for each company for each criterion (**Table 1**) and the percentage weights of each security in each portfolio (the result of the efficient frontier), the weighted average score is established for each of the alternatives or portfolios considering each criterion.

I. To define the degree of importance of one portfolio compared to another, the differences in their fulfillment percentages and the paired fundamental scale (**Table 3**) are considered. To do so, a pxp matrix is completed for each criterion, as shown in **Table 4**.

**TABLE 4.** DIFFERENCES BETWEEN FULFILLMENT PERCENTAGES OF PORTFOLIOS FOR EACH CSR CRITERION

	<i>Portfolio 2</i>	<i>...</i>	<i>Portfolio p</i>
Portfolio 1			
Portfolio 2			
⋮			
Portfolio p			

In this stage, the Expert Choice program is used based on the analytical hierarchy process (AHP) and, as a result, the investor is presented with the alternatives or portfolios he or she has chosen as a final decision ranked by priority according to CSR considerations.

#### 4. RESULTS: CASE STUDY

The procedure proposed in this article is applied to the case of the Colombian Stock Exchange with the following considerations:

##### 4.1. Phase 1: multi-objective optimizations

- Equity securities are analyzed.

A. *Definition of investor objectives, limitations, and preferences*

- A socially responsible, low-risk profile is established

*B. Selection of securities in which the investment will be made*

- In the first filter, the General Index of the Colombian Stock Exchange (Índice General de la Bolsa de Valores de Colombia or IGBC) is considered, specifically the basket established for the August-October 2013 quarter, which contains 41 securities, considering that this index provides an aggregate measure of price evolution for the most representative stocks in the Colombian market in terms of rotation and frequency.

- In order to address this study's interest in the problem of selecting investment portfolios involving the CSR perspective, the second filter is defined to consider the financial assets whose issuers have a sustainability report or memoirs in which they publish the initiatives completed during the year 2012 to support their CSR commitment and, specifically, with the four areas or criteria defined in this article. As a result of this filter, the number of stocks is reduced to 30.

- In the third filter, those stocks that have been traded on the exchange for at least 2 years are selected. As a result of this filter, 22 stocks remain. It is important to note that for the purposes of the present study, a time horizon of two years was chosen (October 2011 to October 2013) since the majority of companies obtained in the previous filter have been presenting reports of their CSR commitment for a short time. Likewise, Fernández (2008), Zavala (2009), and Mendizábal, Miera & Zubia (2002) use periods of 1 and 2 years as a reference in their research to build the Markowitz model or models derived from it. This relatively short period could generate biases in the information and in the expected results. Therefore, to apply this procedure in a more developed market, a longer period is suggested.

- So that the efficient frontier to be built will generate positive performance, in the fourth and final filter, the stocks which have an average individual performance greater than zero are taken. As a result, only 14 stocks remain, which are: Eco-

petrol (ECOPETROL), Grupo Inversiones Suramericana (GRUPOSURA), Almacenes Éxito S.A. (ÉXITO), Canacol Energy Ltd. (CNEC), Grupo Aval Acciones y Valores S.A. (PFAVAL y GRUPOAVAL), Grupo Nutresa S.A. (NUTRESA), Corporación Financiera Colombiana S.A. (CORFICOLCF y PFCORFICOL), Empresa de Energía de Bogotá S.A. E.S.P. (EEB), Banco de Bogotá S.A. (BOGOTÁ), Isagen S.A. E.S.P. (ISAGEN), Organización de Ingeniería Internacional S.A. (ODINSA), and Helm Bank S.A. (PFHELMBANK).

*C. Structuring portfolios that meet the investor's requirement*

- Profitability and risk calculations are made for the stocks obtained by applying the above filters, considering the arithmetic average and the variance of daily profitability. The result are matrices of dominance and co-variance shown in **Tables 5** and **6**, considering that a portfolio's risk calculation not only influences the weighted average of the deviations of each stock, but also affects co-variance between them. As such, a negative co-variance like that of stocks such ÉXITO and PFCORFICOLF, ÉXITO and ISAGEN, PFCORFICOLF and ISAGEN, PFCORFICOLF and PFHELMBANK, EEB and ODINSA, or PFHELMBANK and ODINSA, supposes, in a way, a compensation for the risk of the portfolio in which they are included given that while a stock falls, an increase in profitability in the other could balance the portfolio.

- To apply the Markowitz model and the restrictions method, the program MS Excel is used, specifically the SOLVER function. The result is the efficient frontier shown in **Figure 2**. In general, the restrictions used for this model are related to the portfolio's expected profitability, the non-negativity of the weighting, and the fact that their sum is equal to 100%. However, depending on the investor, additional restrictions could be devised to limit the minimum and maximum weighting of the eligible stocks in order to give, for example, an interval between 5% and 20%, respectively.

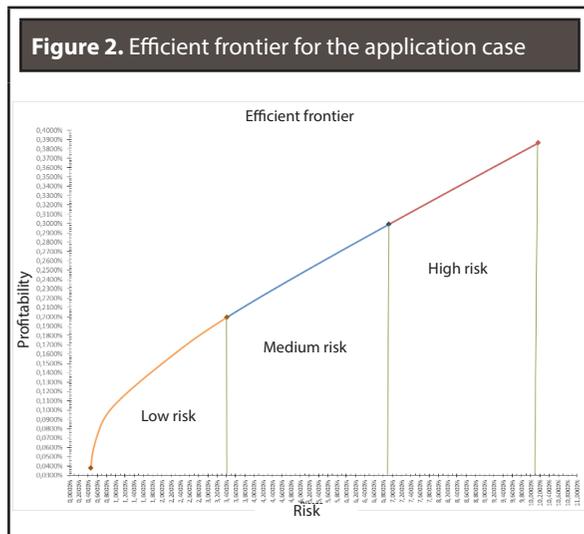
**TABLE 5. DOMINANCE MATRIX OF STOCKS OBTAINED FROM APPLICATION OF FILTERS**

	ECOPETROL	GRUPO SURA	ÉXITO	PFAVAL	GRUPOAVAL	CNEC	NUTRESA	CORFICOLCF	PFCORFICOL	EEB	BOGOTA	ISAGEN	ODINSA	PFHELMBANK
<b>AVERAGE</b>	0.00030799	0.00021982	0.00068137	0.00024755	0.00028074	0.00398922	0.00036288	0.00025061	0.00003604	0.00031522	0.00074972	0.00072748	0.00000000	0.00115583
<b>VARIANCE</b>	0.00018476	0.00018234	0.00022032	0.00013917	0.00014220	0.01129901	0.00011782	0.00008722	0.00011418	0.00020246	0.00008526	0.00015709	0.00011555	0.00033054

**TABLE 6. CO-VARIANCE MATRIX OF STOCKS OBTAINED FROM APPLICATION OF FILTERS**

	ECOPETROL	GRUPOSURA	ÉXITO	PFAVAL	GRUPOAVAL	CNEC	NUTRESA	CORFICOLCF	PFCORFICOL	EEB	BOGOTA	ISAGEN	ODINSA	PFHELMBANK
<b>ECOPETROL</b>	0.000185	0.000058	0.000048	0.000040	0.000032	0.000105	0.000033	0.000031	0.000004	0.000019	0.000013	0.000041	0.000011	0.000006
<b>GRUPOSURA</b>	0.000058	0.000182	0.000057	0.000028	0.000029	0.000134	0.000040	0.000047	0.000010	0.000036	0.000015	0.000067	0.000013	0.000008
<b>ÉXITO</b>	0.000048	0.000057	0.000220	0.000040	0.000031	0.000021	0.000042	0.000026	-0.000002	0.000016	-0.000002	0.000040	0.000002	0.000028
<b>PFAVAL</b>	0.000040	0.000028	0.000040	0.000139	0.000081	0.000075	0.000028	0.000023	0.000013	0.000027	0.000021	0.000028	0.000003	0.000002
<b>GRUPOAVAL</b>	0.000032	0.000029	0.000031	0.000081	0.000142	0.000054	0.000025	0.000015	0.000006	0.000021	0.000024	0.000019	0.000002	0.000006
<b>CNEC</b>	0.000105	0.000134	0.000021	0.000021	0.000054	0.011299	0.000061	0.000091	0.000041	0.000031	0.000008	0.000056	0.000003	0.000022
<b>NUTRESA</b>	0.000033	0.000040	0.000042	0.000028	0.000025	0.000061	0.000118	0.000027	0.000003	0.000037	0.000020	0.000040	0.000009	0.000004
<b>CORFICOLCF</b>	0.000031	0.000047	0.000026	0.000023	0.000015	0.000091	0.000027	0.000087	0.000011	0.000012	0.000007	0.000031	0.000002	0.000007
<b>PFCORFICOL</b>	0.000004	0.000010	-0.000002	0.000013	0.000006	0.000041	0.000003	0.000011	0.000014	0.000008	0.000003	-0.000001	0.000002	-0.000009

<b>EEB</b>	0.000019	0.000036	0.000016	0.000027	0.000021	0.000031	0.000037	0.000012	0.000008	0.000202	0.000000	0.000028	-0.000002	0.000006
<b>BOGOTÁ</b>	0.000013	0.000015	-0.000002	0.000021	0.000024	0.000008	0.000020	0.000007	0.000003	0.000000	0.000085	0.000010	0.000001	0.000003
<b>ISAGEN</b>	0.000041	0.000067	0.000040	0.000028	0.000019	0.000056	0.000040	0.000031	-0.000001	0.000028	0.000010	0.000157	0.000011	0.000004
<b>ODINSA</b>	0.000011	0.000013	0.000002	0.000003	0.000002	0.000003	0.000009	0.000002	0.000002	-0.000002	0.000001	0.000011	0.000116	-0.000001
<b>PFHELBANK</b>	0.000006	0.000008	0.000028	0.000002	0.000006	0.000022	0.000004	0.000007	-0.000009	0.000006	0.000003	0.000004	-0.000001	0.000331



- Considering that a low-risk profile was defined, we included the portfolios that were calculated to build the efficient frontier with a risk of less than 3.3882%, considering the ranges established based on the differences between the maximum and minimum risk of the frontier, where the minimum risk point is 0.4651% with a profitability

of 0.0375%, made up of 12 stocks (ECOPETROL, ÉXITO, PFAVAL, GRUPOAVAL, NUTRESA, CORFICOL-CF, PFCORFICOL, EEB, BOGOTA, ISAGEN, ODINSA, and PFHELBANK), and the maximum risk point is 10.6296% with a profitability of 0.3989%, made up of a single stock (CNEC). As a result, 14 portfolios are considered for the final portfolio selection.

#### 4.2. Phase 2: Multiple criteria optimization

##### D. Final portfolio selection

- A maximum of 12 factors is established for the corporate governance criterion, 13 for the employee relations criterion, 7 for the environment criterion, and 9 for the community relations criterion, as shown in the following table:

**TABLE 7. FACTORS ESTABLISHED FOR THE CSR CRITERIA**

<b>Criterion</b>	<b>Factor</b>
<b>1. Corporate governance</b>	1.1. The company declares its corporate governance structure.
	1.2. If there are support committees, there is at least one that supports management of the company's good governance and/or sustainability.
	1.3. If there are support committees, there is at least one that supports management regarding partners.
	1.4. If there are support committees, there is at least one that supports the company's ethical management and transparency.
	1.5. The company declares the documents and/or rules that guide corporate governance bodies.
	1.6. The company declares that it has a Corporate Governance Code.
	1.7. The company declares that it has a code of ethics and/or good conduct which supports the ethical process inside and outside the organization.
	1.8. The company declares that it has ethical channels..
	1.9. The company declares that it has documents that reject all forms of corruption and/or fraud.
	1.10. The company declares that it has programs to fight corruption.
	1.11. The company declares that it has a system, program, and/or activity for risk management.
	1.12. The company has recognitions and/or certifications that accredit its commitment to practice of good corporate governance.
<b>2. Employee relations</b>	2.1. The report gives details on the workforce by employment, contract, age, gender, and region.
	2.2. The company declares that it has clear policies or procedures for incorporating human talent into the organization.
	2.3. The company declares that it has compensation policies or procedures to guarantee internal equality.
	2.4. The company declares that it has extralegal social benefits for its workers that cultivate a healthy work environment.
	2.5. The company declares that it provides benefits to its workers and their families related to pension matters
	2.6. The company declares that it tracks the work environment within the organization.
	2.7. The company declares that it has programs for education, development, and growth of human talent.
	2.8. The company declares that it has collective agreements to promote good relations between the company and its workers.
	2.9. The company declares that it guarantees its workers the right to association.
	2.10. The company declares that it has a committee that guarantees healthy coexistence between workers
	2.11. The company has programs for education, training, assessment, prevention, and control in occupational health and safety.
	2.12. The company declares its support of eradicating child labor and forced labor.
	2.13. The company has recognitions and/or certifications that accredit its commitment to practices that guarantee proper relations with its partners.
<b>3. Environment</b>	3.1. The company declares that it has a system, policy, and/or general plan for environmental management
	3.2. The company declares that it has programs, policies, and/or strategies for efficient resources management.
	3.3. The company declares that it has programs, policies, and/or strategies for mitigating effects related to climate change.
	3.4. The company declares that it has programs, policies, and/or strategies for conserving biodiversity.
	3.5. The company has educational and/or training programs on topics related to the environment inside and/or outside the organization.
	3.6. The company declares that it has strategic partners for environmental management.
	3.7. The company has recognitions and/or certifications that accredit its commitment to environmental management practices.

**TABLE 7. FACTORS ESTABLISHED FOR THE CSR CRITERIA**

<b>Criterion</b>	<b>Factor</b>
<b>4. Community relations</b>	4.1. The company declares that it has general policies and/or strategies to ensure responsible management of the company's relations with the communities in which it operates.
	4.2. The company declares that it has programs and/or projects to guarantee the communities in which it operates the right to health.
	4.3. The company declares that it has programs/and or projects to guarantee the communities in which it operates the right to education.
	4.4. The company declares that it has programs/and or projects to promote culture and/or sports.
	4.5. The company declares that it has programs/and or projects to guarantee the productive development of the communities in which it operates.
	4.6. The company declares that it has strategic partners for social management in the communities in which it operates.
	4.7. The company declares that it has the support of a foundation or organization to promote social management in the communities in which it operates.
	4.8. The company declares that it has volunteer program that connects workers and their families to the social commitments it has to the communities in which it operates
	4.9. The company has recognitions and/or certifications that accredit its commitment to social management practices in the communities in which it operates.

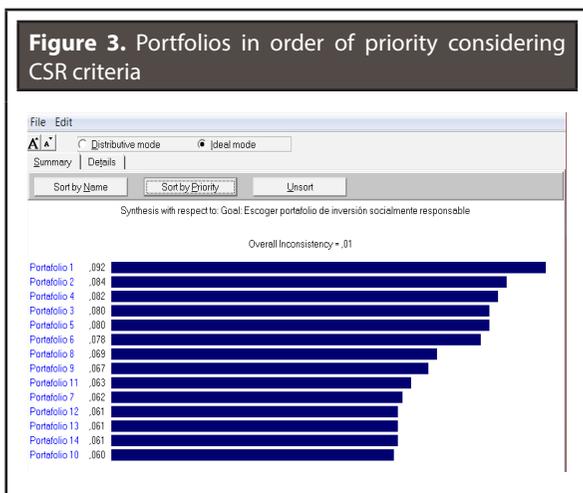
- Based on these factors, a percentage of general compliance is established for each company regarding the criteria of corporate governance, employee relations, the environment, and community relations, as shown below:

**TABLE 8. PERCENTAGE OF COMPLIANCE FOR THE COMPANIES ISSUING SELECTED STOCKS WITH REGARDS TO DEFINED CSR CRITERIA**

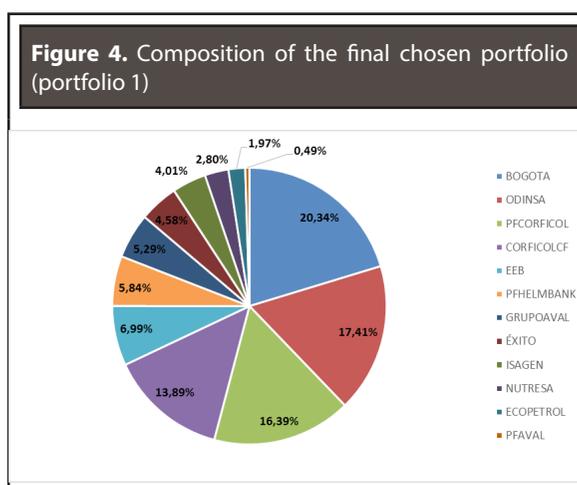
<b>Stock</b>	<b>Corporate governance</b>	<b>Employee relations</b>	<b>Environment</b>	<b>Community relations</b>
Ecopetrol	100	100	100	77.78
Grupo Inversiones Suramericana	83.33	53.85	71.43	66.67
Almacenes Éxito S.A.	100	92.31	85.71	77.78
Grupo Aval Acciones y Valores S.A.	50	23.08	42.86	66.67
Canacol Energy Ltd	50	15.38	57.14	33.33
Grupo Nutresa S.A.	75	76.92	100	88.89
Corporación Financiera Colombiana S.A.	58.33	61.54	100	55.56
Empresa de Energía de Bogotá S.A. E.S.P.	91.67	92.31	100	66.67
Banco de Bogotá S.A.	41.67	38.46	42.86	88.89
Isagen S.A. E.S.P.	75	84.62	100	77.78
Organización de Ingeniería Internacional S.A.	58.33	46.15	71.43	44.44
Helm Bank S.A.	50	38.46	71.43	55.56

- Companies such as Ecopetrol, Almacenes Éxito S.A., and Empresa de Energía de Bogotá S.A. E.S.P. show a percentage of compliance of greater than 90% for the criteria of corporate governance and employee relations. For the environment criterion, the companies with a percentage of compliance of greater than 90% are Ecopetrol, Grupo Nutresa S.A., Corporación Financiera Colombiana S.A., Empresa de Energía de Bogotá S.A. E.S.P., and Isagen S.A. E.S.P., while for the community relations criterion, the companies with a percentage of compliance of greater than 80% (given that none reached 90%) are Grupo Nutresa S.A. and Banco de Bogotá S.A.

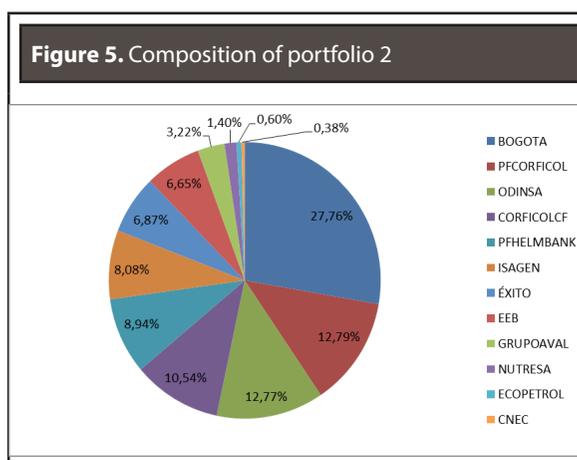
- As the product of applying the analytical hierarchy process (AHP) performed with Expert Choice software, **Figure 3** presents the portfolios chosen for the final decision in order of priority using CSR considerations.



- In accordance with the portfolio selection procedure proposed in this study, portfolio 1 (that with the minimum risk in the efficient frontier) is established as that which can fulfill the low-risk, socially responsible profile defined above, representing for the investor a profitability of 0.0375% with a risk level of 0.4652%. For these figures, the capital invested in this portfolio would have the following composition:



- Despite the fact that portfolios 2, 4, 3, and 5, ranked considering the defined CSR criteria, fulfill the profile of a low-risk, socially responsible investor, their level of risk progressively increases, as well as their expected profitability. For its part, portfolio 2 represents a profitability of 0.0500% with a risk level of 0.4845%, where the participation of stocks is restructured, decreasing the participation of stocks such as ECOPETROL, GRUPOAVAL, NUTRESA, CORFICOLCF, PFCORFICOL, EEB, and ODINSA, while ÉXITO, BOGOTÁ, ISAGEN, and PFHELMBANK increase in participation. CNEC is included in the investment options, and PFAVAL is excluded, as shown in **Figure 5**:



## 5. DISCUSSION

The investment portfolio selection process and other decision-making processes have been considered on the premise that in a decision-making problem, different solution alternatives can be presented, and choosing one of them requires identifying the objective to be achieved.

However, since these problems are so complex today and demand a comprehensive point of view, various objectives must be considered for their analysis and solution. That is why, in an attempt to model the problem, an endless number of tools, methods, and scientific techniques have been created to optimize these objectives, which are frequently in conflict, by introducing the concept of multi-objective programming and multiple criteria decision-making (MCDM).

The multi-objective and multiple criteria techniques have been based on the problem of decision-making. However, their use is influenced by the decision-maker's information, limitations, preferences, and objectives. In the case of multi-objective techniques for investment portfolio selection, the problem's formulation is based on quantitative suppositions or suppositions that can be adapted to mathematical principles, for example, the measurements of profitability and risk. However, these techniques frequently do not fully represent what the investor wants given that some of his or her preferences cannot easily be mathematically modeled, for example, interest in issues related to CSR. For these difficulties, multiple criteria techniques can be found in the literature that have contributed to, or at least founded on scientific elements, decision-making processes which depend on various qualitative or quantitative criteria, or a mix of the two. These techniques provide distinctive improvements to satisfy, as much as possible, the investor's preferences.

For its part, corporate social responsibility is an issue that is becoming more and more important not only in the business world, but also in financial matters, especially those related to investment deci-

sions. Over time, there has been a growing conviction that companies' socially responsible practices contribute to building a more stable, fair, and inclusive global market that fosters more prosperous societies. It is also believed that these practices can lead to an increase in long-term financial profitability and reduced risk.

That is why the process described in this article for investment portfolio selection with corporate social responsibility based on multi-objective and multiple criteria techniques is a tool to support socially responsible investors as they search for a portfolio that can meet their expectations, both economic (profitability and risk) and those related to environmental, social, and/or ethical issues within stock-issuing companies (corporate governance, work relations, the environment, and community relations).

As such, and considering the results of the procedure's application to the case of the Colombian Stock Exchange, in which the best portfolio meets the criteria established in this article for CSR as well as minimum risk, a direct relationship can be perceived in portfolio selection between compliance with social, environmental, and ethical objectives and the optimization of economic objectives (in this case, risk minimization). This observation is made considering that the profile defined before application of the process was low-risk and socially responsible.

### Symbols used

$\sigma_{ij}$	Co-variance between stocks $i$ and $j$
$\sigma_i$	Standard deviation of stock $i$
$\sigma(R_p)$	Standard deviation of portfolio
$\sigma_i^2$	Variance of stock $i$
$\sigma^2(R_p)$	Variance of portfolio
$P_t$	Closing price of stock at end of period $t$
$P_{t-1}$	Closing price of stock at beginning of period $t$
$r_t$	Profitability of stock during period $t$
$r_{it}$	Profitability of security $i$ during period $t$
$r_{jt}$	Profitability of security $j$ during period $t$

- $R_i$  Average profitability of security  $i$   
 $R_j$  Average profitability of security  $j$   
 $T$  Number of profitabilities observed

## REFERENCES

- Antomil, J.; Cañal, V. and Rodríguez, M.V. (2008). La selección de carteras socialmente responsables: Revisión crítica de la literatura. *Revista Electrónica de Comunicaciones y Trabajos de ASEPUMA*, ISSN 1575-605X, (9), pp. 147-172.
- Barnett, M. L. and Salomón, R. M. (2006). Beyond Dichotomy: the Curvilinear Relationship Between Social Responsibility and Financial Performance. *Strategic Management Journal*, 27(11), September, pp. 1101-1122.
- Barrachini, C. (2004). An Ethical Investments Evaluation for Portfolio Selection. [pdf] *Electronic Journal of Business, Ethics and Organization Studies*. Available on: <https://jyx.jyu.fi/dspace/handle/123456789/25347>, [consulted April 14 2013].
- Basso, A. and Funari, S. (2003). Measuring the Performance of Ethical Mutual Funds: a DEA Approach. *Journal of the Operational Research Society*, 54 (5), May, p.p. 521-531.
- Bilbao-Terol, A. M. et al. (2009). Selección de carteras de fondos de inversión socialmente responsables mediante programación por metas con tecnología difusa. *Revista Electrónica de Comunicaciones y Trabajos de ASEPUMA*, (10), pp. 29-57.
- Branke, B. et al. (2009). Portfolio Optimization with an Envelope-Based Multi-Objective Evolutionary Algorithm. *Journal European Research*, (199), May, pp. 684-693.
- Charnes, A. and Cooper, W. (1961). Management Models and Industrial Applications of Linear Programming. *Management Science*, 1(4), October, pp. 38-91.
- Fernández-Romero, J. E. (2008) Modelos de optimización de portafolios: un estudio comparativo basado en simulaciones computacionales. (Trabajo de Grado). Escuela Politécnica Nacional.
- Fontalvo, T. J.; Morelos, J. and Vergara-Schmalbch, J.C. (2012). Aplicación del Método de Decisión Multi-criterio UTASTAR para la Selección de Portafolios de Inversión. *Global Conference on Business and Finance Proceedings* (22-25, May: San José, Costa Rica), 7(2), pp. 961-966.
- Franco-Arbeláez, L.; Avendaño-Rúa, C. y Barbutín-Díaz, H. (2011). Modelo de Markowitz y Modelo de Black-Litterman en la Optimización de Portafolios de Inversión. *Revista Tecno Lógicas*, (26), June, pp. 71-88.
- Hallerbach, W., et al. (2004). A Framework for Managing a Portfolio of Socially Responsible Investments. *European Journal of Operational Research*, 153(2), March, pp. 517-529.
- Kempf, A. y Osthoff, P. (2008). "SRI Funds: Nomen est Omen". *Journal of Business Finance & Accounting*, 35 (9-10), November-December, pp. 1276-1294.
- Mendizábal, A.; Miera, L.M. y Zubia, M. (2002) El Modelo de Markowitz en la Gestión de Carteras. [pdf] Available on: [http://addi.ehu.es/bitstream/10810/7000/1/CdG\\_212.pdf](http://addi.ehu.es/bitstream/10810/7000/1/CdG_212.pdf) [Consultado April 14 2013].
- Minutti, C. (2010) Métodos de optimización en la construcción de portafolios. (Tesis de licenciatura). Universidad Autónoma Chapingo.
- Subbu, P., et al. (2005). Multiobjective Financial Portfolio Design: A Hybrid Evolutionary Approach. *Congress on Evolutionary Computation IEEE*, ISBN: 0-7803-9363-5, 2, September, pp. 1722- 1729.
- Zavala, J. et al. (2009). Modelo matemático multiobjetivo para la selección de una cartera de inversión en la bolsa mexicana de valores. Congreso Internacional de Cómputo en Optimización y Software- CICOS (17-20, November: UAEM México D.F.), pp. 396-408.

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