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Sustainability-Oriented Financial Resource Allocation in a Project Portfolio through Multi-Criteria Decision-Making

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Abstract: Modern portfolio theory attempts to maximize the expected return of a portfolio for a given level of portfolio risk, or equivalently minimize risk for a given level of expected return. The reality, however, shows that, when selecting projects to a portfolio and allocating resources in the portfolio, an increasing number of organizations take into account other aspects as well. As a result of the sole purpose (risk-return), it offers only a partial solution for a sustainable organization. Existing project portfolio selection and resource allocation methods and models do not consider sustainability. Therefore, the aim of this article is to develop a sustainability-oriented model of financial resource allocation in a project portfolio by integrating a composite sustainability index of a project into Markowitz's classical risk-return scheme (mean-variance model). The model was developed by applying multi-criteria decision-making methods. The practicability of the model was tested by an empirical study in a selected construction company. The proposed sustainability-oriented financial resource allocation model could be used in allocating financial resources in any type of business. The use of the model would not only help organisations to manage risk and achieve higher return but would also allow carrying out sustainable projects, thereby promoting greater environmental responsibility and giving more consideration to the wellbeing of future generations. Moreover, the model allows quantifying the impact of the integration of sustainability into financial resource allocation on the return of a portfolio.

Keywords: sustainability; project portfolio; project portfolio selection; financial resource allocation; multi-criteria decision making

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1. Introduction

In the light of growing global environmental problems, organizations are recognizing that business-as-usual is not an option anymore and it is time for a change. Projects are the most appropriate way to introduce change in organizations [1,2]. Considering that one third of the world gross domestic product is generated by projects [1,2], it is very important to integrate sustainability considerations into projects. And project management could make a valuable contribution in this context [3,4]. Today it is increasingly well understood that methods, tools and techniques need to be developed to integrate sustainability criteria into the management of projects [5,6]; moreover, there is a growing need of knowledge and concepts how to incorporate sustainability into the project management process [6–12].

However, the issue of the integration of sustainability considerations into project management has not been explored sufficiently [2–5,13–16]. The existing project management standards do not give adequate attention to sustainability issues or fail to provide project managers with the necessary tools to integrate sustainability into project management and operation [4,7,17,18]. Most works focus on sustainable project management methodologies [15,19]. In some of the first publications on sustainability and project management, sustainable development was linked to project life cycle management in the manufacturing industry [20]. Labuschagne and Brent [20] outlined three goals for sustainable development (namely social equity, economic efficiency, and environmental performance) in various project life cycle management problems. Gareis *et al.* [21] developed a model to deal with relationships between sustainable development and project management. A Maturity Model for integrating sustainability into project management was developed by Silvius and Schipper [18]. The model is used to assess the level (namely business process, business model, and product and services delivered by the project) on which different aspects of sustainability are regarded in the project. Sanchez [19] developed a framework which should contribute to ensuring that organization is carrying out the right projects to implement its business strategy and meet stakeholders' demands. Furthermore, the problem of assembling the best portfolio in terms of the organizational strategy incorporating sustainable goals was considered by Vandaele and Decouttere [22], who developed a data envelopment analysis (DEA) model designed to support strategic research and development portfolio management. Khalili-Damghani and Tavana [23] proposed a comprehensive framework for sustainable strategic project selection problem. A number of articles are concluded by pointing out that integrating sustainability aspects into the project management process would be equivalent to the introduction of a new paradigm [24,25].

Within project management, sustainability, and more specifically the environmental dimension, has been widely applied in construction projects [15]. In the framework of construction projects, sustainability has mainly been regarded in constructing buildings although some attempts have been made in civil engineering over the last few years [9]. Specifically, construction projects have been explored in more depth because of their significant impact on the environment, society and economy [26].

Although there are over 200 publications addressing sustainability and project management [2], there are many questions still to be answered [15] for instance, how to quantify the sustainability of a project, how sustainability could be integrated into project portfolio selection and resource allocation. The analysis of the literature has not given us answers to these questions. Therefore, in our previous article [27] we proposed to use a composite sustainability index to measure the sustainability of a project, which would allow the decision-maker to assess the level of sustainability of a particular project and compare projects with each other. Now, given that project portfolio selection and resource allocation are among the key issues in project management [28,29], this article aims at developing a sustainability-oriented model of financial resource allocation in a project portfolio by integrating a composite sustainability index of a project into classical Markowitz' risk-return scheme. The literature on project portfolio management discussed at length resource allocation in general and project portfolio selection as two distinct problems [30]. Yet, quite a few authors [30–32] propose that this problem should be dealt with at the same time. In our paper, we also combine project portfolio selection and resource allocation and analyze them as a typical multi-criteria decision-making problem.

This article is structured into sections. Section 2 presents a review of the latest literature on sustainability in project portfolio management. Section 3 reviews the development of classical Markowitz' mean-variance model through multi-criteria decision-making methods (Section 3.1) and presents a sustainability-oriented model of financial resource allocation in a project portfolio (Section 3.2). The results of the application of the model in practice and discussions are provided in Section 4. The paper is finished with some conclusions (Section 5).

2. Sustainability in Project Portfolio Management: Latest Literature Review

This section gives a brief overview of the latest literature addressing sustainability in project portfolio management. In order to identify relevant works, we used Google Scholar. The following keywords were selected: "sustainability in project management", "sustainability in project portfolio management", "sustainability in project selection". Moreover, we only considered publications since 2015, assuming that earlier works (until 2015) were addressed in the latest research. Furthermore, we only referred to papers that are in line with our research. Thus, we identified 11 relevant papers, which are summarized in Table 1.

Table 1. Summary of relevant works (2015–2016).

Year	Reference	Article Type	Aim of the Article	Methods Used	Field of Application	Was Sustainability Considered in the Context of Project Portfolio Selection and/or Resource Allocation in a Project Portfolio?
2015	Økland [2]	Literature review	To undertake a review of sustainability in project management	Literature review of 205 papers	Not specified	No
2015	Martens, and Carvalho [3]	Literature review, case studies	To investigate how companies are introducing sustainability into project management	Literature review, multiple-case study approach	Not specified	No
2015	Marcelin-Sádaba *et al.* [15]	Literature review, conceptual	To present the latest developments concerning sustainability in project management and to propose a new conceptual framework to contribute towards sustainable management of a project	Literature review of 110 papers	Industrial and civil engineering projects	No
2015	Silvius and Schipper [16]	Literature review, conceptual	To develop a conceptual model for exploring the relationship between sustainability and project success	Literature review	Not specified	No
2015	Sánchez [19]	Conceptual	To present a theoretical framework to evaluate projects that takes into account profits and economic, environmental and social impacts	Literature review, BSC (balanced scorecard), DEA, case study	Not specified	No
2016	Dobrovolskienė and Tamošiūnienė [27]	Empirical	To develop a composite sustainability index of a project	Literature review, survey, MCDM	Construction projects	Partly
2016	Siew *et al.* [33]	Conceptual	To present a fuzzy-based approach to measure maturity levels.	Literature review, fuzzy-based approach	Not specified	No
2016	Pimentel *et al.* [34]	Literature review	To provide a review of the literature and case studies of Operations Research and Management Sciences in the area of sustainability	Literature review	Mining industry projects	No
2016	Siew *et al.* [35]	Conceptual	To propose a framework for assessing the sustainability of infrastructure projects	Literature review, MCDM	Infrastructure projects	No
2016	Siew [36]	Conceptual	To propose a way to measure sustainability across project portfolio	Literature review	Construction projects	Partly
2016	Higham *et al.* [37]	Structural survey	To assess the use, in practice, of appraisals frameworks regarding sustainability evaluation in social housing sector projects	Literature review, a survey	Housing regeneration projects	No

The review of the latest academic literature shows that considerable attention is further focused on sustainability in project portfolio management. However, most of these works are conceptual in nature. For instance, Marcelino-Sádaba *et al.* [15] show the interrelations between sustainability and project management as well as outline a new conceptual framework to manage sustainable projects. Their work is based on the assumption that project products developed in accordance with sustainability criteria, sustainable project processes, sustainability-oriented organizations committed to sustainability, and projects managers trained in sustainability are the key elements underlying sustainable projects. Siew *et al.* [35] highlight the limitations of existing sustainability reporting tools and offer an alternative framework that could help improve assessment and reporting. Pimentel *et al.* [34] provide an analysis of the literature related to the development and application of quantitative decision-support methods incorporating sustainability consideration in the mining industry. The authors draw the conclusion that no mining activities should be undertaken unless they can make a net positive long-term contribution to human and ecosystem well-being. Our paper differs from the articles discussed above in two main aspects: (1) there is no article that would consider sustainability in the context of project portfolio selection and resource allocation; and (2) our paper broadens the current knowledge about sustainability in project portfolio management by providing an empirically tested financial resource allocation model.

3. Materials and Methods

In this section, we briefly review how Markowitz's [38] mean-variance model was extended in a number of inventive directions, one of them being the incorporation of additional criteria. In this way the classical portfolio selection problem has been linked to the multiple-criteria decision-making (MCDM) paradigm. Further, we present a sustainability-oriented model of financial resource allocation in a project portfolio.

3.1. The Application of Multi-Criteria Decision-Making Methods in Developing Modern Portfolio Theory

Project portfolio selection, which involves computing the proportion of the initial financial resources to be allocated among the existing projects, is essential in the field of project portfolio management [28,39]. A fundamental answer to this problem was given by Markowitz [38], who proposed the mean-variance model laying the basis of modern portfolio theory [40–43]. Markowitz defined the problem as a trade-off between the expected return and the expected risk of a portfolio [44].

Although mean-variance has been the prevalent model in portfolio selection for over sixty years, there have been attempts to extend its scope [42]. The initial Markowitz's [38] mean-variance model was in principle elaborated in three directions [41,45,46] (see Figure 1).

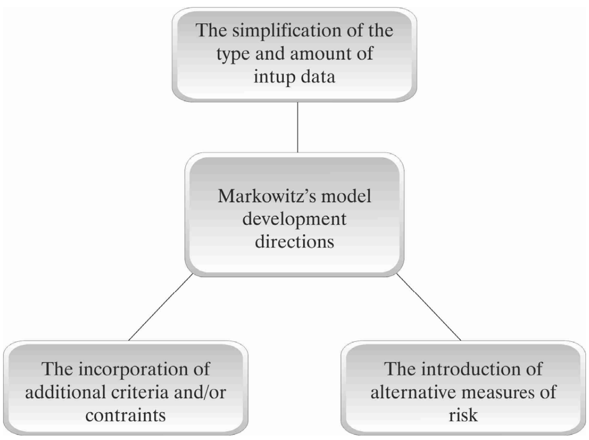

Figure 1. Markowitz's model development directions.

This paper will not address the first two directions and will only focus on the third development direction, even though it is interwoven with the second one, namely the introduction of alternative measures of risk. Lately, more and more authors come to realize the benefit of incorporating an additional criterion and/or constraint in project selection [41–45,47]. The analysis of this direction demonstrates mean-risk-third parameter models [41,42,46,48–54]. In addition to the mean and risk, such models also offer a third parameter, that of the project value (e.g., liquidity [55], investment portfolio size [50], transaction costs [49,56] and so on). However, most recently, the additional criterion that seems to be receiving the most consideration is social responsibility [42,57]. Over the past few years numerous papers on social responsibility in portfolio selection have been published [51,52,54,58–69]. One of the most recent works on this subject comes from Utz *et al.* [52] who extended the Markowitz model by complementing it with a social responsibility objective, in addition to the portfolio return and variance, thereby making the traditional efficient frontier a surface. It is noteworthy that the terms "social responsibility" and "sustainability" are often used interchangeably.

Thus, with new conflicting criteria being added to the traditional conflict between risk and return, portfolio selection and resource allocation have become even more complex. In this context, the application of multi-criteria decision-making methods is very useful. MCDM methods can be used to support decision-makers in circumstances where multiple conflicting decision criteria or alternatives have to be considered simultaneously [63]. In other words, MCDM techniques intend to find compromises in the decision-making process [70].

MCDM models and methods can be divided into two groups [71–74]:

- Multi-Objective Decision-Making (MODM) methods: An optimization problem is solved with an objective function while evaluating certain constraints. These methods are directly applied to solve a portfolio optimization problem.
- Multiple-Attribute Decision-Making (MADM) methods: Decision-making is intended for discrete comparison of alternatives. In scholarly works, methods falling within this group are usually used to rate assets to be included in a portfolio.

MCDM methods are widely used in solving portfolio selection and resource allocation problems. When classifying scholarly articles based on the field of application of MCDM methods (between 2002 and 2014), Zopounidis *et al.* [75] established that 40 percent of scholarly articles addressed portfolio selection. They also established that for the purpose of portfolio selection multi-objective optimization was used in most cases (72 percent). Steuer and Na [76] also considered portfolio analysis to be the prevailing research field in the period before 2002. The popularity of portfolio optimization can be explained by a number of reasons. It is a multifaceted problem that presents a number of algorithmic and modeling challenges (e.g., dynamic nature, data of various types, risk modeling, *etc.*). Most multi-objective optimization and goal programming models used for the purpose of portfolio optimization are based on the combination of multiple risk measures (e.g., skewness/kurtosis, value-at-risk measures, *etc.*), usually with further consideration of some additional goals and objectives (e.g., liquidity, dividends, *etc.*). For that matter, evolutionary algorithms (EA) and metaheuristics (MH) have also been very popular, especially with regard to non-convex portfolio selection criteria and models or when additional real features, such as cardinality constraints, are used in the analysis [75,77].

Given that multi-objective optimization is most commonly used for solving a portfolio selection problem [75], a short overview of multi-objective optimization is presented below. Multi-objective optimization (also known as multi-objective programming, vector optimization, multicriteria optimization, multiattribute optimization or Pareto optimization) is an area of dealing with a mathematical optimization problem where more than one objective function has to be optimized simultaneously. In the case of multi-objective optimization with conflicting objective functions, a set of Pareto optimal solutions is derived rather than one optimal solution because none of these solutions can be regarded as being better than any other with respect to all objective functions.

A multi-objective optimization problem can be defined as follows [41]:

$$\text{optimize } F(x) = [f_1(x), \ldots, f_k(x)] \tag{1}$$

Subject to:

$$x \in X$$

where $x = (x_1, \ldots, x_n)$ is the vector of decision variables and X is the set of feasible solutions. The objective function vector $F(x)$ which contains the values of k objectives maps the feasible set X into the set F which presents all possible values of the objective function. The objective functions may all be maximized, minimized or be in a mixed form. The usual process in multi-objective optimization is to find all non-dominated or Pareto optimal solutions of the problem.

Since all the Pareto optimal solutions are equally good from a mathematical point of view, they can be regarded as equally valid compromise solutions of the problem. Thus, there is no trivial mathematical tool in order to find the best solution in the Pareto optimal set because vectors cannot be ordered completely. For this reason some additional information is required in the decision-making process. Decision-making can take place before or during the multi-objective optimization process. Usually, a human decision-maker is necessary to make tough trade-offs between conflicting objectives as the decision-maker is considered to have a better insight into the problem and can therefore express preference relations between different solutions. Thus, for example, it can be useful for the decision-maker to know the ranges of the objective function values (ideal and nadir points) in the Pareto optimal set. The decision-maker can participate in the solution process, and, in some way, determine which of the obtained Pareto optimal solutions is the most suitable as the final solution.

Depending on the participation of the decision-maker in the problem-solving process, methods are classified as follows [78–80].

- No-Preference Methods (without the presence of a decision-maker)
- Posteriori Methods
- Priori Methods
- Interactive Methods

In no-preference methods, no input from the decision-maker concerning the importance of criteria is used, which results in one Pareto optimal solution. When using posteriori methods (also called Methods for Generating Pareto Optimal Solutions), a set of Pareto optimal solutions is derived, which is presented to the decision-maker who then chooses the most satisfying solution. In priori methods, the decision-maker has to indicate his priorities and objectives before the solution process [81]. If the obtained solution satisfies the decision-maker's requirements, the decision-maker does not have to spend much time for the solution process. However, the problem is that the decision-maker does not necessarily know before the solution process what outcome he could expect and how viable his goals are. As a consequence, when the decision-maker is not satisfied with the solution, he has to change priorities and adjust his goals. Thus, it is very important to involve all stakeholders in decision-making from the outset so as to reach consensus on priorities and targets and thereby avoid their frequent adjustments [81]. In interactive methods, the decision-maker takes active part in the problem-solving process. The specificity of these methods is that, owing to the complexity of the problem concerned, the decision-maker cannot properly identify priorities and goals before the solution process. However, the decision-maker can adjust his priorities and goals during the solution process as the solution process is interactive. Interactive methods are most time-consuming for the decision-maker, as compared to the other methods, yet, they allow solving complex problems with multiple criteria and constraints [82].

The above-given concise overview of the classical portfolio evolution suggests that scholars more and more often conclude that it would be appropriate to include, in addition to return and risk, additional parameters (one of which is social responsibility, or sustainability) in a portfolio selection and resource allocation problem and that the inclusion of new variables in the traditional model has been made possible by multi-criteria decision-making theory.

3.2. Development of a Sustainability-Oriented Model of Financial Resource Allocation in a Project Portfolio

3.2.1. Markowitz's Mean-Variance Model

Markowitz (1952) formulated the portfolio optimization problem by applying two criteria, namely expected return and risk. As a risk measure, the model uses variance (or standard deviation) to quantify the variability of the return [77].

The mean-variance model can be put down as an optimization problem with one objective function (minimizing a portfolio's expected risk) and one constraint (return should be not less than a certain fixed value, e.g., R_{min}):

$$min \sum_{i=1}^{n} \sum_{j=1}^{n} x_i x_j \sigma_{ij}, \quad (2)$$

subject to

$$\sum_{i=1}^{n} R_i x_i \geqslant R_{min},$$
$$\sum_{i=1}^{n} x_i = 1,$$
$$x_i \geqslant 0,\ i = 1, \ldots, n.$$

Alternatively, the maximum level of acceptable risk of a portfolio, e.g., σ_{max}, could be set (one constraint), and a portfolio's expected return maximized (objective function):

$$max \sum_{i=1}^{n} x_i R_i, \quad (3)$$

subject to

$$\sum_{i=1}^{n} \sum_{j=1}^{n} x_i x_j \sigma_{ij} \leqslant \sigma_{max},$$
$$\sum_{i=1}^{n} x_i = 1,$$
$$x_i \geqslant 0,\ i = 1, \ldots, n.$$

Therefore, it is sufficient to understand that return and standard deviations (or variance) can be used in developing an optimal project portfolio [36]. Both expected return and risk are usually calculated on the basis of historical data. Expected return is calculated using the arithmetic mean of returns, whereas risk is calculated using standard deviations or variances of returns for previous periods.

Based on Markowitz's theory, where the projected profitability (return) on financial instrument *i* is $E_i R_i$, and the amount of investment allocated to this instrument is x_i, then the projected return on a portfolio is as follows:

$$ER_p = \sum_{i=1}^{n} x_i E_i R_i, \quad (4)$$

where

$$\sum_{i=1}^{n} x_i = 1.$$

However, in practice, a simple formula is used to calculate the total return on a security because the assessment of the expected return on a security is rather complicated [40]. On the assumption that an investor gains from the buy–sell spread, the return on a security can be calculated as the average of daily, weekly, monthly or annual returns [83]:

$$R_i = \frac{1}{n} \sum_{i=1}^{n} \frac{V_1 - V_0}{V_o}, \quad (5)$$

where

R_i = average return on a security i;
V_1 = selling price of a security;
V_0 = buying price of a security; and
n = number of periods analyzed.

Based on Formula (5), and on the assumption that the project return is the difference between profit and investment [84], the return of a project will be calculated as the average of project returns in different scenarios (given the absence of historical data, scenarios of a project are used):

$$R_i = \frac{1}{n}\sum\nolimits_{i=1}^{n} \frac{G-I}{I}, \tag{6}$$

where:

R_i = average return on a project i;
G = gain from investment;
I = cost of investment; and
n = number of scenarios analyzed.

where the projected return on project i is R_i, and the amount of financial resources allocated to this project is x_i, then the projected return on a project portfolio is as follows:

$$R = \sum\nolimits_{i=1}^{n} x_i R_i. \tag{7}$$

As already mentioned above, the degree of risk of a financial instrument may be expressed by variance, or standard deviation. The variance of a financial instrument is calculated according to the following formula:

$$\sigma^2 = \sum\nolimits_{i=1}^{t} P_t (R_t - E_i R_i)^2, \tag{8}$$

where

R_t = return on a financial instrument for period t;
$E_i R_i$ = average projected return on a financial instrument; and
P_t = probability of return for period t.

Standard deviation shows the average deviation of a financial instrument's return from the mean of the sample in terms of the same measures. A standard deviation is calculated by using the following formula:

$$\sigma = \sqrt{\sigma 2}. \tag{9}$$

It should be noted that under Markowitz's model risk is measured by variance which assesses distribution on either side of the mean. However, in practice, investors are more concerned with deviations to the negative side of the mean [29,41,84,85]. Thus, Markowitz proposed another risk measure, namely semi-variance, which assesses only a decline in profitability around the mean, *i.e.*, it is calculated similarly to variance but only below-mean values are included. Markowitz proposed two statistics for a risk measure: below-mean semi-variance and below-target semi-variance. Quite a few authors use semi-deviation or semi-variance below the mean as a risk measure (downside risk) in portfolio selection [29,39,51,84–88]. However, given that semi-variance is difficult to calculate [89], we, like many other authors [41,44,52,54,90], use variance in our work.

The formula for the variance of the return of a project is as follows

$$V_i = \frac{1}{n}\sum\nolimits_{i=1}^{n} (R_{ij} - R_i)^2, \tag{10}$$

where

V_i = variance of the return of a project i;
n = number of scenarios;
R_{ij} = return on project i in scenario j; and
R_i = average return on project i

When selecting a portfolio and allocating resources, it is important to understand how the risks of different projects interact. In financial markets, the key determinant of the risk of a portfolio is the extent to which the returns vary either together or in the opposite direction. Risk depends on the correlation between returns on different securities in the portfolio. Projects implemented by a particular company are, for the most part, closely interrelated, so a portfolio in principle cannot be qualitatively diversified [38]. Thus, we, like many other authors [39,91–93], do not consider the correlation between projects in this paper.

3.2.2. A Composite Sustainability Index of a Project

In our previous research [27], we proposed a method to measure the sustainability of a business project in the construction industry. We developed a composite sustainability index of a project (CSIP) which is calculated as follows:

$$CSIP = \sum_{i=1}^{m} \omega_i I_i, \quad (11)$$

where

$CSIP$ = a composite sustainability index of a project;
ω_i = the weight of sustainability indicator i; and
I_i = the normalized value of sustainability indicator i;

$$0 \leqslant CSIP \leqslant 1.$$

The value of an index ranges between 0 and 1. A higher value means a higher level of sustainability of a project. The methodology for constructing a composite sustainability index can be found in Dobrovolskiene and Tamosiuniene [27]. It should be noted that only 15 sustainability criteria, comprising four economic, five social and six environmental criteria, were selected as being important for practitioners in the construction industry.

3.2.3. A Sustainability-Oriented Model of Financial Resource Allocation in a Project Portfolio

In this section, a sustainability-oriented model of financial resource allocation in a project portfolio is described. Based on the ways of integrating sustainability into the portfolio theory proposed by Peylo [67] (Figure 2), we chose the third option, namely the integration of sustainability as an additional criterion into a three-objective portfolio optimization

Assumptions and constraints of the model are provided below:

- There is a set of projects competing only for financial resources.
- The available financial resources are lower than the total amount of funds needed for all the projects.
- The maximum value of funds to be assigned to a project is defined.
- A funding decision is taken only once in a given period of time.
- All the projects are scheduled to start at the same time.
- The interdependence of projects is not assessed.
- Projects are not broken down into a set of activities or tasks.

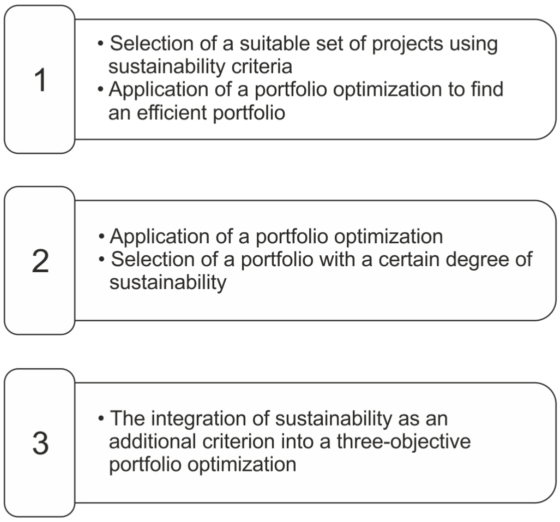

Figure 2. Ways of integrating sustainability into the classical portfolio theory.

A sustainability-oriented model of financial resource allocation in a project portfolio is formulated as follows:

Model:
Objective 1:

$$\max R = \sum_{i=1}^{n} x_i R_i, \tag{12}$$

Objective 2:

$$\min V = \sum_{i=1}^{n} x_i^2 V_i, \tag{13}$$

Objective 3:

$$\max S = \sum_{i=1}^{n} x_i S_i, \tag{14}$$

subject to

$$\forall i\ 0 \leqslant x_i \leqslant 0,2,$$

$$\sum_{i=1}^{n} x_i = 1.$$

where Objective 1 is maximization of the expected return of a portfolio; Objective 2 is minimization of the risk of a portfolio; Objective 3 is maximization of the sustainability of a portfolio; x_i is a fraction of financial resources invested in project i; R_i is the expected return of project i; V_i is the variance of the return of project i; and S_i is a sustainability index of project i, where $S_i = CSIP$ (Formula (11)).

A portfolio is called efficient if it is not dominated by another portfolio (*i.e.*, if there is no other portfolio with the same or better values of all three objectives). Efficient portfolios form a two-dimensional surface in three-dimensional space (Return (R), Variance (V), and Sustainability (S)), which is called the efficient surface of the model. It can be easily drawn if a sufficient number of points (corresponding to some set of efficient portfolios) are known. For practical purposes, however, it is preferable to arrange these portfolios according to two parameters with some simple meaning. Below we use parameters α and β with possible values in [0,1], and the corresponding portfolio is the one which minimizes the following convex combination of V, R and S:

$$min\,(1-\alpha)\,(1-\beta)\,V - (1-\alpha)\,\beta R - \alpha S \tag{15}$$

Parameter α is used to account for the sustainability of a portfolio: its greater values produce portfolios with greater values of S. The value $\alpha = 1$ should be chosen if we are interested only in S, while the other extreme value $\alpha = 0$ corresponds to the situation where we are not concerned with S at all. If $\alpha < 1$ is fixed, parameter β allows us to allocate preferable weights to R and V. Greater values of β produce portfolios with greater expected return, at the expense of risk.

These two parameters (α and β) provide flexibility for decision-makers. Decision makers should demonstrate preferences regarding sustainability, return and risk.

4. Results and Discussion

In order to test the applicability of the model, an experiment was carried out in a construction company having over 25 years of experience in building completion and finishing. Since the company did not want to disclose confidential information about itself and its ongoing projects, only limited information is provided, more specifically, financial and sustainability indicators of 20 projects (see Table 2). The return of each project was calculated in accordance with Formula (6), the risk of a project was calculated according to Formula (10), and the sustainability of a project was estimated using Formula (11).

Table 2. Project data.

Project Code	Return	Risk	Sustainability Index
P1	0.4519	0.0526	0.6700
P2	0.5435	0.0880	0.5700
P3	0.5848	0.0942	0.6600
P4	0.4413	0.0433	0.3300
P5	0.3932	0.0633	0.7400
P6	0.3640	0.0680	0.4500
P7	0.4907	0.0342	0.3300
P8	0.3912	0.0383	0.3900
P9	0.5420	0.0582	0.6500
P10	0.3718	0.0467	0.6400
P11	0.4821	0.0562	0.6700
P12	0.3511	0.1344	0.5700
P13	0.5833	0.0785	0.5600
P14	0.4614	0.0452	0.3700
P15	0.4555	0.1889	0.7200
P16	0.3910	0.0347	0.4500
P17	0.5304	0.0266	0.5500
P18	0.5909	0.0411	0.5900
P19	0.5416	0.0531	0.6100
P20	0.4707	0.1128	0.6500

When testing the model, 11 levels of α and β were analyzed (starting from 0%, going up by 10% up to 100%). The analysis covered all combinations of α and β. For moderate sizes of n, effective portfolios which minimize convex combination $(1-\alpha)(1-\beta)V - (1-\alpha)\beta R - \alpha S$, can be easily found using any computer program for quadratic programming. We used R [94], an open source environment for statistical computing, namely the packages quadprog [95] and lpSolve [96] (the latter only for the case $\beta = 1$). The calculations of 111 effective portfolios in the case $n = 20$ took less than a second. The results are presented in Table S1. Out of all possible portfolio combinations, the decision-maker may select a project portfolio that would reflect his preferences regarding sustainability, return and risk, and allocate financial resources among projects in the portfolio.

The aim of this article was not only to propose a sustainability-oriented model of financial resource allocation in a project portfolio but also to determine the impact of the integration of sustainability into the model on a portfolio's return. The existing literature examining the relationship between sustainability and a portfolio's financial return is undecided. Most studies compare the financial performance of socially responsible investment (SRI) portfolios with that of traditional portfolios [51,54,58,60,66,68,97]. Bilbao-Terol *et al.* [60] showed that investor's attitudes towards risks affect the loss of return which is conditioned by choosing SRIs. The results of the study by Ballestero *et al.* [60] suggested that ethical investments entail higher risk exposure. In their study, Bilbao-Terol *et al.* [62] found that the financial penalties associated with SRIs are quite minor for higher risk-averse investors. Utz *et al.* [66] revealed no support for lower financial performance or higher risk exposures of SRI funds. What is more, they also concluded that SRI funds do not demonstrate higher social responsibility scores compared to their conventional counterparts. Trenado *et al.* [51] reached the conclusion that the inclusion of the sustainability goal has a very moderate negative effect on the achievement of financial goals and a slight positive effect on the achievement of the sustainability goal. Moreover, with the inclusion of the sustainability goal, the structure of portfolios changes. The entirely opposite results were obtained by Peylo and Schaltegger [68] and Gasser *et al.* [54]. Peylo and Schaltegger [68] investigated whether and to what extent different levels of sustainability in stock portfolios impact investment return when other factors with known influence on investment performance are neutralized. Their findings showed a clear nonlinear relationship between sustainability and investment performance. Up to a turning point, the increase in portfolio sustainability contributes to financial performance, whereas a further increase leads to a decrease in financial performance, although even in the case of high portfolio sustainability it is still possible to remain above the benchmark. On the other hand, Gasser *et al.* [54] found that when investors choose to achieve the highest social impact of their investment they actually experience a statistically significant decrease in expected returns. However, the social responsibility/risk-optimal portfolio results in a statistically significant higher social responsibility rating than the return/risk-optimal portfolio [54].

In order to analyze the relationship between sustainability and project portfolio return, a statistical analysis was carried out using IBM SPSS Statistics 22 (Version 22.0., IBM Corp., Armonk, NY, USA). Data of 111 obtained portfolios were analyzed. Research revealed that there is a statistically significant, strong linear correlation between sustainability (α) and portfolio return (see Table 3). The incorporation of sustainability into resource allocation has a negative impact on the return of a portfolio. The higher the parameter α is (consequently, the sustainability of the portfolio is also higher), the lower the return of the portfolio will become.

Table 3. Correlation between sustainability and portfolio return.

		α	Return of Portfolio
α	Pearson Correlation	1	−0.743 **
	Sig. (2-tailed)	-	0.000
	N	111	111
Return of portfolio	Pearson Correlation	−0.743 **	1
	Sig. (2-tailed)	0.000	-
	N	111	111

** Correlation is significant at the 0.01 level (2-tailed).

Simultaneously, three project portfolios were chosen to demonstrate the impact of the incorporation of sustainability on the structure of a portfolio. The first portfolio (sustainable portfolio) $\alpha = 1$, where neither return nor risk is taken into account. The second portfolio (balanced portfolio) $\alpha = 0.5$, $\beta = 0.5$, where equal weight is given to risk and return. The third portfolio (financial portfolio) $\alpha = 0$, $\beta = 0.5$, where sustainability is disregarded while risk and return are given equal weight. The results are presented in Table 4.

Table 4. Portfolio data.

Project Code	Financial Portfolio	Balanced Portfolio	Sustainable Portfolio
	$\alpha = 0; \beta = 0.5$	$\alpha = 0.5; \beta = 0.5$	$\alpha = 1; \beta = 0.5$
P1		0.1244	0.2000
P2	0.0505		
P3	0.0673	0.1024	0.2000
P4			
P5		0.1872	0.2000
P6			
P7	0.1090		
P8			
P9	0.1133	0.1759	
P10			
P11	0.0266	0.1571	0.2000
P12			
P13	0.0957		
P14			
P15		0.0242	0.2000
P16			
P17	0.2000		
P18	0.2000	0.1415	
P19	0.1354	0.0685	
P20	0.0021	0.0188	
Return of portfolio	0.5490	0.5014	0.4735
Risk of portfolio	0.0180	0.0231	0.0467
Sustainability of portfolio	0.5663	0.6640	0.6920

Our research produced results which are very similar to those obtained by Trenado *et al.* [51] and Utz *et al.* [66]. As could have been expected, the integration of sustainability considerations alters the structure of a project portfolio and values of different criteria (portfolio return, portfolio risk and portfolio sustainability).

For further research, we propose the following areas:

- extend the model to a planning-horizon version where resources are allocated over multiple funding periods;
- assess the interdependence of projects;
- incorporate scheduling; and
- use semi-variance or semi-deviation instead of variance.

5. Conclusions

In this paper, a sustainability-oriented model of financial resource allocation in a project portfolio was presented. In order to find non-dominated portfolios, multi-objective optimization was applied. The model optimizes three objective functions, namely expected return, variance and sustainability, and provides the decision-maker with a set of effective portfolios from which he can make his final choice. As is evident from the review of existing literature, this has not been attempted. Consequently, there was no model to compare the results of our proposed model with. The proposed model was applied in a real construction company in Lithuania. Effective portfolios were found using R, an open source environment for statistical computing.

The use of the model would allow decision-makers to decide on their optimal portfolio taking into account their respective preference with regard to return, risk and sustainability, *i.e.*, they should decide what projects to finance and execute (e.g., those providing the greatest business value with the acceptable level of sustainability, or those providing the greatest value of sustainability with acceptable level of return). The model is therefore a suitable tool for most decision-makers to express their individual preference. In light of the increasing understanding that it is not an option to be guided merely by an economic—often self-interest—logic, leaders of organizations could use this model in allocating financial resources to sustainable projects, thus contributing to the sustainable development of companies.

The proposed financial resource allocation model is designed to allocate financial resources in a project portfolio in construction companies. However, subject to certain modifications (*i.e.*, substituting the proposed composite sustainability index of a project which is intended to assess the level of sustainability of a construction project with another index for measuring the sustainability of a project in any other economic sector), this model could be used in allocating financial resources in companies operating in different economic sectors.

The aim of this article was not only to propose a sustainability-oriented model of financial resource allocation in a project portfolio but also to determine the impact of the integration of sustainability into the model on a portfolio's return. In order to analyze the relationship between sustainability and portfolio return, a statistical analysis was carried out using IBM SPSS Statistics 22. Research revealed that there is a statistically significant, strong linear correlation between sustainability and portfolio return. Moreover, the integration of sustainability into the model affects not only the return and risk of a portfolio but also the structure of a portfolio.

This research can be expanded in several different directions. Firstly, with a view to selecting the best portfolio option the interrelation between projects should be taken into consideration. Secondly, in order to ensure the optimized use of resources, scheduling would be required. Extending the model to a planning-horizon version where resources are allocated over multiple funding periods would be of interest, same as the inclusion of other risk measures in the model (e.g., semi-variance or semi-deviation). Furthermore, additional tests of the model could be run in other companies in the same sector, or in another sector altogether. A higher number of tests would allow drawing more reliable conclusions with regard to the impact of sustainability on the return of a project portfolio.

Supplementary Materials: The following are available online at www.mdpi.com/2071-1050/8/5/485/s1, Table S1: Optimal portfolios.

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Abbreviations

The following abbreviations are used in this manuscript:

BSC	balanced scorecard
DEA	data envelopment analysis
EA	evolutionary algorithms
MH	metaheuristics
MCDM	multiple-criteria decision-making
MADM	Multiple-Attribute Decision-Making
MODM	Multi-Objective Decision-Making
SRI	socially responsible investment

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