



Project Portfolio Selection from a Priority Ranking with Synergic Effects

Abstract

In this paper, a good portfolio is found through an ant colony algorithm (including a local search) that approximates the Pareto front regarding some kind of project categorization, cardinalities, synergy, discrepancies with priorities given by the ranking, and the average rank of supported projects; this approach is an improvement that includes synergy in the preferences model. The available information is only projects' ranking and costs, a list of projects that are in synergy and usually, resource allocation follows the ranking priorities until they are depleted. The results show that our proposal obtains good results for different types of decision makers such as: conservative, strict or relaxed.

Introduction

Project portfolio optimization is one of the most important strategic-decision problems faced by any organization. The construction of the best portfolio that accomplishes a certain balance among the selected projects can be defined as follows:

$$\max_{x \in R_F} \left\{ \left\langle z_1(x), z_2(x), \dots, z_p(x) \right\rangle \right\} \quad (1)$$

where R_F is the space of feasible portfolios, and $z(x) = \langle z_1(x), z_2(x), \dots, z_p(x) \rangle$ represents the functions z_i that characterize the impact of a portfolio x over the considered criteria.

Although typical, Problem (1) is not the unique way in which decision makers (DMs) are concerned with project portfolio selection. Several papers (Fernandez 2009, Fernandez 2013, Bastiani 2015 and Fernandez 2017) have approached a problem with a distinctive feature, which is that the only information available about the projects is their rank, (they are ordered according to the DM's preferences) and their budgetary requirements. This situation is related to the fact that sometimes a DM may i) prefer simpler decision methods; ii) agree easily on a priority ranking, or when the DM is a complex collective entity for which is very hard to evaluate the project objectives and to solve a multi-criteria optimization problem like (1).

Bastiani et al. (2015) y Fernández et al. (2017) proposed an optimization approach based on maximizing the cardinality and minimizing the discrepancies in a portfolio; *cardinality* refers to the total number of supported projects; the term *discrepancy* is a concept that reflects the negative effect that is applied over the DM's thinking because one of the projects, when it is compared against others, seems to have merits that belong to the portfolio but it is not in it.

Synergic effects in subsets of projects are not considered by the works from Bastiani et al. (2015) and Fernández et al. (2017), what is perhaps their most important limitation. The purpose of this contribution is in incorporating synergy in the proposal of Fernández et al. (2017). Synergy is related to the existence of complex interdependencies among projects. They compete for resources, but some can share them, becoming more advantageous when they are supported together. Likewise, it is very common for synergy to be manifested in subsets of projects and that, therefore, the combined contribution of them to the impact of the portfolio is greater than the sum of their separate contributions. We propose here to use a strategy based on creating artificial projects that represent synergic coalitions, with their own budgetary requirements (usually less than the sum of their components), and their specific rank (better than the rank of their component projects). Such strategy would need a re-definition of the objectives in the

optimization problem. The objectives related to discrepancies may keep their original meaning, but those related to cardinality should be modified through some way to take into account the impact increased by synergy.

Materials and Methods

In the literature the sub-problem of synergy has been approached from different approaches of solution. In this work, the works of: in Liesio et al. [Liesio et al., 2008], proposes a strategy through the creation of artificial projects that represent synergistic coalitions, with their own levels of inputs and benefits, in addition, in Carazo et al. [Carazo et al., 2010], a modification is proposed in the optimization model where those functions responsible for the calculation of costs and objectives are modified to consider the impact of the synergy.

In this work, each of the projects compete for resources, but when synergy is included, two or more projects are combined, and now the resources are assigned to the set of projects. The synergy can be positive, that is, when two or more projects are combined that combination can provide more benefit, we also have the case of negative synergy or cannibalization that is when a group of projects provides a lower than expected profit when they were independent projects [Rivera, 2015].

For the solution of the sub-problem of synergy, modeling inspired by the aforementioned works of literature was proposed. To accomplish this, a modification was made to the objective function of Problem 1 as shown below in Problem 2.

$$\text{Optimize } \left\{ \left\langle N_1, n_{wd1}, n_{sd1}, N_2, n_{wd2}, n_{sd2}, N_3, n_{wd3}, n_{sd3}, P, S_1, S_2, S_3 \right\rangle \right\}, \quad (2)$$

$C \in R_P$.

Where N_1, \dots, N_3 , is the cardinality of each category, $n_{wd1}, n_{sd1}, \dots, n_{sd3}$, are the discrepancies of the portfolio by category and S_1, S_2, S_3 , represent the number of synergistic projects that are within the portfolio under evaluation by category.

In the initial process, the portfolio starts with a set of projects known as the C_{ref} reference portfolio, this portfolio contains each of the projects individually. When synergy is included, artificial projects will be generated, which are those that are combined in more than two projects in a set and will be added to the end of the list of original projects. Next, the methodology for forming artificial projects is presented:

1. Of the total projects, 10% of the projects will be randomly selected.
2. Of the 10% of projects selected in step 1, up to four projects are selected with which all possible combinations will be made without repetition and in a random manner.
3. From the set of combinations generated in step 2, 25% of the total combinations made will be selected, as shown in Table 1.

Table 1. Example of creation of synergistic combinations

Projects in synergy: 10, 12, 25, 32, 37, 51, 59, 66, 72, 79
Combinations = {(32 51 25), (25 72), (37 66 10 25), (59 25 72), (37 66 10), (32 37 66 10), (37 59 51), (66 59 51 10), (37 66 79 59), (32 37)}

Next, the ACO-SOP algorithm with the indicated modification is shown.

Algorithm 1. ACO-SOP () with synergy

Input: P_r, B, tot_iter, n_a

1. Construct an initial portfolio C_{ref} with synergy
2. Initialize $Iter=0$, pheromone matrix and $NS=\emptyset$

Output: The new set of portfolios NS

Begin PROCEDURE

3. Repeat
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4. Initialize $S_F = \emptyset$
 5. Generate Feasible Solutions S_F with synergy (According to Total budget)
 6. Perform local search to the set S_F
 7. Calculate objective functions of Problem 2 on the set S_F
 8. Calculate objective functions of Problem 2 on the set S_F
 9. Generate non-dominated fronts on S_F (considering the objectives of Problem 2)
 10. Updating the pheromone matrix with the set F_0
 11. Assign $NS = NS \cup F_0$
 12. **until** ($iter=tot_iter$)
 13. Generate non-dominated fronts on NS (considering the objectives of Problem 2)
- End PROCEDURE**

Results and Discussion

In order to continue the improvement in the set of final solutions, it was proposed to explore a sub-problem such as synergy. To carry out the experimentation with the ACO-SOP algorithm with synergy, an experiment was designed with the aim of solving the instances by applying the quality means. After having carried out the experiment, the results were obtained in 110 seconds. Once the parameters were configured and the objective function of Problem 2 modified, the generation of the set of final solutions is given, which are shown in Table 2 and 3 in terms of decision space and objectives.

Table 2. solutions in the decision space

<i>Solutions</i>	<i>Assignment</i>															
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
<i>ACO-SOP₁</i>	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
<i>ACO-SOP₂</i>	1	1	1	1	1	1	1	1	1	1	1	0	1	1	1	1
<i>ACO-SOP₃</i>	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
<i>Solución</i>	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32
<i>ACO-SOP₁</i>	1	1	0	1	0	1	0	0	1	1	1	1	1	1	0	0
<i>ACO-SOP₂</i>	1	1	0	1	0	0	0	0	1	1	1	1	1	1	1	1
<i>ACO-SOP₃</i>	0	0	0	1	0	0	0	0	1	1	1	1	1	1	1	1
<i>Solución</i>	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47-100	
<i>ACO-SOP₁</i>	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	
<i>ACO-SOP₂</i>	1	1	1	1	1	1	1	0	0	0	0	0	0	0	0	
<i>ACO-SOP₃</i>	1	1	1	1	1	1	1	0	1	0	0	1	0	1	0	

Table 3. Solutions in the objectives space

<i>Solutions</i>	<i>Priority category</i>				<i>Satisfactory category</i>				<i>Acceptable category</i>				<i>P</i>	<i>Card(C)</i>
	<i>N₁</i>	<i>n_{wd1}</i>	<i>n_{sd1}</i>	<i>S₁</i>	<i>N₂</i>	<i>n_{wd2}</i>	<i>n_{sd2}</i>	<i>S₂</i>	<i>N₃</i>	<i>n_{wd2}</i>	<i>n_{sd2}</i>	<i>S₃</i>		
<i>ACO-SOP₁</i>	27	2	0		1	0	0	0	0	0	0		85.10	28
<i>ACO-SOP₂</i>	27	4	0	3	6	0	0	0	0	0	0	0	81.03	33
<i>ACO-SOP₃</i>	26	3	2	3	9	0	0	1	0	0	0	1	79.08	39

Tables 2 and 3 show non-dominated solutions (ACO-SOP1, ACO-SOP2 and ACO-SOP3) obtained through the ACO-SOP algorithm with synergy in the space of objectives and projects, respectively.

It can be seen in Table 3 that the ACO-SOP₃ solution is a candidate to be chosen as one of the best compromise solutions, since it has the greatest number of projects in synergy and cardinality. Note that in the priority category the number of synergistic projects is high ($S_1 = 4$) and under the number of weak discrepancies ($n_{wd1} = 3$). Therefore, a DM inclined to have a large number of projects in synergy in the portfolio with the least number of possible discrepancies would select ACO-SOP₃. Comparing the ACO-SOP₃ solution with ACO-SOP₁ in terms of the total number of synergistic projects, it is observed that the latter reports only 3 projects in synergy and two weak discrepancies in the n_{wd1} objective. Therefore, ACO-SOP₃ outperforms ACO-SOP₁ in the total number of projects within the portfolio and in the number of projects in synergy.

As we can see in Table 3, the ACO-SOP₂ solution obtains 5 synergistic projects within the portfolio, an acceptable number of projects within the portfolio ($Card(C)=33$), however, it has 4 weak discrepancies. Therefore, a decision maker inclined to have a large number of projects in the portfolio with the least number of possible discrepancies would select ACO-SOP₃. After having performed the analysis of the results presented in Tables 2 and 3, it was determined that the best solution, with respect to the considered attitudes of a decision maker is: ACO-SPO₃. However, there are other attitudes of a decision maker that would lead to selecting different solutions (eg. ACO-SOP₂). These results were consistently generated in 28 of 30 runs.

Conclusions

In this work, a support system of knowledge-based decisions was proposed for the problem of portfolio selection in a set of ordered projects which include projects in synergy. This problem usually has a lack of available information, so the incorporation of knowledge mechanisms in their solution strategies can improve the quality of their solutions. This work is a crucial refinement from a recent proposal that models the attitude of a decision maker through a problem of multi-objective optimization. Its high dimension is a major concern for meta-heuristic approaches to generate an acceptable approach to the Pareto border. Here we have presented a method that incorporates projects in synergy to be evaluated by the decision maker through a diffuse preferences model. One advantage of the proposal is that it is very robust with respect to a growing number of objective functions. This is important in order to make a finer representation of the preferences of the decision maker, since it includes the synergistic effects in the projects. Therefore, this contribution should be significant in this field of portfolio optimization.

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