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A method for project portfolio risk assessment considering risk interdependencies – a network perspective

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Abstract

Project portfolios represent the bridge between projects and strategy. However, the final results may not be as expected because materialization of risk factors. Hence, literature has acknowledged project portfolio risk assessment as an element of the project portfolio risk management, being the element that provides information on the importance of risk factors. For that, some specific characteristics should be considered, such as risk interdependency influence and the risk factors impact over portfolio higher levels. Thus, this study is focused on the development of a method for project portfolio risk assessment that considers both risk factor interdependencies and their impact on the strategic objectives as a network. In addition, the method also allows incorporating both risk factors derived from projects and derived at project portfolio level. A representative example is provided to illustrate the proposed method.

Keywords: Project portfolio; risk assessment; risk factors; network theory

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1. Introduction

A project portfolio is "a collection of projects, programs, subsidiary portfolios, and operations managed as a group to achieve strategic objectives" [1, p. 3]. Consequently, Project Portfolio Management (PPM) represents coordinated management of a set of projects carried out by a specific organization, which allows strategic management of the projects. PPM help to create a decision-making process that adds value to the organization, guiding the portfolio to achieve strategic benefits. In fact, PPM is a central mechanism to implement successfully the strategy [2–5]. Thus, the importance of PPM lies in its impact on the achievement of competitive advantages for the organization, and it is considered a strategic weapon that represents the investment priorities of the organization to achieve its strategic objectives [4,6,7].

The effect of risk management at the project level has been studied, evidencing positive impacts on the success of each individual project [8], however, managing risks only at the level of projects is not enough because a strategic view of the project portfolio is not considered. In this regard, the literature in the field of risk management has progressively evolved from project risk analysis to Project Portfolio Risk (PPR) analysis [9,10]. A project portfolio for which the risks are analyzed, evaluated, and distributed across several projects, has a better probability of success [11,12].

Project Portfolio Risk Assessment (PPRA), like PPR identification and PPR response, is an element of project portfolio Risk Management. PPRA is oriented to providing information on the importance of risks and risk trends, among other factors, in support of risk response decisions [1]. In this concern, the PPRA must allow to identify, qualify, and quantify the effects of risk factors. It would generate greater approximations to reality, giving the decision-makers a systemic and dynamic project portfolio view. PPRA would allow focusing efforts and resources on the factors that are relevant, and that are representative of the project portfolio execution [13,14].

Among others, the literature highlighted two components which should be considered as part of risk assessment from a project portfolio perspective. On one hand, the risk impact assessment over higher levels such as portfolio level or strategic objectives level [1,10,14]. On the other hand, risk interdependencies qualification and quantification [10,13,15]. Therefore, this research deepens in these two components; and proposes a method for PPRA considering impacts on strategic objectives and risk factors interdependencies. Therefore, in this study risk was conceptualized with a set of outcomes with known probability [16], which can represent impacts on the results expected [17]. Risk factors were considered as the different variables that influence or generate, directly or indirectly, exposure [18,19], or in other words, the variables that impact the risk of the project portfolio.

The remainder of the paper is organized as follows. Firstly, the PPRA background is presented; whereupon, based on network theory and the concept of systemic and non-systemic risk derived from Modern Portfolio Theory, the method proposed is addressed and described. This is followed by an illustrative example of the method application. Finally, conclusions and suggestions for future research are summarized.

2. Risk assessment from a project portfolio perspective

Considering the financial impact of the project portfolio on the organization, some approaches for PPRA have been proposed. In this regard, Costa et al. [20] suggest that not all the risk factors have the same weight in the PPR quantification of IT project portfolios. For this reason, they used expert judgment through pairwise comparison to estimate the influence of each risk factor on the portfolio and they used credit risk theory and Montecarlo simulation to estimate the probability distribution of portfolio earnings and losses. Also for IT project portfolios, Peters and Verhoef [16] propose a method to evaluate the risk effects in the project portfolio execution phase, and define a methodology to evaluate this impact on the net present value of each project and the whole project portfolio.

In addition to the risk measure based on monetary units, other proposals have integrated some attributes such as interdependencies between projects and interdependencies between risks. For example, to evaluate the impact of the interaction between projects on PPR, Guan et al. [11] describe an approach based on set theory and Bayesian networks. Cooley et al. [21] used the risk dependencies quantification approach to allow a systemic analysis of the impact that the risk factors could generate on the portfolio; however, the high amount of historical data necessary to obtain reliable information represent the main weakness of this proposal [21].

Another approach is proposed by Bolos et al. [22], which, based on structural funds of European Union Member States environment, developed an indicator for monetary loss risk. The indicator is structured with statistical measures, such as mean, standard deviation and covariance of the monetary expected values, and it is the result of the integration of the monetary loss probability derivative of delays in the execution of each project. In this case the duration of the projects represents the incorporation of operational measures associated to the projects within the project portfolio.

From another perspective, also considering risk interdependencies or dependencies between projects, but based exclusively on impacts on project operational measures more than on financial measures, other approaches have been proposed. In this regard, under a project interdependencies perspective, Neumeier et al. [23] highlight that Bayesian networks is an approach that has been widely used to assess cascading effects on other research fields and they suggest that technical and resources dependencies can be assessed through a transitive dependencies model based on Bayesian networks. Thus, a Bayesian network approach is proposed for critical analysis in IT project portfolios context, using the failure cost impact of each project on the entire portfolio, and identifying the critical projects of the portfolio, given the cascading effect that each project can generate on the success or failure of other projects. Also, in the IT project portfolios context, Wang et al. [15] propose that a project portfolio can be seen as a biological network, and apply complex network theory and social network analysis to quantify PPR, being the risk evaluated as the success or failure probability. Moreover, network theory has been integrated with epidemiology approaches to represent and assess the "domino effect" derived from project interdependencies on the PPR; for example, Guggenmos et al. [24] adopt an approach integrating network theory with a susceptible-infected model to analyze the portfolio risk in IT portfolios, while Zou et al. [25] integrate network theory with a susceptible-infected-recovered-failed model for research and development project portfolios.

Considering that in real cases the risk factors have interdependencies, Namazian and Yakhchali [13] posit that the effect of the occurrence or non-occurrence of one risk on other risks can be quantified through Bayesian networks and Montecarlo simulation. Thus, Namazian and Yakhchali [13] propose an approach based on Bayesian networks to represent and quantify the risk interaction under a perspective associated with schedule delays and cost overruns in gas field development projects portfolios. Also, considering project interdependency but focused exclusively on project portfolio resource risk, Bai et al. [26] posit an approach through which the portfolio risk is derived from resources shared between projects and resource constrains. Therefore, risk factors derived from resources project interdependencies were identified, Bayesian network method to assess the risk interdependencies was implemented, and fuzzy set theory to capture the subjectivity of expert judgments was integrated.

Other proposals have sought to integrate both risk interdependencies and dependency between projects into the PPRA. In this regard, Ghasemi et al. [14] represent the project interdependency as part of the risk factors of the project portfolio, and based on the Bayesian network approach, propose a PPRA approach that allows assessing the influence of risk interdependencies on the project portfolio expected result. Also, but with a PPR response perspective, Ahmadi et al. [27] propose an approach that allows assessing the portfolio risk considering both risk interdependencies and dependency between projects. Thus, an optimization model is proposed which allows the evaluation of risk as a function of the total cost. In the same vein, Wang et al. [28] posit that the project portfolio analysis cannot be separated from the strategic goals for which the project portfolio was structured. Thus, they propose a model based on system dynamics and project interdependencies representation, which is oriented to assess the impact as the difference between the expected value and the realized value of the organization's project portfolio .

Hence, different approaches for PPRA have been proposed, such as credit risk theory and Montecarlo simulation, used to estimate the probability distribution of earnings and losses [20]. Also, mathematical modeling [22], complex network theory and social network analysis [15], set theory [11], Bayesian networks [11,13,14,23] and system dynamics [28]. Some of these approaches have considered financial measures as representation of risk impact measure at project portfolio level, while in other proposals risk impact is represented based on operational or tactical project measures. Additionally, both interdependencies between projects and risk interdependencies have been considered and assessed from different perspectives as part of PPRA.

3. Proposed method

This section presents the structure of the proposed method for PPRA. Fig. 1 shows the proposed method conceptualization. The method is based on the conceptualization that risk factors are derived from each project, but also considering that some risk factors are shared between projects such as the case of shared resources between projects showed by Bai et al. [26]. In addition, and following the perspective adopted by Ghasemi et al. [14] and Bai et al. [26], among others, it was adopted the perspective of considering the influence of project interdependency and representing it through risk factors. Finally, acknowledging that some risk factors emerge at project portfolio level and influence the whole project portfolio [9,14], risk factors at the project portfolio level were also considered.

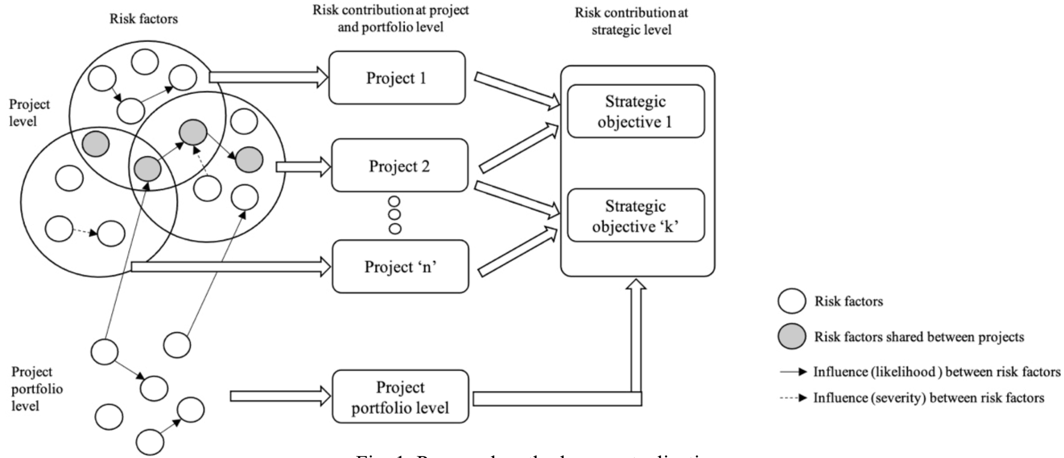

Fig. 1. Proposed method conceptualization.

Project portfolios are structured to achieve, or contribute to the achievement, of a set of strategic goals. In this regard, the proposed method addresses the PPR impact towards the set of strategic objectives. Thus, the method seeks to identify the risk factors impact on the strategic aspects for which the project portfolio was structured.

To achieve its purpose the method is based on network theory. The literature highlighted that PPRA should incorporate the complexity associated with risk factor interactions to obtain a comprehensive risk-based decision-making process [14,23]. Network theory allows such a comprehensive representation of risk factor interactions [15], and, additionally, approaches based on network theory, allow the representation of the dynamic propagation of risk in the portfolio network [25]. In the case of the proposed method, the portfolio network corresponds to Fig. 1. Based on the above conceptualization, Fig. 2 shows the process under which the PPR can be assessed.

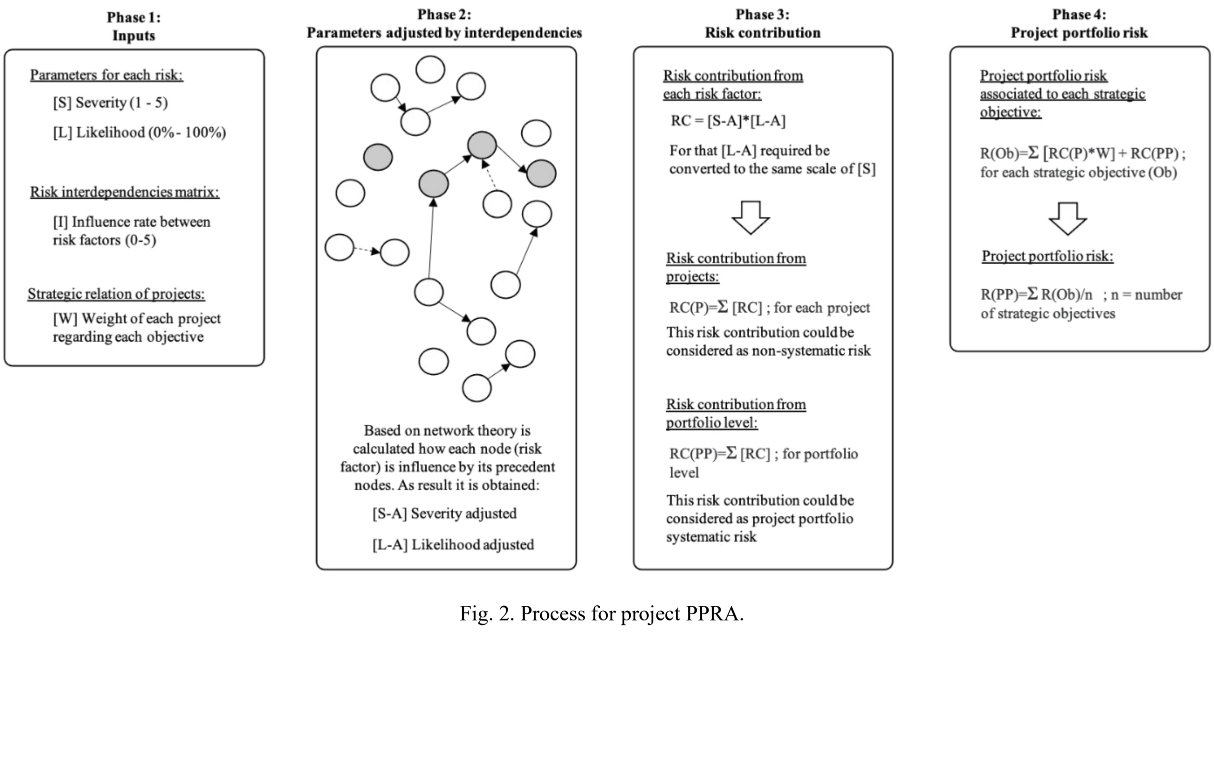

Fig. 2. Process for project PPRA.

Phase 1 corresponds to inputs representations, specifically, severity and likelihood of each risk factor, and the weight of each project. Phase 2 is associated with assessing the influence of risk interdependency on the parameters of the risk factors; therefore, risk interdependency is represented as a risk factors network. Phase 3 is oriented to establish the contribution of each risk factor for the PPR. The extent and the way in which risk factors impact on projects and project portfolio was adopted to be represented as systematic and non-systematic [30]. Non-systematic risk factors refer to risk factors that generate impacts only for one or some projects, and those impacts that do not affect the project portfolio performance in a systemic way. If a risk factor impacts on the project portfolio in a general way, then, it can be considered as source of systematic risk. Finally, in Phase 4, risk factors impacts are extended throughout the network towards strategic objectives.

4. Illustrative example

The illustrative example is represented as a portfolio composed of five projects, three strategic objectives, and 15 risk factors. Table 1 shows the relation between projects and strategic objectives. Fig. 3 illustrates the interdependencies between risk factors associated with likelihood and severity. In Fig. 3 the weight of the influence between each pair of risk factors is showed by the number on each arrow. The illustrative example only considers that risk interdependencies generate increases in likelihood or severity – likelihood or severity decreases derived from the influence of risk factor interdependencies are not considered.

Table 1. Relation between strategic objectives and projects.

	Project 1	Project 2	Project 3	Project 4	Project 5
Strategic Objective 1	50%			20%	30%
Strategic Objective 2		60%		40%	
Strategic Objective 3			100%		

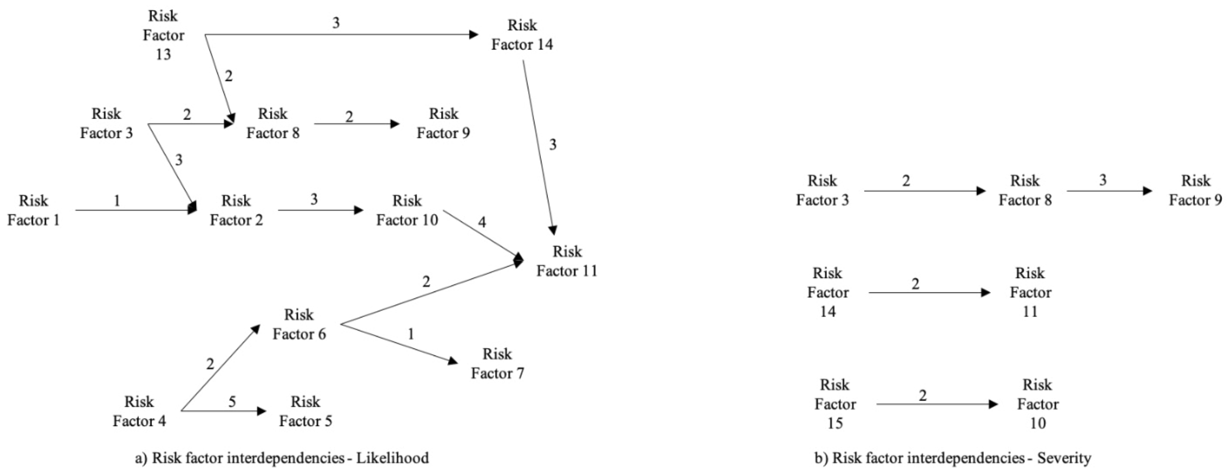

Fig. 3. Risk factor interdependencies.

Table 2 presents the relation between risk factors and projects and portfolio, showing the initial likelihood and severity for the risk factors, as well as the likelihood and severity adjusted by risk interdependencies (values into parenthesis). For example, in the case of risk factor 1 the likelihood was not modified because risk factor 1 does not have dependence from other risk factor. In the case of risk factor 2, which is affected by risk factor 1 and risk factor 3, its likelihood was modified, moving from 60% to 86% (See Table 3). The same process was performed for the other risk factors.

Table 2. Likelihood and severity for each risk factor

	Likelihood	Severity					
		Project 1	Project 2	Project 3	Project 4	Project 5	Portfolio level
Risk factor 1	30% (30%)	4 (4)					
Risk factor 2	60% (86%)	3 (3)			3 (3)		
Risk factor 3	50% (50%)	2 (2)		2 (2)			
Risk factor 4	50% (50%)		3 (3)				
Risk factor 5	70% (85%)		2 (2)				
Risk factor 6	20% (40%)		3 (3)			3 (3)	
Risk factor 7	20% (28%)		4 (4)				
Risk factor 8	30% (70%)			2 (3)			
Risk factor 9	60% (88%)			3 (4.4)			
Risk factor 10	80% (97%)				3 (3.8)		
Risk factor 11	30% (100%)				4 (4.9)	4 (4.9)	
Risk factor 12	40% (40%)					1 (1)	
Risk factor 13	50% (50%)						2 (2)
Risk factor 14	70% (85%)						2 (2)
Risk factor 15	40% (40%)						3 (3)

Table 3. Example of estimation of contributions to the likelihood of risk factor 2

Risk Factor	Likelihood	Weight (W) of influence on risk factor 2	Maximum feasible contribution (MC)	Expected value of the contribution (EC)
1	30%	1	Max[W;5-L(RF2)*5] Max[1;5-0.6*5] = 1	MC * L(RF1) (1)*(0.3) = 0.3
3	50%	3	Max[W;5-L(RF2)*5] Max[3;5-0.6*5] = 2	MC * L(RF3) (2)*(0.5) = 1.0

In Table 3, L(RF1), L(RF2) and L(RF3) refer respectively to likelihood of the risk factor 1, 2 and 3; for the estimation of the maximum feasible contribution (MC) the likelihood of the risk factor is multiplied by 5 to obtain an equivalent scale regarding the scale used of the weight of influence values, so that, the highest possible value which can be obtained for any risk factor is 5 (equivalent to 100%). Finally, the total contribution derived from risk factors 1 and 3 on risk factor 2 is 1.3, in this case moving from the value of 3 (equivalent to 60%) to value of 4.3 (equivalent to 86%). For estimation of likelihood adjusted of each risk factor the summation does not exceed the value of 5 (equivalent to 100%).

Following the structure described for phase 3 in fig. 2, the risk contribution of each risk factor is calculated. Table 4 shows an example of the estimation of risk contribution for project 1 and for project portfolio level. In this case, according to Table 2, project 1 is affected by risk factors 1, 2, and 3, and portfolio level is affected by risk factors 13, 14, 15. In both cases the example showed in Table 4 is based on the initial case, e. g., without risk interdependency considerations.

Table 4. Example of estimation of risk contribution for project 1 and for portfolio level – initial case

Risk factor (RF)	Risk contribution (RC)	Rik contribution to the project 1	Risk contribution to portfolio level
1 2 3	[L(RF1)/5]*I(RF1) = 6 [L(RF2)/5]*I(RF2) = 9 [L(RF3) /5]*I(RF3) = 5	RC(RF1) + RC(RF2) + RC(RF3) 6 + 9 + 5 = 20	
13 14 15	[L(RF13)/5]*I(RF13) = 5 [L(RF14)/5]*I(RF14) = 7 [L(RF15) /5]*I(RF15) = 6		RC(RF13) + RC(RF14) + RC(RF15) 5 + 7 + 6 = 18

Table 5 shows the results obtained according to the risk contribution from each project and from the portfolio level, for both the initial scenario and the scenario with risk interdependencies.

Table 5. Risk factors contribution at project and portfolio level.

Risk Contribution	Project 1	Project 2	Project 3	Project 4	Project 5	Portfolio level
Initial	20.0	21.5	17.0	24.0	11.0	18.0
Considering risk interdependency	23.9	27.6	34.9	55.6	32.3	19.5

Then, following the structure described for phase 4 in fig. 2, the influence of risk factors on the strategic level is calculated. Table 6 shows an example of estimation of non-systematic risk associated to strategic objective 1; according to Table 1, strategic objective 1 is related to projects 1, 4 and 5. The example illustrated in Table 6 is based on risk contribution considering risk interdependency. Table 7 shows the PPR consolidation by considering the risk derived from the projects as source of non-systematic risk and the risk derived from project portfolio level as source of systematic risk.

Table 6. Example of estimation of influence on strategic objective 1

	Project 1	Project 2	Project 3	Strategic objective 1
Risk contribution	23.9	55.6	32.3	(23.9*50%)+(55.6*20%)+(32.3*30%)
Weight	50%	20%	30%	= 32.7

Table 7. Risk factors importance at strategic level

	Non-systematic	Systematic	Portfolio risk
Strategic Objective 1	32.7		
Strategic Objective 2	38.8	19.5	53.5
Strategic Objective 3	34.9		

5. Conclusions

This paper proposes a method for risk assessment from a project portfolio perspective. Analyzing the interdependency between risks allows a better representation of the PPR, by the recognition of the impact not just due to a direct influence, but also through the influence on other risk factors. Like traditional approaches for risk assessment, the proposed method allows identifying that PPR is influenced by risk factors derived from projects within the portfolio. However, the proposed method also recognizes that PPR is affected by risk factors derived from the project portfolio level. Risk factors derived from the project portfolio level have a general or global impact on the project portfolio expected results, therefore, the proposed method helps decision-makers to identify their influence and importance. In this regard, both portfolio managers and organizational managers can orient their efforts and resources on providing risk response strategies to those risk factors that have the greatest direct impact on each project and the overall project portfolio, and those that have the greatest influence on other risk factors.

Future research is needed on the integration of project interdependencies that could lead to a more integral representation of the PPR. To attain that, an approach based on meta-networks could be explored, and techniques such as 'Matrice d'Impacts Croisés Multiplication Appliquée à un Classement' (MICMAC) can be used to determine the drive and dependence power of each risk factor. Moreover, scenario analysis or analysis based on simulation could be explored to test the robustness of the proposed method. Finally, considering that just threats were considered for this illustrative example, incorporation of opportunities and the interdependency between them, as well as the interdependency between threats and opportunities could be explored to assess the compensatory effects.

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