Journal of Industrial and Systems Engineering
Vol. 12, Special issue on Project Management and Control, pp. 100-109
Winter (January) 2019

Balancing construction projects by considering resilience factors in crisis

Zahra Jalili Bal[1], Ali Bozorgi-Amiri[2*], Siamak Haji Yakhchali[2]

[1] *Department of Industrial Engineering, Shahed University, Tehran, Iran*
[2] *School of Industrial Engineering, College of Engineering, University of Tehran, Tehran, Iran*

zjalili222@gmail.com, alibozorgi@ut.ac.ir, yakhchali@ut.ac.ir

Abstract

Macroeconomic investment at the corporate level has grown rapidly in recent years. Given that the resources of the organization are usually less than the number of projects ahead in the organization, selecting projects from a portfolio of projects and making decisions in this regard is inevitable in the organization. Choosing the wrong one will have many negative consequences, including wasting resources in the organization. It also destroys resources within the organization that, if used correctly in a more appropriate project, will have benefits for the organization. In recent years, due to some problems, the country's economic markets have fluctuated. These fluctuations are largely unpredictable in nature, which have a significant negative impact on economic and investment organizations. Given this need, the current research is attempting to provide a solution to best balance project portfolio in uncertain terms. Therefore, this paper has proposed a model for project balancing under uncertainty conditions considering resilience factors in crisis, as stated, to prevent some projects from continuing if necessary. 4 scenarios are defined and a stochastic programming is implemented. So far, the concept of project portfolio balancing and modeling has rarely been addressed. Most of the time, a financial portfolio is presented and a balancing model is provided for it, especially in the field of equity, or generally, taking into account indicators such as risk, prioritizing projects and providing a conceptual model to apply.

Keywords: investment organizations, balancing, project portfolio, uncertainty.

1-Introduction

At present, how to institutionalize project management in project-oriented organizations and its long-term benefits is one of the major issues in project management and less attention is paid to specific project management techniques. Project quality is the most important factor in the success or failure of projects. Particularly in project-oriented organizations, which often handle large projects, this success or failure is very evident. In this regard, project portfolio management can be a useful tool to help increase the efficiency and effectiveness of a company's project portfolio. Project evaluation in the organization is important, especially when most organizations are involved so that even a significant portion of their revenue comes from their projects.

On the other hand, by scrutinizing the projects of these organizations it can be concluded that a large number of projects have been stopped due to lack of access to sufficient facilities or resources or lack of

---

*Corresponding author
ISSN: 1735-8272,

benefit in the final stages and failure to comply with the objectives of the organization or they are semi-finished, at this stage the high importance of project evaluation is determined by considering organizational constraints and goals and priorities. The key tools for implementing project-oriented organization strategies, which include selecting and executing projects correctly, play an important role in the success of organizations. In other words, project selection is aligned with the organization's strategies and ensures that resources are used effectively and plays a key role in achieving the strategic goals of the organization. Many organizations have defined and keyed a multitude of projects that actually require more than ten times of the approved budget to run these projects. Therefore, the role of top level management, which allocates and prioritizes the appropriate projects at a given time according to the strategic requirements of the resource organization, as well as suspends or suspends them when necessary.

In the event of any crisis that adversely impacts the projects, a model has been developed that takes into account the current situation, making a decision to stop some projects despite the percentage improvement and to consume part of the resources or to continue some other projects. The proposed model allocates resources within the organization between re-active projects, referred to as balancing. It may be argued that abandoning some projects, despite its progress, would be a significant disadvantage to the organization, while making the decision to stop and exit these projects, although for the managers of these organizations. It is very difficult and difficult, but on the other hand, if these projects do not stop, the organization will suffer enormous losses and irreparable blows. Therefore, one of the problematic issues in organizations facing a large number of projects is choosing the optimal portfolio mix of projects. Therefore, this paper has proposed a model for project balancing under uncertainty conditions, as stated, to prevent some projects from continuing if necessary. So far, the concept of project portfolio balancing and modeling has rarely been addressed. Most of the time, a financial portfolio is presented and a balancing model is provided for it, especially in the field of equity, or generally, taking into account indicators such as risk, prioritizing projects and providing a conceptual model to apply. Another contribution is considering resilience factors for balancing project portfolio.

Guo et al. (2018) have proposed balancing strategic contributions and financial returns with a project portfolio selection model under uncertainty. Two goals are proposed for the portfolio to achieve, strategic contributions and financial returns. The uncertainties involved are addressed with fuzzy real options. Dupin (2018) have proposed portfolio balancing strategy for the integration of renewable energy sources to the day ahead market. New methods of government support and marketing of renewable production push the renewable energy sources (RES) to be more integrated to the wholesale day-ahead market. Horan et al. (2018) have proposed a Portfolio-Balancing Approach to Natural Capital and Liabilities.

Qin et al. (2016) presented an optimization model for balancing investment projects uncertainly. In this study, risk and rate of return are considered uncertain. This uncertainty stems from the expert's inaccurate evaluation. Finally, they discuss the proposed model to ensure applicability and applicability by implementing a numerical example. Kumar et al. (2015) presented a model to recalibrate financial portfolios taking into account parameters such as risk, transaction cost, mathematical expectation of rate of return, and so on. They have also taken advantage of the interval approach within the limitations of this proposed model. Mittal and Mehlawat (2014) have presented a multi-objective model for portfolio balancing of financial projects by combining transaction cost based on incremental discount. In this risk study, the rate of return on equity and liquidity are considered as key measures of the portfolio of financial projects. In the proposed model, this study minimizes the risk and maximizes the rate of return on capital and maximizes liquidity. Dernovak and Rankovic (2014) developed the Markowitz re-balancing model. They added volume monitoring to other benchmarks in the Markowitz model and tested two different balancing strategies. The first model is based on market risk and the second model is based on the optimal amount of risk-return swap. They also used optimal portfolio volatility as a benchmark for allocating and balancing the initial portfolio. Das et al. (2014) calculated the optimal value of the number of reconfiguration iterations for the optimal logarithmic portfolio. In this study, the question was asked how often, on average, the project portfolio balancing is performed per project investment horizon. It also develops a hierarchical framework for calculating the mathematical expectation of logarithmic portfolio growth with the feature of alternating and discrete balancing reconfigurations in this portfolio. They have also shown that investor desirability can be improved and enhanced by the use of combined balancing strategies. Dichtl et al. (2014) analyzed and compared the performance of different balancing strategies on real market conditions and analyzed relevant data from 3 US, UK and Germany countries as well as 3 different class types. Wang et al. (2014) presented a model for portfolio balancing of financial projects based on reverse optimization with the least number of investments. They are looking at the question of when to adjust the initial portfolio and then perform the balancing operation on it. They also identified a variable in their proposed model as a penalty and also incorporated the transaction cost into their proposed model, showing that their model performs better than the general balancing model. Oriakhi and Lucas (2013) presented a model for balancing the portfolio of existing financial projects, taking into account the investment horizon and transaction costs. Transaction costs in this model can be considered fixed or variable. The proposed model is assumed to be a quadratic integer programming model with explicit constraints. This model has been implemented on 1317 assets and its results have been analyzed. Gupta et al. (2012) developed a valid multi-criteria model to rebalance projects. Also, uncertainty conditions were considered as key factors considering fuzzy parameters such as return, risk and liquidity. The transaction cost is considered nonlinear in this study and the proposed model follows an idealized programming and a hybrid fuzzy simulation method and genetic meta-algorithm are used to solve this model. Finally, the performance of the model and the solution approach for recalibration is analyzed and implemented on a real case. Iscoe et al. (2012) have balanced financial projects by minimizing the risk of these projects and have proposed a two-objective model by minimizing the risk-weighted value parameters as well as minimizing the average deficit. Yu and Lee (2011) proposed and compared 5 models for portfolio balancing of financial projects taking into account transaction cost and other criteria such as risk, return on capital, elongation, and short-term sales. These 5 models have been evaluated. Caron et al. (2007), presented a model for project balancing that helps managers make decisions by considering the Value at Risk Index (VaR). This model accomplishes the goal of balancing projects with managers taking into account the amount of net present value plus the amount of risk at risk plus the net present value. Eilat et al. (2006) have focused on balancing and selecting product research and development projects. In this study, they proposed a combination of two methods of data envelopment analysis and the concept of a balanced scorecard, an efficient and effective model for selecting and balancing R&D projects.

As can be seen in all of these studies, balancing on the financial projects carried out while in the present study is implemented on the executing projects. Therefore, one of the innovations of this research is balancing on project portfolio. Another innovation is the consideration of resilience factors in this model, which is applied for the first time in the project concept. Consideration of the uncertainties in the model and implementation of the case study is another innovation of this study. In this article, we will present a model for balancing projects under uncertainty. For modeling we use a stochastic integer programming that considers the constraints of raw materials, machines, and human resources. In this model, resources should be allocated to selected projects in addition to taking into account existing priorities, including organizational goals. In the proposed model, the concept of resilience indices is used to balance the portfolio of projects so that, based on the score obtained for each project, the decision to stop or continue the ongoing projects is taken. We have also defined the scenario in crisis and scenario-based ways that under each scenario it may take different balancing decisions. We will first introduce the indicators of resilience and then explain the proposed model to rebalance the portfolio of projects.

2-Research methodology

2-1-Introducing resilience and effectiveness indicators on project portfolios

2-1-1-Fault tolerance

An organization consists of a set of interrelated components, which fails if one of these components crashes or falls down. Then communication between system components becomes disrupted. Therefore, for each of the elements of a failure threshold resilience organization is defined that the higher this level of failure tolerance the system has a higher tolerance level against destructive shocks. Thus, the overall failure level of an organization is affected by the failure tolerance of each of its constituent elements (Woods et al., 2012).

2-1-2-preparedness

The criterion of preparedness determines the amount of information and awareness that staff and the contracting team should be aware of the occurrence of future unexpected events or events, or the importance of considering the views of those who will inform potential executives of future events. The level of readiness of the contracting complex to collectively prevent and deal with future events and events that may cause damage to the employer and the contractor and sometimes destroy part of the project is generally assessed and evaluated (Woods et al., 2012).

2-1-3-Flexibility

Flexibility is one of the most essential and useful tools in today's competitive marketplace. Given the importance of time in the competitive marketplace among contractors, flexibility is a vital issue for the organization. Researchers often disagree about flexibility between planned and unplanned changes, but most consider unplanned changes to be flexible. Unplanned changes occur independently of the project management, but the organization must adapt its ongoing projects to these changes. Where planned changes are prudent decisions made by the organization's management team to change some aspects of the organization or expand the organization's relationship with the environment (Hollnagel, 2013).

2-1-4-Redundancy

Redundancy often occurs in organizations where humans and machines are present, meaning that there are no critical components of the system that fail or fail to cause them to crash. Redundancy occurs when two or more people in a project work together to accomplish part of a task to accomplish the tasks required by accessing the information they need. One of the most important features of designing a redundancy organization is that it is one of the most important requirements in the performance safety standard (Boran, 2009).

2-2-Proposed model of project portfolio balancing

Table1. Indices description

indices	
Number of selected projects	i
Number of new proposed projects	j
Number of scenarios	s

Table 2. Scenario description

$s = \{s_1, s_2, s_3, s_4\}$	
Occurrence of natural disasters	s_1
Occurrence of economic crisis	s_2
Occurrence of both natural disasters and economic crisis	s_3
No crisis occurred	s_4

Table 3. Parameters description

parameters	
Selected status of i^{th} project before balancing	x_i^0
Total funding available to the organization under the s^{th} scenario	B^s
Estimated cost of i^{th} project under the s^{th} scenario	${c_i}^s$
Estimated cost of j^{th} project under the s^{th} scenario	${c_j}'^s$
The costs used before balancing i^{th} Project, which includes cash costs as well as the cost of resources consumed.	c_i^*
weight of the i^{th} project obtained from the interview	w_i
Occurrence probability of s^{th} scenario	p^s
Amount of flexibility of i^{th} project under s^{th} scenario	$flex_i^s$
Amount of i^{th} project preparedness under s^{th} scenario	pre_i^s
Amount of i^{th} project redundancy under s^{th} scenario	red_i^s
Amount of i^{th} project fault tolerance under s^{th} scenario	$fault_i^s$
Alert level of organization resilience under s^{th} scenario	$alert\ level^s$
amount of primary resources required for i^{th} project fault tolerance under s^{th} scenario	rs_i^s
amount of human resources required for i^{th} project fault tolerance under s^{th} scenario	rh_i^s
amount of machines required for i^{th} project fault tolerance under s^{th} scenario	rm_i^s
amount of primary resources required for j^{th} project fault tolerance under s^{th} scenario	rs_j^s
amount of human resources required for j^{th} project fault tolerance under s^{th} scenario	rh_j^s
amount of machines required for j^{th} project fault tolerance under s^{th} scenario	rm_j^s
Total amount of primary resources	Rs
Total amount of manpower	Rh
Total number of machines	Rm
Estimated sustainability score of j^{th} project	$score_j$

Table 4. Variable description

variables	
If i^{th} project stops after balancing 1, otherwise 0 considered under s^{th} scenario	x_{is}^-
Final status of i^{th} project after balancing under s^{th} scenario	${x_i}^s$
If one of the new proposed projects, j^{th} project is selected 1, otherwise 0	y_j

$$max \sum_{j=1}^{m} score_j y_j, \quad (1)$$

$$min \sum_{i=1}^{n} \sum_{s=1}^{k} p^s c_i^* x_i^-, \quad (2)$$

$$max \sum_{i=1}^{n} \sum_{s=1}^{k} p^s (flex_i^s + pre_i^s + red_i^s + fault_i^s)\, x_i{}^s, \quad (3)$$

$s.t.$

$$\sum_{i=1}^{n} c_i{}^s x_i{}^s + \sum_{j=1}^{m} c_j'^s y_j \leq B^s, \quad (4)$$

$$x_i{}^s = x_i^0 - x_{is}^-, \quad (5)$$

$$w_i(flex_i^s + pre_i^s + red_i^s + fault_i^s) \leq alert\ level^s \;\; \rightarrow \; x_{is}^- = 1. \quad (6)$$

$$\sum_{i=1}^{n} rs_i^s x_i{}^s + \sum_{j=1}^{m} rs_j^s y_j \leq Rs, \quad (7)$$

$$\sum_{i=1}^{n} rh_i^s x_i{}^s + \sum_{j=1}^{m} rh_j^s y_j \leq Rh, \quad (8)$$

$$\sum_{i=1}^{n} rm_i^s x_i{}^s + \sum_{j=1}^{m} rm_j^s y_j \leq Rm, \quad (9)$$

This section describes the proposed balancing model. As has been elucidated to this point, this problem has three objective functions and mathematical programming with linear modeling and stochastic programming has been used. The first objective function considers the maximization of the score obtained from the project sustainability factors in the problem. This score is calculated using the weights obtained from the expert interview. The second objective function is to minimize the stoppage losses of some projects that are not cost-effective in terms of resilience factors. The third objective function maximizes the scores obtained from the project's resilience factors under different scenarios.

In the structure of mathematical modeling, first the objective functions and then the constraints are introduced. Therefore, this section introduces the constraints of the problem. Constraint (4) states the allocation of funds to projects with estimated costs for each project. Because of limited funding, we are not able to select all the proposed projects and this budget is only responsible for some projects. Constraint (5) indicates a restructuring of the projects so that the final vector of the selected projects is equal to the sum of the selected projects in Phase II, the projects that were terminated in this phase, and the projects that decided to proceed. Constraint (6) indicates a measure of the robustness and safety index of each project, according to which if each of the selected projects is lower than the alert level given the weight gained from phase III. We will stop the project and also if the resilience score exceeds the alert level in a project. It was decided to keep the project going. Finally, constraints (7), (8) and (9) state the constraints of primary resources, human and machine resources with respect to new proposed projects as well as other projects already started.

3- Numerical results

In order to balance the project portfolio, the proposed model is implemented in this paper. Therefore, the selected projects (19 projects) are used in this model and after a period of time the selected projects will be implemented. In other words, some of the projects selected have used the amount of resources needed as well as the funding needed for the first period. In this model, the balancing model is implemented based on the concept of Resilience factors and after reviewing the conditions of each project with regard to disruption occurring during the execution of projects, it is decided to continue or stop these projects. In addition, 10 new projects are proposed to the organization, which together with the balancing model is also decided upon, if qualified, given the organization's limited resources or rejected. The proposed model of this paper is modeled using stochastic programming which is investigated under various scenarios.

After implementing the proposed balancing model, decisions are made to stop some projects under different scenarios, as can be seen in table 1. Each scenario in this model causes system disruptions that lead to significant impacts on ongoing projects. Given the selection phase, ongoing projects can be incorporated into this implementation and decisions can be made about whether or not to continue. Scenario 1 relates to the occurrence of natural disasters, the first column in table 5 illustrating which projects should be stopped in the event of natural disasters. Scenario 2 deals with the occurrence of the economic crisis, which is actually the second column in the table that indicates which projects will be halted in the event of an economic crisis. Scenario 3 deals with the simultaneous occurrence of an economic crisis and natural disasters, which in column 3 of table 5 shows the results of project stoppages, and finally scenario 4 describes the situation of disruption and crisis. Table 6 also indicates the final status of the selected projects after balancing.

Table 5. Status of stopping projects

Status of stopping projects	scenario1	scenario2	scenario3	scenario4
project 3				
project 5		*		
project 6				
project 8	*			
project 9			*	
project 12	*	*	*	*
project 15	*	*	*	*
project 17		*	*	
project 19		*	*	
project 23	*			
project 26			*	
project 27			*	
project 29	*	*		
project 30		*		
project 37			*	
project 38		*		
project 41	*		*	
project 42	*	*		*
project 45	*		*	*

Table 6. Final selection status of projects after balancing

Final selection status of projects after balancing	scenario 1	scenario 2	scenario 3	scenario 4
Project 3	*	*	*	*
project 5	*		*	*
project 6	*	*	*	*
project 8		*	*	*
project 9	*	*		*
project 12				
project 15				
project 17	*			*
project 19	*			*
project 23		*	*	*
project 26	*	*		*
project 27	*	*		*
project 29			*	*
project 30	*		*	*
project 37	*	*		*
project 38	*		*	*
project 41		*		*
project 42			*	
project 45		*		

Table 7. Selection status of new project

New Projects	Selection status of New Projects
New Project 1	
New Project 2	*
New Project 3	*
New Project 4	
New Project 5	
New Project 6	
New Project 7	*
New Project 8	
New Project 9	*
New Project 10	

4-Conclusion

After implementing the proposed balancing model, decisions are made to stop some projects under different scenarios. Each scenario in this model causes system disruptions that lead to significant impacts on ongoing projects. Given the selection phase, ongoing projects can be incorporated into this implementation and decisions can be made about whether or not to continue.

At present, how to institutionalize project management in project-oriented organizations and use its long-term benefits is one of the major issues in the field of portfolio management and less attention is paid to specific project management techniques. In this regard, project portfolio management can be a useful tool to help increase the efficiency and effectiveness of project portfolio of organizations. Project evaluation is important in an organization, especially when most organizations are involved so that even a significant portion of their revenue comes from their projects. Many organizations have defined and keyed a multitude of projects that actually require tens of times the approved budget to run these projects. Therefore, the role of top level management in allocating resources according to the strategic requirements of the organization and selecting and prioritizing the appropriate projects at any given time become very important. Future research may be on implementing robust programming for considering uncertainty or proposing a balancing mathematical model for financial portfolio by considering resilience factors and also combining a multi criteria method with a mathematical programming for rebalancing project portfolio.

References

Boran, F. E., Genç, S., Kurt, M., & Akay, D. (2009). A multi-criteria intuitionistic fuzzy group decision making for supplier selection with TOPSIS method. *Expert Systems with Applications*, *36*(8), 11363-11368.

Caron, F., Fumagalli, M., & Rigamonti, A. (2007). Engineering and contracting projects: A value at risk based approach to portfolio balancing. *International journal of project management*, *25*(6), 569-578.

Das, S. R., Kaznachey, D., & Goyal, M. (2014). Computing optimal rebalance frequency for log-optimal portfolios. *Quantitative Finance*, *14*(8), 1489-1502.

Dichtl, H., Drobetz, W., & Wambach, M. (2014). Where is the value added of rebalancing? A systematic comparison of alternative rebalancing strategies. *Financial Markets and Portfolio Management*, *28*(3), 209-231.

Drenovak, M., & Ranković, V. (2014). Markowitz portfolio rebalancing with turnover monitoring. *Ekonomski horizonti*, *16*(3), 211-223.

Dupin, N. (2018). Portfolio balancing strategy for the integration of renewable energy sources to the day ahead market.

Eilat, H., Golany, B., & Shtub, A. (2006). Constructing and evaluating balanced portfolios of R&D projects with interactions: A DEA based methodology. *European journal of operational research*, *172*(3), 1018-1039.

Guo, Y., Wang, L., Li, S., Chen, Z., & Cheng, Y. (2018). Balancing strategic contributions and financial returns: a project portfolio selection model under uncertainty. *Soft Computing*, *22*(16), 5547-5559.

Gupta, P., Mittal, G., & Mehlawat, M. K. (2013). Expected value multiobjective portfolio rebalancing model with fuzzy parameters. *Insurance: Mathematics and Economics*, *52*(2), 190-203.

Hollnagel, E. (Ed.). (2013). *Resilience engineering in practice: A guidebook*. Ashgate Publishing, Ltd.

Hollnagel, E., Woods, D. D., & Leveson, N. (Eds.). (2006). *Resilience engineering: Concepts and precepts*. Ashgate Publishing, Ltd.

Horan, R. D., Fenichel, E. P., Finnoff, D., & Reeling, C. (2018). A Portfolio-Balancing Approach to Natural Capital and Liabilities: Managing Livestock and Wildlife Diseases with Cross-Species Transmission. *Environmental and resource economics*, *70*(3), 673-689.

Iscoe, I., Kreinin, A., Mausser, H., & Romanko, O. (2012). Portfolio credit-risk optimization. *Journal of Banking & Finance*, *36*(6), 1604-1615.

Kumar, P., Panda, G., & Gupta, U. C. (2015). Portfolio rebalancing model with transaction costs using interval optimization. *Opsearch*, *52*(4), 827-860.

Mittal, G., & Mehlawat, M. K. (2014). A multiobjective portfolio rebalancing model incorporating transaction costs based on incremental discounts. *Optimization*, *63*(10), 1595-1613.

Qin, Z., Kar, S., & Zheng, H. (2016). Uncertain portfolio adjusting model using semiabsolute deviation. *Soft Computing*, *20*(2), 717-725.

Wang, M., Xu, F., & Wang, G. (2014). Sparse portfolio rebalancing model based on inverse optimization. *Optimization Methods and Software*, *29*(2), 297-309.

Woodside-Oriakhi, M., Lucas, C., & Beasley, J. E. (2013). Portfolio rebalancing with an investment horizon and transaction costs. *Omega*, *41*(2), 406-420.

Yu, J. R., & Lee, W. Y. (2011). Portfolio rebalancing model using multiple criteria. *European Journal of Operational Research*, *209*(2), 166-175.