Towards an Effective Project Portfolio Selection Process

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Abstract

Maximizing the business value while preserving the alignment to strategic objectives is a permanent concern of every organization. Therefore selecting the project portfolios that are more likely to convert a company vision into a business success is a crucial process. The project portfolio selection problem has caught the researcher's interest since more than four decades and has been approached in different methodologies, techniques and decision support systems. However, there is no agreement today on a universal approach addressing this problem's major aspects in a flexible and practical way. This paper is aiming to provide project management practitioners with a fundamental background towards an effective project portfolio selection process. It provides a detailed problem clarification and breakdown from both best practices and literature perspectives. It also synthesizes the various approaches and methods that have been so far proposed in the literature with regards to project portfolio selection. Thus a critical analysis of the most widely used approaches is presented. Furthermore, a concept of an effective project portfolio construction framework is outlined in order to guide future research in that area.

Keywords
Project portfolio management, organizational strategy, portfolio selection process, decision-making

1. Introduction

Project Portfolio Management (PPM) has seen growing interest in modern organizations over the last four decades, especially in the project-based structures including R&D, IT and construction. It has been adopted as the commonly employed methodology aiming to align an enterprise-wide project portfolio with a company strategic goals. As a bridge between Strategy and Operation, project portfolio management enables organizations to transform their visions into realities and successfully implement their corporate strategies (Morris and Jamieson 2005, Dey 2006).
From a methodological perspective, the PPM can be structured into three groups of processes: planning, aligning and controlling processes. This paper will focus on the portfolio selection process as part of portfolio aligning processes group. Project portfolio selection is then presented as a strategic and complex decision problem, considering a dynamic, very competitive and uncertain decision making environment.

This paper is organized in three sections, the first section describes the project portfolio selection problem, it starts by presenting the relationship between organizational strategy and project portfolio management. It also provides some standard definitions and models in order to set a clear positioning of portfolio selection issue within the frame of organizational strategy and also highlight some important parameters that are necessary to consider in project portfolio building process. As far as second section is concerned, it presents how project portfolio selection was approached in the literature, it also describes the different dimensions of the issue that have been handled in the literature and also summarizes the available methods and techniques into six main categories. A critical review is then introduced in the

third section in which a targeted framework of project portfolio selection is finally outlined while setting the directions for future studies.

2. Research problem definition

An organization's success relies on its ability to completely align its strategic themes "vision, mission and values" with its day-to-day operations. This critical alignment could never be achieved without an effective strategy implementation, focusing on the one hand, on doing the right projects (portfolio management) and on the other hand on doing the projects right (project management).

2.1 Relationship between portfolio management and organizational strategy

The organizational strategy is the outcome of the strategic planning cycle where the vision and mission are translated into a strategic plan, subdivided into a set of initiatives that are influenced by multiple factors including market dynamics and competitiveness, customer satisfaction, shareholders requirements and government regulations. These initiatives are translated into projects and programs making up the portfolio while demonstrating of many-to-many relationship with strategic objectives (Figure 1).

A portfolio is a "collection of projects or programs and other work that are grouped together to facilitate effective management of that work to meet strategic business objectives". A program is defined as a "group of related projects managed in a coordinated way to obtain benefits and control not available from managing them individually". (Project Management Institute, 2008a). The portfolio management is then the set of activities employed to manage these programs and projects in a coordinated way to reach organizational objectives. (Project Management Institute, 2008b).

MoP (Management of Portfolio) of AXELOS standard defines portfolio management as: "A coordinated collection of strategic processes and decisions that together enable the most effective balance of organizational change and business as usual." The guideline emphasizes that portfolio management seeks to build on, and better coordinate, existing processes such as strategic planning, investment appraisal as well as project and program management.

PMI and MoP models of project portfolio management cycle are respectively represented in Figure 2 and Figure 3.

From a methodological perspective, the project portfolio management can be structured into three groups of processes: planning, aligning and controlling processes. The project portfolio selection process this paper is interested in falls within the aligning process group and is considered to be the main component of the portfolio management system.

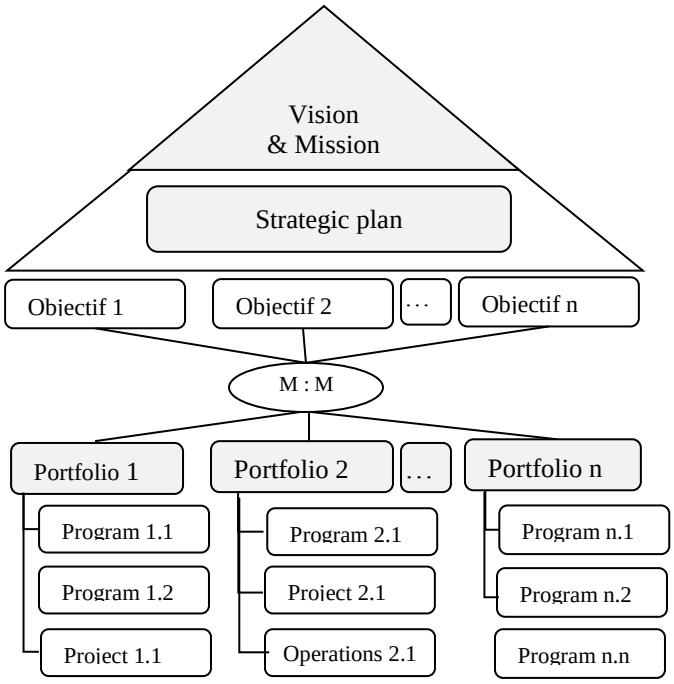

Figure 1 – Portfolio management and Organizational strategy

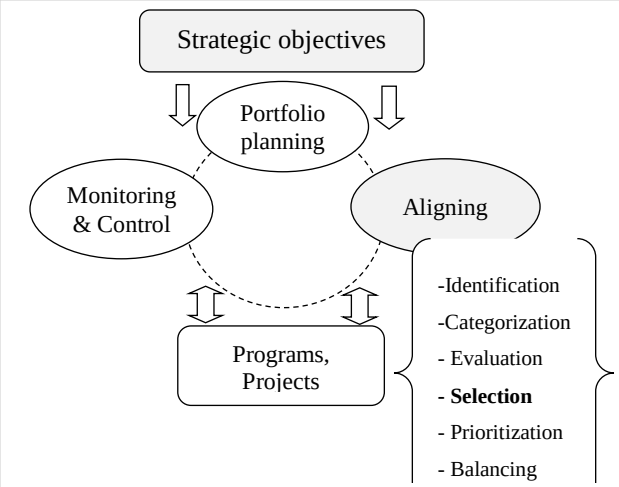

Figure 2– Portfolio Management process cycle (PMI)

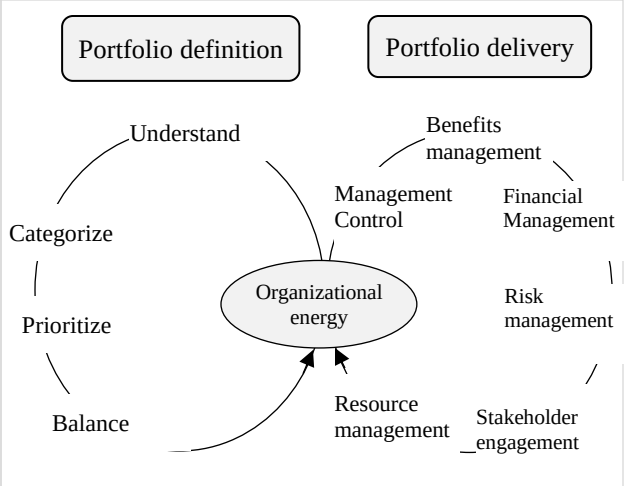

Figure 3– Management of Portfolio model (MoP)

2.2 Project portfolio selection process

As far as project portfolio selection is concerned, it is defined as a process that involves the assessment of a set of available project proposals in order to undertake a group of them that make it possible to achieve some strategic goals. Project portfolio selection can be also defined as "the periodic activity involved in selecting a portfolio of projects, that meets an organization's stated objectives without exceeding available resources or violating other constraints" (Archer and Ghasemzadeh 1996).

In general, project portfolio selection process looks for the best balance in terms of return, investment, risk, timing, sustainability and other factors depending on each organization sector and business environment.
In other words, various programs and projects, having different time horizons, are competing for limited resources, considering one or more corporate goals and objectives. At the same time portfolio components are identified by a group of decision makers whose members are not necessarily aligned regarding the contribution level of the proposed alternatives in the strategic goals. In addition to that, some of these competing initiatives are quantifiable whereas others are based on just qualitative intuition. Also, whatever is the strategic planning process of a running company, the project portfolio selection process is initiated while other projects and programs are still ongoing and then have to be reconsidered and reassessed among the candidate initiatives.

2.3 Research problem statement

Establishing a comprehensive but a practical portfolio selection model is today an important concern. As it is dealing with various constraints and multiple objectives that are often conflicting, the subject has been indeed handled through different approaches in the literature, involving on the one hand numerous project selection tools and techniques, and developing on the other hand decision-aid approaches and systems. However, there is no common agreement today on which is the most effective approach of selecting the best project portfolio.

3. Related work

The project portfolio selection has been approached in literature as a very challenging issue mainly for project-based organizations. Even though the problem has been raised since more than four decades, the combinatorial nature of the topic is very broad such that there are always opportunities for future research (Iamratanakul et al. 2008).

3.1 Main characteristics of project portfolio selection problem

Most of all research works on the topic agree that the portfolio selection is a multi-dimensional problem (Figure 4).

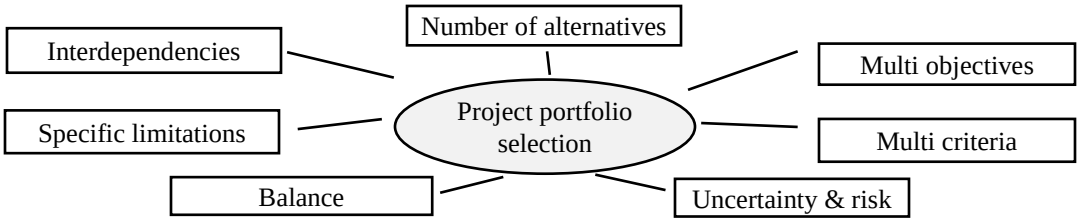

Figure 4– Portfolio selection problem characteristics

Multi-objectives: as described in the previous section, the strategic planning process often lead to multiple goals and objectives to be achieved in different time horizons. Multi-objective optimization was often called in literature through mathematical models. Christian Stummer and Kurt Heidenberger (2003) used a multiobjective integer linear programming model to determine the solution space of all efficient (i.e., Pareto-optimal) portfolios.
Medaglia, Graves, & Ringuest (2007) also proposed a multi-objective evolutionary method for linearly constrained projects selection problems with partially funded projects and multiple stochastic objectives. Carazo et al. (2010) solved a multi-objective project portfolio selection model using a metaheuristic procedure, taking into account multiple objectives without requiring a priori specifications regarding the decision-maker's preferences.
Archer and Ghasemzadeh (1999) used one single objective function to integrate multiple objectives and noted that linear goal programming, weighted scoring and AHP are possible techniques for project value determination.

Multiple-criteria: both qualitative and quantitative, tangible and intangible criteria are considered depending on organization objectives. Criteria are often conflicting, considering the typical example of maximizing revenues while reducing costs. Siddhartha Sampath and co-workers (2015) developed a multi-criteria optimization model while building a decision-making framework for project portfolio planning at Intel.
Project portfolio selection has been also considered by some researchers as a typical multi-criteria decision-making (MCDM) problem. Shang et al. (2004) applied the Analytical Network Process (ANP) technique to evaluate transportation projects, along with the benefits, opportunities, costs, and risks analysis. AHP (Saaty 1980, Liberatore 1987) and Electre family (Martel and Khoury 1988, Hurson, and Zopounidis 1995) are scoring and ranking methods popular among decision makers for port-folio selection, as they allow considering various quantitative and qualitative characteristics using hierarchical criteria and pair wise comparisons.

Huge number of alternatives: number of feasible sets of projects and programs is certainly finite, nevertheless it can be very huge in organizations implementing simultaneously many initiatives. Each combination of items fulfilling certain constraints is indeed a potential alternative. Therefore typical methods for portfolio selection do not explicitly generate all possible portfolios, but try to build the optimal portfolio from a set of potential projects and programs. Stummer and Heidenberger (2003) employed a screening procedure in the first phase of their decision support system in order to identify project proposals that are worthy of further evaluation keeping the number of projects entering the subsequent phase within a manageable size. Also Archer and Ghasemzadeh (2000) introduced the screening stage to eliminate any obvious non-starter and thus reduce the number of projects to be considered by the decision committee.

Specific limitations: market conditions, raw materials availability, government regulations, probability of technical success, social and environmental constraints could affect the project portfolio performance.
High level guidance to the portfolio selection process is generally provided beforehand and includes strategic focus determination as well as resource constraints and limitation setting (Archer and Ghasemzadeh 2000). These constraints are then considered in an optimization model, along with timing, project interdependencies and balancing. Vetschera and Teixeira de Almeida (2012) defined a project portfolio selection as a problem of selection of one or several out of a set of possible items, under some constraints, and where outcomes are determined by some aggregation of properties of the selected items. They proposed a computationally ‘‘light’’ method to deal with portfolio selection based on PROMETHEE multi-criterion method, considering the case of non-compensatory attributes, cost and other resource limitations as constraints. Mavrotas and co-workers (2008) developed a two-phase approach of project selection under segmentation, policy and logical constraints. They first obtain a multicriteria evaluation of the projects using an MCDA method that evaluates the individual projects and then use this information in the objective function of an IP model that incorporates the constraints and derive the final selection.

Project interdependencies: as also explained in the previous section, the programs making a portfolio are by definition sets of interrelated projects in terms of both resource utilization and benefit realization. Several types of project interdependencies exist and have been introduced in literature.
Schmidt 1993 presented three different types of interactions in his portfolio construction model which combines the effects of resource interactions, benefit interactions and outcome interactions among projects, using a matrix-based representation. Benefit interactions occur if the total amount of the benefits of interacted projects is different from the situation in which the projects are executed individually. This difference is positive (synergy effect) if the projects are complementary and it is negative (cannibalization effect) if they are competitive. Outcome interactions occur if the probability of success of a project changes by undertaking another project in the same portfolio. This interaction reflects the relationship among the project successes. Resource interaction occurs when the projects share the same resources, where portfolio resource requirements are less than the sum of individual project requirements. Killen et al. 2012 emphasized the learning interdependency which is “the need to incorporate the capabilities and knowledge gained through another project”.

Archer and Ghasemzadeh (1999) and also Krishnan and Ulrich (2001) noted that when projects have many interdependencies, project selection is typically best realized using integer optimization techniques.
Dickinson and co-workers 2001 presented a real world application of product portfolio optimization at Boeing Company, using a dependency matrix which quantifies the revenue interactions between projects. A nonlinear, integer program model was then developed to optimize project selection, considering constraints about the budget, the maximum number of projects in a portfolio and about the minimum number of projects that must support each of the strategic objectives.

Balance and effectiveness: in addition to maximizing organization value, a project portfolio should endorse balance and effectiveness dimensions. The portfolio can be balanced in dimensions such as long-term vs. short-term, low risk vs. high risk and breakdown by strategic pillars or market segments. Therefore balance constraints should be considered in order to ensure portfolio diversification in terms of various trade-offs. Dickinson and co-workers 2001 support portfolio balance with graphical tools. Liesiö and et al. 2008 provided portfolio balance using logical constraints. Strategic effectiveness implies that project composing the portfolio are consistent with company's core objectives and that the projects mix allows high feasibility and also provides a good economic fit.
Besides that, the definition of the minimum and maximum number of projects in a portfolio support both effectiveness and balance objectives. On the one hand, the minimum limit could be required since the portfolios which do not contain enough projects generally might not benefit from synergy effect and might not provide enough strategic fit. On the other hand, the maximum limit could prevent feasibility issues of complex projects as well as human resources dispersal, the latter issue is often neglected when constructing project portfolios in many organizations.
The three portfolio objectives including efficiency, balance, and strategic effectiveness have been recently considered in Canbaz and Marle research study (2016), including numerous constraints and various types of interdependencies among project investments and resources. They handled the issue as a constraint satisfaction problem through mathematical programming.

Uncertainty and risk:
It is often emphasized that risk and uncertainty should be taken into account in project portfolio problems. The decision-maker, whether it is a single person, or a group of people, usually does not have the complete and precise information about the future implications of the decision because the decision environment is changing constantly. So the assumptions and data the decision maker is asked to provide for each individual project are uncertain and even inaccurate and incomplete. Even, if it is possible to get more precise information, the deep analysis task may require considerable time and cost decision maker cannot practically engage in the portfolio planning phase.
Fuzzy methodology, among others, was applied to model the evaluation data uncertainty (Chen and Gorla 1998, Wang and Hwang 2007, Ravanshadnia et al. 2010, Ahari et al. 2011, Ghapanchi et al., 2012). Sampath and co-workers (2015) applied Monte Carlo simulation to obtain more accurate values of variables' estimates related to objective, constraints and resource metrics to take into account the uncertainty as well as the time dimension associated with projects metrics.

3.2 Project portfolio selection methods classification

Different portfolio selection approaches have been proposed in the literature and all of them share the objective of providing a methodology to guide the project selection process. Nevertheless, they all provide a partial coverage of this combinatorial issue by addressing few aspects among the ones described in the previous section.

The taxonomy presented in table 1 categorizes the various approaches of selection methods and refers to some papers which utilized each technique. This taxonomy is a synthesis of literature review developed by previous authors (Hall and Nauda 1990, Stummer and Heidenberger 1999 and Iamratanakul 2008) and it is extending their work to include hybrid techniques that emerged since 2006. The available methods have been summarized into six groups, including: benefit measurement methods, mathematical programming models, cognitive emulation methods, simulation and heuristics models, real options and hybrid tools. The list of references is not exhaustive, but is representative of available and sometimes recent literature.

There is a consensus today that none of the mentioned techniques provides a comprehensive and universal answer to the project portfolio selection problem, Stummer and Heidenberger (2003) highlighted the correlation between the level of effort in R&D and the sophistication of methods used, indeed the higher the amount of resources at stake, the more managers will be willing to go through the barriers complexity may create. It should be also noted that user-friendly decision support approaches using advanced decision-making techniques have been proposed in the literature (Archer and Ghasemzadeh 2000, Stummer and Heidenberger 2003, Sampath et al. 2015), subdividing the portfolio selection process into several related steps rather than just evaluating and scoring projects, or solving an optimization problem.

Table 1. Project portfolio selection methods classification

Project portfolio selection category	**Main sub-categories**	**References**
1. Benefit measurement methods	1.1 Comparative models	- Helin, A. F., and Souder, W.E., 1974 - Baker, N., and Freeland, J., 1975 - Souder, W. E., and Mandakovic, T., 1986 - Martino, J. P., 2003
	1.2 Multicriteria decision making tools	- Lockett, G., Hetherington, B., and Yallup, P., 1984 - Martel, J-M., Khoury, NT., 1988 - Hurson, C., Zopounidis, C., 1995 - Bouri, A., Martel, J-M., Chabchoub, H. A 2002 - Zopounidis, C., and Doumpos, M., 2002 - Shang, J. S., Tjader, Y., and Ding, Y., 2004 - Ravanshadnia, M., Rajaie, H., Abbasian, H. R 2010 - Vetschera, R., and Teixeira de Almeida, A. 2012
	1.3 Economic models	- Paolini, A., and Glaser, M. A., 1977 - Liberatore, M. J 1987 - Gupta, S. K., and Mandakovic, T, 1992
2. Mathematical programming models	2.1 Linear programming	- Archer, N.P., Ghasemzadeh, F., 2000 - Stummer C., Heidenberger K., 2003 - Medaglia, L., Graves, B., Ringuest, L 2007
	2.2 Non-Linear programming	- Schmidt, R.L., 1993 - Santhanam, R. & Kyparisis, G., 1995 - Canbaz, B. and Marle, F 2016 - Dickinson, M.W., Thornton, A.C. & Graves, S. 2001
	2.3 Integer programming	- Paolini, A., and Glaser, M. A., 1977 - Winkofsky,, E. P., Baker, N. R., and Sweeney, D. J. 1981 - Sampath, S., Gel, E.S., Fowler, J.W., Kempf, K.G.2015
	2.4 Goal programming	- Badri, M. A., Davis, D., and Davis, D., 2001 - Winkofsky,, E. P., Baker, N. R., and Sweeney, D. J., 1981
	2.5 Dynamic programming	- Nemhauser, G. & Ullmann, Z., 1969 - Grossman, G. M., and Shapiro, C., 1987 - Rosen, E. M. and W. E. Souder, 1965
	2.6 Stochastic Programming	- Lockett, G., and Freeman, B., 1970 - Charnes, A., and Stedry, A. C., 1966
	2.7 Fuzzy mathematical programming	- Werners, B., 1987 - Weber, R., Werners, B., and Zimmermann, H.-J., 1990. - Chen, K., and Gorla, N.,1998 - Wang, J. & Hwang, W.L., 2007 - Liesiö, J., Mild, P., and Salo, A., 2008
3. Cognitive Emulation Models	5.1 Decision-tree approaches	- Hespos, R. F. and P. A. Suassman 1965 - J. P. Martino, 1995
	5.2 Game-theoretical approaches	- Grossman, G. M., and Shapiro, C., 1987 - Ali, A., Kalwani, A.U., and Kovenock, D., 1993
	5.3 Group decision techniques	- Lockett, G., Hetherington, B., and Yallup 1984 - Cook, W. D., and Seifford, L. M., 1982
	5.4 Statistical approaches	- Schwartz, **S.** L., and Vertinsky, 1977 - Mathieu, R. G., and Gibson, J. E., 1993 - J. P. Martino, 1995
	5.5 Expert systems	- Hall, D. L., and Nauda, A., 1990 - Liberatore, M. J., and Stylianou, A. C, 1993
	5.6 Decision process analysis	- Winkofsky,, E. P., Baker, N. R., and Sweeney, D. J., 1981 - Schmidt, R. L., and Freeland, J. R., 1992
4. Simulation & heuristics models		- Mandakovic, T.,Souder, W. E.,1985 - Carazo, A.F., Gómez, T., Molina, J., Hernández-Díaz, A.G., Guerrero, F. M., Caballero, R., 2010 - Sampath, S., Gel, E.S., Fowler, J.W., Kempf, K.G., 2015

5. Real options models		Luehrman, T. A., 1998
6. Hybrid techniques	MCDM (AHP) with goal programming	Schniederjans, M. & Wilson, R., 1991
	Mathematical programming and decision tree	Gustafsson, J., and Salo, A., 2005
	MCDM (PROMETHEE V) with Interger programming	Mavrotas, G., Diakoulaki, D., Kourentzis, A, 2008
	MCDM (AHP with multi-attribute decision-making)	Dey, P.K., 2006
	MCDM (AHP) with Fuzzy set theory	Ahari, S. G., Ghaffari-Nasab, N., Makui, A., Ghodsypour, S. H., 2011
	Fuzzy logic with group decision (expert judgment)	Riddell, S. & Wallace, W.A., 2011
	Mathematical programming (DEA with Fuzzy set theory)	Ghapanchi, A.H., Tavana, M., Khakbaz, M. H., Low, G., 2012
	Mathematical programming (DEA, IP) and MCDM (TOPSIS)	Tavana, M.., Keramatpour, M., J. Santos-Arteaga, F., Ghorbaniane, E., 2015

4. Setting a framework for project portfolio selection

As presented in the previous section of literature review, many approaches to solve project portfolio selection problem have been proposed in different sectors and mainly in R&D based-organizations, aiming to address one or many aspects of the issue described in section "3.1". Also few attempts to build integrated support system for portfolio selection have been reported. However, these have been limited and specific to the methods used, rather than providing flexible options and quite interactive approaches for decision-makers.

4.1 Critical analysis of available approaches

Among the models presented in the previous section, mathematical programming and MCDA methods are the ones that have been widely used in the literature in a broader context of project portfolio management. Even though MCDA methods can provide adequate support to project portfolio selection problem, they omit some important aspects of the issue mainly the project interdependencies, such as the resources sharing in specific timeframes of strategy execution, among which there may be complementarity, incompatibility or synergies produced by sharing costs and benefits. MCDA methods are also less applicable in situations with multiple constraints (e.g. resource, time, strategic or political constraints). Most of applicable MCDA methods used in evaluating, scoring or ranking projects are pair-wise comparison-based which would rule them out of the possible options when huge number of projects is involved in the portfolio selection process.

These limitations have led to increasing interest in mathematical programming models as they can integrate such considerations into the project portfolio selection process. However, mathematical models are known by their data-demanding inconvenient while decision makers are not often motivated to provide consistent amount of data at early stages of portfolio selection process. Besides that, mathematical programming models did not demonstrate of suitability for alignment issues and also showed a lack of transparency from decision maker's perspective as he is less involved during the data processing stages, while a decision making process is usually affected by emotional and psychological considerations. Some MCDA practitioners argue that the decision making process today is extending beyond the classical model: Optimizing a single objective function over a set of feasible solutions. In fact, many conflicting aspects are to be handled at the same time and hence the decision is no longer an optimal one but a satisfactory one (Guitouni and Martel 1997). Trying to fill the limitations of each model, some hybrid approaches have been developed (Table 1) with, most of the time, the purpose of achieving good balance between analytics and decision makers satisfaction. Furthermore, models reported in this paper, as well as many others, are based on assumptions that should be challenged. They indeed expect that the decision-maker is familiar with the latest developments in decision analysis (Nowak 2013) and that the organizations have well-established organizational strategy and portfolio management standards.

4.2 A concept of project portfolio selection framework

As emphasized in the problem definition section, the project portfolio management is a continuous process, thus it is open to continuous improvement cycle. Therefore, the portfolio selection problem should be specified as a project portfolio construction, but rather as a reconstruction (Nowak 2013) taking into account the ongoing projects and programs re-assessment to decide whether or not they should be continued in a new portfolio.

Beyond the sophisticated techniques and models, strategy requires effective change to be successfully implemented and then realize a business expected vision. Projects are undertaken to deliver new capabilities but the business change is highly required to transfer this added-value to the operations and make benefits realization happening. That is why programs are critical components of a company portfolio and needs to be carefully and specifically managed. Organization readiness to change has indeed to be well anticipated and undertaken during the portfolio building process, nevertheless, this aspect has been rarely highlighted in the literature as available approaches are considering same handling of both projects and programs.

It is also worth to mention that, in general contexts, a company portfolio is not only new investment oriented, structural, business improvements and compliance related initiatives are actually becoming substantial components of companies' strategies in several domains, as they are continuously challenged by social, political, technological and environmental changes. So such categorization of potential initiatives has to be considered at the strategic planning level. In addition to contributing in the alignment of portfolio components with a company strategy, this categorization will help to compare components that address similar organizational needs and strategic concerns. Consequently, the processes of portfolio selection needs to be applied at category level rather than the whole candidate projects as it is often the case in most of research studies in this area. It is also commonly assumed that a portfolio should be built with the objectives of maximizing business value, ensuring strategic effectiveness and good balance. So an effective project portfolio construction process cannot be established aside from a comprehensive framework that includes the processes of identifying, categorizing, evaluating, prioritizing the projects then finally balancing the portfolio.

In the light of these conclusions along with the literature review and analysis previously reported, a framework concept of project portfolio construction (instead of selection) is presented in figure 5. It shows how a set of potential initiatives should be identified considering first of all the "Mission, Vision and Values" theme of a given company then the analysis of any external factors that might influence its business context. The ongoing portfolio assessment is also considered as a preliminary step to the stage of new projects identification. It provides the decision maker with an important input for the evaluation stage to decide whether or not a running project should be continued, reinforced or removed from the new portfolio. Once all new potential initiatives are identified along with current portfolio assessment, all the projects and programs candidates can be classified into main strategic categories, such as profitability improvement, efficiency increase, enterprise risk mitigation and compliance. After that, qualitative and quantitative analysis is performed based on criteria derived from strategic categories. These criteria are specific to each organization needs but pertain in general to the criteria related to financials, risk, legal or regulatory compliance, market share and organization readiness that mainly includes technology and human resources capabilities but also interdependencies. Evaluation stage is then conducted and a list of ranked portfolio components is produced for each strategic category. A potential grouping of components into programs is also provided to ensure incorporation of cost and benefit dependencies. At this stage, prioritization is required to eliminate the components with lower level of benefits and allow the organization to focus its resources on works that are delivering more value. Hence, a potential portfolio is delivered and balanced afterwards, taking into account risk, capacity constraints and any other balance metrics specific to the organization. The set of potential and practical techniques to be used at each stage will be developed in a future study.

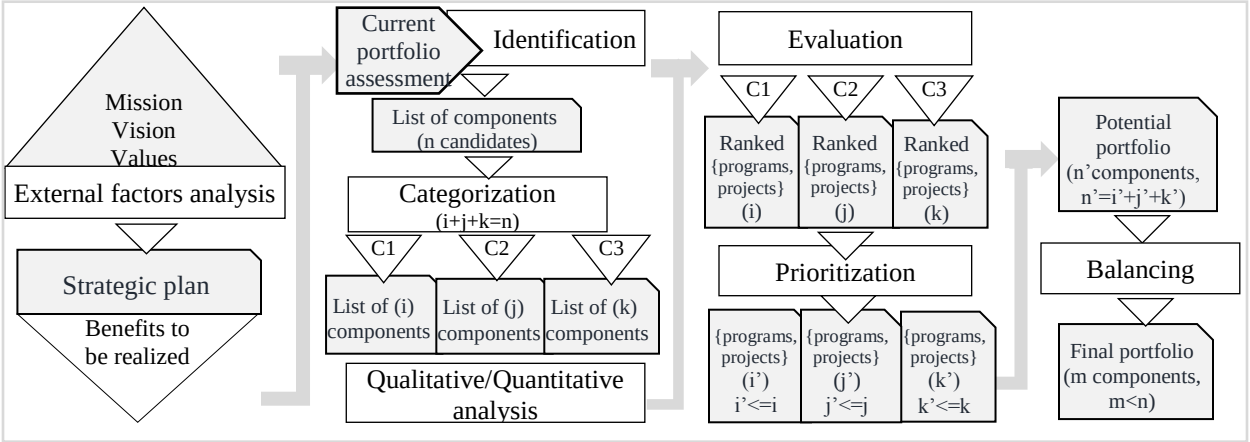

Figure 5. Project portfolio construction framework

4.3 An illustrative example of the components of the project portfolio construction framework

To better explain this framework, let's take the example of a major company that is operating in the automotive sector.

Its mission statement is about exceling at serving its customers every day and its vision is to be the uncontested leader in all the countries the company is operating in, where it is challenged by different government regulations, different market conditions and customer behaviors.

The top management will, first of all, work on the translation of this vision into strategic goals including achieving complete customer satisfaction, increasing sales and marketing aggressiveness while meeting shareholders expectations in terms of profitability levels.

Figure 6 is illustrating the outcomes of portfolio components identification and categorization processes and also presenting, for each category, the possible criteria to be used for evaluating and prioritizing potential portfolio components.

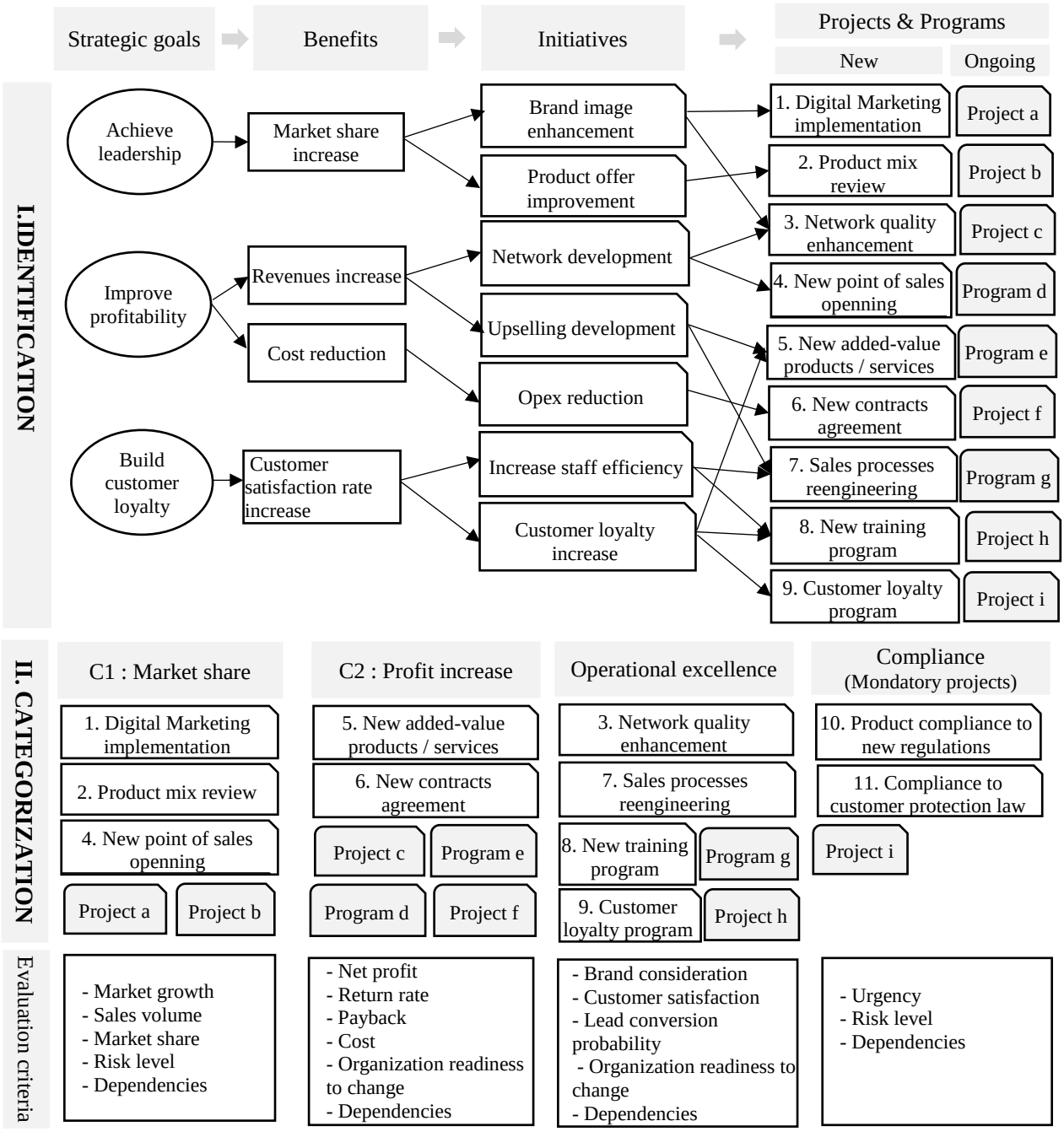

Figure 6. Illustrative example of identification and categorization processes

Conclusion

Building the optimal project portfolio in a fast moving business environment is an important concern for every organization. The process of creating the portfolio component mix with the greatest potential, under various constraints, is complex and knowledge consuming. This complexity mainly remains in the multiple dimensions decision maker has to deal with including multiple objectives, multiple criteria, interdependencies between components, uncertainty and risk and effective balance with respect to the diverse goals of the organization, in addition to the fact that the decision is often made by a group of top managers with different viewpoints and perspectives that require continuous alignment across the portfolio construction related stages.

Beyond the sophisticated techniques of project portfolio selection, this paper's purpose is to provide project portfolio managers and decision makers with a fundamental baseline towards an effective project portfolio construction process including a practical approach from decision maker point of view. An extensive literature review has been delivered along with a critical analysis of the most available approaches in the literature, emphasizing the necessity of tackling the portfolio selection problem within a multi-stage and continuous process that starts from the vision and mission of a company and bridges its strategic goals with its operational level. In a broader context of business organizations, a concept of portfolio construction rather than selection has been described with an illustrative example, showing the flow of potential components identification along with ongoing ones, and also highlighting the importance of conducting the processes of evaluating and prioritizing potential components within strategic categories that are addressing specific organization concerns, where the readiness to change is a crucial part of the evaluation criteria.

This work will be continued as part of a research project in the frame of project portfolio management. In sum, we plan to propose a comprehensive framework of project portfolio construction including practical techniques suggestion throughout the processes of evaluation and prioritization of portfolio components while keeping in mind the objective of a good balance between the analytics and the managerial intuition and expertise.

References

Archer, N.P., Ghasemzadeh, F., An integrated framework for project portfolio selection, International Journal of Project Management vol. 17, no. 4, pp. 207–216, 1999.

Archer, N.P., Ghasemzadeh, F., Project portfolio selection through decision support. Decision Support Systems vol. 29, pp. 73-88, 2000.

Ahari, S. G., Ghaffari-Nasab, N., Makui, A., Ghodsypour, S. H., A portfolio selection using fuzzy analytic hierarchy process: A case study of Iranian pharmaceutical industry, International Journal of Industrial Engineering Computations vol. 2(2), pp. 225-236, 2011.

Ali, A., Kalwani, A.U., and Kovenock, D., Selecting product development projects: pioneering versus incremental innovation strategies, Management science, vol. 39, no. 3, pp. 255-274, 1993.

Axelos, Management of Portfolios (MoP). The Stationery Office, Norwich, 2011.

Axelos, Managing successful programmes (MSP). The Stationery Office, Norwich, 2011.

Badri, M. A., Davis, D., and Davis, D., A comprehensive 0–1 goal programming model for project selection. *International Journal of Project Management*, vol. 19, no. 4, pp.243– 252, 2001.

Baker, N., and Freeland, J., Recent advances in R&D benefit measurement and project selection methods, Management Science, vol. 21, pp. 1164-1175, 1975.

Baker, N. R., and Pound, W. H., R&D project selection: where we stand, IEEE Transactions on Engineering Management, vol. 11, 1964.

Bouri, A., Martel, J-M., Chabchoub, H. A., Multi-criterion approach for selecting attractive portfolio. Journal of Multi-Criteria Decision Analysis vol. 11, no. 4–5, pp. 269–77, 2002.

Chen, K., and Gorla, N., Information system project selection using fuzzy logic. *IEEE Transactions on Systems Management Cybernetics - Part A*, vol. 28, no. 6, pp. 49–55, 1998s.

Canbaz, B. and Marle, F. 'Construction of project portfolio considering efficiency, strategic effectiveness, balance and project interdependencies', Int. J. Project Organization and Management, Vol. 8, No. 2, pp.103–126, 2016.

Carazo, A.F., Gómez, T., Molina, J., Hernández-Díaz, A.G., Guerrero, F. M., Caballero, R., Solving a comprehensive model for multiobjective project portfolio selection, Computers & Operations Research. Vol. 37, Issue 4, pp. 630–639, 2010.

Charnes, A., and Stedry, A. C., A chance-constrained model for real-time control in research and development management, Management Science, vol.12, pp. 353-362, 1966.

Cook, W. D., and Seifford, L. M., R&D Project Selection in a Multi-Dimensional Environment: A Practical Approach, Journal of the Operations Research Society, vol. 33, pp. 397-405, 1982.

Dey, P.K., Integrated project evaluation and selection using multiple-attribute decision-making, International Journal of Production Economics, vol. 103, pp.90–103, 2006..

Dickinson, M.W., Thornton, A.C. & Graves, S., Technology portfolio management: Optimizing interdependent projects over multiple time periods. IEEE Transaction on Engineering Management, vol. 48, pp. 518–527, 2001.

Ghapanchi, A.H., Tavana, M., Khakbaz, M. H., Low, G., A methodology for selecting portfolios of projects with interactions and under uncertainty. International Journal of Project Management, vol. 30(7), pp. 791–803, 2012.

Grossman, G. M., and Shapiro, C., Dynamic R&D competition, The Economic Journal, vol. 97, pp. 372-387, 1987.
Guitouni, A., and Martel, J-M., Tentative guidelines to help choosing an appropriate MCDA method. European Journal of Operational Research, vol. 109, pp. 501-521, 1998.
Gupta, S. K., and Mandakovic, T., Contemporary approaches to R&D project selection: a literature search, in Kocaoglu, D. F. Ed, Management of R&D and Engineering, Amsterdam: North Holland, pp. 67-87, 1992.
Gustafsson, J., and Salo, A., Contingent portfolio programming of risky projects, Operations Research, vol. 53, no. 6, pp. 946–956, 2005.
Hall, D. L., and Nauda, A., "An interactive approach for selection IR&D projects," IEEE Transactions on Engineering Management, vol. 37, pp. 126-133, 1990.
Helin, A. F., and Souder, W. E., Experimental Test of a Q-Sort Procedure for Prioritizing R&D Projects, IEEE Transactions on Engineering Management, vol. EM-21, no. 4, 1974.
Hespos, R. F., and Suassman, P. A., Stochastic Decision Trees for the Analysis of Investment Decisions, Management Science, vol. 11, no. 10, pp. 244-259, 1965.
Hurson, C., Zopounidis, C., on the use of multi-criteria decision aid methods to portfolio selection. Journal of Euro-Asian Management, vol. 1, no. 2, pp. 69–94, 1995.
Iamratanakul, S. A., Patanakul, P. B., Milosevic, D. C., Project portfolio selection: From past to present, Proceedings of the 4th IEEE International Conference on Management of Innovation and Technology, ICMIT, art. no. 4654378, pp. 287-292, 2008.
Killen, C.P. et al., Advancing project and portfolio management research: Applying strategic management theories. International Journal of Project Management, vol. 30, no. 5, pp.525–538, 2012.
Krishnan, V., Ulrich, K.T., Product development decisions: A review of the literature. Management Science. Vol. 47, no. 1, pp. 1–21, 2001.
Liberatore, M. J., An Incremental Approach for R&D Project Planning and Budgeting, Research Management, March 1981.
Liberatore, M. J., An extension of the analytic hierarchy process for industrial R&D project selection and resource allocation, IEEE Transactions on Engineering Management, vol. 34, pp. 12-18, 1987.
Liberatore, M. J., and Stylianou, A. C., The development manager's advisory system: a knowledge-based DSS tool for project assessment, Decision Sciences, vol. 24, pp. 953-976, 1993.
Liesiö, J., Mild, P., and Salo, A., Robust Portfolio Modeling with Incomplete Cost Information and Project Interdependencies. *European Journal of Operational Research*, vol. 190, pp. 679–695, 2008.
Lockett, G., and Freeman, B., Probabilistic networks and R&D portfolio selection. Operation Research Quarterly, vol. 21, no. 1, pp. 353-359, 1970.
Lockett, G., Hetherington, B., and Yallup, P., Modeling a research portfolio using AHP: A group decision process, R&D Management, vol. 16, pp. 151-160, 1984.
Luehrman, T. A., Investment Opportunities as Real Options: Getting Started on the Numbers, Harvard Business Review, vol. 76, pp. 51-61, 1998.
Mandakovic, T., and Souder, W. E., An interactive decomposable heuristic for project selection, Management Science, vol. 31, pp. 1257-1271, 1985.
Martel, J-M., Khoury, NT., An application of a multicriteria approach to portfolio comparisons. Journal of the Operational Research Society, vol. 39, no.7, pp. 617–28, 1988
Martino, J. P., Research and Development: Project Selection. New York: John Wiley & Sons, 1995.
Martino, J. P., Project selection, in Project management toolbox: tools and techniques for the practicing project manager, Milosevic, D. Ed. New Jersey: John Wiley & Sons, pp. 53-64, 2003.
Mathieu, R. G., and Gibson, J. E., A methodology for large-scale R&D planning based on cluster analysis, IEEE Transactions on Engineering Management, vol. 40, pp. 283-292, 1993.
Mavrotas, G., Diakoulaki, D., Kourentzis, A, Selection among ranked projects under segmentation, policy and logical constraints, European Journal of Operational Research, vol. 187, pp. 177-192, 2008.
Medaglia, L., Graves, B., Ringuest, L., A multiobjective evolutionary approach for linearly constrained project selection under uncertainty. European Journal of Operational Research, Vol. 179, Issue 3, pp. 869–894, 2007.
Meredith, J.R., Mantel, S.J., Project Management – A Managerial Approach, 7th ed. John Wiley & Sons, New York, 2009.
Morris, P., & Jamieson, A., Translating corporate strategy into project strategy: Realizing corporate strategy through project management. Newtown Square, PA: Project Management Institute.
Nemhauser, G. and Ullmann, Z., Discrete dynamic programming and capital allocation, Management Science, vol. 15, no. 9, pp. 494–505, 1969.
Nowak, M., Project Portfolio Selection Using Interactive Approach, Procedia Engineering vol. 57, pp. 814 – 822, 2013.
Paolini, A., and Glaser, M. A., Project selection methods that pick winners," Research Management, vol. 20, pp. 26-29, 1977.
Project Management Institute. A Guide to the Project Management Body of Knowledge (PMBOK® Guides), 4th ed. Project Management Institute, Newtown Square, PA, 2008.
Project Management Institute. The Standard for Portfolio Management, 3rdd ed. Project Management Institute, Newtown Square, 2012.
Ravanshadnia, M., Rajaie, H., Abbasian, H. R., Hybrid fuzzy MADM project-selection model for diversified construction companies, Canadian Journal of Civil Engineering vol. 37(8), pp. 1082-1093, 2010.
Riddell, S. & Wallace, W.A., The use of fuzzy logic and expert judgment in the R&D project portfolio selection process. International journal of technology management, vol. 53, no. 2-3-4, pp.238 – 256, 2011.

Rosen, E. M., and Souder, W. E., A Method for Allocating R&D Expenditures, IEEE Transactions on Engineering Management, vol. EM-12, pp. 87-93, 1965.

Saaty, T. L., Rogers, P. C., and Pell, R., Portfolio selection through hierarchies. J. Portfolio Management, vol. 6, no. 3, pp. 16-21, 1980.

Sampath, S., Gel, E.S., Fowler, J.W., Kempf, K.G., A Decision-Making Framework for Project Portfolio Planning at Intel Corporation. Interfaces vol. 45, no. 5, pp. 391-408, 2015.

Santhanam, R., and Kyparisis, G., A multiple criteria decision model for information system project selection. Computers & Operations Research, vol. 22, no. 8, pp. 07–18, 1995.

Schmidt, R.L., A model for R&D project selection with combined benefit, outcome and resource interactions. IEEE Transaction on Engineering Management, vol. 40, pp. 403–410, 1993.

Schmidt, R. L., and Freeland, J. R., Recent progress in modeling R&D project-selection processes, IEEE Transactions on Engineering Management, vol. 39, pp. 189-201, 1992

Schniederjans, M. & Wilson, R., Using the analytic hierarchy process and goal programming for information system project selection. Information & Management, vol. 20, no. 3, pp.33–42, 1991.

Schwartz, **S.** L., and Vertinsky, I., Multi-Attribute Investment Decision: A Study of R&D Project Selection, *Management Science*, vol. *24*, no. 3, pp. 285-301, 1977.

Shang, J. S., Tjader, Y., and Ding, Y., A unified framework for multi-criteria evaluation of transportation projects, IEEE Transactions on Engineering Management, vol. 51, pp. 300-313, 2004.

Souder, W. E., and Mandakovic, T., R&D project selection models, Research Management, vol. 29, pp. 36-42, 1986.

Stummer, C., and Heidenberger, K., Research and development project selection and resource allocation: A review of quantitative modeling approaches, Int. J. Manag. Rev., vol. 1, pp. 197–224, 1999.

Stummer C., Heidenberger K., Interactive R&D portfolio analysis with project interdependencies and time profiles of multiple objectives. IEEE Transactions on Engineering Management, vol. 50, no. 2, pp. 175–183, 2003.

Tavana, M.., Keramatpour, M., J. Santos-Arteaga, F., Ghorbaniane, E., A fuzzy hybrid project portfolio selection method using Data Envelopment Analysis, TOPSIS and Integer Programming, Expert Systems With Applications, vol. 42, pp. 8432–8444, 2015.

Vetschera, R., Teixeira de Almeida, A., A PROMETHEE-based approach to portfolio selection problems. Computers & Operations Research vol. 39, pp. 1010–1020, 2012.

Wang, J. & Hwang, W.L., A fuzzy set approach for R&D portfolio selection using a real options valuation model. *Omega*, vol. 35, pp. 247–257, 2007.

Weber, R., Werners, B., and Zimmermann, H.-J., Planning models for research and development, European Journal of Operational Research, vol. 48, pp. 175-188, 1990.

Werners, B., Interactive multiple objective programming subject to flexible constraints, «European Journal of Operational Research, vol. 31, pp. 342-349, 1987.

Winkofsky,, E. P., Baker, N. R., and Sweeney, D. J., A decision process model of R&D resource allocation in hierarchical organizations, Management Science, vol. 27, pp. 268-283, 1981.

Zopounidis, C., and Doumpos, M., Multi-criteria decision aid in financial decision making: methodologies and literature review. Journal of Multi-Criteria Decision Analysis, vol. 11 no. 4-5, pp. 167–186, 2002.

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