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The Potential of Artificial Intelligence in IT Project Portfolio Selection

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ABSTRACT

The rapid growth of innovative technologies and the complexity of IT projects lead to the change in the tools and competency required for organization management and project management. Also, the scope of an IT product is no longer within a single project and team but requires the collaboration among multiple projects, teams and the alignment with the organization's strategies. Therefore, project portfolio selection becomes a challenging process due to the complexity and uncertainty of various factors and risks. In the IT industry, the emergence of artificial intelligence (AI) could bring opportunities to organizations to address different challenges including challenges in project portfolio selection. In this paper, we have discussed the current challenges in IT project portfolio selection, the available methods and tools and their limitations. Then an overview of the potential applications of AI in IT project portfolio selection is explored. Finally, we conclude the paper by providing future research directions.

Keywords

Artificial intelligence, IT portfolio management, project selection, portfolio project selection.

INTRODUCTION

IT projects cover a broad spectrum from IT services to software development, hardware and networking. Therefore, IT organizations are engaging in ever-increasing IT project types and a large pool of projects to select from. As limited resources and capacity to select and undertake projects are a common challenge among IT firms, having a suitable process and procedure to effectively manage and coordinate organizations' activities of the projects is of prime importance. These activities are focusing on maximizing projects' business values and have attracted an exponential interest both from researchers and industries. IT Project Portfolio Management (ITPPM) is the area that deals more specifically with this concept in IT organizations.

Project portfolio management (PPM) deals with the collaboration of multiple projects sharing a pool of resources and follow the strategic goals to deliver the best business values (Cooper et al. 1997) and fundamentally at a higher abstract level than program and project management. While project and program management are about execution and delivery of the requirements within the constraint of quality, time and budget, PPM, on the other hand, focuses on aligning the project and program deliveries with organizations' strategic goals to maximize their business values. PPM considers the entire portfolio of projects an organization is engaged in to make decisions on project selection and priority (Lycett et al. 2004). Thus, rather than doing projects right, PPM is concerned with doing the right projects (Oltmann 2008), mostly by aligning the projects with organizations' overall strategic objectives.

PPM in organizations is imperative because strategic planning, linking of technology and corporate strategies, and new project selection were rated the most important management of technology problems (Killen et al. 2007). The current trend is toward increasing the role of PPM in IT projects collaborated with other aspects to maximize the organization benefits (De Reyck et al. 2005). PPM has five phases: (1) clarifying business objectives; (2) capturing and researching; (3) selecting the best projects; (4) validating and initiating; and (5) managing and monitoring (Oltmann 2008) and with the following objectives: maximizing the value, linking the portfolio to the strategy and balancing the portfolio (Cooper et al. 1997). Consequently, PPM efficiency is based on strategy fit, single project success, the interdependence between projects, and portfolio balance.

Consequently, it is concluded that the success of PPM depends on the success rate of projects satisfying each of these objectives and factors. In this regard, the focus of this research is on project selection, which is the foundation stage and has a critical role in the overall success of an ITPPM.

To ensure having a robust project selection phase in the portfolio, organizations need to have accurate project selection criteria. Nevertheless, the procedure of proper project selection has been negatively affected due to the complexity of business activities, uncertainty and volatility that are continuously increasing, especially in IT projects. This necessitates managers to take strategic decisions under non-deterministic situations (Costantino et al. 2015). To support decision making, different methods and techniques are available in project portfolio selection (PPS), ranging from financial model to non-financial model, with single criteria cost-benefit analysis to multicriteria methods, or subjective committee evaluation methods (Lee and Kim 2001). However, with the rise of the complexity from both internal and external factors in organizations and IT projects, there is always a need to improve the project selection process for better performance.

In this research, the attempt is to critically review the literature to explore the role of artificial intelligent (AI) in the process of project selections in ITPPM, by addressing the challenge of Multi-Criteria Decision Making (MCDM). This article is organized as follow: the research background is reviewed in the 'Research Background' section; the research methodology is explained in the 'Research Methodology' section the results and findings are presented in 'Research Findings'; and the paper is concluded with the 'Discussion and Conclusion' section.

RESEARCH BACKGROUND

In PPM, the common challenges are: (1) no link between business strategy and projects selection; (2) poor quality portfolio with weak or mediocre projects; (3) lack of focus on right projects; and (4) project trivialization aka projects selection with no breakthrough or innovative outcome (Nicholas and Steyn 2008). Therefore, one of the critical and challenging activities in ITPPM is project selection (Iamratanakul et al. 2008). This selection ensures the success of projects and portfolio by maximizing the shareholders' value and balancing resource allocation and risks (Costantino et al. 2015). Thus, PPS is a process of evaluating and choosing a set of right projects from available proposals and current projects, to facilitate and support organizations to reach their business objectives (Archer and Ghasemzadeh 1999).

Challenges in PPS

The complexity in ITPPM comes from different factors, such as uncertainty, interdependencies among projects, changes, and immeasurable factors (Coldrick et al. 2005). Although defining selection criteria is vital for the success of the project, it is difficult to have a consensus on a set of selection criteria (Costantino et al. 2015). Therefore, selecting the right projects is still problematic although the list of project selection models is nearly endless (Pedersen 2016). By interviewing portfolio managers from different organizations, Pedersen (2016) observes a common situation that the portfolio managers rely on experienced-based intuition to overcome their limitations by utilizing personal networks/connections. Although the advantages of the reliance on experienced-based intuition are present in decision making, biases that distort intuition have also been identified (Bonabeau 2003). The root cause could be the relation between goals clarification and decision-making behavior, where clearer goals push the decision-makers to be more rational; and in contrast, uncertain or unmeasurable goals push the decision-makers to be more intuitive. There are also some gaps between the research and practice when managers make decisions using their experience, information and rules (Pedersen 2016). Thus, human decision making takes a critical role in the PPS process.

In IT projects, the challenge is even greater. The ITPPM area is large and complex, including hundreds of projects and a multitude of interdependencies that cannot be overseen or anticipated by project or portfolio managers alone (Neumeier et al. 2018). In ITPPM, the interdependencies are more complicated than in other sectors and can be classified into resource, technical, or benefit dependencies (Lee and Kim 2001). The transitive dependencies in ITPPM are very complex and it distinguishes between IT project portfolio and other industries (Beer et al. 2015; Wolf 2015). The risk that a portfolio is threatened by a single project's failure is higher corresponding with the size of the ITPPM (Neumeier et al. 2018). Moreover, the traditional PPM is not designed to work well with the short-term market of IT projects (Hoffmann et al. 2017). Therefore, making decisions in the ITPPM is more complicated.

Project portfolio selection approaches

To address the discussed issues, different methods have been proposed and used. However, besides the intuition of decision-makers, popular models for project selection demonstrate several limitations. Iamratanakul et al. (2008) combined two schools of thought on classification approaches for project selection and categorized the models into six dimensions: (1) benefit measurement methods, (2) mathematical programming approaches, (3) simulation and heuristics models, (4) cognitive emulation approaches, (5) real options and (6) ad-hoc models. A deep review of these dimensions has been performed and it implies that no single methodology could fit all the project selection, as each methodology has its strength and weakness (Iamratanakul et al. 2008).

Chaparro et al. (2019) summarize the popular selection methods and identify the benefit of combining multiple single methods. To address radical innovation projects, four key aspects that PPM selection methods should meet are identified as dynamism, interdependency management, uncertainty treatment, and required input data (Chaparro et al. 2019). In this regard, Multi-Criteria Decision Analysis (MCDA), Constrained Optimization, Scoring Models and Linear Programming are the most used techniques in PPS process (Asosheh et al. 2010; Karasakal and Aker 2017; Kumar et al. 2007). Some other methods such as Ranking, Scoring and Analytic Hierarchy Process (AHP) have also been used in IT PPS. These methods provide simplicity and comfort for the decision-makers, although they cannot address the project interdependence constraints (Lee and Kim 2001).

In ITPPM project selection dealing with a large number of projects (Neumeier et al. 2018) and project interdependencies (Aldea et al. 2019) emerged as the main challenges that cannot be easily addressed by traditional methods. To address these issues, Aldea et al. (2019) propose a method combining MCDA and enterprise architecture model-based techniques. Nevertheless, this approach brings complexity, and it heavily relies on managers' and practitioners' skills. Other approaches try to associate fuzzy logic with some traditional methods including AHP, the Technique for Order of Preference by Similarity (TOPSIS), Data Envelopment Analysis (DEA), and Quality Function Deployment (QFD). The main purpose of these integrations was to deal with the uncertainties and interdependencies in PPS procedure. Anisseh et al. (2018) propose a solution by combining fuzzy AHP and fuzzy TOPSIS. Jafarzadeh et al. (2018) introduce fuzzy QFD and DEA integration solution. These proposals, however, somehow show the potential to address the challenges still rely on practitioners' skills and lack real-time ability to adapt to rapid changes in IT projects' innovation and globalization.

In contrast, AI can be used for decision-making and problem-solving as it is built to simulate human intelligence. It has demonstrated numerous advantages in dealing with uncertainties by applying probability computations to the existing data (Chowdhury and Sadek 2012). Although various methods have been introduced in ITPPM, AI approaches can optimize the performance of IT project selection. Therefore, a study in the potential of AI in ITPPM and project selection is a need to enhance the knowledge in this area. In this research, we attempt to explore this potential to enhance the performance of PPS process and reduce the subjective decision of humans. This study discusses the potential of AI in PPS. We have analyzed the data to inform the trends in PPM and the collaboration between AI and PPS process.

RESEARCH METHODOLOGY

A qualitative critical review was approached to analyze and understand the potential of AI in ITPPM in the project selection phase. The aim was to critically analyze the literature on the topic to identify the weakness, controversies differences and inconsistencies (Paré et al. 2015). The scope of this research was limited to IT projects and like other critical reviews, we tried to reach the result of the starting point for further evaluation (Maria J and Andrew 2009). The identified articles were carefully assessed and evaluated to be included in the data analysis for drawing any conclusions. This research attempts to evaluate and identify which AI techniques have the most potential to be used in PPS.

The review was limited to English articles from 2015 to August 2020 to capture the latest trends. The utilized databases were Scopus, IEEEXplore, ScienceDirect and Google Scholar. The first searching query applied to Scopus and IEEEXplore was ("project selection" AND "artificial intelligence" AND ("IT project portfolio" OR "IT project management")). The second search query in ScienceDirect and Google Scholar was ("project selection" AND "artificial intelligence" AND "project portfolio management"). The detail of the processes is presented in Figure 1.

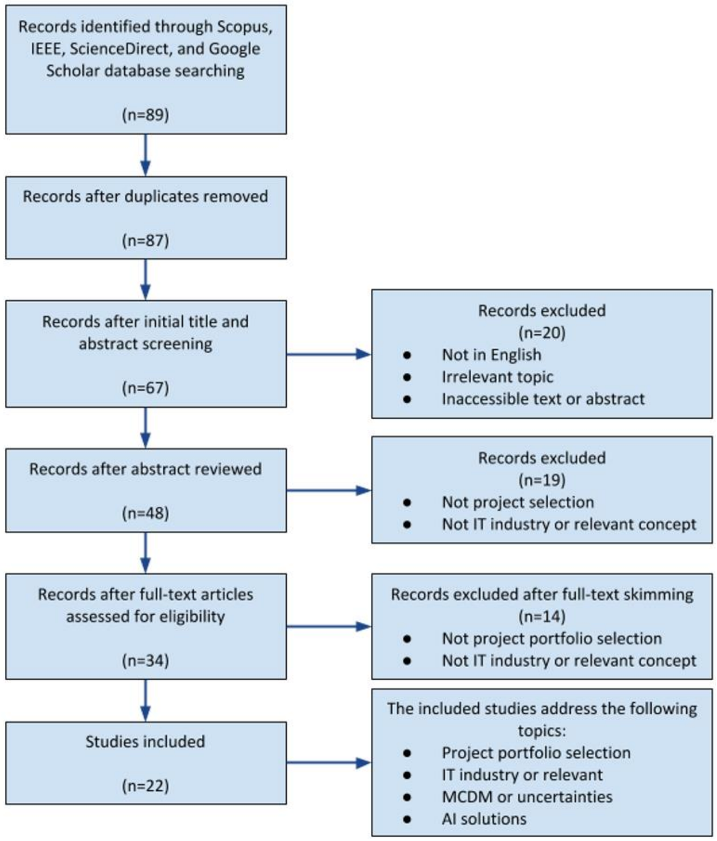

Figure 1. Critical Review Process

RESEARCH FINDINGS

With the development of project portfolio, PPS has become more popular in the last two decades. To illustrate the trend, the term "project portfolio selection" was searched in SCOPUS on September 15, 2020. The results are shown in Figure 2, with the following highlights:

- A significant growing trend within the last 20 years
- Majority of the results are from academic (93.4%) that implies the growing interest of researchers

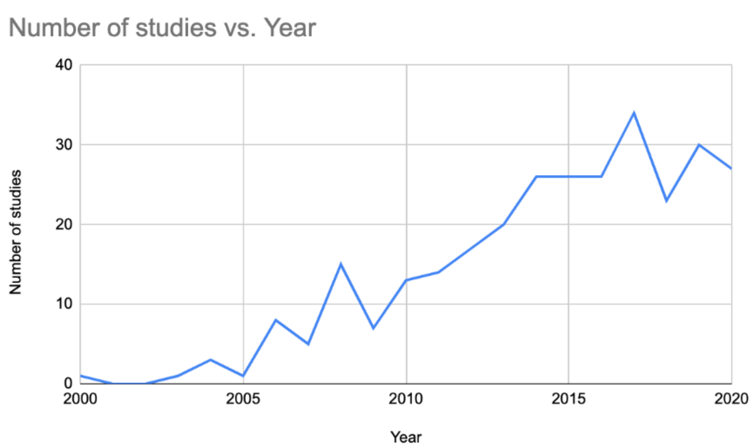

Figure 2. The Trends of PPS Based on SCOPUS

Improving the PPS process is emerging as a need for all organizations. Although AI is showing great benefits in many industries, the attention of AI in PPM is not noticeable. This can be indicated by the number of studies related to both PPM and AI. For instance, searching the term ("project portfolio" AND "artificial intelligence") in SCOPUS on September 15, 2020 only returns 27 results. Therefore, this research provides a comprehensive review for business owners and portfolio managers to have an overview of PPM, its challenges, AI potential to address the challenges, and the main and top trends in AI approaches.

Knowledge of the PPS and its challenges emphasizes the difficulty of making decisions in many interdependent projects with multi-criteria factors. The data analysis results come from 89 articles from various databases, with 22 related articles in total. A critical review and discussion are presented to identify the potential of AI in this area and suggest further studies.

Top challenges in IT PPM

Among the top challenges in ITPPS, MCDM emerges as the top concern discussed in 14 of 22 studies in this research as the challenge requires urgent action. In another study, MCDM was not directly pointed but differentiate projects through multiple attributes and levels (Dash et al. 2018). Thus, MCDM is the main challenge in 68% of the analyzed studies. Other challenges include uncertainty, strategic alignment, project interdependency, and the subjective decision making that can negatively affect the effectiveness of ITPPM and project selection (Table 1).

	Number of Studies	Percentage
MCDM	15	68.2%
Uncertainty	5	22.7%
Strategic alignment	2	9.1%

Table 1. Top Challenges in IT PPS

Our analysis suggests MCDM and uncertainty have closely related and significantly impacted the ITPPM selection process. The quality of MCDM depends on the information received by decision-makers; while decisions mostly are made under multiple, conflicting, and uncertain criteria (Bakshi et al. 2018) largely due to the lack of availability of comprehensive information. This negatively affects the quality of decisions that in turn hardly helps managers to have reasonable actions (Bakshi et al. 2015). MCDM is always complicated and challenging because of the uncertainty and imprecision in the process (Shih et al. 2005). Moreover, in the ITPPM, the criteria to determine the success or failure of projects are ambiguous (Neumeier et al. 2018) and depends on the nature of projects. Besides, some studies indicated the success of MCDM rely on the intuition and experience of the decision-makers (Bakshi et al. 2015; Maki 2019) that makes most of the decisions subjective.

AI trends for IT PPS

Recently, AI has been considered as innovative technology and tool to support decision-making. AI is a system's ability to correctly interpret data, to learn and to use those learnings to achieve specific goals and tasks (Kaplan and Haenlein 2019). AI and decision theory are complementary (Pomerol 1997). For instance, Bayesian Networks to improve the effectiveness and accuracy of problem-solving in MCDM issues (Watthayu and Peng 2004). Jarrahi (2018) discussed the potential of partnership between humans and AI in decision making. AI performs better than human in complex tasks but would not replace human in decision making, instead help by aiding and augmenting to the process in uncertainty and complexity, leading to a balanced approach.

Humans have already been overtaken by AI solutions in accomplishing some quantitative objectives with computational criteria (Parry et al. 2016). Although humans still perform better at the qualitative matter, the success here relies on their intuitive capabilities. This perspective introduced numerous arguments on the relationship between intuition and rationality and opened questions for the abilities of intuition enhancement by using AI (Frantz 2003). Consequently, research on using AI in PPM and PPS is raising. Costantino et al. (2015) introduced a model for early assessment of project success based on critical success factors using an Artificial Neural Network (ANN). In information system (IS) projects, there are several studies on applying AI to solve the MCDM when evaluating and selecting projects. Yeh et al. (2010) introduced a fuzzy multi-criteria group decision-making approach in IS project selection process. Similarly, Deng and Wibowo (2008) proposed an intelligent decision support system to facilitate the MCDA approach and address IS project selection challenges.

Based on our findings, many AI models were found to address the challenges. After assessing the articles, fuzzy approach and ANN are identified as the top trends approaches on PPS (Table 2) and further discussion on these approaches is presented in this section. Other approaches include Bayesian network, Ant colony, Decision tree, and Machine learning.

	Number of studies	Percentage
Fuzzy approach	7	31.8%
ANN	4	18.2%

Table 2. AI-Related Approaches for PPS

Researching the applicability of fuzzy to PPS suggests that fuzzy theory is mostly used to deal with the uncertainty. Ali et al. (2017) proposed an approach to use fuzzy logic to evaluate the profitability of the projects to overcome the uncertainty. In this approach, fuzzy sets are used to determine and transform project qualitative characteristics into a mathematical model, increasing the possibility of describing projects' uncertainties for decision-makers. Fuzzy theory key characteristic is the ability to handle uncertain information and deal with the selection parameters under uncertainties (Ali et al. 2017). Moreover, the fuzzy approach is used with other techniques in other studies. Bakshi et al. (2015) when building a hybrid model of decision-making problem, applied the fuzzy method to find the weight of criteria from which the best projects could be selected. Here, the fuzzy model helps to optimize the choice under the imprecise information (Bakshi et al. 2018). Furthermore, fuzzy can be used to cluster and rank different projects in multiple criteria contexts, which enhance the performance of MCDM in the PPS process (Razi et al. 2015).

Alongside with fuzzy theory, ANN is another top trend in applying AI to ITPPM. ANN is a model to search for relations between data that solve two different problems: function approximation and classification, and each node has two functions, extracting and storing knowledge (Costantino et al. 2015). These neural networks, work like a human brain, have the capability of learning relationships in complex data by detecting patterns, and deduce prediction (Mossalam and Arafa 2018). ANN in ITPPM is widely used over other AI technologies because of the capability to handle the uncertainty, unpredictable and noisy environments (Costantino et al. 2015). Based on our analysis, there are two main streams in ANN for ITPPM including cost approach and managerial approach (Costantino et al. 2015). ANN is not only applied to PPS process alone; it can also be combined with other techniques. Ghodoosi et al. (2016) suggest a hybrid methodology using ANN, Shuffled Frog Leaping Algorithm (SFLA) and K-mean to address the PPS process, where ANN is used to investigate and predict the most relevant parameters to the project tasks through multiple criteria, including recourses amount, time, cost, and income. The potential of this methodology is evaluated by experimenting with a dataset of 420 different projects.

DISCUSSION AND CONCLUSION

Reflecting on ITPPM and project selection, a mixture of quantitative and qualitative criteria and project interdependency are some of the complicated factors. The findings of this research's demonstrate the potential of AI approaches in ITPPM and project selection. Recently, different AI-based models have been used to analyze the projects interdependency under uncertainty; models such as Monte Carlo simulation method or a hybrid risk-based estimate approach using fuzzy theory (Zhang et al. 2017). Most of the approaches try to address the issue of MCDM. In the research background, the challenges, and approaches in ITPPM project selection were presented. The traditional models show limitations due to many projects in the portfolio, constant changes in the IT market and technologies, and the complexity and uncertainty of the criteria. Nowadays, researchers are interested in applying AI to solve these challenges. Many studies propose AI approaches as a solution, such as a fuzzy or ANN. However, the hybrid approach is emerging as a potential solution as there is no perfect solution for all organizations.

From the research background, the study identified the most challenging issues, which are MCDM and uncertainty. These issues led to several problems in the project selection process as follows: unclear criteria, a large number of criteria and projects, qualitative rather than quantitative assessment, and subjective decision making. The traditional approaches such as financial methods cannot address all issues. Based on this research, AI has the great potential to become a new trend in PPS. The results of this study are not a confirmation that AI is the best solution for project selection in a portfolio. The purpose of the study is exploring the potential of AI and giving an overview of a new approach and trend in PPM.

AI in PPS, which shows some potential in performance improvement, still includes some limitations. Firstly, these AI techniques can be viewed as supportive tools that can give better insights to the decision-makers, but the final decision is still subjective to humans. The AI benefits are not quantifiable; therefore, it is harder to convince organizations to apply AI in PPM. Furthermore, the number of AI frameworks is very large, which leads to confusion when determining which frameworks are suitable for each organization or portfolio. Later, in the ITPPMs, the complexity and uncertainty are higher than others, and it may be a problem to identify all necessary factors before AI can analyze and process the data. Besides, applying AI approaches into ITPPM generally and project selection process specifically faces several challenges including approach selection and deployment. AI has numerous approaches, and selecting the most suitable one may be challenging. After deciding the technologies, organizations may face challenges in deployment and training. Another issue that may become critical is the human factor. AI is still quite new for many people and using AI approaches in ITPPM is a big change, which can cause a lot of staff resistance and lack of stakeholders' buy-in.

In this research, we investigated the potential of AI in ITPPM and project selection. The identified challenges in PPS include MCDM, uncertainty and strategic alignment, and the research results suggested that AI has the potential to address the challenges. The research has identified the two top techniques widely used, fuzzy and ANN. Fuzzy approach focuses on dealing with uncertainties, and ANN has more advantages in decision-making under the multi-criteria portfolio. Some other AI techniques are proposed but mostly lead to a finding that each one may only be suitable for a certain organization or circumstance. Thus, some hybrid approaches were proposed to take benefit of various approaches and reduce their limitations. However, further studies are required to identify any potential practical and ethical issues of AI for ITPPM and project selection.

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