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Análisis y diseño de un Sistema de Gestión de Portafolio de Proyectos (PPMS)

Analysis and Design of a Project Portfolio Management System (PPMS)

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RESUMEN

Una investigación basada en herramientas de minería de texto [1] demostró que la Gestión del Portafolio de Proyectos (PPM) ha sido una tendencia importante en los trabajos de investigación desde 2002 hasta el año en que se realizó el estudio, 2019. Kaczorowska et al [2] definen PPM como conjuntos de proyectos implementados, financiados y administrados simultáneamente dentro de la misma organización o en parte de la misma. El propósito de este artículo es elaborar un diseño práctico para el desarrollo de un Sistema de Gestión de Portafolio de Proyectos (PPMS). Para lograr este objetivo, se ha revisado literatura relacionada con PPM y PPMS. Luego, se han destacado los hechos más importantes sobre algunos marcos teóricos y prácticos en PPM. Estos marcos utilizan la toma de decisiones multicriterio (MCDM), AHP, IPSOS, lógica difusa y otros modelos para el proceso de evaluación y selección de proyectos. Finalmente, definimos los requisitos funcionales y los no funcionales, y desarrollamos un modelo teórico para el desarrollo de un sistema de priorización de proyectos y construcción de cartera.

Palabras clave: sistemas de gestión del portafolio de proyectos, sistemas de gestión de portafolios de proyectos, priorización de proyectos, toma de decisiones multicriterio, modelado de software

ABSTRACT

Research based on text mining tools [1] proved that Project Portfolio Management (PPM) has been an important trend in research papers since 2002 until the year the study was performed, 2019. Kaczorowska et al [2] define PPM as sets of projects implemented, financed, and managed simultaneously within the same organization or its part. The purpose of this article is to implement a practical design for the development of a Project Portfolio Management System (PPMS). To achieve this goal, we have investigated some literature related to PPM and PPMS. Then, we highlighted the most important facts about some theoretical and practical frameworks in PPM. These frameworks use Multi-criteria Decision Making (MCDM), AHP, IPSOS, Fuzzy logic and other models for the project evaluation and selection process. Finally, we defined the functional requirements and non-functional requirements, and developed a theoretical model for the development of a system to prioritize projects and portfolio construction.

Keywords: project portfolio management (PPM), project portfolio management systems (PPMS), project prioritization, multi-criteria decision making, software modeling

1. INTRODUCTION

Before going deep into the specific topic of the present text, it is important to review the basic concepts and methodologies of project management. First of all, Project Management can be defined as the utilization of a variety of skills, tools and techniques with the objective of providing value to people. Many activities can be considered projects such as the construction of a structure, the development of a software and the expansion of a company into new markets [3].

In 2020, a research based on text mining tools [1] to find out the latest trends in the project management area was published. In Figure 1 you can appreciate some of the results, in which Project Portfolio Management (PPM) has been highlighted. This trend appeared in 2002 and lasted until the end of the research, in 2019. Also, it has been recognized as one of the most important management approaches to meet the expectations of project

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managers [4]. The article by Wawak et al. [1] allows us to have a clue about the importance of PPM for the researchers in the Project Management fields in the current century.

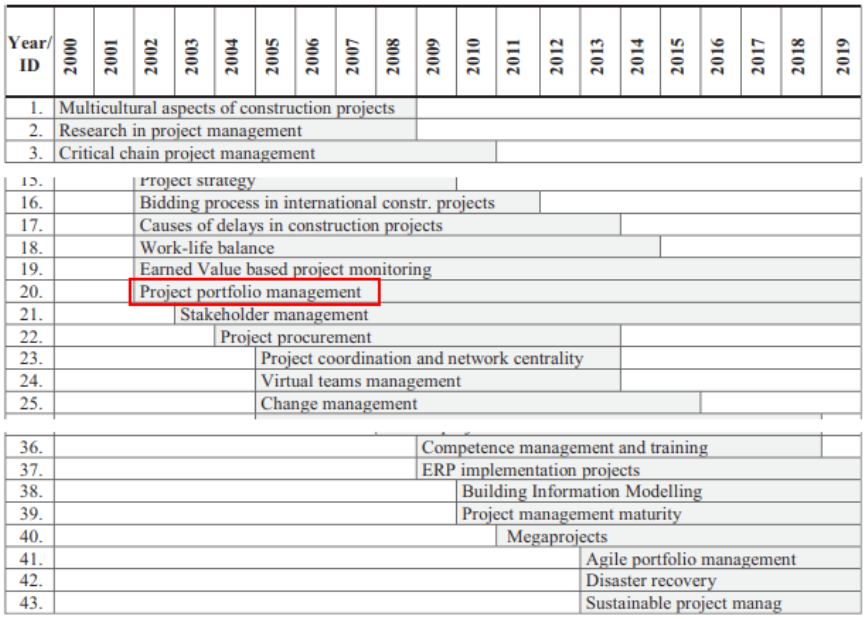

Figure 1. *Latest trends in research on project management [1]*

Nowadays, there are different frameworks available regarding how Project Management should be executed. They have been developed by highly reputable institutions and have been used by several institutions. It is worth mentioning that all of them have their pros, cons and are more suitable for some scenarios than for others [5].

The Project Management Body of Knowledge (PMBOK) was developed by the Project Management Institute (PMI), and it establishes standards for managing projects in different industries. This approach is widely supported around the world and is based on 12 principles [6]. However, this framework might be too complex or bureaucratic for small projects or for the ones that are subject to changes during their lifetime.

On the other hand, it is acknowledged that Agile Project Management is an approach that consists in delivering reiterative products or progress through the entire lifetime of the project. Moreover, the main benefit of this approach is that it allows making changes and adjusting the requirements along the process, instead of waiting until the end [7]. The execution of agile projects is suggested to follow the principles of the Agile Manifesto [8]. This approach was originally developed for IT development but nowadays it is recommended to be used in projects where the requirements are not completely defined, prone to be modified and when the client prefers to be involved [9].

PRINCE 2 stands for Projects in Controlled Environments, and is characterized for dividing the project into stages that can be classified as Technical or Management to divide responsibilities. This approach is suggested to be utilized in environments where the project leader is not highly proficient in management, because the project board will assume this responsibility and also in portfolio management because the supervision of the same project board guarantees one same direction in all the projects that are taking place [5]. In other words, PRINCE 2 is focused on controlling the project from the start point, through the development and to the final step, including the changes and risks that might occur [10].

Kaczorowska et al. [2] define PPM as sets of projects implemented, financed, and managed simultaneously within the same organization or its part. Also, PPM refers to the ability to effectively manage and monitor the success of the organization's project success [4]. Many more definitions can be found in PPM related literature

[11] [12] [13] [14], and the main idea consists of having multiple projects but not enough resources to execute them all at the same time. We can summarize some characteristics of PPM as follows:

- Existence of multiple projects within the same organization to select from.
- As the resources are limited, the projects compete with each other to get some of them.
- It is highly important that the projects support the organization's strategy. The ones that better fit with this requirement will have a bigger chance to get the resources needed for its executions.
- All portfolios must have a well defined and documented prioritization criteria. Projects must be evaluated according to the standard procedure to select the best candidates.

2. MATERIALS AND METHODS

2.1. Instruments

On the instruments view we are considering two important items: the criteria used to evaluate the project, and the method that performs the project prioritization in the portfolio.

Regarding the criteria utilized for the decision making process, we have evaluated a series of frameworks for project selection. Ma et al. [12] developed a multi-criteria framework for project selection in uncertain decision-making environments, and it was implemented in a large-scale paper manufacturer. Ratajová [14] analyzed two projects, a small and a big one, in a consulting firm. The analysis was based on matrices for project selection, which were useful for evaluating some criteria such as: profitability, strategic alignment, duration. Also, a Cobit 5-based approach [11] was implemented for a university in Morocco. This framework uses a combination of AHP and TOPSIS methodologies for the selection and prioritization of IT projects. Previous study cases used different methodologies and applied them into a specific company to prove the usefulness of their frameworks. However, some researchers took a different approach by performing a theoretical study for the development of a PPM system. In the article by Dezhkam et al [4], the authors created a 5-step framework for project analysis and prioritization. Also, they detailed some information related to roles and maturity models in PPM. Furthermore, El Hannach et al [13] wrote a paper focused on the analysis and design of a PPM system. This article explains some basic topics, such as: prioritization criteria, prioritization methods, challenges in project selection, and advantages of the framework. Their analysis and design include some UML diagramas (use case diagram, class diagram, activity diagram) explaining the requirements and functionalities of the system. In Table 1 you can see a summary of the models, methodologies, and prioritization criteria used in the articles previously mentioned.

Criteria \ Article	Husam [18], 2021	Dezhkam et al [2], 2019	El Hannach et al [6], 2019	Ahriz et al [4], 2018	Ma et al [5], 2020	Ratajová [11], 2019
A practical application was performed	☑	☐	☐	☑	☑	☑
Where was the framework applied?	Oil company	-	-	Consulting firm	Paper manufacturer	Moroccan university
What are the steps of the PPM framework?	- Data collection - Determine criteria weights - Define optimal alternative	- Explain status of projects - Analysis & evaluation - Prioritization - Matching to organization resources - Portfolio management system	- Evaluation - Planification - Monitoring	- Projects identification - Criteria evaluation - Project selection - Prioritization - Portfolio adjustment	- Candidates selection - Project evaluation - Optimal portfolio calculation	- Project evaluation - Evaluation of opportunities
What methodologies/models were used?	- TOPSIS - AHP - Fuzzy logic	- Engagement profitability models - Budget alignment model - Maturity model for PPM	- Unified Modeling Language (UML) - Model View Controller (MVC) - AHP, Q-sort	- Cobit 5 - AHP - TOPSIS	- TOPSIS - Fuzzy logic model	- Matrices
What type of indicators are used?	- Profitability - Environmental	- Profitability	- Profitability	- Profitability	- Economic (Profitability) - Environmental - Social	- Profitability
What is the criteria for project prioritization?	- Time - Quality - Cost - Safety - Environmental sustainability	- Fit - Utility - Balance	- Discounted Cash Flow (DCF) - Net Present Value (NPV) - Internal Rate of Return (IRR) - Pay-back period - Weighted scoring	- Multi-criteria decision making (MCDM)	- Key Performance Indicator (KPI) - Multi-criteria decision making (MCDM) - Net Present Value (NPV)	- Profitability - Duration - Strategic alignment - Potential for further business - Good reference

Table 1. *Summary of different approaches considered for this article*

The most common category of metrics are the ones related to the profitability of a project, such as: DCF, IRR, NPV, and pay-back period. DCF consists of estimating the value of an investment by discounting future cash flows at a fixed rate. NPV and IRR are the most extensively used and accepted DCF indices [15]. Unlike the basic DCF, NPV also considers the initial cash flow in its calculation. For more information about NPV, IIR, or Pay back you can review the articles [12] [15].

We also suggest other types of metrics in the project evaluation process:

- Alignment with the company's strategy
- Environment, Social, and Governance (ESG): the company's activities must result in positive effects for the stakeholders (shareholders, community, and others).
- Legal/regulatory: these indicators are related to the accomplishment of the government regulations.

2.2. Methodological design

As for the method used for the project prioritization, we have decided to base our approach oh the following methods: Multi-Criteria Decision Making (MCDM), Analytic Hierarchy Process (AHP), and Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS).

The multi-criteria decision making (MCDM) is widely used to evaluate multiple criteria, as well as to compare and rank several alternatives with respect to criteria and eventually prioritized [16]. Several methods have been developed for the MCDM approach, some of them were identified and divided into categories by Zavadskas and Turskis [17]. In Figure 2 you can see a representation of a MCDM approach.

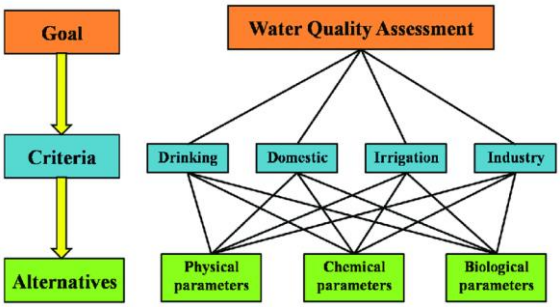

Figure 2. *Approach for Single-Criteria Decision making (left side),*

and Multi-criteria Decision Making (right side).Source: Research Gate

TOPSIS is one of the most popular methods for decision making [16] [18], it was developed by Hwang and Yoon in 1981. This method consists of two artificial alternatives that are hypothesized: Ideal solution (IS), that presents the solution that has the best level for all attributes considered, and negative ideal solution (NIS) for the one which has the worst attribute values [11].

Thus, after calculating the separation of each alternative from the IS and NIS, the ones that are closest to the IS must be prioritized.

Figure 3 is very helpful to explain the selection process in the TOPSIS method.

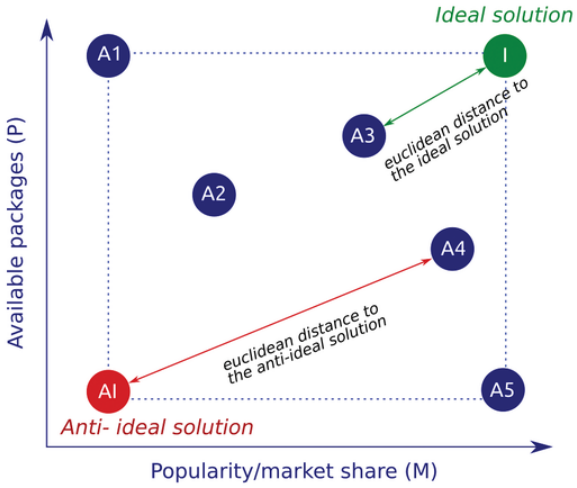

Figure 3. *Selection process from different alternatives by TOPSIS method.*

Source: Linux magazine

AHP was developed by Saaty. It is a systematic decision making method which includes both qualitative and quantitative [11], and is also frequently used for decision making in the areas of evaluation and selection [16]. According to Mohammed [16], decision makers must make a decision or judgment based on pairwise comparisons in between each pair of criteria or alternatives by using Saaty's scale. Saaty's scale is a 1-9 scale where values lie between 'equally important' and ''extremely important.' In Table 2 you can see a representation of Saaty's scale.

AHP Scale of Importance for comparison pair (aij)	Numeric Rating	Reciprocal (decimal)
Extreme Importance	9	1/9 (0.111)
Very strong to extremely	8	1/8 (0.125)
Very strong Importance	7	1/7 (0.143)
Strongly to to very strong	6	1/6(0.167)
Strong Importance	5	1/5(0.200)
Moderately to Strong	4	1/4(0.250)
Moderate Importance	3	1/3(0.333)
Equally to Moderately	2	1/2(0.500)
Equal Importance	1	1 (1.000)

Table 2. *Saaty's scale for AHP*

Source: https://www.researchgate.net/figure/Saaty-scale-for-factor-ranking-Figure-1-describes-the-different-factor-ranking-based-on_fig5_299837810

We decided to use the approach by Ahriz et al. [11], because this methodology divides the PPM into relevant intuitive steps, suggests tools for prioritization and was successfully implemented in IT environments. However, this methodology is complemented with tools and suggestions from different authors. In Figure 4 you can see the flow of steps proposed by Ahriz et al. [11].

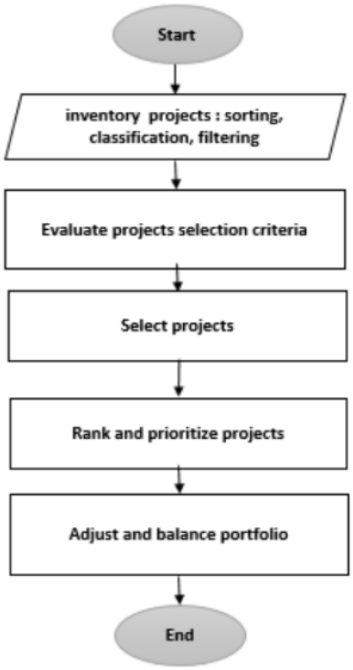

Figure 4. *PPM approach proposed by Ahriz et Al [11]*

3. RESULTS

- **PPMS specifications**

3.1. Roles

The following roles have been identified in the project selection process:

- Decision maker: refers to all the people who will rate the project candidates for the portfolio construction. It is highly recommended that the list of decision makers include the following members: the head of the department that will execute the project, the head of the project management department, and a top-level manager in the organization.
- Head of department: professional who leads the area responsible for the execution of the projects.
- Head of project management department: professional who leads the project management department, who is responsible for the supervision of the project execution, and compliance of the organization procedures.
- System administrator: this role is assigned by the head of the project management department to one of the supervisors from the team. The responsibilities of these roles are: verify the correct use of the system, keep the dimension tables updated, and to help the users from different departments to properly apply the project management procedure.
- System operator: this user can work in any department inside the organization, and his main responsibility is to enter all the required data in the PPMS.

3.2. Functional requirements and Non-functional requirements

In software development it is essential to define the features of the product before the development stage. These specifications might be divided into functional and non-functional requirements. Wiegers and Beatty [19] define the functional requirements (FR) as a description of a behavior that a system will exhibit under specific conditions, whereas non-functional requirements (NFR) describes a property or characteristic that a system must exhibit or a constraint that it must respect. Both functional and nonfunctional requirements will be listed and detailed in this section.

First, we will detail the functional requirements of the PPMS. In Table 1 we can see that the most common category of indicators for project evaluation is profitability, although other frameworks also take into consideration some categories such as environmental and social. For each type of indicator there might be many criteria that could be used to assess a list of possible candidates for prioritization. For instance, NPV and IRR can be included in the profitability category. However, these are not all possible types of indicators and criteria. It is possible that some new regulation gets introduced and companies must urgently make their process fit this new requirement.

- FR1: user should be able to manage a type of indicator
- FR2: user should be able to manage a criteria of evaluation

The aim of the PPMS is to select the candidates that best fit the criteria of evaluation. After defining the types of indicator and the criteria, it is necessary to input the candidates, which can be registered without any restriction of time and quantity.

- FR3: user should be able to manage a list of candidates for the portfolio selection

To evaluate the candidates using the criteria a proper assessment scale is required. Saaty's scale (see Table 2) for AHP must be introduced into the system so that decision makers can rate all projects that compete for the company resources. Also, Saaty's scale could be modified by any authorized user.

- FR4: user should be able to manage Saaty's scale for AHP

As the evaluation criteria might have different importance or relevance, they must be weighted by the decision makers. PPMS is required to allow every decision maker to enter a weight for all criteria according to his point of view.

- FR5: decision maker should be allowed to enter the weights for every evaluation criteria
- FR6: PPMS should calculate the final criteria weight

All the project candidates should be evaluated by the decision makers. The software should have a form to allow these users to enter the required input for the project selection. Then, the system shall determine the final score for all projects.

- FR7: decision maker should be allowed to register the input for all projects regarding the evaluation criteria
- FR8: PPMS should determine the normalized score for every project
- FR9: PPMS should determine the weighted decision matrix
- FR10: PPMS should calculate the Ideal Solution (IS) and Non-Ideal Solution (NIS) following the TOPSIS approach.
- FR11: PPMS should calculate the distance between every candidate to the IS and NIS.
- FR12: PPMS should identify the prioritized portfolio
- FR13: user should be able to generate some report with the final prioritized portfolio from the system

The PPMS must also include some security features to prevent users from accessing non-authorized data. Access is granted by department according to the user needs, only users with granted access must be able to log in to the system.

- FR14: PPMS should authenticate users by a username and password
- FR15: PPMS should validate the access of the authenticated user inside the system

Unlike functional requirements, non-functional requirements are not always visible to the final users as they might represent some abstract feature or behavior, but they are as important as functional requirements. These are some of the non-functional requirements that must meet the PPMS:

- Usability: the software must possess a customer-oriented interface. The UI must be friendly, intuitive, and easy to use.

- Performance: the system should not take too long to respond to a user's request. The software must accomplish the following parameters:

    - identity validation in the log in form should not take longer than 3 seconds
    - report generation must not take longer than 5 seconds
    - save new record or save changes to an existing record must not take longer than 2 seconds
    - load any record or group of records should not take longer than 3 seconds
- Reliability: is related to the probability that a software operates failure-free. These are some of the metrics used to measure reliability in our PPPMS:

    - Mean Time to Failure (MTTF): average time between two successive failures. MTTF for this project must be 2 weeks.
    - Mean Time to Repair (MTTR): average time to fix a failure after it has been detected. MTTR for the project must be 2 days.
    - Probability of Failure on Demand (POFOD): it is the probability that the software will fail after a request made by the user. POFOD for this project must be 5%.
    - Availability (AVAIL): is the probability that the system will be available to use at a certain time. It must take into consideration the time to repair an error, and the time to restart the system. AVAIL for this project must be 95%.
    -
- Robustness: software must properly cope with errors during execution time and incorrect inputs. Validations must be included in the algorithms, all possible scenarios that generate an error must be taken into consideration.

3.3. Software modeling

In this section we will show some graphics to illustrate the functionalities, design, and architecture of the PPMS. First, the following UML diagram will be used to model some of the most important views of the system: use case diagram, class diagram, and deployment diagram.

According to Bell [20], one of the purposes of UML was to provide a stable and common design language that could be used to develop and build computer applications.

A use case illustrates a unit of functionality provided by the system [20]. In Figure 5 you can see the use case diagram for the PPMS, in which the functional requirements have been included.

Basically, the use case diagram shows the features (use case) defined within the system and links them to the role (actor) who is responsible for their execution.

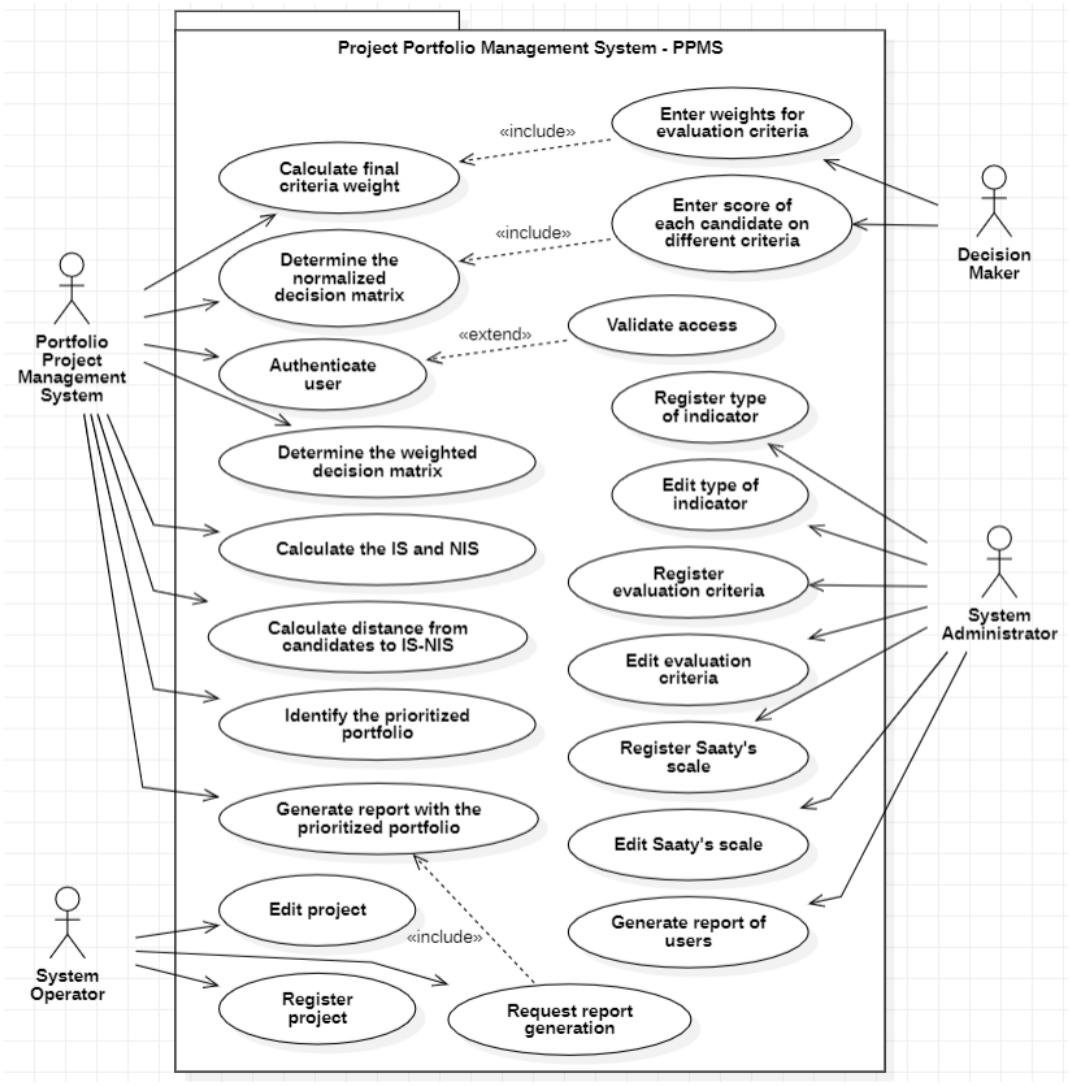

Figure 5. *Use Case diagram for the PPMS*

According to Bell [20], the class diagram (from UML) shows how the different entities (people, things, and data) relate to each other; in other words, it shows the static structures of the system. In Figure 6 you can see the class diagram for the PPMS, in which several entities have been identified from the functional requirements, and linked in accordance with their interaction. For instance, the entities Project and Portfolio are linked by a specific type of relation called Aggregation (part-whole relation), which implies that a Project is a part of a Portfolio but the existence of the part is not linked to the whole.

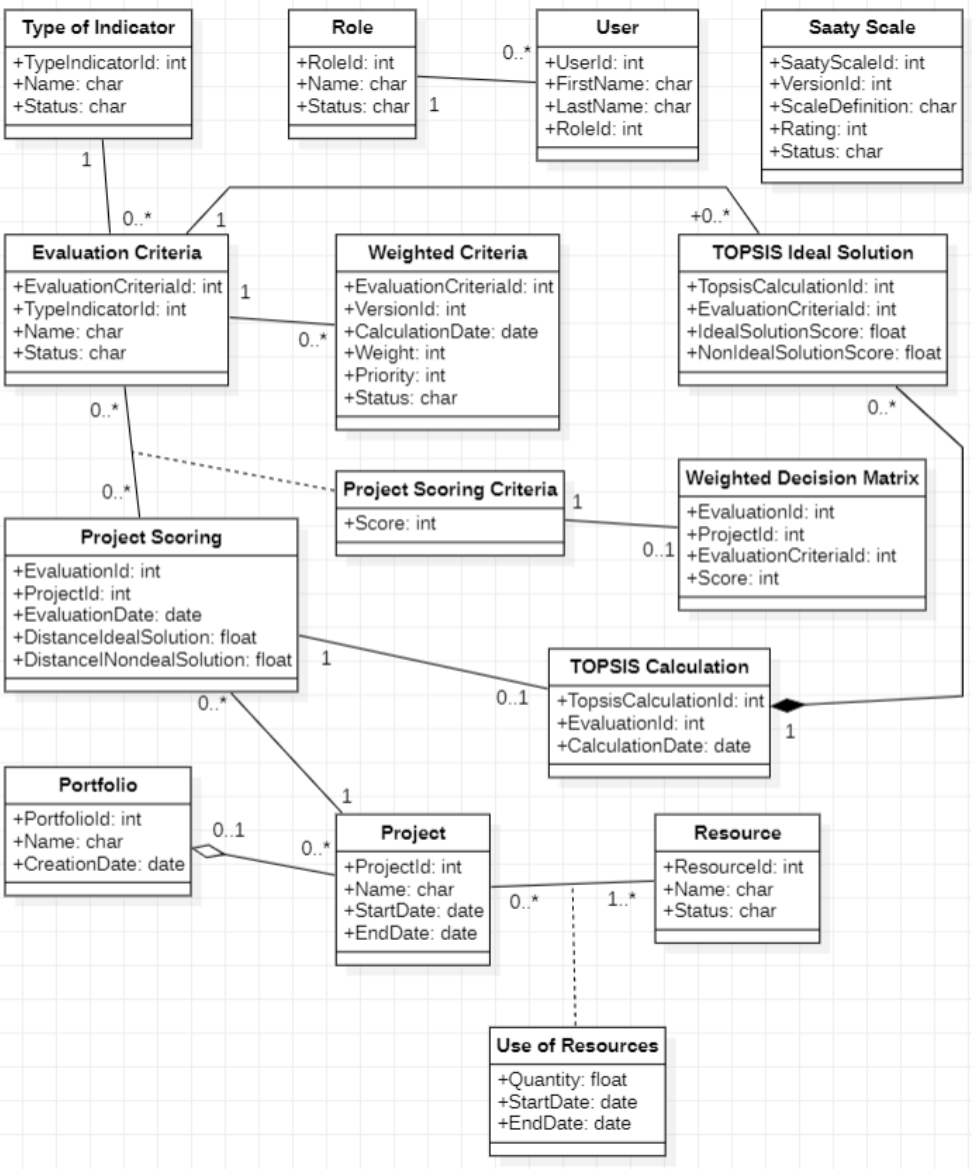

Figure 6. *Class diagram for the PPMS*

As stated by Bell [20], the purpose of the deployment diagram is to show where the different components of the system will physically run and how they will communicate with each other. In Figure 7 you can see the deployment diagram for the PPMS. The user will access the system by using the web browser in his local computer, the application will be hosted in the company application server. Finally, the application server will use TCP/IP to communicate with the database, which will be hosted in the cloud. We can also highlight that the architecture is built on Microsoft architecture, operating system and database management system.

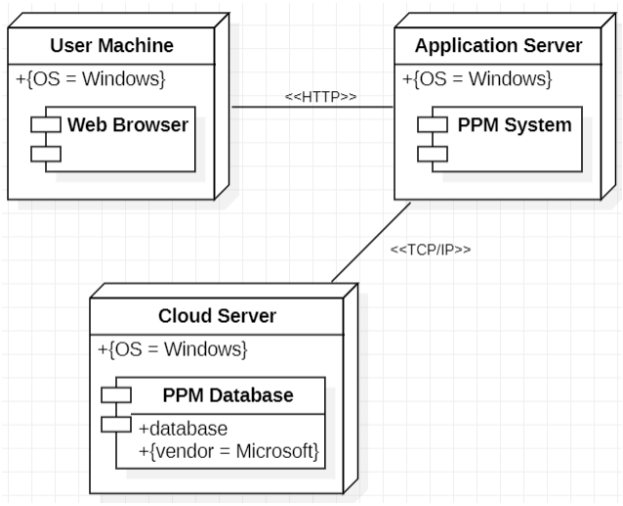

Figure 7. *Deployment diagram for the PPMS*

3.4. Interface Prototype

Following the described functionalities and characteristics, we developed some prototypes of the forms to illustrate the user experience.

- Log in window: requires login credentials (user and password)
-

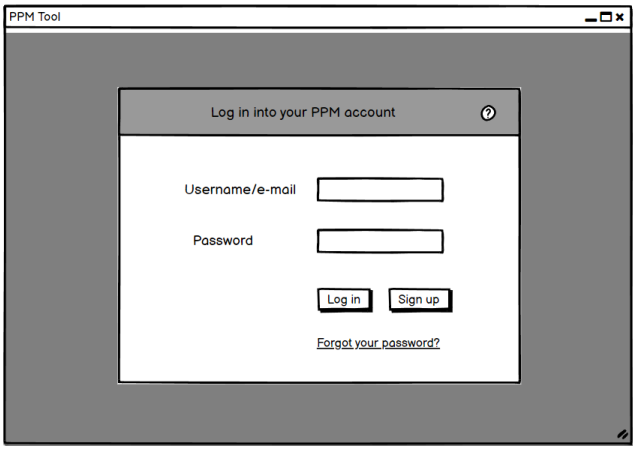

Figure 8. *Log in window*

- Project creation window: used for the registration of a new project. The software requires the user to enter relevant information such as project name, assigned portfolio, estimated initial and end dates of the project. In addition to the amount of resources needed which can be monetary, machinery, materials, human resources, etc. can also be entered.

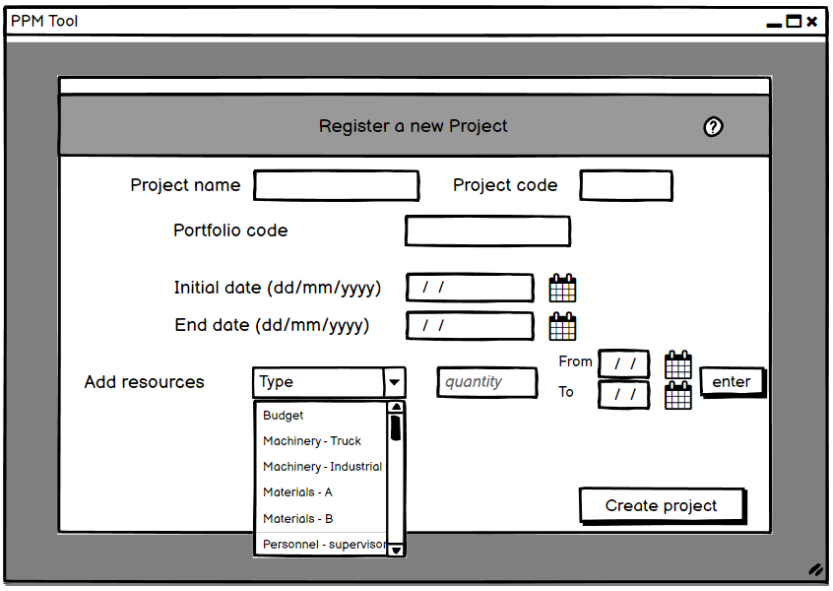

Figure 9. *Project creation window*

- Project selection and optimization window: it is possible to rank the projects among the portfolio. The first step (see Figure 10) is to enter the score per project and criteria in values that go from 0% to 100%. Next, the software will run the mathematical model and will give as an output the project prioritization as shown in Figure 11.

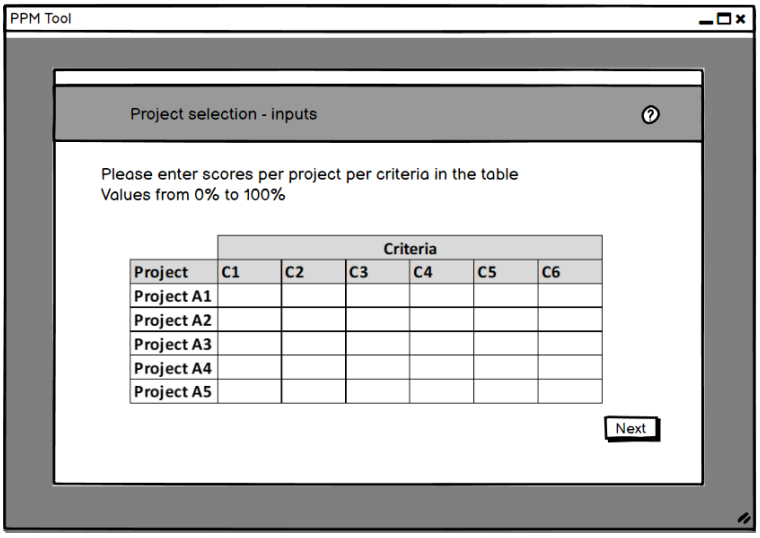

Figure 10. *Enter score per Project/Criteria Window*

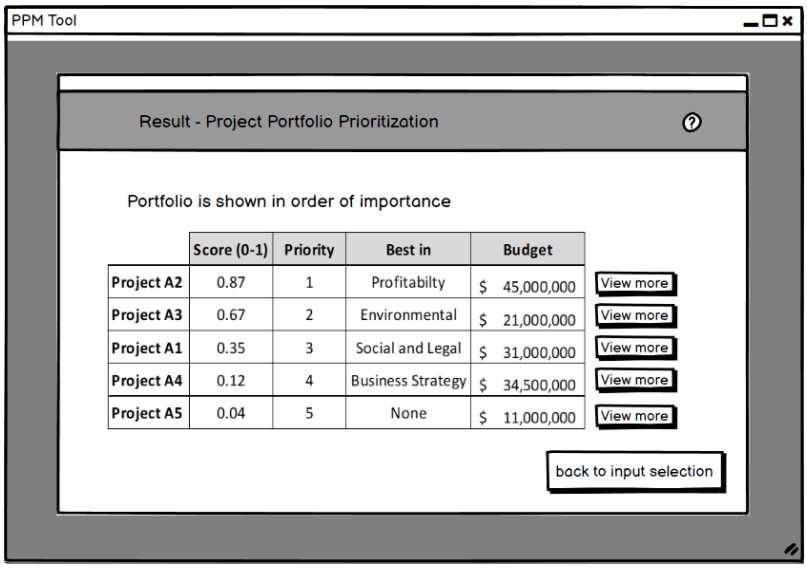

Figure 11. *Results window*

4. DISCUSSION

The designed PPMS takes into consideration different contributions from various researchers in the field of PPM, being multi-criteria decision making, AHP and TOPSIS the most relevant influences for the proposed system. As a result, we have developed a software model for prioritizing projects. which also include the possibility to consider different categories of criteria for project evaluation. We base our model on the approach proposed by Ahriz et al. [11]. This new functionality offers flexibility for being applied in different industries although its application might be complicated due to the complexity of the mathematical model.

5. CONCLUSIONS

A research based on text mining tools [1] positions Project Portfolio Management into the latest trends in project management. Multiple approaches on Project Portfolio Management System [4] [11] [12] [13] [14] [16] were analyzed for this article, most of them concur in the need of analyzing multiple factors while prioritizing projects using different mathematical models. PPMS can be very helpful by assisting organizations in the evaluation and selection of different candidates inside a project portfolio.

REFERENCES

[1] K. W. &. S. Wawak, "Evolution of project management studies in the XXI century," *International Journal of Managing Projects in Business*, Vols. IJMPB-01-2020-0002, 2020.

[2] J. S. S. M. Anna Kaczorowska, "Portfolio approach to project management in creation of the organization's value," *MATEC Web Conf.*, vol. 252, 2019.

[3] PMI, "What is Project Management?," 2022. [Online]. Available: https://www.pmi.org/about/learn-about-pmi/what-is-project-management. [Accessed September 2022].

[4] S. X. Z. L. Majid Dezhkam, "Project portfolio management system, concepts and approach foundations," *IOP Publishing Ltd*, vol. Earth Environ. Sci. 310 052081, 2019.

[5] R. Al-Maghraby, "Project Management Frameworks: Comparative Analysis," in *IPMA 2010 World Congress*, Istanbul, Turkey, 2010.

[6] P. M. I. (PMI), PMBOK® Guide, 2021.

[7] Association for Project Management, "What is agile project management?," 2021. [Online]. Available: https://www.apm.org.uk/resources/find-a-resource/agile-project-management/. [Accessed September 2022].

[8] K. e. a. Beck, "The Agile Manifesto," 2001. [Online]. Available: http://agilemanifesto.org/. [Accessed September 2022].

[9] S. Guy, "Philosophical makeover," *PM Network,* vol. 24(5), p. 38–42, 2010.

[10] C. Bentley, PRINCE2™: A Practical Handbook, 2009.

[11] S. A. e. al, "Cobit 5-Based Approach for IT Project Portfolio Management: Application to a Moroccan University," *International Journal of Advanced Computer Science and Applications,* vol. 9.10.14569/IJACSA.2018.090416, 2018.

[12] J. D. H. R. M. J. B. K. S. Junfeng Ma, "Sustainability Driven Multi-Criteria Project Portfolio Selection under the Uncertain Decision-Making Environment," *Computers & Industrial Engineering,* vol. 140(2):106236, 2019.

[13] R. M. Z. E. A. M. D. Driss El Hannachi, "Analysis and Design of a Project Portfolio Management System," *Canadian Center of Science and Education,* vol. 12(3), 2019.

[14] K. Ratajová, "Strategic Management of a Project Portfolio in a Consulting Firm," *Univerzita Karlova, Fakulta sociálních věd, Institut ekonomických studií. Vedoucí práce Balcar, Petr.,* 2019.

[15] Y. Z. Ruoxin Yan, "The Introduction of NPV and IRR," *Atlantis Press,* vol. Proceedings of the 2022 7th International Conference on Financial Innovation and Economic Development (ICFIED 2022), 2022.

[16] H. J. Mohammed, "The optimal project selection in portfolio management using fuzzy multi-criteria decision-making methodology," *Journal of Sustainable Finance & Investment ,* vol. DOI: 10.1080/20430795.2021.1886551, 2021.

[17] Z. T. Edmundas Kazimieras, "Multiple criteria decision making (MCDM) methods in economics: an overview," *Technological and Economic Development of Economy,* vol. 17:2, pp. 397-427, 2011.

[18] W. S. Krzysztof Palczewskia, "The fuzzy TOPSIS applications in the last decade," *Procedia Computer Science,* vol. 159, no. C, p. 2294–2303, 2019.

[19] J. B. Karl Wiegers, Software Requirements, Microsoft Press, 2013.

[20] D. Bell, "An Introduction to the Unified Modeling Language," IBM, 2003. [Online]. Available: https://developer.ibm.com/articles/an-introduction-to-uml/. [Accessed September 2022].