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MARILIA BOTELHO COELHO

EVALUATING EFFICIENCY IN PROJECT MANAGEMENT OFFICES:
A longitudinal evaluation using Data Envelopment Analysis

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A thesis submitted to the UNISINOS University for the doctoral degree in Production and Systems Engineering.

Supervisor: Prof. Daniel Pacheco Lacerda, D.Sc.

Co-supervisor: Prof. Fábio Antonio Sartori Piran, D.Sc.

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ABSTRACT

A project is a temporary effort to create a unique product, service or result. Due to their temporary nature, they have a life cycle made up of six processes: initiation, planning, execution, monitoring, control and closure. Thus, they combine a set of desirable results and organizational resources throughout each process, using an approach structured in metrics and standards with the aim of meeting the demands and opportunities of organizations. Projects represent a way of keeping companies growing and competitive in a scenario of increasing change and technological demands. As a result, more and more organizations are investing in projects as a way of increasing their results and becoming competitive in the market. Project Management Offices are part of this context with a central responsibility for efficient management within organizations, being the central point of support for outlining metrics and standards that meet the business strategy. The PMO is a structure in the organization that is established in order to standardize how projects are managed and to ensure efficiencies by generating best practices from the delivery of a project portfolio. PMOs can be defined as a governance structure for organizational Project Management and many project-oriented companies are implementing a PMO. One of the indicators used in a company's PMO is the success of projects after they have been closed, thus assessing the effectiveness of the project. This strategy only looks at a few projects in the portfolio, with cost and maturity characteristics. Project maturity is reflected in the FEL methodology. The company uses this methodology to advance gates and thus evolve the maturity of the project scope over time and life cycle.

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LIST OF ACRONYMS

ABNT	Associação Brasileira de Normas Técnicas
ANN	Artificial Neural Networks
DEA	Data Envelopment Analysis
DMU	Decision-making units
FID	Final Investment Decisio
GP	Gestão de Projeto
NBR	Normas Brasileiras de Regulação
PMOs	Project Management Office
SLR	Systematic Literature Review

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1 INTRODUCTION

A project is a temporary effort to create a unique product, service, or result (PMI, 2023). Due to their temporary nature, they have a life cycle of six processes: initiation, planning, execution, monitoring, control, and closure (PMBOK, 2021). Thus, they combine a set of desirable results and organizational resources throughout each process, using a structured approach in metrics and standards to meet the demands and opportunities of organizations (Oliveira; Martins, 2018).

Projects represent a way of keeping companies growing and competitive in a scenario of increasing technological changes and demands (Alves et al., 2013) and, as a result, more and more organizations are investing in projects as a way of increasing their results (Kerzner, 2011) and becoming competitive in the market (Le Dinh; Van; Nomo, 2015). Investing in projects is one of the ways to leverage innovation and competitive advantage (Rodrigues; Jesus; Oliveira, 2019), as well as being important agents of change and development for organizations (Oliveira; Martins, 2018).

To support these market challenges, projects have become important mechanisms for developing and monitoring strategic scenarios, and many organizations have been adapting their processes and operations through the dynamics of projects (Lacerda; Martens; Maccari, 2015). Their management has become a prominent and important group in organizations, as they can bring successful results by increasing the efficiency rates of projects and organizations (Alves et al., 2013).

However, project success, i.e., delivery on time, cost and quality, and the need for adequate documentation of the results of previous projects (lessons learned) continues to be a worrying factor for companies (Favoretto; Carvalho, 2021). Although there are tools and methodologies to support successful practices in projects, they are still heterogeneous and cultural and require knowledge for their application (Joslin; Müller, 2016). Not having a solid mapping of the main failures and management without concise and adequate practices can negatively affect project completion and conduct (Le Dinh; Van; Nomo, 2015). This negative result in the completion of projects is often related to determining factors such as complexity, volatility, and competitive pressure from organizations (Mckay et al., 2013).

Project Management (PM) is the area that has the primary function of minimizing unplanned impacts on projects by planning appropriately, leveraging results to achieve standards established by the organization, and by planning, knowledge, skills, and techniques (Crawford et al., 2012). However, it can be considered a complex area for organizations, mainly due to adverse factors and the enigmatic technology that can influence project operations (Hansen et al., 2021).

With the significant increase in projects, project portfolios emerge with the purpose of strategic prioritization for the company. They can contain, in their portfolio, the most different projects, with variety and different segments (Chen et al., 2020). Portfolio management defines which projects should be prioritized and takes on the role in organizations of managing a portfolio (number of projects) of projects (Araújo; Medeiros Júnior, 2017), selecting which will receive resources and in what period (called multi-year planning), which should be closed, which should be postponed and which need more resources to mature in scope and costs (Jugend; Barbalho; Silva, 2016).

Thus, portfolio management takes an approach aimed at expanding the achievements of projects in a portfolio by identifying, prioritizing, and analyzing the potential value of each project and program so that they are cohesive and aligned with the company's objectives (Ko; Kim, 2019). It supports project development and directly manages projects and programs (Steyn, 2016).

Project management should not work individually but should have structural support to standardize and manage projects in the best way possible, with the aim of having an expanded management that meets the organization's strategy associated with the growing number of projects and their complexity (Viglioni; Cunha; Moura, 2016). It is therefore necessary to have someone formally responsible for managing and directing the standards of these projects (Oliveira; Martins, 2020). Project Management Offices (PMOs) are inserted in this context with a central responsibility for efficient management within organizations (Le Dinh; Van; Nomo, 2015), being the central point of support for outlining metrics and standards that meet the business strategy (Oliveira; Martins, 2018). The PMO is a structure in the organization that is established to standardize how projects are managed and to ensure efficiencies by generating best practices from the delivery of a project portfolio (Philbin; Kaur, 2020).

PMOs can be defined as a governance structure for organizational Project Management (PM) (Aubry; Hobbs; Thuillier, 2009) and many project-oriented companies have been implementing PMOs (Otra-Aho et al., 2018). Project-oriented companies have the characteristic of creating value for the organization through their projects (Bugarˇci'c; Slavkovi', 2023). They can be responsible for identifying synergies between projects, standardizing practices, increasing the availability of information, improving the flow of communication and governance, and disseminating lessons learned (Weydmann et al., 2023). Research by Ko and Kim (2019) shows an 87% increase in the implementation of this area in companies. The implementation of PMOs is a modern management practice that has been gaining ground due to the recognition of its results, as it has the potential to gain efficiency in projects (COELHO et al., 2023).

PMOs can operate at three levels: strategic, tactical, or operational. The strategic level is related to the organization's results; the tactical level refers to the processes and methodology for implementing projects, and the operational level refers to the results of projects (Ramos, 2013). Thus, by determining the level of action of each PMO, it is possible to establish measurable parameters and criteria in metrics to measure a PMO, and with this, it is possible to determine the efficiency of this entity for organizations (Oliveira; Martins, 2018).

However, there still needs to be more in the definition of the efficiency of a PMO. Practical and meaningful results considering various internal and external environmental variables can contribute to the assertiveness of PMO efficiency (Ko; Kim, 2019). Thus, this research is part of the theme of evaluating the efficiency of PMOs, considering the project portfolio of a petrochemical company using Data Envelopment Analysis (DEA), identifying the prevalent variables on PMO efficiency through artificial neural networks (ANNs), in addition to contributing to the analysis of the influence of PMOs on projects. The following section outlines the object of study and the research problem.

1.1 Object and Research Problem

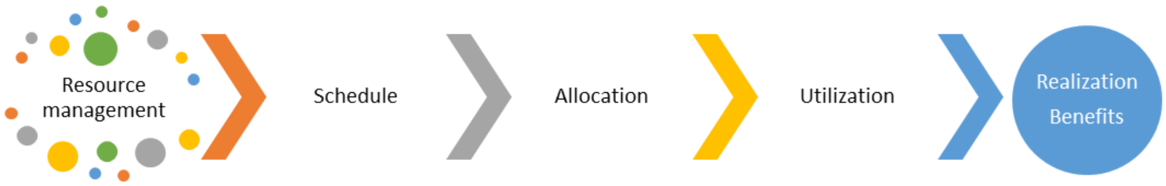
Academic studies show that the PMO is a growing topic (Machado; Martens, 2015; Rezende; Blackwell; Gonçalves, 2018), as it is considered an excellent manager that supports and assists project managers and teams, functional areas, and all organizational levels on strategic, tactical and operational issues that impact on project management (Aubry, 2015; Bredillet; Tywoniak; Tootoonchy, 2018a; Lacruz; Cunha, 2018). However, the efficiency of the PMO and its influence on project efficiency is questioned, mainly because they are restricted to analyzing indicators such as scope, time, and cost (Barbalho; Da Silva; De Toledo, 2017; Oliveira; Martins, 2020).

The company where the study was carried out is a petrochemical industry with international operations. The company uses a tactical and operational PMO, i.e. one that focuses on processes and methodology, but which also monitors project results (Oliveira; Martins, 2018). One of the indicators used in the company's PMO is the success of projects after their closure, i.e. project effectiveness. This strategy only points to a few projects, included in the portfolio, with cost and maturity characteristics. Project maturity is reflected in the FEL methodology. The company uses this methodology to advance gates and thus evolve the maturity of the project scope over time and life cycle. The definition of effectiveness is closely related to the results and objectives achieved from a process and is thus linked to the fulfillment of objectives originating from these results (Pinto; Coronel, 2017).

Efficiency and effectiveness are two topics that evaluate the performance of an organization, as well as the expectations of users and the people who use the resources during the service process. However, both topics are divergent. There can be efficient and ineffective organizations and PMOs and inefficient and effective organizations and PMOs.

Measuring efficiency in companies is a key factor in designing appropriate theories and policies (Piran; Lacerda; Camargo, 2018). A PMO can become technically efficient when it uses a minimum level of resources to achieve a particular result (Ko; Kim, 2019). It is through the management of these resources that the PMO articulates, using synergies, the realization of results and benefits. Figure 1 summarizes these relationships.

Figure 1 - Resource Management in a PMO



Source: Prepared by the author.

Evaluating the efficiency of the PMO can strengthen planning practices (Weydmann et al., 2023) and project control, increasing efficiency and improving the delivery of results (Coelho et al., 2023). This finding reinforces that important contextual elements for developing a model to measure the PMO in a global company have not yet been mapped, are not related, or have not been studied enough in the literature. Knowing or disregarding the contextual elements can lead to critical contextual characteristics for a PMO's emergence, growth, and development, which need to be more known and, eventually, disregarded in the organization's planning or the company's Project Management.

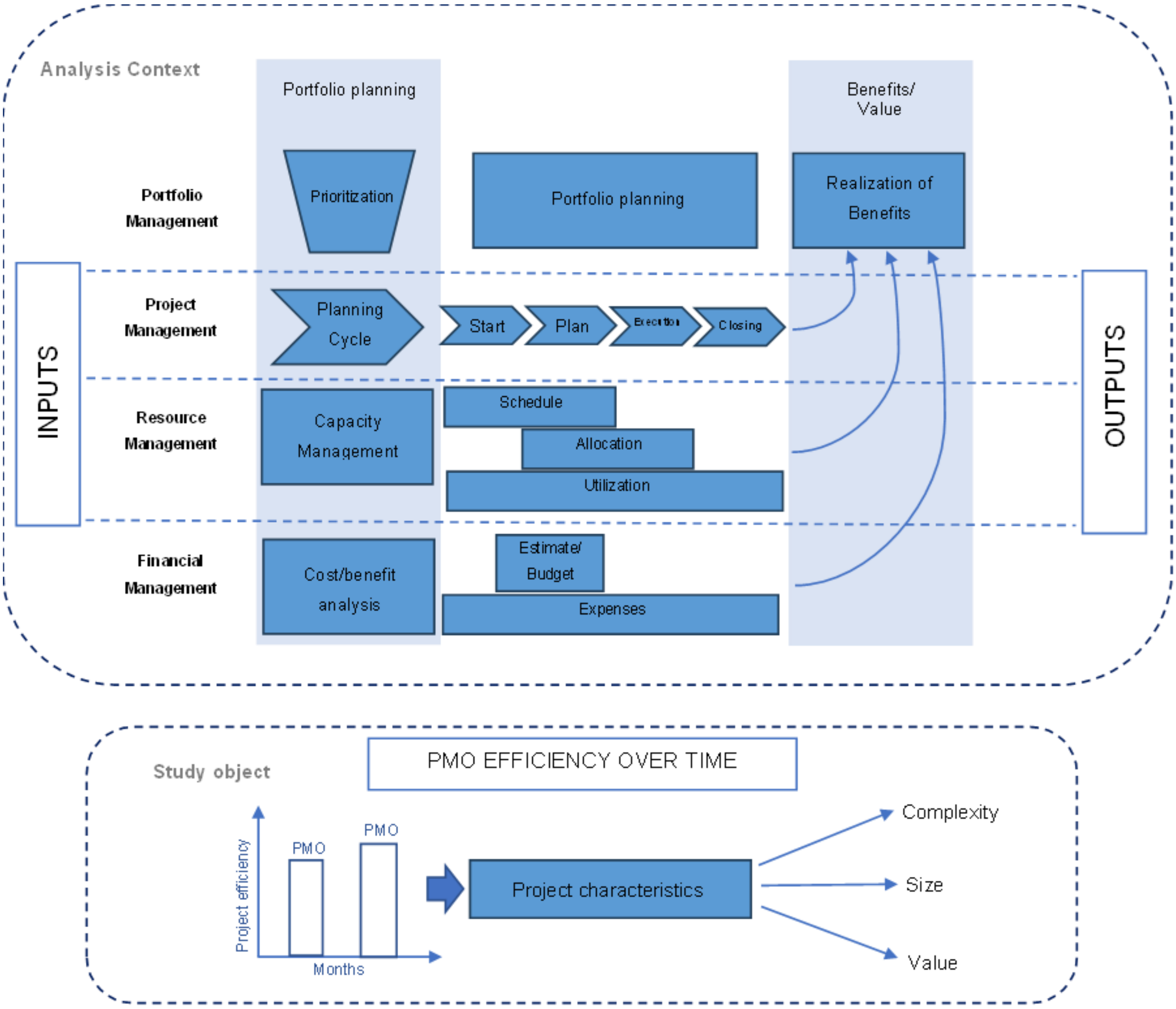
In this sense, the company works with various projects, making its portfolio complex and large in volume. The company's projects are classified into asset sustainment and value addition projects. In this classification, they are divided into twelve types: (i) safety; (ii) environment; (iii) reliability; (iv) catalysts; (v) health; (vi) innovation and technology; (vii) infrastructure; (viii) quality; (ix) IT investment; (x) productivity; (xi) commercial and; (xii) capacity.

The company under study is made up of a tactical and operational PMO. PMOs fill different roles in organizations and potentially contribute in different ways (Hobbs; Aubry, 2007), contributing positively to the efficiency of projects and the organization, thus becoming a legitimate object of study (Coelho et al., 2023). The efficiency of a PMO contributes directly to the organization's return on investment (Aubry et al., 2011).

Dai and Wells (2004) correlate project efficiency with PM and that this variable should be considered when evaluating PMO efficiency. However, assessing the performance of a management entity in organizations goes far beyond a list of criteria and indicators (Aubry; Richer; Lavoie-Tremblay, 2014). Strategy, organizational factors, information systems, project portfolio management, and relationship networks are simple metrics that can contribute to PMO performance (Oliveira; Martins, 2020).

Based on this scope, the objectives of this research are outlined. Figure 2 shows the research design and the main stages of the study.

Figure 2 - Research design



Source: Prepared by the author.

The research design shown is divided into two blocks: the context of analysis and the object of study. The context of analysis refers to the work of the PMO, which directly influences projects in the company studied. The PMO's work in the company includes four areas: Portfolio Management, Project Management, Financial Management, and Resource Management. Portfolio management is the stage at which it is defined which projects will be carried out over the year and the forecast for execution five years ahead (N+5). Among the main parameters defined are project prioritization and portfolio planning.

Complexity can be related to managing multiple stakeholders due to the diversity of agendas or multiple social interactions or divergent opinions throughout the project, the ambiguity of project characteristics, resources, and phases, external influences, use of new technology for the company, and significant internal influences

(PMI, 2023). The size of the project is directly related to its duration, which can be as short as six months or as long as 18 months (Lanz; Lanz, 2013). Lanz and Lanz (2013) also point out the importance of adopting a value criterion for projects, where projects can vary in value from investments of less than US$200,000 to projects worth more than US$2 million. Table 1 shows the main explanatory dimensions for characterizing a project.

Table 1 - Project Classification

	Classification		
Dimension	Low	Medium	High
Complexity	Low	Average	High
Size	< 6 months	6-18 months	> 18 months
Value	Up to US$ 200 thousand	From US$ 200,000 to US$ 2 million	> US$ 2 million
Objective	Process mapping, continuous improvement	Change management, systems projects	Infrastructure projects; Strategy
Degree of innovation	Cost reduction	Product improvement, addition to existing line, new to the company, repositioning.	New to the world
Technological uncertainty	Technology largely mastered	Technology not mastered and few suppliers	Technology unknown or to be developed
Scope instability	Changes of up to 5% in scope	Changes between 5 and 20% in scope	Changes of more than 20%
Management scope	Up to 3 departments or 3 companies involved	Between 3 and 9 departments and/or companies involved	More than 9 departments or companies involved
Risks	Changes of up to 5% in cost, time or quality	Changes of 5% to 20% in cost, time or quality	Changes of more than 20% in cost, time or quality
Stakeholder interference	Low	Medium	High
Business value	Low	Medium	High
Level of organizational change	Low	Medium	High

Source: Prepared by the author, adapted from Lanz and Lanz (2013) and PMI (2023).

These classifications can be adapted to the reality of each organization and the objectives of using a project classification system. This classification can be used for other purposes, such as for project management methodology, project organization, for the appropriate personnel to carry out the project, project managers, project performance indicators, project success criteria, criteria for adopting legal, cultural, and philosophical systems, projects for technology transfer (Lanz; Lanz, 2013).

Thus, each stage in the evolution of project maturity takes place according to the company's execution strategy and Portfolio Management. Resource and financial management are congruent stages of project management and align with the planning. Capacity management and cost/benefit analysis are essential in these stages. The performance of these stages is related to proper planning and prioritization, i.e., the better the capacity and cost planning, the lower the deviation in project completion.

The operation of the PMO is made up of inputs that are processed and transformed into outputs. Inputs can be seen as the indicators needed for all the stages managed by the PMO to be completed as planned. In this case, they relate to project deadlines, costs, quality, and resources. The outputs can be seen as the result of the PMO management process, from all the Portfolio Management stages to Financial Management. These outputs are the budget and the closure of a given project in the portfolio. Chapter 4 provides more details on the company studied.

The object of study is the longitudinal analysis of the technical efficiency of the PMOs operated through the process described in the context of analysis. Technical efficiency can be understood as the ability to obtain maximum production from a given set of inputs and, thus, it is possible to obtain a greater volume of results using the same resources and produce the same results using a smaller volume of resources (Piran; Lacerda; Camargo, 2018) (the concept of technical efficiency will be presented later in Chapter 2). Longitudinal analysis makes it possible to identify whether the behavior of technical efficiency varies according to the period analyzed.

Since the PMO has a global vision of Project Management, it can show efficiencies in each stage of its processes that show individualized results, such as Portfolio Management, which shows portfolio efficiency and, thus, respectively, each management area. Measuring the efficiency of a PMO requires a set of factors that can be evaluated during the execution of a project and according to each organization's strategy, such as portfolio efficiency, project efficiency, corporate culture, and cost planning.

In the PMO's vision, individualized processes result in their results and are characteristic of each process. When assessed globally and considered as a PMO vision, these variables can provide results for measuring PMO efficiency, which needs to be considered by companies. The effectiveness of projects in organizations assumes the PMO's efficiency.

To characterize the variables for evaluating a PMO, it is necessary to identify how it operates in the organization (Oliveira; Martins, 2018). By establishing clear, measurable, and realistic metrics to monitor the activities under its responsibility, the PMO can demonstrate its real efficiency to the organization (Spalek, 2013). Thus, PMOs manage project resources to support managers and staff in developing and carrying out projects, helping improve project performance and effectiveness. Figure 3 shows a map of the PMO's objectives in an organization.

Figure 3 - Map of the PMO's objectives

Source: Prepared by the author.

The inputs of a PMO require a set of projects to manage, i.e., a project portfolio, and thus financial management and resource management, in line with appropriate planning and within estimates. With portfolio management, prioritization takes place through business strategy and appropriate planning. In Project Management, the results of execution and closure are part of the process and output to the PMO. Resource Management is directly related to people and culture—moreover, Financial Management is part of every process and output of a PMO.

In addition, the academic literature recognizes the existence of the so-called PMO efficiency gap, which is related to what type of metrics to use and how to correlate them with independent factors such as stakeholder preference or project maturity that do not influence the results (Duarte et al., 2019; Aubry, 2015; Aubry and Hobbs, 2010; Mckay et al., 2013; Ko; Kim, 2019). In addition, the most common PMO-related topics in academic papers are those that explore the appropriate roles, functions, and services (Mckay et al., 2013).

Academic studies show that the PMO is a growing topic (Machado; Martens, 2015; Rezende; Blackwell; Gonçalves, 2018), as it is considered an excellent manager that supports and assists project managers and teams, functional areas, and all organizational levels in strategic, tactical and operational issues that impact on project management (Aubry, 2015; Bredillet; Tywoniak; Tootoonchy, 2018; Lacruz; Cunha, 2018; Oliveira; Martins, 2020). Even so, the efficiency of the PMO and project management itself is questioned, mainly because they are restricted to analyzing scope, time, and cost (Oliveira; Martins, 2020; Barbalho; Da Silva; De Toledo, 2017).

Given the research object, the problem linked to it is contextualized, first addressing a PMO vision model. Thus, project management looks at the process as a whole, addressing cost, people, culture, and business strategy.

Thus, the central question of this thesis project is: Does the PMO influence project efficiency? How can the efficiency of a PMO be measured in a company that deals with projects of various natures and complexities? In this sense, the PMO efficiency gap must (or should) be related to how to achieve an efficient PMO and which metrics best encompass this measurement according to the company's strategy. Which metrics support the efficiency of a PMO?

Therefore, the starting point for defining this thesis's problem emerges from some gaps in the literature. The first relates to how companies assess the efficiency of PMOs. It is understood that companies need to establish a set of variables to assess the benefits of PMO efficiency. These are outlined in the research design.

The following section, 1.2, outlines the work's primary and specific objectives.

1.2 Objectives

To solve the research problem, the primary and specific objectives are listed.

1.2.1 Primary objective

The primary objective of this research is to conduct an exploratory analysis to identify the variables present in the PMO process, using Data Envelopment Analysis to evaluate the technical efficiency of operations.

1.2.2 Specific objectives

To meet the primary objective, the following specific objectives are listed:

a) To critically evaluate studies that analyze PMO efficiency and efficiency in the area of Project Management, whether or not they use DEA;

b) To evaluate the influence of PMOs on the technical efficiency of projects, taking into account the complexity, size, and value of projects;

c) Create a model to measure the efficiency of PMOs, identifying opportunities for improvement by evaluating two-stage data envelopment analysis (DEA);

d) Quantifying PMO efficiency, evaluating its behavior over time, and identifying prevalent variables for process improvements.

Section 1.3 describes the arguments justifying this study.

1.3 Justification

The company studied needs help in assessing productivity and evaluating the effectiveness of projects, not the efficiency of the PMO. The main reason is that it has a portfolio with specific characteristics and projects of varying complexity regarding costs, resources, and deliveries. Project effectiveness does not represent PMO efficiency. In this sense, the model developed in this research contributes to the PMO's operating process, as it allows and enables visibility of the actual efficiency in each part of the process: portfolio, project, costs, and resources. This visibility is possible because the model uses variables from the PMO operating process to measure efficiency.

Organizational factors such as strategic planning, project portfolio management, operations, financial management, resource management, relationship networks, people, knowledge management, and organizational culture have been investigated in isolation in project management (Oliveira; Martins, 2018). The argument is that these organizational factors, when integrated in favor of the PMO, without distinction of a specific type, imply the success of projects and organizational results, in addition to contributing to the efficiency of the PMO. Therefore, demonstrating how theoretical knowledge connects with the organization's natural processes is a considerable contribution.

To justify this research from a theoretical point of view, a systematic literature review was carried out in line with the topic of study. According to Morando and Camargo (2015), systematic literature reviews are secondary studies used to map, find, critically evaluate, consolidate, and aggregate the results of relevant primary studies on a research question or topic and identify gaps to be filled, resulting in a synthesis.

The literature review was carried out in two phases: the first focused on the topic of PMO efficiency, and the second on the application of data envelopment analysis to evaluate the efficiency of PMOs. The first phase aimed to identify research that addresses information on the subject of PMOs in their general context. These articles were then selected by title and abstract to select studies aimed at applying and analyzing the efficiency of PMOs. The search for articles was carried out in international databases. The databases used were SCOPUS, WEB OF SCIENCE, and EBSCOHost. Keywords were defined for the broad search phase. Table 2 shows the terms defined for the first phase of the review.

Table 2 - Keywords used in the first review phase

Source	**Keywords**	**Connector**	**Link keyword**
International	Project Management Office	AND	Performance

Source: Prepared by the author.

The works identified in the review phase are shown in Table 3.

Table 3 - Results of the first research phase

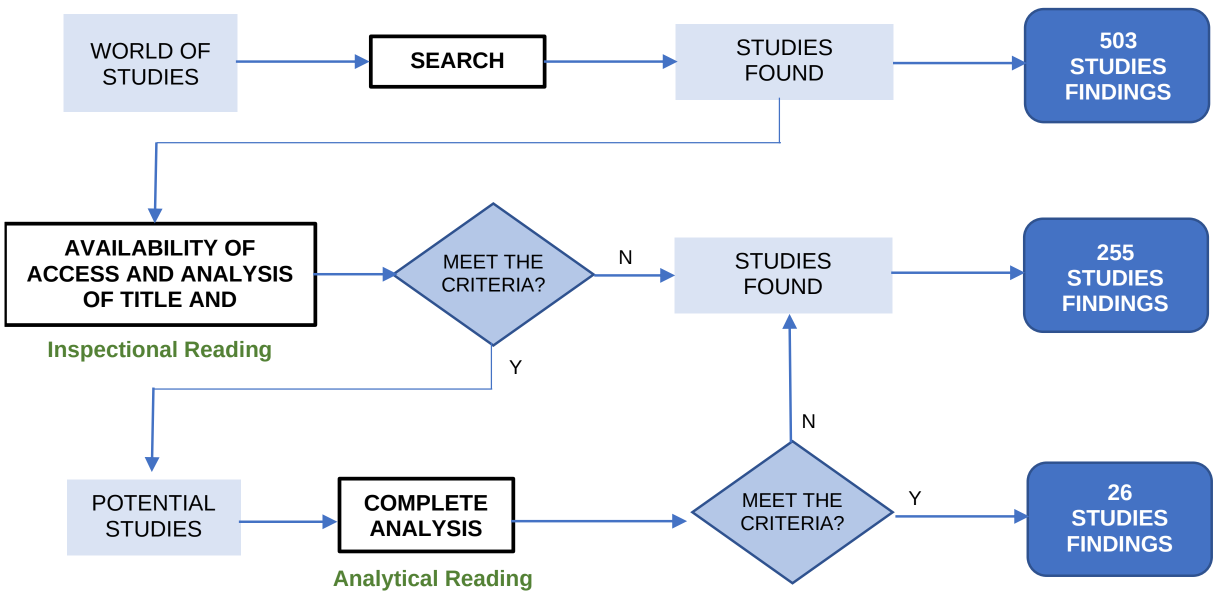
Keywords	**SCOPUS**	**WEB OF SCIENCE**	**EBSCOHOST**
Project Management Office AND Performance	287	160	56

Source: Prepared by the author.

This review followed six stages for its preparation: (i) definition of questions and concept; (ii) research strategy; (iii) search, eligibility, and coding; (iv)) quality assessment; (v) synthesis of results; and (vi) presentation of the study (Morandi; Camargo, 2015).

An inspectional reading was carried out from the papers identified to select the bibliography adhering to the theme. According to Adler and Van Doren (1972), inspectional reading is a level of reading used to probe and pre-read material to check whether it should be read analytically. Analytical reading consists of three stages: discovery of the content, interpretation of the content, and critique of the content (Adler; Doren, 1972). Figure 4 shows the search and eligibility process for the first stage of the research.

Figure 4 - Search and eligibility

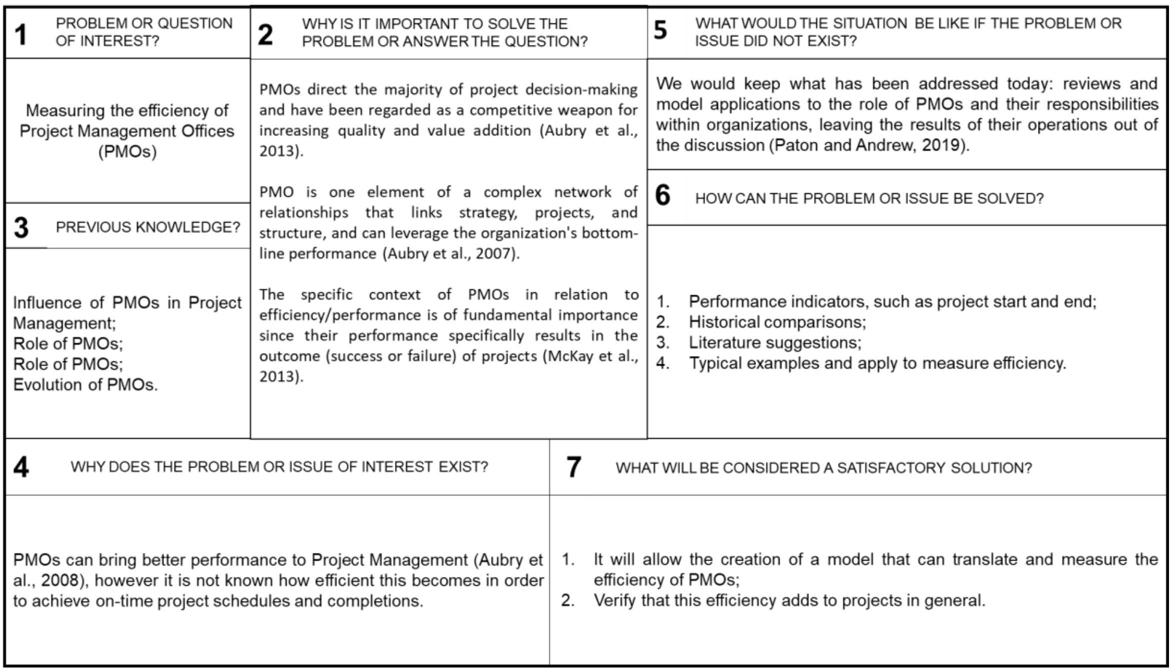


Source: Prepared by the author based on Morandi and Camargo (2015).

A systematic review can be subject to bias due to the study selection process. Therefore, the inclusion and exclusion criteria for the studies were defined based on the premises of the review (Morandi; Camargo, 2015). The criteria selected for this research were as follows: works in English and Portuguese, works in which it was possible to access the full text, and works in which the keywords were in context and content.

In addition, the selection of the scope and keywords was based on two stages: the preparation of the research protocol to structure the search strategy based on the model of (Ermel, 2021), as shown in Appendix A, and the conceptual framework, with the function of outlining the scope of the systematic literature review (SLR), as shown in Figure 5.

Figure 5 - Conceptual framework



Source: Prepared by the author based on Ermel (2021).

Thus, through analytical reading, studies were identified that strengthened the need for research on the object of study. Oliveira and Martins (2018) evaluate PMO efficiency using constructs that are interconnected with PMO management: "implementation strategy," "staff training and capacity building," and "control of the project operations environment." This study reports that staff training contributes to the efficiency of PMOs. Even though the research is significant for the academic and business areas, there is no assessment of whether the PMO is efficient; it just shows some factors that can influence the PMO's efficiency. From this perspective, this research develops a model that makes it possible to evaluate the efficiency of PMOs, considering variables related to cost, time, and quality used in project operations.

Barbalho, da Silva, and de Toledo (2017) analyzed the role of PMOs in project performance indicators, time, cost, and scope in 35 companies that have an active PMO in their management. They also found that the success of time, cost, and scope results are separate from the activities carried out by the PMO. As a result, this study suggests evaluating the PMO's performance regarding management indicators, such as project management indicators, maturity, portfolio value, and strategic level. Corroborating this, this research tends to involve management indicators in its analysis of PMO efficiency. Portfolio value and project value are part of the object of study.

Viglioni, Cunha, and Moura (2016) propose a PMO efficiency evaluation model for the software industry based on a multi-criteria approach. This makes a relevant contribution to the academic and operational areas. However, it uses the managers' point of view, which can risk the results obtained since the client is not in this analysis, compromising the analysis. In this context, this research analyzes PMO efficiency from the perspective of statistical results and integrates the perspective of the client and the company.

After this first phase of the research, a second phase of the literature review was carried out. This second phase of the review aimed to identify studies that use Data Envelopment Analysis (DEA) to assess the efficiency of PMOs. New search keywords were defined to carry out this phase, as shown in Table 4.

Table 4 - Keywords used in the second phase of the review

Source	Keywords	Connector	Keyword link
International	Project Management Office	AND	Data Envelopment Analysis

Source: Prepared by the author.

The works identified in the second phase of the research are shown in Table 5.

Table 5 - Results of the second research phase

Keywords	SCOPUS	WEB OF SCIENCE	EBSCOHOST
Project Management Office AND Performance	05	03	01

Source: Prepared by the author.

The results of the second phase totaled 09 papers. The inclusion and exclusion criteria were the same as those used in the first phase of the research. Through inspection, it was possible to identify that these papers, as well as being duplicated in the databases, were covered in the first phase of the review. Thus, only two studies used DEA to evaluate PMO efficiency: Ko and Kim (2019) and Ko, Park and Kim (2015).

Ko and Kim (2019) use DEA to measure the efficiency of PMOs but through a qualitative analysis of the Likert scale results with an evaluation of management levels. Although the research makes significant contributions, it is a fact that concluding results based on perceptions can compromise the validity of the research results, especially when added to the perceptions of leaders who, in some cases, are far removed from the project team. Evaluating efficiency only from the perspective of project or portfolio managers can create risks, as the service can be efficient for the manager and inefficient for the client. To overcome these shortcomings, this paper analyzes PMO efficiency from the perspective of statistical results and the perspective of the integrated client and company.

Ko, Park, and Kim (2015) evaluate the efficiency of PMOs in Information Systems projects using DEA for evaluation. This study uses five input variables: practice management, infrastructure management, resource integration, technical support, and business alignment. As outputs, four variables are mapped: project efficiency, meeting deadlines, meeting costs, and sufficiency of requirements. The choice of variables is timely and contributes to developing DEA research in projects. However, once again, the analysis is based solely on perceptions, i.e., evaluation with the indication of directed positions. Another important issue that should have been chosen for efficiency evaluation is variables relating to the quality of delivery.

There is a need to develop a new model for assessing efficiency in PMOs. Developing a model that includes efficiency from the company's perspectives, quality, and the influence of project characteristics could fill important gaps in the literature. To fill these gaps, unlike other studies, statistical techniques were used synergistically to support the study's conclusions. The combined use of these techniques is a unique aspect of this research and can provide empirical support for this area of study and the research problem.

This study is important for the company being researched because it helps managers and staff in the company's decision-making processes in the investment area. In this way, it enables the company to achieve greater competitiveness in the area, increasing the satisfaction of the end customer (internal) and moving towards cost reduction initiatives and the qualification of resources. As a result, this work contributes to society, with the possibility of being used in other companies that use PMOs in their project management and have difficulties mapping and justifying the efficiency of their operations. The following section presents the structure of the work.

1.4 Research structure

This study consists of a thesis based on articles and is structured in 6 chapters. The first chapter, considered as an introduction, presents aspects related to projects and portfolios in organizations, the role of PMOs, and a brief contextualization of the efficiency of PMOs, as well as the object of study, research problem, primary objective, and specific objectives. This chapter concludes with the research justification, which addresses the relevance of this work for organizations and academia.

The second chapter outlines the research methodology. This section presents the research method, DEA model, data collection process, and research limitations. The results obtained from the procedures adopted in the initial chapters are presented in chapters 3, 4, and 5 (each chapter consists of an article). Finally, chapter 6 presents the discussion, conclusions, and limitations of the research, as well as suggestions for future work.

In the first article (chapter 3), a literature review focuses on empirical studies on PMO efficiency with and without the use of DEA. This article addresses the specific objective: "To critically evaluate studies that analyze PMO efficiency and efficiency in the area of Project Management, whether or not they use DEA."

The second article (chapter 4) evaluates the influence of the PMO on the efficiency of the organization's projects. The article seeks to answer the specific objective: "To evaluate the influence of PMOs on the technical efficiency of projects, taking into account the complexity, size, and value of the projects."

The third article (chapter 5) evaluates the efficiency of the PMO and analyzes the variables that affect efficiency. The article seeks to respond to the specific objectives: "To create a model that allows the efficiency of PMOs to be measured, identifying opportunities for improvement through a two-stage data envelopment analysis (DEA) evaluation" and "To quantify the efficiency of the PMO, evaluating its behavior over time and identifying prevalent variables for process improvements." Table 6 summarizes the relationship between the thesis objectives, the chapters, and the articles.

Table 6 - Relationship between thesis objectives, chapters and articles

Primary Objective	Specific objective	Chapter and scope	Article	Journal to be submitted
Analyze the variables present in the PMO process that affect the technical efficiency of operations.	1) Critically evaluate studies that analyze PMO efficiency and efficiency in the area of Project Management, whether or not they use DEA.	Chapter 3: Literature review focusing on empirical studies of PMO efficiency with and without the use of DEA	Article 1 Efficiency of Project Management Offices: An exploratory analysis	Engineering Management Journal Impact Factor: 4,6 Percentile Scopus: 77% Status: Submitted and under review at the journal
	2) Evaluate the influence of PMOs on the technical efficiency of projects, taking into account the complexity, size and value of projects	Chapter 4: Evaluation of the influence of the PMO on the efficiency of the projects of the organization under study	Article 2: Measuring Project Management Efficiency with Data Envelopment Analysis: A Case in a Petrochemical Company	Applied System Innovation Impact Factor: 4,9 Percentile Scopus: 85% Status: Published
	3) Create a model to measure the efficiency of PMOs, identifying opportunities for improvement through a two-stage data envelopment analysis (DEA) evaluation; 4) Quantify the efficiency of the PMO, evaluating its behavior over time and identifying prevalent variables for process improvements.	Chapter 5: Evaluation of PMO efficiency and analysis of prevalent variables under efficiency	Article 3: Longitudinal Analysis of the Efficiency of a Project Management Office	Project Management Journal® Impact Factor: 8,8 Percentile Scopus: 88% Status: to be submitted

Source: Prepared by the author.

2 RESEARCH METHOD

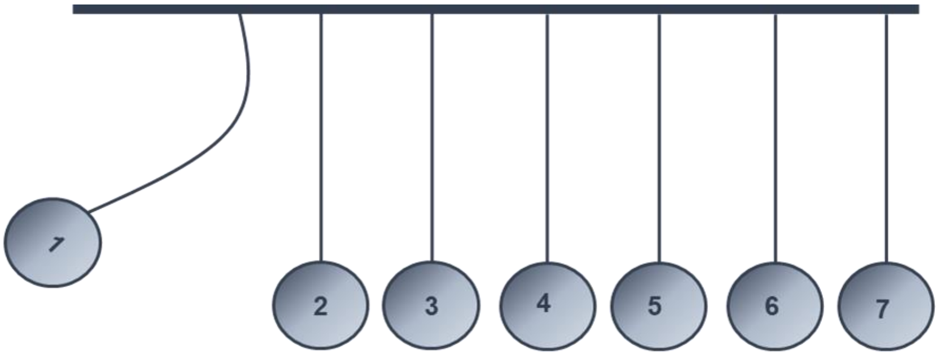
In management, scientific research must reconcile theory and practice, as it seeks to improve existing systems and assist in developing new systems, products, and services (Dresch; Lacerda; Júnior, 2015). To ensure that scientific research is recognized as having a solid context and relevance, both in the academic field and in society, the research must demonstrate that it has been developed rigorously and is subject to debate and verification (Lacerda et al., 2013). In this sense, selecting an appropriate method is fundamental to the success of all research, helping to conduct the study by articulating, systematizing, and supporting the generation and evaluation of new scientific or technological knowledge (Ermel, 2021).

This chapter aims to present the method used to assess the efficiency of PMOs. Initially, the criteria that will be applied to the research are defined. Subsequently, the working method is presented, including the steps to achieve the research objective. The following section presents the research design.

2.1 Research design

The design of scientific research is related to the planning of the study in broad terms: planning the work, defining data collection, and interpreting the information obtained. Thus, the main objective is to consider the environment in which the data will be collected, analyze the control of the variables involved, and examine the procedures adopted to collect this data (Yin, 2014). Figure 6 shows the pendulum strategy Dresch, Lacerda, and Júnior (2015) proposed for conducting scientific research, which has a priority order of elements that must be considered.

Figure 6 - Pendulum strategy for conducting scientific research



1) Reasons for conducting research
2) Research objectives
3) Scientific methods
4) Research methods
5) Working method
6) Data collection and analysis techniques
7) Reliable results

Source: Prepared by the author, adapted from Dresch, Lacerda and Júnior (2015).

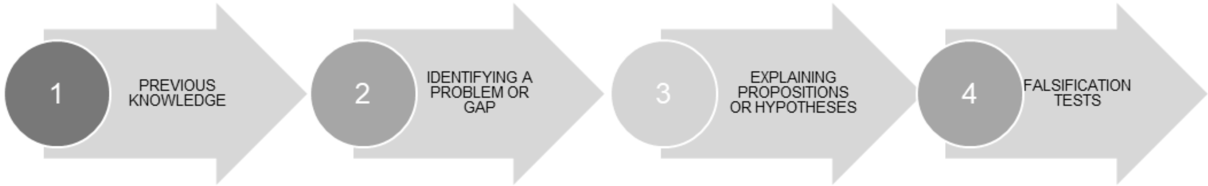
The justifications for starting a research project can be based on the following main topics: the researcher's desire to share new information, the search for answers to an important question, an in-depth understanding of a phenomenon, and possible gaps in the literature that serve as a starting point (Dresch; Lacerda; Júnior, 2015). According to Dresch, Lacerda, and Júnior (2015), after defining a reason for the research, the researcher must establish the objectives they wish to achieve with their investigation. The objectives can be associated with exploring, describing, explaining, or predicting some behavior or phenomenon. The reasons for carrying out this research are described in Chapter 1.

In line with the objectives, this research is considered explanatory, as it aims to explain the reason for a phenomenon, deepening knowledge of a particular reality (Yin, 2014). In this case, the phenomenon is related to the efficiency of PMOs in a project-oriented industry, and the reality is the operational context of the company studied. The research can also be considered exploratory, as it identifies the prevalent variables in the efficiency of PMOs.

This research uses the hypothetical-deductive scientific method, as hypotheses will be considered to evaluate the efficiency of PMOs. Philosopher Karl Popper suggested the hypothetico-deductive method to develop a scientific method to seek the truth (Dresch; Lacerda; Júnior, 2015). According to Dresch, Lacerda, and Júnior (2015), in a simplified way, this method can be made up of four stages, as shown in

Figure 7, and thus suggests that from the knowledge previously built and with a gap identified, the researcher can propose new theories by forming hypotheses or prepositions and putting them to the test.

Figure 7 - Steps that make up the hypothetical-deductive method



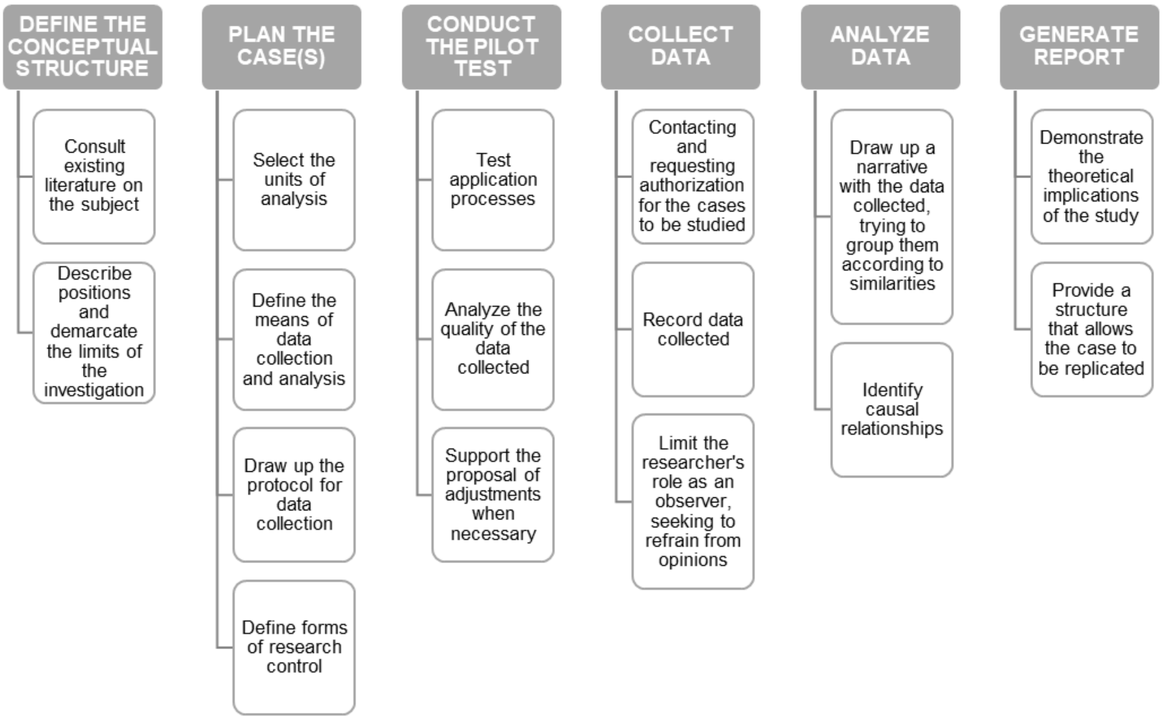
Source: Prepared by the author, adapted from Dresch, Lacerda and Júnior (2015).

In addition, this research is defined as a case study. According to Dresch, Lacerda, and Júnior (2015), case studies are identified to investigate complex situations in their real context, as they enable greater depth in the investigation and understanding of the problem and usually use sources based on diverse data. This work aims to learn about the prevalent variables in the efficiency of PMOs, which makes it necessary to develop an in-depth case study that is not based on perceptions.

Case studies comprise a combination of data collection methods, interviews, questionnaires, observations, etc., in which the evidence collected supports the researcher and can be either quantitative or qualitative (Dresch; Lacerda; Júnior, 2015). The authors indicate using a mixed approach, using mathematical techniques in addition to qualitative variables. For this research, a mixed approach was considered, as mathematical and statistical techniques are used to assess the variables that prevail over the efficiency of PMOs. Although less used, the qualitative technique is also used to understand better the variables used in the study.

Cauchick (2007) states that explaining the research variables is the most important characteristic of quantitative approaches. Therefore, for a case study to achieve its objectives, several stages must be completed in developing the research: defining the conceptual framework, planning the cases, conducting a pilot test, collecting, and analyzing data, and preparing the report. Figure 8 shows the details of these stages that must be carried out to apply a case study.

Figure 8 - Case study stages



Source: Prepared by the author, adapted from Cauchick (2007) and Dresch, Lacerda and Júnior (2015).

Therefore, the general classification of the research is shown in Table 7, presenting the classification of the nature, approach, objectives, and technical procedures applied.

Table 7 - General classification of the survey

Classification	Type of research	Description
Nature	Applied	• It aims to generate knowledge for practical application to solve specific problems. • To analyze the efficiency of PMOs in a project-oriented company.
Approach	Quantitative	• Applied research through statistical studies aimed at quantifying the object of study. • Use of mathematical and statistical techniques to assess which variables influence efficiency.
	Qualitative	• Research where the process of interpreting phenomena and assigning meanings are basic to the research process. • Better understanding of the variables applied in the study.

Classification	Type of research	Description
Objectives	Explanatory	• It aims to explain the reason for a phenomenon, deepening knowledge of a given reality. • The phenomenon is associated with the efficiency of PMOs and the reality is the context of the company studied.
	Exploratory	• Aims to identify factors that determine or contribute to competition. • It identifies the variables that contribute to the efficiency of PMOs.
Technical procedures	Case study	• An in-depth and exhaustive study of one or a few objects, so that broad and detailed knowledge is possible. • The development of an in-depth case study is necessary and not just based on existing perceptions.

Source: Prepared by the author based on Dresch, Lacerda e Júnior (2015) and Yin (2014).

After considering the research method, the following section presents the working method.

2.2 Work method

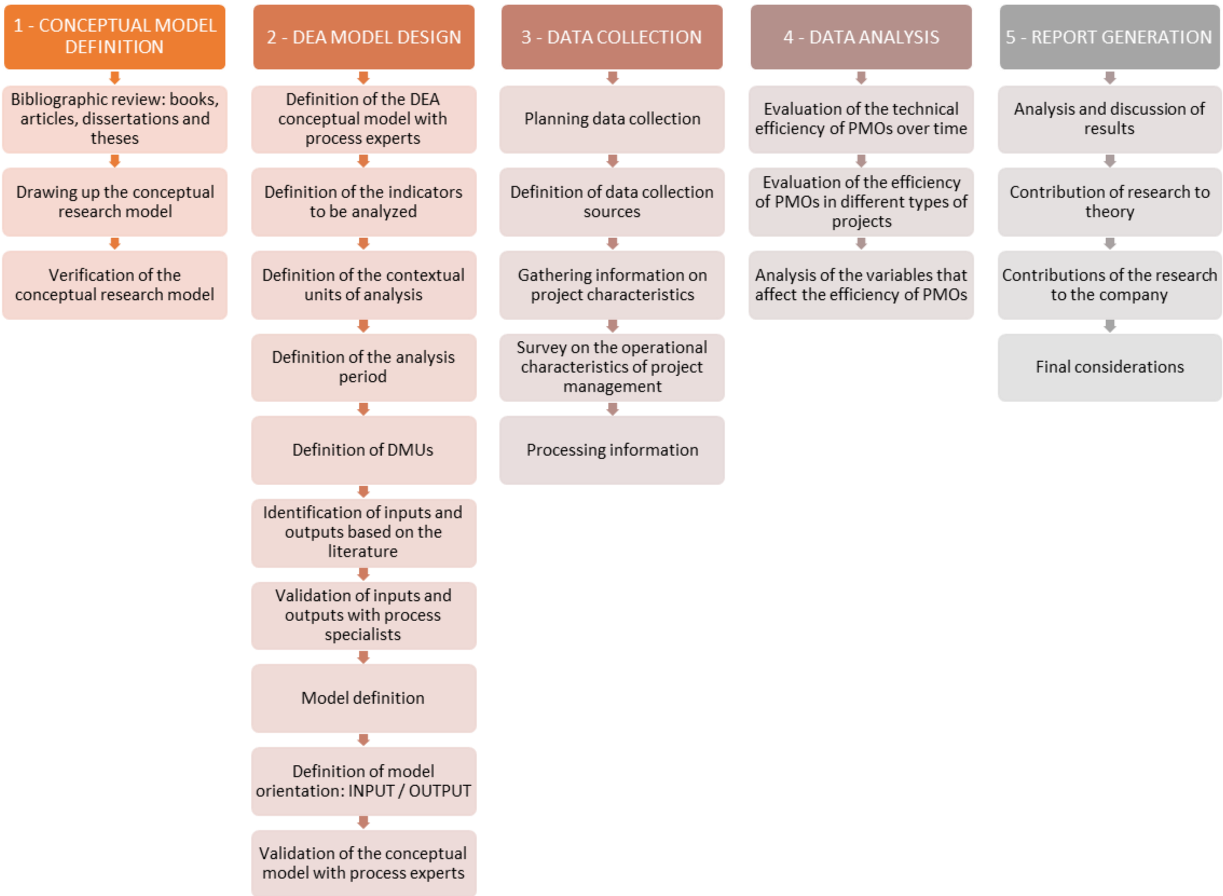
The purpose of the working method is to define the sequence of logical steps that the researcher must carry out to achieve the research objectives. At this stage, the researcher must unfold and detail the chosen research method, using the fundamentals of the defined scientific method (Dresch; Lacerda; Júnior, 2015; Yin, 2014). As well as explaining the data collection and analysis techniques, the researcher must demonstrate the reasons for their choices (Dresch; Lacerda; Júnior, 2015).

The working method suggested for the research was based on the steps for applying a case study mentioned by Cauchik (2018). This method consists of five stages: 1) Define the conceptual model; 2) Plan the DEA model; 3) Collect the data; 4) Analyze the data; and 5) Generate the report, as shown in Figure 9.

Stage one of the working method defines the theoretical conceptual model for the research. This stage includes the Systematic Literature Review, which includes books, articles, dissertations, and theses in relevant national and international databases. At this stage, research is carried out into Project Management Offices (PMOs), Portfolio, Project Management, and the efficiency of PMOs. The preliminary design and evaluation of the conceptual research model follow this. These stages are presented in section 1 of this paper.

In stage two, the aim is to design the DEA model. After defining the conceptual research model, this phase is carried out with the help of experts from the project area (petrochemical industry). Then, based on the literature and with the support of the company's experts, the DEA model is designed, defining the indicators to be analyzed, defining the analysis time, defining the DMUs, and identifying the inputs and outputs. Once the DEA model has been developed, adjustments are made, and a final evaluation is carried out. The DEA model is then validated by the company's experts who helped develop the study.

Figure 9 - Working method



Source: Prepared by the author.

The planning and execution of data collection for the working method occurs in the next phase, phase three. Before starting data collection, it is necessary to carry out detailed planning, incorporating the stages the researcher must follow to carry out this collection and its conduct. Next, the sources for data collection are defined, i.e., how the information will be gathered to build the theoretical model.

In phase four, the results obtained will be analyzed using two-stage Data Envelopment Analysis (DEA). An evaluation is carried out to verify the behavior of technical efficiency in a project management system over a given period. Subsequently, statistical analyses are carried out to quantify project size's impact on PMO efficiency—an analysis of prevalent variables behind Artificial Neural Networks (ANNs).

Phase five, which corresponds to generating the report, will present the results and discussions about the research. The results generated in this stage are presented to the experts with the main aim of creating a debate and discussion, highlighting the contributions of this research to the company analyzed and to theory. In closing, the conclusion on the problem analyzed is written, with the delimitations of the study and suggestions for future research being presented. The following section describes the processes involved in designing the DEA model.

2.3 DEA model design

This section presents the process involved in designing the DEA model. The company in which this study is carried out is a petrochemical industry that is looking to measure the efficiency of its PMO and improve the processes of this measurement model. Authors support the selection of the company found in the literature who highlight the importance of measuring the efficiency of a PMO and the benefits that achieving this efficiency can bring (Ko; Kim, 2019; Ko; Park; Kim, 2015; Kutsch Et Al., 2015; Viglioni; Cunha; Moura, 2016). Furthermore, the company was chosen because it had access to the information and data needed to develop the DEA model.

After defining the company and the theoretical conceptual framework of the work, the design phase of the Data Envelopment Analysis (DEA) model begins, which is used to measure the PMO's efficiency variables. For this stage, the conceptual model was defined with the help of seven specialists in the enterprise process, the project, and the PMO areas of the company under study.

The experts were chosen because of their experience in the company's project management area, their knowledge of the processes, because they agreed to take part in supporting the development of the research and, above all, because they actively participated in the search for the variables and the implementation of the proposed model. During the development of the study, unstructured meetings were held with the aim of obtaining preliminary information and guidance on the definition of the variables and the data collection and processing process. The company professionals consulted at this stage of the research also took part in the subsequent stages. Table 8 shows the professional role of each specialist, their participation in the project, the length of time they have worked at the company and their training.

Table 8 - Experts from the company studied

Position in the company	**Participation in the project**	**Time in business**	**Education**
Planning analyst	Support in model definition, process data collection and data interpretation	15 years	Business Administration
Development Engineer	Support in model definition and data interpretation	4 years	Mechanical Engineering
Development Engineer	Support in model definition and data interpretation	4 years	Mechanical Engineering
Portfolio Engineer	Support in model definition and data interpretation	12 years	Mechanical Engineering
Project Coordinator	Support in model definition, model validation, and data interpretation	22 years	Mechanical Engineering
Portfolio and PMO Coordinator	Support in model definition, model validation, and data interpretation	16 years	Oil and Gas Engineering
Project Manager	Model validation	20 years	Electrical Engineering

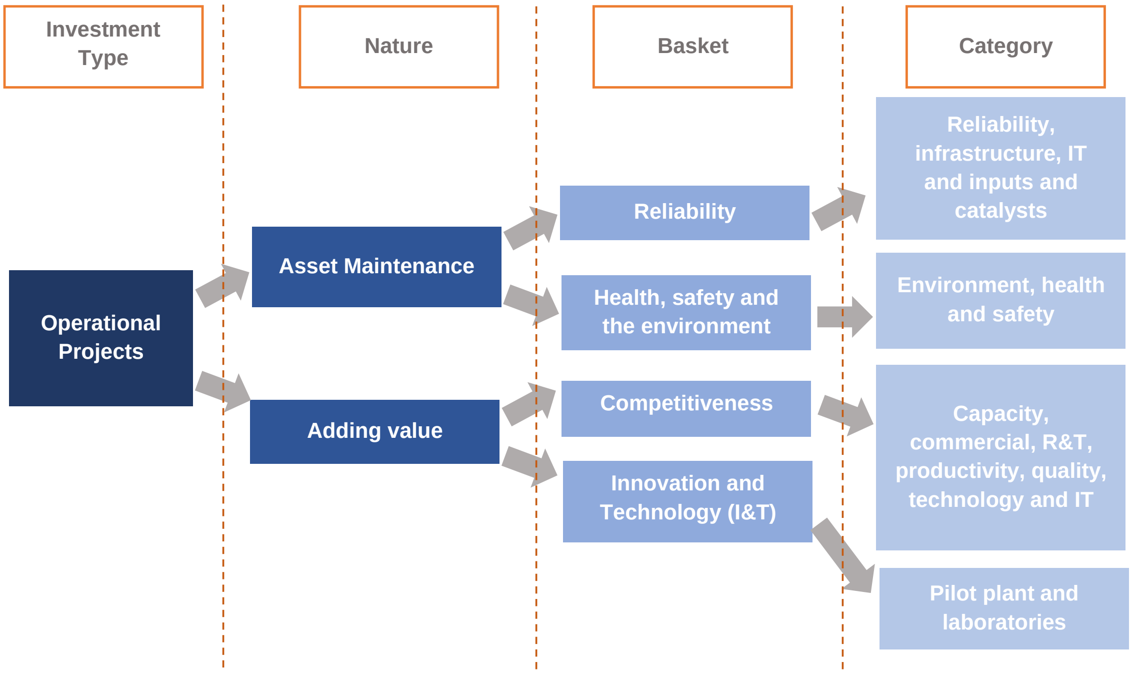
Source: Prepared by the author.

The professionals selected form a multidisciplinary team, as they hold operational (e.g., planning analyst), tactical (engineers and coordinators), and strategic (manager) positions. The formation of a multidisciplinary team with experience in the subject helps the researcher to have greater involvement and knowledge of the subject to be studied, with different opinions that can directly influence the interpretation of events (Barbosa et al., 2017a; Piran et al., 2017). After defining the experts for the process, the DEA project development phase begins. The following section discusses the characteristics of the projects to be analyzed. The following section presents the projects to be analyzed.

2.3.1 Definition of the projects to be analyzed

The company analyzed has projects classified by type of investment, nature, basket, and category, as shown in Figure 10. The efficiency assessment covered projects considered to be Operational Projects. The experts recommended that the study be carried out considering all types of investment projects, as they have the same importance for the different areas. In addition, the experts recommended disregarding product development and prototype projects since these projects have different characteristics, monitoring platforms, teams, and processes.

Figure 10 - Characteristics and classification of projects



Source: Prepared by the author.

Thus, the delimitation of the scope of work allows the researcher to provide further focus to the development of their research. In this study, priority was given to all the projects involved in asset maintenance, i.e., those implemented to increase or improve the useful life of the asset and the value-added projects to bring some financial gain to the company that has been closed down. These projects align with the research topic and are relevant to the company studied.

The company's experts also pointed out that studying all the investment projects allows for an analysis of the behavior over time of each project, each project by its characteristics, or even each class of project. In this longitudinal analysis, it is possible to identify whether implementing a model that allows the efficiency of the PMOs to be verified has affected the technical efficiency of the system. This can be seen by analyzing the behavior of the system's technical efficiency before and after applying the proposed model for each type of project.

One comment aligned with the experts was about the changes and improvements that may occur during the research period, which impact both projects and may have some measurement interference in the database. Thus, improvements to the project management software, management changes, or the renewal and adaptation of employees are not considered. It was pointed out that the company should have presented significant management changes in the period analyzed, in addition to having a low employee turnover of less than 3%. Thus, the experts agree that all the project classifications have a similar characteristic (development of FEL, discussed below) that allows for the proposed analysis.

Therefore, these projects are relevant to the research, as they have variables that can influence the PMO's efficiency, such as cost adherence (budget vs. actual gap), adherence to closure, and project quality. The constant interaction of clients (an area belonging to the company that seeks to invest in projects) throughout maturing projects can affect the operation's productivity. The following section deals with the research analysis period.

2.3.2 Definition of the analysis period

As the research is longitudinal, covering the period before and after the implementation of the PMO efficiency model, one of the steps is to determine the period of analysis. The first aspect of this decision is to assess when the PMO was implemented and whether there have been any changes in the classification of projects and their characteristics. After consulting the experts, it was found that PMO-oriented project management began in 2002, but there have been company mergers since then, which makes the data collection base unstable. The last company to be acquired by the group was in 2009. The experts also pointed out that projects existed before the PMO.

With this information, we checked with the company's experts when information was available for data collection. They discovered that in 2020, the company changed some of its premises for managing and moving forward with projects. About this change, the experts pointed out that this new way of managing projects, used from 2020 onwards, provides more detailed and reliable information on projects and classifying projects and the individual means by which each one progresses. Projects before this period were classified automatically by the system and, if necessary, adjusted in the management software by the engineers and project managers. The initial analysis period was set from 2018 to 2021, considering the variables of closed projects. The choice of this period assumes that the software investment system was stable and that the company would have material available for data collection.

Another premise for analyzing the period is the end of the year. For investment planning, we constantly evaluate from January to December. So, all financial planning is based on 12 months (N, N+1, N+2, and so on). Therefore, experts recommend starting in January 2020 and ending in December 2022. In the next step, the definition of the decision-making units will be presented.

2.3.3 Definition of decision-making units (DMUs)

After defining the period of analysis, it is proposed to define the DMUs on a longitudinal basis over the five years (January 2018 to December 2022) of data analysis of the projects in terms of their nature (Investment Order, R&T, reliability and integrity, health, safety and environment, competitiveness and productivity - C&P, high-risk potential - PRA and value addition - strategic).

The initial proposal was to consider each project as a DMU. However, after arguments from the system specialists, it was found that this was not possible, as although each project is developed according to the client's request, more complex projects tend to require a longer life cycle than less complex ones. In other words, a given client may start a complex project at the same time as a less complex one, and due to the specialties involved, the hours allocated to engineering, and the higher value, they may have different completion times, presenting DMUs with different characteristics and making the use of DEA unfeasible.

In the software used by the company, when the project is registered, it is obliged to fill in six questions regarding complexity: scope, duration of execution/implementation, technical complexity, planning challenges, HSE risks and stakeholders; Nature of the Project; Size of the Project. These questions, using an equation (Equation 2), classify the project according to its class: class I, class II, class

III, class IV and class V. Class I projects are the least complex when it comes to scope, deadline, technical complexity, planning challenges, HSE risks, interfaces involved and value, and so respectively for the other classes. Table 14 shows the questions, answers and score for the complexity classification that will result in the project class.

Table 9 - Classification according to complexity

Question	Answer	Score
1. Scope	a) Simple acquisition ("Plug and Play") b) Straightforward (Existing equipment - minor adjustments) c) Somewhat challenging (Process modification/Modernization/Technological upgrades) d) Complex (Various technology alternatives/options)	a) -2 b) 1 c) 2 d) 3
2. Duration of Execution/Implementation	a) Short (Up to 9 months or simple purchase with a long delivery period) b) Medium (More than 9 months to 18 months) c) Long (More than 18 months)	a) 1 b) 2 c) 3
3. Technical complexity	a) No Basic Engineering required (Installation of equipment - up to 50 hours of Detailed Engineering) b) Low (from 50 to 500 hours of Detailed Engineering) c) Moderate (Interface of up to 3 engineering disciplines - 500 to 2000 hours of Detailed Engineering) d) High (Multidisciplinary engineering - 2000 to 5000 hours of Detailed Engineering) e) Very High (Multidisciplinary engineering - more than 5000 hours of Detailed Engineering)	a) 1 b) 2 c) 3 d) 4 e) 5
4. Planning challenges	a) Low (Few interfaces with other areas) b) Medium (Interface with part of the company: maintenance/reliability/corporate) c) High (Many interfaces or external resources / modularization / technology licensors)	a) 1 b) 2 c) 3
5. HSE risks	a) Low (No downtime/no classified areas/no contaminants) b) Medium (Work at height / congested area / risk of gas leak) c) High (Work in a confined space/explosive atmosphere)	a) 1 b) 2 c) 3
6. Stakeholders	a) Few interrelationships. Relationships restricted to one asset b) Moderate interrelationships / relationships	a) 1 b) 2 c) 3

Question	Answer	Score
	c) Multiple interrelationships / relationships with external entities / media exposure)	
7. Value	a) Less than USD 102 thousand b) Between USD 102mil and USD 0.8 MM c) Between USD 0.8 MM and USD 3.1 MM d) Between USD 3.1 MM and USD 10.2 MM e) More than USD 10.2 MM	a) 1 b) 2 c) 3 d) 4 e) 5

Source: Prepared by the author.

This score is calculated automatically in the management software. In order to classify the projects, there is a balance between the nature (X) of the projects, their value (Y), and their complexity (Z). This classification will guide the evolution and maturation of the company's FEL methodology. Equation 1 shows how the classification is calculated.

Equation 1 - Project ranking equation

$$Class = x + \mathrm{y} + \frac{(\sum \mathrm{Z})\ \mathrm{X}\ 2}{6}$$

$$x = nature\ of\ the\ project$$
$$\mathrm{y} = value$$
$$\mathrm{Z} = complexity$$

Table 10 shows the scores according to the class of each project.

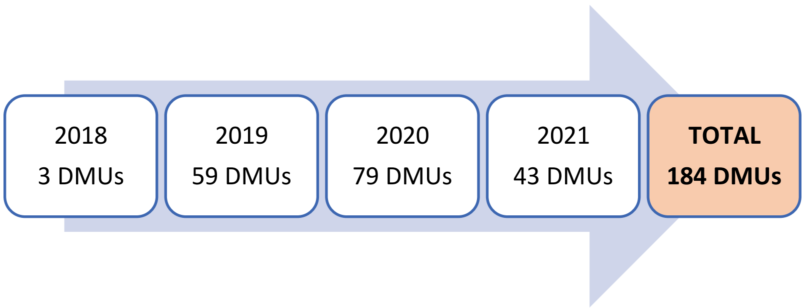
Table 10 - Classification of projects according to score

Class	Score
I	<= 5
II	> 5 - < 8,5
III	=> 8,5 - <= 10
IV	> 10 - <= 12,5
V	> 12,5

Source: Prepared by the author.

In this sense, the experts in the system suggested that the annual conclusions of a given type of project, i.e., each project by class, be used to form the DMUs. Therefore, the annual evaluation of each type of project is essential for the company in terms of comparing the results of this evaluation with the indicators it uses. The PMO's efficiency can also be analyzed in terms of the type of project (class I, II, III, IV, or V) and also the year in which it had the best or worst results in terms of the PMO's efficiency. Figure 11 shows the period of analysis and the number of DMUs considered.

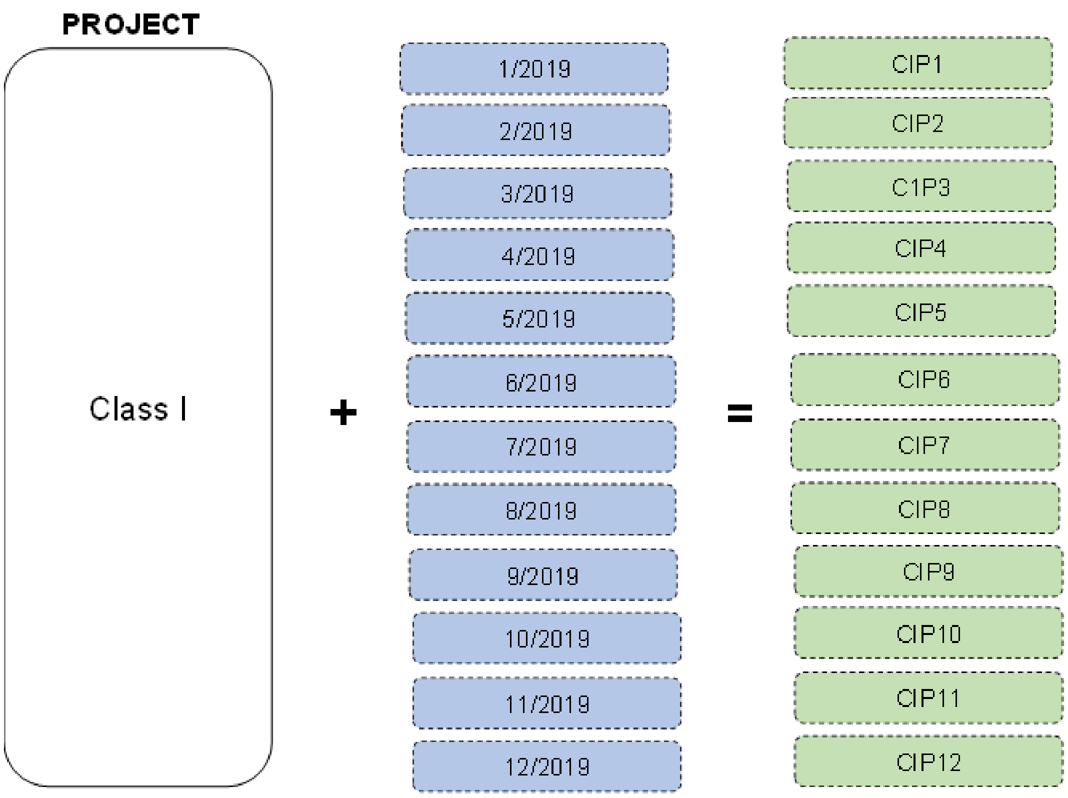
Figure 11 - Analysis period and number of DMUs



Source: Prepared by the author.

Based on the projects' classification, five projects were selected for closure between 2018 and 2021. Combining the classes with the analysis time interval resulted in 184 DMUs. Coding was defined to help trace the DMUs throughout the model run, as shown in Figure 12. Figure 11 shows that the DMU called CIP1 combines the project class (class I) and analysis period 1 (P1 = January 2019).

Figure 12 - Example of coding DMU



Source: Prepared by the author.

The following section presents the definition of the variables in the DEA model.

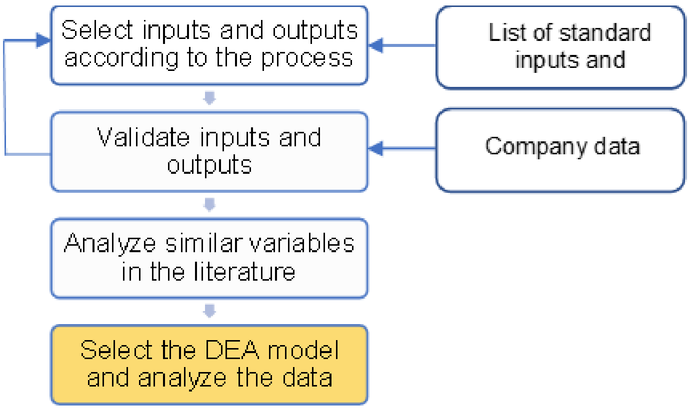
2.3.4 Definition of DEA model variables (input or output)

When developing a model, the variables are as important as the method applied (Nurcan; Köksal, 2021). The input and output variables compared to the DMUs, when they have a high number, can cause discrimination errors in the DEA analysis (Cook; Zhu, 2014). In DEA, it is desirable to have more DMUs, and if the number of DMUs is small, it is more likely that most of them will form the efficiency frontiers (Ko; Kim, 2019). A general rule, argued by Cooper, Seiford, and Zhu (2011), is that the DUMs should be more than three times the sum of the input and output variables.

Analyses using DEA in processes tend to have more easily identifiable inputs and outputs, in which the resources used represent the inputs and the finished products the outputs (Cook; Zhu, 2014). In addition, Cook and Zhu (2014) point out that it is impossible to ensure that all the relevant variables have been included in the defined model in analyses using DEA. However, every effort must be made to include the variables that make the most practical sense to the study.

Thus, the DEA result can vary according to the quantity and quality of the input and output variables chosen, which is why a procedure is recommended to decide which of the original correlated variables can be omitted with the minor loss of information and which should be kept (Liu; Lu; Lu, 2016). Figure 13 shows how to proceed with choosing and defining the DEA Variable.

Figure 13 - Definitions of DEA variables



Source: Prepared by the author.

The process of determining the variables began with an analysis of the literature and an internal analysis of the company's processes. The purpose of consulting the literature was to identify the inputs and outputs currently used in research with data envelopment analysis in the area of projects, and the purpose of researching the company was to provide practical variables to complement the model. The search for support in the literature to define the variables of the DEA model reinforces the rigor of the modeling carried out by the research (Piran, 2021). In the internal analysis of the processes, a search was made for documentation in the company's knowledge base, which provides guidance through procedures, lists of activities and a training base with materials that are easily accessible to everyone. Table 10 shows the variables identified in the literature in research involving data envelopment analysis in its method and Table 11 shows the primary variables reported by the experts.

Table 11 - List of variables used for reference

Authors / Variables	Practice Management	Working hours	Quality	Capacity	Infrastructure Management	Number of employees	Integration of resources	Technical Support	Business Alignment	Project efficiency	Timekeeping	Cost compliance	Meeting the requirements	PMO efficiency
Ko, Park and Kim (2015)	x				x		x	x	x	x	x	x	x	
Marques (2017)		x	x	x		x								
Ko and Kim (2019)	x				x		x	x	x					x
Telles (2019)		x				x					x			
Piran (2021)		x												

Source: Prepared by the author.

Table 12 - Primary variables reported by experts

Name	Description	Unit
Project execution time	Number of months to close a project	Months
Number of interfaces	People considered in the project team	Quantity
Number of disciplines	Number of specialties involved in the project	Quantity
Compliance with deadlines	Projects delivered on the planned date	Percentage
Number of projects delivered	Number of projects closed	Projects
Cost compliance	Compliance with planned costs	Percentage
Quality compliance	Compliance with project delivery quality	Percentage
Number of canceled projects	Projects canceled after progressing through the first FEL stage	Projects
Number of unfinished projects	Projects that could not be closed	Projects
Project management software errors	Error presented by the software during the FEL development process	Quantity
Project downtime	Time in which the project does not advance in its maturity without an impeding factor	Days
Communication	Efficient communication between PMO and PM	Percentage

Source: Prepared by the author.

The primary variables are essential to guide the initial process of verifying the variables. However, applying them to the conceptual model is impossible in some cases, as there may be a need for more company data or restricted access to information. To support the choice of variables, the literature was analyzed, considering research that uses DEA for service efficiency since Project Management is considered a service within the company analyzed and DEA for the efficiency of PMOs.

The variables and the inputs and outputs of the model were then defined. Table 13 shows the final list of variables in the DEA model, followed by a description of what each variable represents in the research, the unit of measurement used, and the literature references from previous studies.

Table 13 - Final list of DEA model variables

Variable	Name	**Description**	**Unit**	**Reference**
Input01	Number of interfaces	Maintenance Operation Automation Logistics Laboratory Enterprise HSE Processes	People	(Aubry; Hobbs, 2011; Dai; Wells, 2004; Oliveira; Martins, 2020)
Input02	Project time	Number of days from project opening (TR1) to delivery for start-up (RFO)	Months	(Aubry; Hobbs, 2011; Barbalho et al., 2014)
Input03	Number of specialties	Electrical Civil Mechanical Instrumentation Automation Process Piping	Specialties	(Aubry; Hobbs, 2011; Aubry; Richer; Lavoie-Tremblay, 2014; Otra-Aho et al., 2018)
Input04	Project value	Value of FID approval (Final Investment Decision)	USD	
Output01	Cost adherence	Difference from planned to FID approval	USD	(Ko; Park; Kim, 2015)
Output02	Projects on time	Difference in days between actual and planned closure	Days	(Duarte et al., 2019; Spalek, 2013)
Output03	Adherence to closure	Number of days from delivery to start (RFO) to closure (PCL)	Percentage	(Duarte et al., 2019; Spalek, 2013)

Source: Prepared by the author.

After choosing the variables to be used in the analysis, the next step is to define the DEA model to be used and the final orientation of the input or output model.

2.3.5 Definition of the DEA model (CRS/VRS)

The literature on DEA points to two models used to apply the technique, which is used according to the proposed study (Ko; Kim, 2019). The first model is CRS (Constant Returns to Scale), which proposes an input-oriented analysis and is recommended when the objective is to compare decision-making units (DMUs) with variables of similar amplitudes (Charnes; Cooper; Rhodes, 1978). The second model is the VRS (Variable Returns to Scale), in which a DMU cannot be compared with all the DMUs in a given sector but with DMUs operating on a scale similar to its own and is therefore recommended when the objective is to compare DMUs of variables with different amplitudes (Banker; Charnes; Cooper, 1984).

Thus, data envelopment analysis models can be input-oriented or output-oriented. Efficiency in the input-based model is more efficient by reducing the level of inputs while keeping the level of outputs fixed, and in the case of the output-based model, efficiency reaches its best level as output levels increase while input levels are fixed (Ko; Park; Kim, 2015).

Therefore, the model used in this research is the CRS since an internal comparative analysis is carried out in the company studied, and there is a scale variation oriented towards inputs. Thus, the amplitude and scale of the variables chosen are similar between the DMUs, indicating the use of the CRS model. The CRS model is therefore used to assess the efficiency of the PMOs.

2.3.6 Definition of the orientation of the DEA model (input or output)

The DEA model has two orientations: input and output. If the aim is to maintain resource consumption (e.g., the project's financial resources) and maximize outputs (e.g., doing more on the project with the same resources), the model should be output oriented. On the other hand, if the aim is to keep the outputs constant and check that the inputs used in project management are being used more effectively, the model should be input-oriented.

This research is output-oriented. This choice is due to the objective of measuring the outputs of each class of project throughout the analysis but verifying efficiency at the end of the process, i.e., the PMO. For the company analyzed, due to the investment system and management software currently used, any changes to the project scope require approval, which impacts deadlines. Therefore, the model's premise is not to make more scope than the project envisages, with the minimum amount of resources, but rather to make the project conclude and close within the cost and timeframe envisaged.

2.3.7 General DEA model classification

Data Envelopment Analysis (DEA) is based on non-parametric mathematical models, i.e., it does not use statistical benchmarks or measures of central tendency. Functional relationships between inputs and outputs are not necessary in DEA, and it is not restricted to single, unique measures of inputs and outputs (Ferreira; Gomes, 2020).

To develop the DEA model design, characteristics are considered for its elaboration, and it is necessary to define these characteristics before starting the data collection and analysis phase. The characteristics proposed for the DEA model developed in this study and their descriptions are summarized in Table 14.

Table 14 - Overview of the DEA model

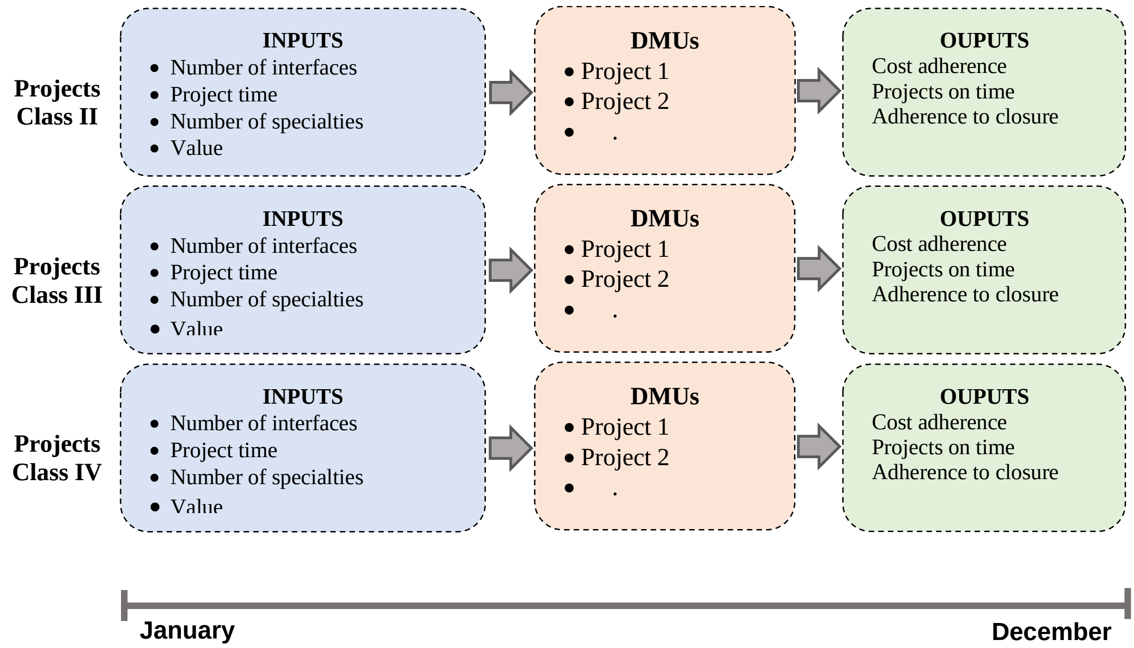
Assumptions	**Description**
Definition of the projects to be analyzed	• Defined the types of project that will make up the PMO efficiency analysis model. • Product and prototype projects are not considered.
Definition of the analysis period	• The initial period of analysis was defined as January 2018 and the final period as December 2021.
Definition of the decision-making units (DMUs)	• Considering projects in the year. • Analysis of projects includes 184 DMUs
Definition of the DEA model variables	• It presents potential variables reported by process experts. • The literature was analyzed, considering works on PMO efficiency that use DEA and project efficiency.
Definition of the DEA model	• The model used in this work is the CRS.

Assumptions	Description
	• An internal comparative analysis is carried out in the company being studied.
Defining the orientation of the DEA model	• The orientation used in this work is output. • To compare the efficiency of the PMOs over the period analyzed, making a comparison with the type of project.

Source: Prepared by the author.

The final stage in defining the design of the DEA model consists of validating the model with experts in the field. An outline was drawn up for this validation to facilitate the experts' assessment and judgment. Figure 14 shows the scheme to be validated by the company's PMO and Investment specialists.

Figure 14 - DEA model diagram



Source: Prepared by the author.

The model was structured based on the units of analysis of this work, such as analysis of the efficiency of the PMO by type of project. The following section presents the work schedule.

2.3.8 Artificial Neural Networks (ANNs)

An artificial neural network is essential for designing and analyzing any complex algorithm or process (Chattopadhyay; Gayen, 2023). Artificial neural networks (ANNs) are part of the artificial intelligence (AI) group and are parallel-structured systems made up of neurons that simulate the human brain (Şengüneş; Öztürk, 2023). AI aims to develop methodologies or algorithms that possess or multiply the human rational ability to reason, perceive, make decisions, and solve problems (Haykin, 2001). Thus, research models' specific intelligent artifacts are usually presented in diagnostic, prognostic, or visualization tools, simplifying the performance of complex tasks (Barbosa et al., 2017b).

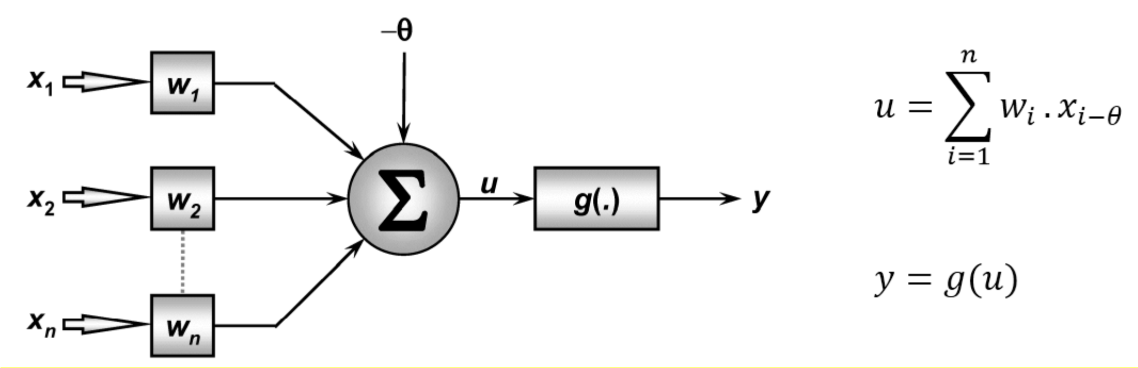
The first publications on ANNs in engineering occurred in 1989, but studies intensified and became more applicable in 2016. In design, studies began in 1996 and intensified in 2019. This may be due to technological developments that have increased computer processing capacity, more efficient and robust optimization algorithms, and advances in studying the biological nervous system.

The practical applications of ANNs are present in various situations in our daily lives, including identifying determining factors for investigating an analysis (Umuhoza; An, 2023). However, the performance of the ANN depends significantly on the architecture and hyperparameters used (Şengüneş; Öztürk, 2023).

Thus, an ANN can be a means of processing data that uses artificial neurons that communicate via numerous connections (artificial synapses) and are capable of acquiring and maintaining knowledge based on information and recognizing patterns (Haykin, 2001). ANNs tend to follow the same logic as the human brain: they can learn through information adapted to the scenario being analyzed; they can store knowledge through synaptic strengths (Haykin, 2001), represented by synaptic weights, and have the ability to find efficient solutions using natural and inaccurate data (Marques et al., 2014).

Like the brain, the artificial neuron is fundamental to processing information in an ANN (Haykin, 2001). The artificial neuron model shown in Figure 15 can translate the workings of a neural network with parallel analysis and high connectivity.

Figure 15 - Mathematical model of the artificial neuron



Source: Adapted from Silva, Spatti and Flauzino (2019).

ANNs tend to raise hypotheses to overcome obstacles to computational generation, offering the possibility of solving the problem of deep learning (Chattopadhyay; Gayen, 2023).

Although there is commercially available software for creating ANNs, a standard model is still being prepared for each application. This is because the structure of the ANN is subject to the input data, the functions used, and the type of output sought. Thus, it is necessary to carry out a sequence of configurations to build and process it (Silva; Spatti; Flauzino, 2019).

To start analyzing ANNs, defining the problem by selecting the variables is necessary. Then, define the structure of the ANN, where the learning method, layers, and neurons are established. There is no rule for determining the number of neurons to be used; it is usual to test several possible networks with different numbers of neurons and compare them to see if they respond to the proposed problem and if the error is within the acceptable limit (Barbosa et al., 2017b). It is finished and available once the network has been trained and tested. New input data can be entered, and the network will process it and generate a result according to the training.

In this study, the Artificial Neural Network (ANN) was used to identify the prevalent variables, as it allows the variables to interact without being related to each other, has no assumptions about the distribution of dependent and independent variables, and the sample size does not interfere with the result of the analysis (Marques et al., 2014). ANNs belong to the artificial intelligence (AI) layer to replicate the functional structure of human brain neurons to solve problems and establish relationships, with the capacity to organize and process agilely (Haykin, 2001). Thus, ANNs identify the prevalent variables that have a preponderance on the efficiency of the PMO.

After analyzing efficiency using the DEA model, the prevalent variables on the effect of PMO efficiency were identified using ANNs, which consist of a set of input variables classified according to their characteristics (Barbosa et al., 2017b). IBM SPSS Statistics software was used for this analysis. The conceptual model of the ANNs was defined as follows: multilayer perceptron type and backpropagation training algorithm. This type of artificial neural network is the most widely used due to its ability to map input and output layers using historical data to capture data characteristics (Marques et al., 2014).

The ideal training rate is obtained heuristically and experimentally. Thus, there are varying training rates for artificial neural networks according to each test. In this analysis, the rate used was 75% of the data rate for training and 25% for testing, obtaining a relative error of 14.1%. The results and discussion of the detailed results of the artificial neural networks designed for this study are available in the next section.

3 ARTICLE 1 - EFFICIENCY OF PROJECT MANAGEMENT OFFICES: A EXPLORATORY ANALYSIS

Abstract: This research was conducted under the approach of Literature Grounded Theory - LGT, a method indicated when the objective is the generation of knowledge along with the selection, analysis, and synthesis of the literature. It is a method that provides a set of scientific data resulting from a specific approach to knowledge, promoting growth in the theme for researchers in the area and indicating the main trends. This method consists of generating theories or hypotheses through research on existing scientific and technological knowledge. This research aims to investigate how PMO efficiency assessment is treated in the literature and what is the understanding of the concept of efficiency in PMO. The results indicate a lack of conceptual rigor regarding the efficiency concepts used in PMO evaluation. A significant portion of the empirical evaluation instruments found in the explored literature does not adequately address the concepts. The contribution identifies the strongest relationship of how PMO is evaluated in organizations, where project efficiency is identified as a benchmark for measuring PMO efficiency. The second contribution is related to cross-tabulation of the identified efficiencies, looking for key correlations. The state of the art can be classified in three phases: a phase that presents articles that address PMO topics; an intermediate phase that allows deepening the knowledge of some studies related to specific methods and techniques; and a phase that can be called “content analysis”, in which it is possible to verify what has been approached and how the researchers have measured the PMO efficiency.

Keywords: Project Management Office; PMO; Evaluation efficiency; Systematic literature review.

3.1 Introduction

Performing management in organizations requires effort and, therefore, organizations end up assigning Project Management responsibilities to the Project Management Office (PMO) generating new knowledge and lessons learned (Barbalho; Carlos De Toledo; Cintra Faria, 2021). Many companies consider implementing the Project Management Office (PMO) in order to develop Project Management competencies, because the PMO acts in a way to integrate competencies and support managers, allowing them to improve project effectiveness (Martins; Martins, 2012) as well as having an impact on the effectiveness of the project portfolio - which is a composition of projects that compete for resources and business strategies (Jonas; Kock; Gemünden, 2013), since project management and control has an impact on the quality of portfolio management (Patanakul, 2022). The PMO has a facilitating responsibility in the dissemination of knowledge in projects (Wiewiora; Chang; Smidt, 2020) and have a responsible role in coaching, mentoring, and governance of projects that goes beyond setting project management standards for organizations (Patanakul, 2022). Project management needs to have structural support to standardize and manage projects with the goal of having extended management that meets the organization's strategy. Thus, it is necessary to have a formally responsible person to manage and direct the project standards (Oliveira; Martins, 2020).

The PMO is considered fundamental in the implementation of Project Management strategies (Bredillet; Tywoniak; Tootoonchy, 2018a) being the fulcrum for outlining the completion of projects meeting the business constraints (Oliveira; Martins, 2018), becoming the focal point for controlling the management of multiple projects in organizations (Artto et al., 2011). The PMO is an organizational unit that is established in order to standardize the way projects are managed and to ensure efficiencies by generating best practices from the delivery of a portfolio of projects (Philbin; Kaur, 2020). The PMO is seen as a framework for innovation within organizations by stimulating the entire life cycle of projects (Sergeeva; Ali, 2020).

Also, it can be considered a complex area for organizations, mainly because of the adverse factors, such as culture (Bredillet; Tywoniak; Tootoonchy, 2018a), the role they play in the organization and complexity of the projects, where there are multiple projects that end up becoming competitors (Aubry; Lavoie-Tremblay, 2018), and the technological diversity that can influence project operations (Hansen et al., 2021).

There are still gaps in the literature about the definition of a PMO's efficiency. Practical and meaningful results that consider internal and external environmental variables can contribute to the assertiveness of PMO efficiency (Ko; Kim, 2019). Thus, this research aims to investigate how the efficiency of a PMO is evaluated, contributing to the area of Project Management, through a literature review.

The academic literature recognizes the existence of the so-called PMO efficiency gap. Oliveira and Martins (2018) assess PMO efficiency through constructs linked to PMO management: "implementation strategy", "personnel training and education", and "control of the project operations environment". Oliveira and Martins (2018) report that personnel training contributes to the efficiency of the PMO, and even though it presents relevant significance to the academic and business area, there is no assessment of whether the PMO is efficient or not, it only demonstrates some factors that can influence the efficiency of the PMO.

Ko, Park and Kim (2015) present a model that seeks to measure PMO efficiency in large-scale information systems (IS) projects using DEA. However, it uses as a case of analysis a specific and limited example. It is “specific” because it considers only one business segment, strongly oriented to the information technology area. It is “limited” because it does not consider the other segments of organizations, which have other management characteristics and another way of using the PMO. Nevertheless, the proposed model analyzes the impacts of efficiency on project results such as meeting time and costs but does not analyze the size of these projects and their interfaces and specialties involved. This research advances in this sense since it seeks to identify and analyze the efficiency of the PMO over time considering the interfaces and related parts of the projects and how the complexity can interfere with this analysis.

Ko and Kim (2019) analyze PMO efficiency by means of a seven-point Likert scale using DEA analysis. However, it uses a limited analysis, considering only the Likert scale to measure PMO efficiency and only the evaluator's perception.

It is evident in the literature the characteristics, objectives, functions, and expected results in relation to the PMO. There are also discussions about some factors that influence the efficiency of the PMO, although without clarity about the metrics that should be used for this. However, there are still gaps in the literature about what would be the efficiency of the PMO and the metrics to perform this evaluation. Likewise, the scale for performing this evaluation is not clear. This research expands the knowledge in this sense by exploring how the literature approaches the way companies to organize project management through the PMO, seeking to identify and analyze the set of processes, indicators, and structure required as a necessary condition for the functioning and achievement of results by the PMO, constituting a theoretical and applied contribution. Furthermore, this research seeks to address a theme that, as far as we know, is unique in the literature. Thus, there is no empirical research on the efficiency of the PMO. Our research has generated findings that can contribute to the development and monitoring of PMO in organizations.

This paper contributes to existing research on key PMO definitions. First, it addresses an explanation of how scientometric and bibliometric research is performed. Second, the results of these analyses are exposed, presenting an overview of the development of the state of the art of a PMO with the identification of the authors and institutions that have published the most on PMO in order to support the existing literature. In the next section, the results are discussed, presenting critical issues on the topic with discussions and opportunities for future research, presenting the main lines of research on the topic and evolution of the subject, in order to highlight our attention to the existing topic. Finally, the conclusions made by the study are presented, along with recommendations for future studies under the effect of the current results obtained.

3.2 Theoretical Review

3.2.1 Project Management Office

Organizations began to identify the benefits of the PMO in the mid-1990s and have been implementing it over the years (Otra-Aho et al., 2018). These benefits have broadened the adoption of the PMO for the project and program delivery and management (Kutsch et al., 2015) and centralized Project Management through the PMO (Alves et al., 2013). The PMBOK® (2021) establishes the PMO as an organizational unit that has responsibilities that correlate to centralized and coordinated project management. The PMO aims to reduce duration and budget while maintaining the scope and quality established

(Philbin, 2016) in addition to promoting Project Management maturity in organizations (Anantatmula; Rad, 2018). Thus, it is necessary to understand the context in which this PMO is inserted and the evolution of maturity it represents internally in organizations (Aubry; Richer; Lavoie-Tremblay, 2014).

The PMO started from a merger of functions, including project management, corporate cultures, technology development, and organizational strategy, and is now considered a dynamic management tool that guides individual projects to meet strategic goals in organizations (Sandhu; Al Ameri; Wikström, 2019). Its main objective is to standardize projects and meet stakeholder expectations (Viglioni; Cunha; Moura, 2016). It is an organizational body or entity that various responsibilities related to centralized and coordinated project management have been assigned, ranging from providing project management support functions to actually being responsible for the direct management of a project (Müller; Glückler; Aubry, 2013).

The PMO can present a variety of functions (Aubry; Brunet, 2016) and various structures and types according to each company's organizational context (Bredillet; Tywoniak; Tootoonchy, 2018b). Furthermore, there is research that highlights these different roles and presents functional changes over time with regard, specifically, to its function and tasks (Braun, 2018). Patanakul (2022) states in his study that there are different PMO responsibilities and that the PMO plays important roles in portfolio effectiveness with responsibilities directed to portfolio effectiveness results. For Desouza and Evaristo (2006) the PMO can be classified into two dimensions: administrative, which has the function of managing information about projects, tasks, resources, and the like, and reporting such information, and knowledge-intensive, which has an active role in managing project best practices, learning from projects (both failures and successes), and improving project maturity in the organization. It can also be delineated into five functions: monitoring and controlling project efficiency; developing project management skills and methodologies; multiple-project management; strategic management; and organizational learning (Hobbs; Aubry, 2007). For Müller et al. (2013) a PMO model can have three basic functions: service, control, and partnership. Thus, you can classify the PMO as an area of the organization that provides functions and services ranging from maintaining the standardization system to managing people and resources in order to assist executive management and the project portfolio (Kutsch et al., 2015).

Philbin (2016) and Aubry (2015) cite three definitions for the PMO: a) support PMO; b) control PMO; c) PMO that has direct control of projects. The support PMO provides an advisory role for projects through the provision of templates, improving project management, practices, training, access to information, and lessons learned from other projects; the control PMO has the function of providing support and control for project compliance through various means, such as the adoption of project management standards, the use of templates, specific forms, or compliance with certain governance agreements; and the direct PMO has a direct action on projects through the provision of project management services to enable project delivery.

According to Oliveira and Martins (2020), the PMO is an organizational structure that supports Project Management and establishes a standardization, and achieves better efficiency for the organization, delivering value and quality by meeting customer expectations. Finally, Tywoniak et al. (2015) argue that the PMO can have the function of a center of excellence since it is an organizational entity whose main objective is to implement practices, methodologies, and strategic choices. And beyond this, to better the question of doing more with less there is a knowledge management aspect in order to share good and new practices (Aubry; Müller; Glückler, 2011).

Table 15 presents a summary of the definitions of the PMO presented in the literature. Most authors in the literature define the PMO as a manager, three authors highlight the PMO's function as a control function, and most of them with results focused on the organization's efficiency.

Table 15 - Definitions of the PMO

Role of the PMO	Author
1. Administrative: a) Support b) Manage information 2. Knowledge-Intensive: a) Knowledge management b) Training	Desouza and Evaristo (2006) and Pemsel and Wiewiora (2013)
1. Monitoring and controlling project efficiency 2. Developing skills and methodologies in project management 3. Multiple-project management	Hobbs and Aubry (2007)

Role of the PMO	Author
4. Strategic management 5. Organizational learning	
1. Service 2. Control 3. Partnership	Müller et al. (2013)
1. It provides functions and services 2. Maintains the standardization system 3. Managing people and resources 4. Supporting the executive management and the project portfolio	Kutsch et al. (2015)
1. Center of excellence 2. The organizational entity that aims to implement practices, methodologies, and strategic choices	Tywoniak, Tootoonchy and Bredillet (2015)
1. Development of project management methodologies 2. Development of project management tools and software 3. Knowledge and lesson learned in management 4. Training and developing project management competency Mentoring and coaching in project management 5. Governance and human resource development 6. Monitoring and controlling projects 7. Portfolio management 8. Participate in strategic planning 9. Management customer interfaces 10. Management vendor and contractor interfaces	Parchami Jalal and Matin Koosha (2015) and Anantatmula and Rad (2018)
1. Support 2. Control 3. PMO that has direct control of the projects	Philbin (2016)
1. Develop improvements by developing or providing global project management methodologies, policies, standards, and reports for the organization	Müller, Drouin and Sankaran (2019)
1. An organizational structure that supports Project Management 2. Establishes a standardization 3. Search for efficiency for the organization, delivering value and quality by meeting customer expectations	Oliveira and Martins (2020)
1. PMO in coordinating and stimulating innovation and change by detecting and identifying innovation opportunities for more assertive and successful projects	Sergeeva and Ali (2020)
1. Most important facilitator to capture and share project learning	Wiewiora, Chang and Smidt (2020)
1. They recognize multiple PMO functions but argue the need to define the direction and purpose of knowledge flow and organization characteristics. These functions should develop within and across three levels of hierarchy: project, PMO, and management.	Hadi, Liu and Li (2021)

Source: Prepared by the author.

The PMO can leverage the efficiency of the organization's results (Aubry; Hobbs; Thuillier, 2007) and promote organizational learning (Wiewiora; Chang; Smidt, 2020), improving actions through greater knowledge, standardization, and training, but according to Tsaturyan and Müller (2015), there must be an integration of these factors and governance. The agility and time to include these standards in the projects are reflected in the way project managers can absorb the information and how it will be implemented in the organizations (Le Dinh; Van; Nomo, 2015).

Despite the benefits related to the PMO, implementing it is a complex task subject to multiple challenges, mainly because it represents a cultural change (Raharjo et al., 2018). As the PMO varies from one organization to another, its implementation requires customization to meet the organizational reality (Duarte et al., 2019). Consequently, it takes significant time and effort to properly incorporate this structure into the organization (Philbin, 2016).

Even though it is a complex and changing task for organizations, the PMO can be a mechanism to promote the success of projects, developing standards and methodologies, and aiming to meet the deadline, cost, and quality. According to Aubry (2009), a way to manage projects to have traceability, control, quality, standardization, and indicators is associated with the PMO. A good PMO performance directly affects the result of the projects, yielding better results (McKay et al., 2013), as it is responsible for reducing operational risk for an organization by managing project efficiency and risk mitigation (Marcondes; Leme; Carvalho, 2019). As such, seeking efficiency in these structures is fundamental to the successful completion of projects.

PMOs with higher efficiency rates result in better meeting deadlines, cost compliance, and resource integration (Ko; Park; Kim, 2015). However, scientific research has been more focused on reviewing and applying models to the PMO's role (Aubry, 2011) and responsibilities, leaving the results of its operations out of the discussion (Paton; Andrew, 2019), as well as the importance of the PMO in organizations (Hobbs; Aubry; Thuillier, 2008) and the integration of organizations with multi-purpose PMOs. (Aubry et al., 2010). Quantifying the true value of a PMO is difficult and there is no standard by which to measure it (Bredillet; Tywoniak; Tootoonchy, 2018a). The next section will explore the issues directly linked to PMO efficiency found in the literature.

3.2.2 Project Management Office Efficiency

Efficiency is the ratio between a performance indicator and its maximum theoretical value, obtaining, as a result, a value between 0 and 1, or, in terms of percentage, a value between 0% and 100%, as represented in the equation in Equation 2 (Piran; Lacerda; Camargo, 2020). In the context of project management, the literature highlights efficiency in several areas, such as project efficiency, organization efficiency, PMO efficiency, perceived efficiency, portfolio efficiency, project management efficiency, and communication efficiency. Ko and Kim (2019), Steyn (2016), and Unger et al. (2012) are researchers responsible for works in the line of research on project efficiency, presenting the significant benefits to organizations, such as return on investment, cost reduction, and greater assertiveness of projects.

Equation 2 – Efficiency

$$\text{Efficiency} = I / (I\ max)$$

Where:

I: Current performance indicator;

Imax: Maximum possible value for this indicator.

The efficiency of the PMO may depend on factors such as culture, structure, and organizational governance (Too; Weaver, 2014), which can influence the results and guide the success of the projects (Alnasri; Busch, 2018). Barbalho et al. (2021) present in a study that there are three factors that influence the success of the PMO: results achieved through the use of best practices, stakeholder support, and the dedication of a person responsible for implementing PMO practices. Defining a way to assess PMO efficiency can serve the interests of project managers and stakeholders, and at the same time act as a strategic tool for organizations (Viglioni; Cunha; Moura, 2016), because it gives support for following a methodology, controlling how it is done, and managing in order to organize Project Management.

Aubry and Hobbs (2010) permeates organizational efficiency, and so, for this evaluation, indicator criteria and values that contribute to and include the efficiency of the PMO and the projects are listed. Ko and Kim (2019) measure the efficiency of the PMO using a Data Envelopment Analysis (DEA) model and are able to identify that the maturity of the project portfolio is directly related to the efficiency of the PMO. Unger, Gemünden and Aubry (2012) evaluate the efficiency of the PMO by mainly analyzing the quality of the project portfolio management. Also, according to Steyn (2016), the efficiency of the PMO can be associated with the efficiency of the projects and the organization.

With this, it is possible to identify, through the literature, that a PMO can exercise more than one function in organizations and positively affects the success of projects. In the next section, the methodological procedures of the research will be presented.

3.3 Methodological procedures

This research was conducted under the approach of Literature Grounded Theory - LGT, a method indicated when the objective is the generation of knowledge along with the selection, analysis, and synthesis of the literature. It is a method that provides a set of scientific data resulting from a specific approach to knowledge, promoting growth in the theme for researchers in the area and indicating the main trends (Ermel et al., 2021). This method consists of generating theories or hypotheses through research on existing scientific and technological knowledge.

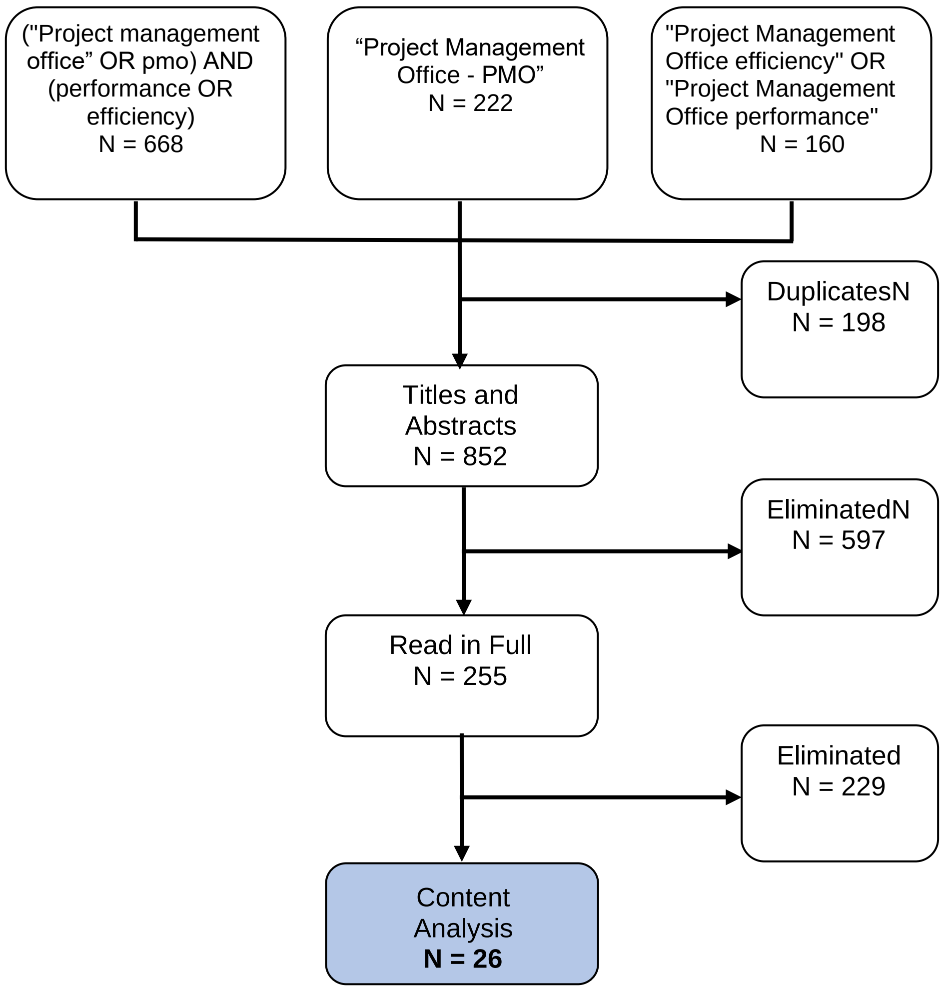
3.3.1 Sampling process

The database used to collect bibliographic material was Scopus. This was chosen because it provides quick access to the main worldwide citation databases and offers traceability tools for search analysis and visualization (Morandi; Camargo, 2015). For research reproducibility, it is emphasized that the data were collected in January 2021.

The selection of the scope and keywords was based on three steps: (i) preparation of the search protocol, in order to structure the search strategy based on Ermel et al. (2021), according to Table A3 (Appendix); (ii) elaboration of the conceptual framework, with the function of outlining the scope of the systematic literature review (SLR); and (iii) preliminary readings of the most recent and cited articles on the subject, published in impact journals.

A search sequence was performed with different terms to analyze all studies referring to the PMO theme. The initial sample was 1,050 documents in a time frame from 1973 to 2022. For this initial sample, the following search terms were used: ("Project management office" OR pmo) AND (performance OR efficiency), "Project Management Office - PMO" and "Project Management Office efficiency" OR "Project Management Office performance". All papers were analyzed by reading the title, abstract, and keywords (Gough et al., 2012). Then, the selected articles were analyzed in depth as recommended by Adler and Doren (1972). The next step was to select the articles that addressed PMO efficiency, aiming to analyze what researchers are addressing regarding the theme, as indicated in Figure 16.

Figure 16 - Select the articles



Source: Prepared by the author.

Out of the 1,050 studies found, 198 were duplicates. Titles and abstracts were read and the papers that did not specifically address the PMO theme or were about a specific project were eliminated. Thus, 255 papers were left to be read in full. Of these 255 papers, 26 presented efficiency. There are several software tools for performing in-depth scientific mapping analysis (Ferreira; Silva, 2019). In this research, SciMAT was used, some software that presents as one of its main features in the pre-processing module the detection of duplicates and items with spelling errors (Cobo et al., 2012). In addition, it allows data reduction that can be used in cases where there are significant keyword results and it is necessary to group them in order to evaluate more important and representative data (Kipper et al., 2019). Table 16 presents the exclusion criteria and their respective statistics.

Table 16 - Exclusion criteria

Exclusion criteria	Exclusion Nº	Percentage
Absence of the "efficiency PMO" theme	597	56,9%
Duplicate articles	198	18,9%
Project-specific discussion	140	13,3%
Project management	89	8,5%
Source not available	23	2,2%
Focus Risk matrix	3	0,3%
Total	**1,050**	**100%**

Source: Prepared by the author.

3.3.2 Data analysis

A bibliometric analysis was carried out that allowed the generation of co-citation maps and keywords, with the formation of clusters that group works whose interaction is stronger. The objective of this analysis was to identify research groups, the relationships within and among these groups, and their changes and evolution over time. The inclusion criteria for the articles in this analysis were: papers with more than two citations that presented a link to at least one study, to identify influence and similarity. The co-occurrence analysis of keywords was also performed, seeking to map studies on the theme and the main lines of research addressed.

A minimum limit of two works per cluster was defined. The scientometric analysis was performed in the Scopus database itself, and the bibliometric analysis was performed using the VOSviewer software, due to its simplicity and popularity in building bibliometric networks (Van Eck; Waltman, 2017).

The next methodological step was content analysis. In this step, the units of the register were coded, that is, the content of the text was considered as the basis for this analysis (Bardin, 2016).

Thus, categorical and open codes were established. The categorical codes were defined even before the readings and content analysis, and the open codes emerged throughout the analytical reading (Dresch; Lacerda; Júnior, 2015). The codes were established as shown in Appendix A (Table A4).

One of the first categorical codes to be created were the codes related to knowledge areas such as cost, scope, quality, risk, and human resources. Codes such as project management maturity, PMO model, and standardization were generated from the in-depth reading of the texts. With the code system, it was possible to analyze the frequency of these codes in the unit of context, that is, the number of times these codes appear in the corpus of analysis (Bardin, 2016). The frequency in this study is relevant because it seeks papers directed to the efficiency of the PMO.

Thus, having the initial codes, the next step was to codify the papers and treat the results obtained from this coding system. To do this, we used the qualitative data analysis software Atlas Ti (ATLAS.ti 8 for Windows, 2018). Table 17 presents the group of codes that were created for the analysis of the methodologies and tools applied in the studies resulting from the search. The codes were created to facilitate the analysis and classified by type: statistical analysis, database, tool, method, and software.

Table 17 - Group of codes

Code Description	**Coding**	**Code Description**	**Coding**
Training	**C1**	PMO Implementation	**C24**
Competitiveness	**C2**	Indicators	**C25**
Complexity	**C3**	GP Maturity	**C26**
Control of Operations	**C4**	PMO Model	**C27**
Schedule	**C5**	Standardization	**C28**
Culture	**C6**	PMO Role	**C29**
Cost	**C7**	Performance	**C30**

Code Description	Coding	Code Description	Coding
Difficulty in measuring efficiency	**C8**	Portfolio	**C31**
GP Efficiency	**C9**	Internal Processes	**C32**
Organization Efficiency	**C10**	Product	**C33**
PMO Efficiency	**C11**	Program	**C34**
Portfolio Efficiency	**C12**	Quality	**C35**
Project Efficiency	**C13**	Human Resources	**C36**
Perceived Efficiency	**C14**	Networking	**C37**
Scope	**C15**	Competitive Advantage	**C38**
Project Management Office - PMO	**C16**	Communication Efficiency	**C39**
Business Strategy	**C17**	PMO Performance	**C40**
PMO Structure	**C18**	PMO Benefits	**C41**
PMO Evolution	**C19**	Communication	**C42**
PMO Function	**C20**	Organizational Structure	**C43**
Project Management	**C21**	Lessons Learned	**C44**
Change Management	**C22**	Risk	**C45**
Knowledge Management	**C23**		

Source: Prepared by the author.

The next step was to perform an association analysis by means of the structural analysis, the a priori algorithm, and that was applied to R (R core team, 2020). Then, association rules were analyzed in order to identify how the contexts and the set of initiatives (antecedent factors, called lhs) influence a given outcome (consequent factor, called rhs).

As a last methodological step, a correlation analysis was performed on the efficiency codes, a simplified network analysis, and a center-periphery analysis with the aim of assisting the treatment of the most addressed codes.

The results of these analyses are presented in the next chapter.

3.4 Results

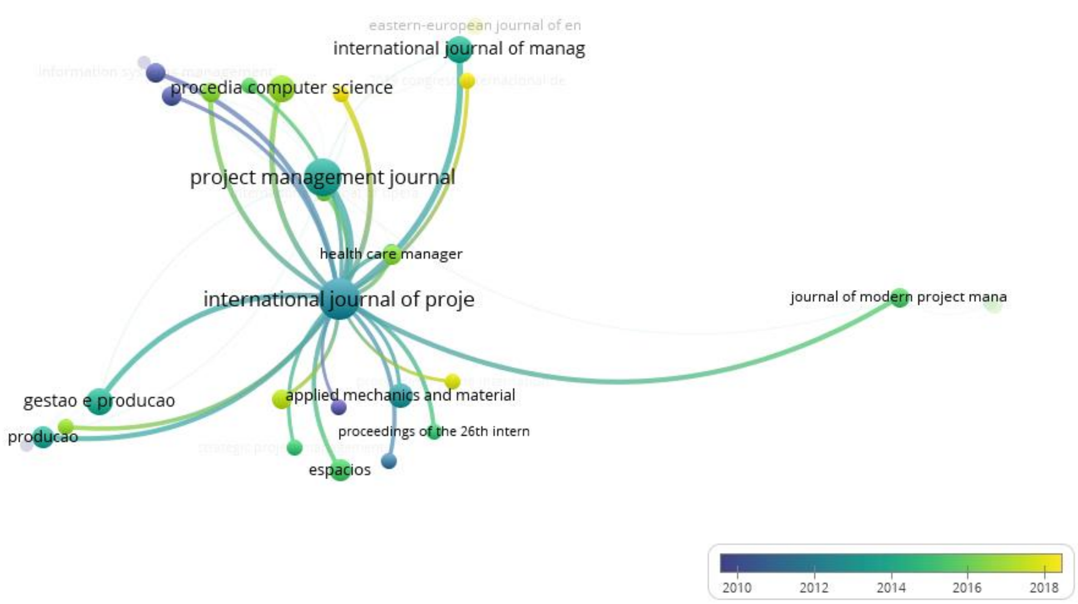
3.4.1 Results of the Scientometric and Bibliometric Analyses

In this section, considering the 26 filtered articles, the results of the bibliometric and scientometric analyses are presented using graphs of the chronological distribution of the publications in the final sample. Next, the journals, authors, institutions, and countries that published the most on PMO are analyzed. Finally, co-occurrence and co-authorship maps are identified.

This analysis allowed the verification of studies that directly works to approach the efficiency theme, highlighting models, techniques, and ways to justify the benefits of the PMO, its efficiency, project, organization, and portfolio efficiency. Besides the broad search for the term PMO, additional analyses were performed to identify how this research has been associated with some more emerging topics in the scientific field, such as results and efficiency.

When analyzing the period of publications of the most relevant journals, one notices, according to Figure 17, the evolution of publications in the period from 2010 to 2018. The analysis presented in the VOSviewer® image, software specifically designed for the construction and visualization of bibliometric maps, pays special attention to the graphic representation of such maps, representing density (size of the circles), centrality (position of the circles) and proximity (distance between the circles). In addition, the network formed allows visualizing the existing connection between the main journals used in the studies, complementing the characteristics of density, centrality, and proximity. The colors of the graph represent the date of publication in the journals, on a scale, where lighter colors are the most recent papers and darker colors are the oldest.

Figure 17 - Publications in the period from 2010 to 2018



Source: Prepared by the author.

Table 18 shows the 10 authors who have contributed the most to the topic of efficiency in the PMO area. Aubry, M. is the most cited author on the subject, publishing mainly in the line of PMO implementation and its results. His first papers were published in (YEAR) and focused on the theme of PMO implementation and the benefits of this action for companies. It can be seen that 25% of the papers are focused on implementation in the healthcare sector. Aubry, M. has several papers coauthored with Hobbs, B., who is the second author who has contributed the most to the topic. Hobbs, B. has publications on the topic as far back as 2011, directed at the advantages and the best way to understand the PMO. The third most cited author, Thuillier, D., publishes with the two most cited authors: Aubry, M. and Hobbs, B. and follows in the line of research on PMO implementation in organizations and how this action can benefit Project Management in organizations. Besides this, it focuses on the transformations of the PMO over time, its evolution, and its meanings for organizations. The criterion used for this classification was authors with at least 2 papers and 5 or more citations.

Table 18 - Authors with the most publications in the PMO area

Position	Author	Institution	Citations
1	Aubry, M.	Université du Québec, Montreal	721
2	Hobbs, B.	Université du Québec, Montreal	442
3	Thuillier, D.	Université du Québec, Montreal	294
4	Müller, R.	BI Norwegian Business School, Oslo	197
5	Blomquist, T.	Umea University, Sweden	93
6	Gemünden, H. G.	Technische Universität Berlin, Germany	89
7	Wiewiora, A.	Queensland University ofTechnology, Australia	83
8	Glückler, J.	University of Heidelberg, Heidelberg, Germany	81
9	Lavoie-Tremblay, M.	McGill University Health Centre (MUHC) in Montréal, Québec	79
10	Richer, M. C.	McGill University Health Centre (MUHC) in Montréal, Québec	64

Source: Prepared by the author.

Based on the volume of citations, Table 19 presents the 10 most cited papers in Project Management Office. The first most cited paper from Anthony

Cox (2008) addresses the topic of risk matrix in construction projects and the impact on decision making. Dai and Wells (2004), with the second most referenced work, studied the PMO as an alternative to minimize project failures. Besides this, it carried out a case study for two years and applied the tools and methods, and then made a comparison, which resulted in the success of its analysis, that is, the function of minimizing failures and flaws in projects. The third most cited work, Aubry, Hobbs and Thuillier (2007), addresses a theoretical contribution to the study of organizational project management and the PMO.

Table 19 - Most cited articles in PMO

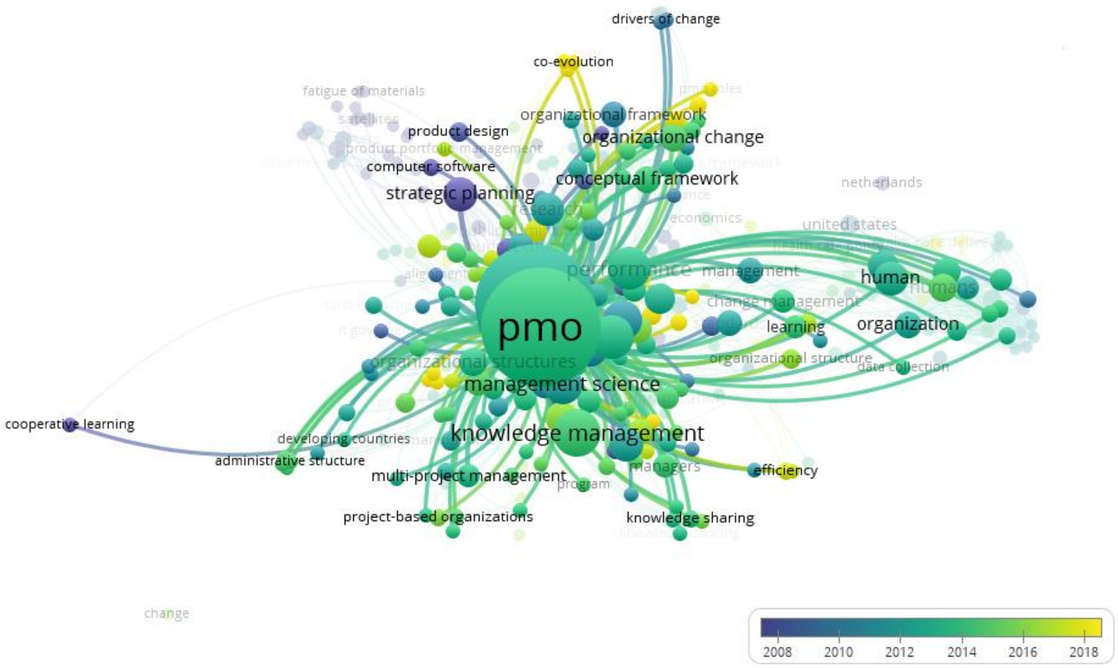
Position	Title	Author	Year	Journal	Citation
1	An Exploration of Project Management Office Features and Their Relationship to Project Performance	Dai, C. X.	2004	International Journal of Project Management	142
2	The Three Roles of a Project Portfolio Management Office: Their Impact on Portfolio Management Execution and Success	Unger, B. N.	2012	International Journal of Project Management	88
3	A Fresh Look at the Contribution of Project Management to Organizational Performance	Aubry, M.	2011a	Project Management Journal	56
4	IS Project Management: Size, Complexity, Practices, and the Project Management Office	Martin, N. L.	2007	Journal of Computer Information Systems	34
5	The Contingent Effects on Project Performance of Conducting Project Reviews and Deploying Project Management Office	Liu, L.	2007	IEEE Transactions on Engineering Management	32
6	Pluralism in PMO Performance: The Case of a PMO Dedicated to a Major Organizational Transformation	Aubry, M.	2011	Project Management Journal	25

Position	Title	Author	Year	Journal	Citation
7	Governance performance in a complex environment: The case of a major transformation in a university hospital	Aubry, M.	2014	International Journal of Project Management	24
8	Project Management Office Transformations: Direct and Moderating Effects That Enhance Performance and Maturity	Aubry, M.	2015	Project Management Journal	16
9	Improving Industrial Engineering Performance through a Successful Project Management Office	Spalek, S.	2013	Engineering Economics	14
10	Project Management Office Implementation	Johnson, M. A,	2002	AACE International. Transactions of the Annual Meeting	9

Source: Prepared by the author.

The network of keywords allows us to visualize the connection between the main words used in the studies, complementing the characteristics of density, centrality, and proximity, used in the analysis of co-authorship, with the addition of a temporal factor. Figure 18 allows us to see the evolution over time of each of these words, identifying mainly the words used in the past (blue color) and the words used recently (yellow color).

Figure 18 - Network of keywords



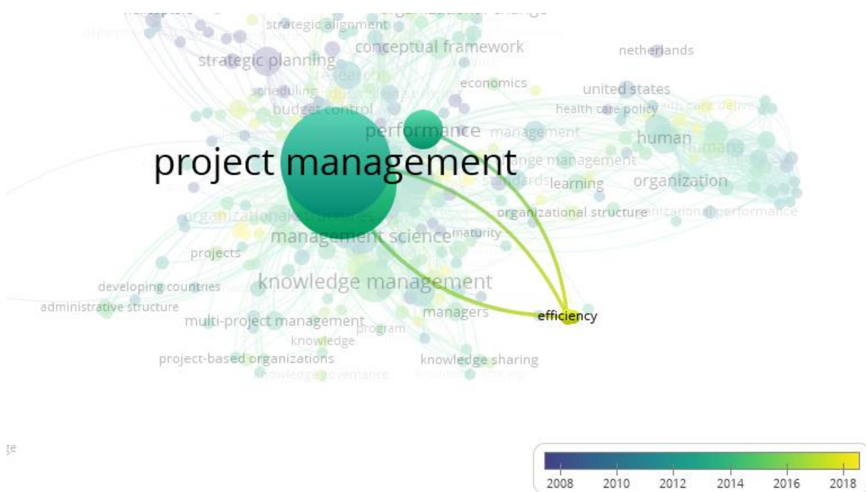
Source: Prepared by the author.

Five main clusters were identified that are interconnected by the term "PMO". The most intense Cluster, which involves the word "pmo" is formed by the terms:

a) “construction projects”,
b) “corporate strategies”,
c) “critical success factors”,
d) “exhibitions”,
e) “financial data processing”,
f) “integration management office”,
g) “investments”,
h) “longitudinal case study”,
i) “management environments”,
j) “maturity model”,
k) “new product development”,
l) “portfolio management”,
m) “portfolio management",
n) “product development”,
o) “product portfolio management”,
p) “program management”,
q) “project management”,
r) “project management maturity”,
s) “project success”,
t) “public administration”,
u) “resource management”,
v) “software engineering”,
w) “strategic initiative”,
x) “strategic management”,
y) “sustainable development”
z) “technology-based”

Figure 19 presents the cluster formed by the keyword "efficiency". This cluster brings the term "efficiency" as a new keyword in the searches (as of 2018) and correlated with the words "pmo", "Project management" and "performance".

Figure 19 - Cluster formed by the keyword "efficiency"

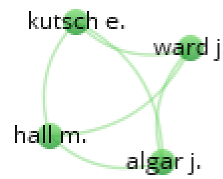
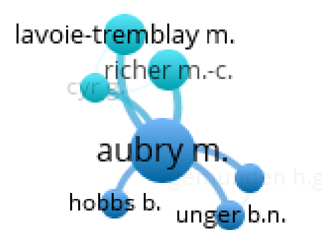
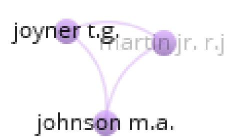


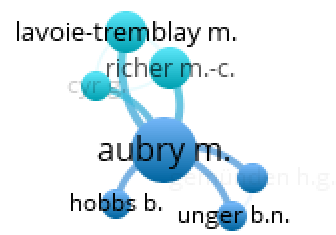
Source: Prepared by the author.

Thus, the bibliometric analysis, directed in the network of citation and keywords, allowed us to observe a transition of the Project Management theme, which as of 2013 has begun to expand and share its applications with an area focused on standardization and results: PMO. With this analysis, it was possible to verify that the first articles published had the main focus on projects and their deliveries, presenting an absence of the theme of efficiency in the PMO area. Subsequently, there are stages of evolution of the PMO theme and correlation with efficiency. The organizational strategy permeates Project Management and the PMO enters an important role in management.

In all, the 26 studies were prepared by 58 authors. The co-authorship analysis allows establishing if there is any relationship or proximity among these authors, evidencing 10 clusters formed by 29 authors (see Table 20).

Table 20 - Clusters

Cluster	Authors	Docs	Research Line	Network
1	Barbalho S. C. M. Amaral D. C. Kernibichler T. S. Richter E. H. Torres L.	4 1 1 1 1	Improvements of PMO Efficiency Assessment	
2	Algar J. Hall M. Kutsch E. Ward J	1 1 1 1	Contributions of the PMO to project efficiency	
3	Aubry M. Gemünden H. G. Hobbs B. Unger B. N.	5 1 1 1	Contribution of GP and PMO to Organizational efficiency	
4	Furumo K. Martin N. L. Pearson J. M.	1 1 1	PMO success and failure points	
5	Johnson M. A. Joyner T. G. Martin Jr. R. J.	1 1 1	PMO implementation and success factors	

Cluster	Authors	Docs	Research Line	Network
6	Lavoie-Tremblay M. Richer M. C. Cyr G.	2 2 1	PMO Efficiency Evaluation Factors	
7	Steyn H. Van Der Linde J.	1 1	Portfolio Management Efficiency	
8	Dai C. X. Wells W. G.	1 1	Project Efficiency	
9	Liu L. Yetton P.	1 1	PMO Benefits	
10	Spalek S.	1	Improving industrial efficiency through the PMO	

Source: Prepared by the author.

The analysis of the co-authorship network, presented in the VOSviewer® images, represent density (size of the circles), centrality (position of the circles), and proximity (distance between circles). Clusters 1 and 6 represent the central theme addressed in this thesis. Clusters 1 and 3 are the most representative, with two authors: Aubry and Barbalho.

In addition to the coauthorship analysis, the network of keywords allows us to visualize the connection between the main words used in the studies, complementing the characteristics of density, centrality, and proximity, used in the coauthorship analysis, with the addition of a temporal factor. The next section presents the results of the content analysis.

3.4.2 Content Analysis Results

Content analysis began by mapping the codes found in the selected articles and in which studies they are present. Next, the types of efficiencies related to the PMO theme were identified, such as project efficiency and organization efficiency.

This analysis allowed us to identify researchers and their lines of research according to the theme addressed. Kutsch et al. (2015) address the functionality of the PMO in organizations to improve project efficiency. Moreover, it is exposed that even being strategic for improving project deliverables, the PMO does not have the proper recognition and justification of its existence. To investigate how the PMO adds value, an exploratory study was conducted, with the application of questionnaires to managers, to identify what this value means from the perspective of project stakeholders. Kutsch et al. (2015) conclude that before deploying a PMO it is necessary to define its function in the organization and, with this, there may be highlighting and appreciation in the organizations.

Another research group evaluates the main factors for assessing a PMO efficiency. Lavoie-Tremblay et al. (2018) present the unique opportunity to understand how a PMO facilitates the successful implementation of a project. This study by Lavoie-Tremblay et al. (2018) is conducted through a case study and presents the main factors of an efficient PMO. Among them are: developing a support model and providing rigorous project guidance (methods, evaluation, analysis, promoting collaboration, dedicated expert support, etc.); developing and providing rigorous and enduring tools and methods that are linked to continuity (data, evaluations, frequent process reviews, dashboards); providing or offering training for project management; and introducing and using communication (Lavoie-Tremblay et al., 2018).

Steyn (2016) indicates measuring portfolio efficiency or the organization's ability to execute its projects by pre-established indicators, such as forecast accuracy of capital expenditures. Furthermore, he suggests measuring a PMO, quantitatively, by these portfolio indicators.

Dai and Wells (2004) state that projects, even with efficient management support, still experience errors and failures. The study suggests a continuous exploration of new process models and organization structures to fuel strong project performance. An important candidate for improving these results is project management offices (PMO). To achieve these results, a regression analysis was conducted that primarily demonstrated the increase in project efficiency through PMO implementation.

Industrial efficiency is a topic with several lines of research that can develop in different ways. The PMO can be one of the factors to develop this environment. To obtain satisfactory results, PMOs must be divided into two periods: short-term (up to one year) and long-term (two or more years). The effectiveness of operations in a multi-project environment is a crucial goal for professionals. This study was based on questionnaires with PMI members (Spalek, 2013).

Of the 1,050 articles analyzed from the database search, only 26 were related to the research topic efficiency related to the PMO area. Thus, with this codified corpus of analysis, there was a binary conversion for a more precise analysis of the frequency of these codes. In Table 21 it is possible to identify the analyzed papers and which efficiency each one portrays. The numbered areas present what each author is addressing in his study. In some cases, it is possible to identify that the author addresses more than one type of efficiency in the same article.

Table 21 - Articles and efficiency

		C39 Communication Efficiency	C9GP Efficiency	C10 Organization Efficiency	C11 PMO efficiency	C40 PMO performance	C12 Portfolio Efficiency	C13 Project Efficiency	C14 Perceived Efficiency	Author Freq.
Primary Studies	(Philbin; Kaur, 2020)		**1**							**1**
	(Bettin et al., 2010)					**1**				**1**
	(Aubry; Hobbs, 2011)		**1**	**1**		**1**		**1**		**4**
	(Aubry et al., 2011)			**1**		**1**			**1**	**3**
	(Aubry, 2015)		**1**	**1**		**1**		**1**		**4**
	(Ko; Park; Kim, 2015)				**1**			**1**		**2**
	(Ko; Kim, 2019)			**1**	**1**		**1**	**1**	**1**	**5**
	(Kutsch et al., 2015)			**1**				**1**	**1**	**3**

	C39 Communication Efficiency	C9GP Efficiency	C10 Organization Efficiency	C11 PMO efficiency	C40 PMO performance	C12 Portfolio Efficiency	C13 Project Efficiency	C14 Perceived Efficiency	Author Freq.
(Liu; Yetton, 2007)							**1**		**1**
(Martin; Pearson; Furumo, 2007)							**1**		**1**
(Otra-Aho et al., 2018)							**1**		**1**
(Philbin, 2016)		**1**							**1**
(Unger; Gemünden; Aubry, 2012)									**1**
(Viglioni; Cunha; Moura, 2016)			**1**		**1**				**2**
(Jaber; Al-Zwainy, 2018)	**1**								**1**
(Barbalho; Da Silva; De Toledo, 2017)					**1**		**1**		**2**
(Aubry; Richer; Lavoie-Tremblay, 2014)			**1**				**1**		**2**
(Barbalho et al., 2009)							**1**		**1**
(Barbalho; De Toledo, 2013)							**1**		**1**
(Barbalho et al., 2014)							**1**		**1**
(Le Dinh; Van; Nomo, 2015)									**1**
(Oliveira; Martins, 2018)					**1**		**1**		**2**
(Qing-Lan, 2008)			**1**						**1**
(Spalek, 2013)			**1**						**1**
(Steyn, 2016)			**1**			**1**	**1**		**3**
(Dai; Wells, 2004)							**1**		**1**
Frequency by theme	**1**	**4**	**11**	**2**	**8**	**3**	**16**	**3**	
Relative frequency	**4%**	**15%**	**42%**	**8%**	**31%**	**12%**	**62%**	**12%**	

Source: Prepared by the author.

It is possible to identify that project efficiency and organization efficiency are the most studied themes when compared to PMO performance, representing 33.3% and 22.9% of the studies, respectively. PMO performance is the third most addressed theme in the scientific studies analyzed, with 20.8%.

In Table 22 it is possible to identify the most significant elements of efficiency related to PMO. They were identified, based on the counting principles and the frequency matrix, because of the aggregated synthesis of the selected empirical studies and associated with the coding scheme.

Table 22 - Most significant elements of efficiency

Code group: Efficiency	Frequency Absolute	Frequency Relative	Primary Studies
C13	18	35%	R1, R2, R3, R5, R6, R7, R10, R11, R13, R14, R15, R16, R20, R21, R22, R24, R25, R26
C11	11	22%	R6, R7, R8, R14, R15, R16, R19, R21, R24, R25, R26
C10	11	22%	R4, R6, R8, R10, R12, R14, R16, R17, R19, R20, R25
C14	4	8%	R1, R8, R16, R25
C9	3	6%	R6, R14, R18
C12	3	6%	R9, R20, R25
C39	1	1%	R23
Total	**51**	**100%**	

Source: Prepared by the author.

Design efficiency (C13) represents the most frequent context layer (35%) observed in the literature. In primary studies R1, R2, R3, R5, R6, R7, R10, R11, R13, R14, R15, R16, R20, R21, R22, R24, R25, R26, the authors made it clear that PMO efficiency is measured through project efficiency. As for organization efficiency (22%) and PMO efficiency (22%), only 11 out of 26 primary studies addressed inputs regarding the organization and PMO efficiency. This is critical to understanding how PMO efficiency is expected to be measured. Perceived efficiency (C14) appears in four of the primary studies. Project Management efficiency (C9) and portfolio efficiency (C12) appear at 6% in the literature explored. Communication efficiency (C39) appears in 1 of the 26 primary studies. Regarding initiatives, the results indicate that project efficiency (C13) is a critical input for the PMO. Communication efficiency (C39), Project Management efficiency (C9), and portfolio efficiency (C12) were the least mentioned. The analysis of the empirical studies also indicates that the inputs are still very traditional and not much attention has been paid to topics such as ways to achieve an efficient PMO or how to measure it. This lack of attention was observed in several selected studies in this research and represents a vast field of action for scholars and practitioners.

After this, Table A1 (Appendix) was generated in the form of a binary matrix, where all the codes established in the analysis are. Table A1 was reorganized to provide an understanding of the association rules. Finally, through structural analysis, the a priori algorithm was applied to R (R core team, 2020), and the association rules identified how the contexts and the set of initiatives (antecedent factors, called lhs) influence a certain outcome (consequent factor, called rhs). Twenty association rules were identified as shown in Table 23.

Table 23 - Association rules

	lhs		rhs	support	confidence	coverage	lift	Count
[1]	{}	=>	{*C13*}	0,69	0,69	1,00	1,00	18,00
[2]	{}	=>	{*C10*}	0,42	0,42	1,00	1,00	11,00
[3]	{}	=>	{*C11*}	0,42	0,42	1,00	1,00	11,00
[4]	{*C11*}	=>	{*C13*}	0,35	0,82	0,42	1,18	9,00
[5]	{*C13*}	=>	{*C11*}	0,35	0,50	0,69	1,18	9,00
[6]	{*C10*}	=>	{*C11*}	0,23	0,55	0,42	1,29	6,00
[7]	{*C11*}	=>	{*C10*}	0,23	0,55	0,42	1,29	6,00
[8]	{}	=>	{*C14*}	0,15	0,15	1,00	1,00	4,00
[9]	{*C10*, *C13*}	=>	{*C11*}	0,15	0,67	0,23	1,58	4,00
[10]	{}	=>	{*C9*}	0,12	0,12	1,00	1,00	3,00
[11]	{}	=>	{*C12*}	0,12	0,12	1,00	1,00	3,00
[12]	{*C14*}	=>	{*C10*}	0,12	0,75	0,15	1,77	3,00
[13]	{*C10*}	=>	{*C14*}	0,12	0,27	0,42	1,77	3,00
[14]	{*C14*}	=>	{*C11*}	0,12	0,75	0,15	1,77	3,00
[15]	{*C11*}	=>	{*C14*}	0,12	0,27	0,42	1,77	3,00
[16]	{*C14*}	=>	{*C13*}	0,12	0,75	0,15	1,08	3,00
[17]	{*C13*}	=>	{*C14*}	0,12	0,17	0,69	1,08	3,00
[18]	{*C10*, *C14*}	=>	{*C11*}	0,12	1,00	0,12	2,36	3,00
[19]	{*C11*, *C14*}	=>	{*C10*}	0,12	1,00	0,12	2,36	3,00
[20]	{*C10*, *C11*}	=>	{*C14*}	0,12	0,50	0,23	3,25	3

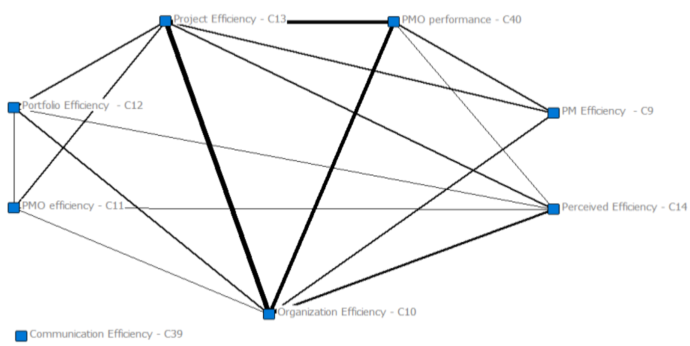
Source: Prepared by the author.

Rules 2 and 3 indicate that the design problem classes $C10$ and $C11$ co-occurred, individually, in 42.0% of the primary studies. Still, from these rules, it is possible to infer that $C13$ is more likely to appear (69.2%) individually. The same reasoning can be applied to rules 8, 10 and 11 but at lower levels of support. Regarding rules 4 and 5, the design problem classes $C13$ and $C11$ co-occurred in

34.6% of the primary studies. From these rules, it is possible to infer that $C13$ is more likely to appear (81.8%) when $C11$ is present, but the opposite is not the case with the same level of confidence (50%). In this same logic, according to these rules, it is possible to apply rules 6, 7, 12, 13, 14, 15, 16, and 17. However, if $C11$ is considered together, as put by rules 9 and 18, the lift value increases, and the confidence reaches the level of 66.7% and 11.5%, respectively. Rules 19 and 20, in turn, follow the same pattern.

Figure 20 shows the relationship between the efficiency codes where line thickness expresses the intensity of the relationship. It is possible to observe a strong triangulation between Project Efficiency, Organization Efficiency, and PMO performance.

Figure 20 - Relationship between the efficiency codes



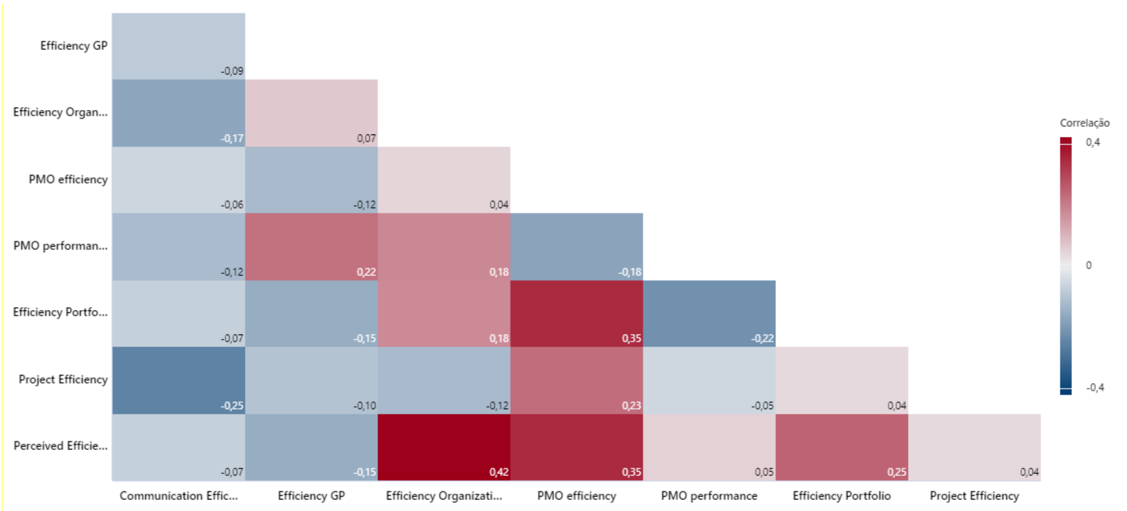
	C39	C9	C10	C11	C40	C12	C13	C14
C39	1	0	0	0	0	0	0	0
PM Efficiency - C9	0	4	2	0	2	0	2	0
C10	0	2	11	1	4	2	6	3
PMO efficiency - C11	0	0	1	2	0	1	2	1
PMO performance - C40	0	2	4	0	7	0	4	1
Portfolio Efficiency - C12	0	0	2	1	0	3	2	1
Project Efficiency - C13	0	2	6	2	4	2	16	2
Perceived Efficiency - C14	0	0	3	1	1	1	2	3

Source: Prepared by the author.

This network presents the relationships between PMO and efficiency and can suggest some perspectives that may be treated in future studies. It is possible to identify that PMO efficiency and project efficiency are mentioned simultaneously in some articles. From this, it is possible to suggest that PMO efficiency is associated with project efficiency. With the integrative PMO focus, there is a natural link between the organization, portfolio, programs, projects, and measurement systems. Thus project management is the essential element of the PMO and the efficiency of these projects directly affects the efficiency of the PMO (Oliveira; Martins, 2018).

In response to the relationship between the efficiencies studied, a correlation matrix of the codes related to efficiency was performed. The objective was to capture the degree of link strength between codes. This matrix was generated using Minitab software (Minitab, 2021) where the intensity of the color varies according to the strength of the relationship. Figure 21 shows colors and correlation values for each code.

Figure 21 - Correlation values for each code

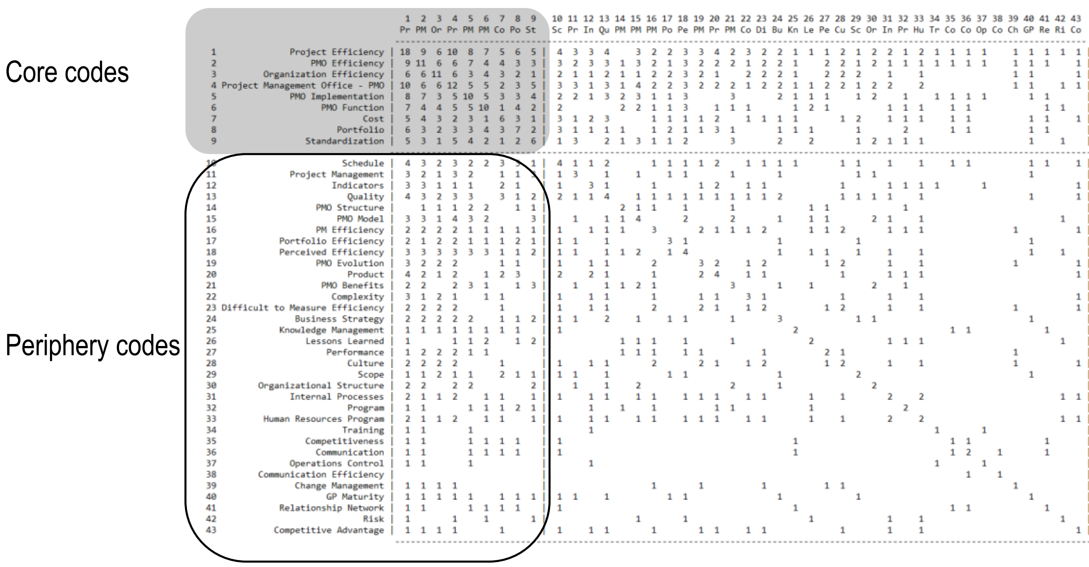


Source: Prepared by the author.

By analyzing the articles that address PMO efficiency, it is possible to identify the strong relationship of this topic with portfolio efficiency, project efficiency, and perceived efficiency. As the portfolio of a company increases, so does the ability of this company to achieve its goals, which can directly influence the efficiency of the PMO (Ko; Kim, 2019). In addition, the level of efficiency of a project that can be realized by comparing the initial milestones with the project closure, considering time, cost, and quality, can directly affect the efficiency of the PMO in cases where the company manages its portfolio through the PMO (Philbin; Kaur, 2020). If the success of a project is evaluated by customer satisfaction and opinion, it is timely to assess that the perceived efficiency can impact the efficiency of the PMO (Ko; Kim, 2019).

Taking all these results together, i.e., all the generated codes, it can be stated that there are some core and peripheral codes as a result of the framework. In Figure 22, the "peripheral core fit" measurement is given, which was developed by Borgatti and Everett (1999) to investigate the structure of the peripheral core. This measurement, lying between 0 and 1, indicates the extent to which the actual data network fits the network that has the ideal core-periphery structure. The closer the coefficient is to 1, the closer to the ideal core-periphery structure the network structure is. The networks for each code can be said to significantly fit the core-periphery structure. The core codes are project efficiency, PMO efficiency, organization efficiency, PMO, PMO deployment, PMO function, cost, portfolio, and standardization. The centrality measurement allows us to analyze how central the codes are in the network.

Figure 22 - Peripheral core fit



Core/Periphery fit (correlation) = 0,7941

Source: Prepared by the author.

It is possible to reaffirm the strong correlations, at the core, between project efficiency and PMO efficiency, and PMO efficiency with organizational efficiency. Portfolio management has a strong relationship with project efficiency because it acts as an influencer of project performance and is a mechanism that guarantees monitoring and controlling with the objective of ensuring the business results and objectives (Oliveira; Martins, 2020). The discussion of the results is presented below.

3.5 Discussions

In addition to the broad search of the term PMO, further analyses were conducted to identify how this search has been associated with some more emerging topics in outcomes and efficiency research. For example, when the search was conducted among the sample papers for terms such as 'Project Management Office Efficiency', two papers were found (Ko; Kim, 2019; Ko; Park; Kim, 2015). Another exploratory search was done with terms related to 'Agile methods for PMO', 'PMO in large organizations, and 'PMO in scenario changes'. In this case, there were no returns in the searches. These results illustrate the lack of research on the term PMO associated with the most emerging and current topics in project management. Therefore, there is an opportune moment for researchers to expand their research to bring new opportunities for study and implementation in organizations, focusing mainly on efficiency.

The bibliometric analysis, directed in the network of co-citations and keywords, allows us to observe a transition of the Project Management theme, which as of 2016 has begun to expand and share its applications with an area focused on standardization and results: PMO. The first articles published focus on projects and their deliveries. Subsequently, stages of improvement occur but they are not always supported by hierarchical management. Organizational strategy permeates Project Management, and the PMO enters an important role in the management and measuring PMO results has been continuously neglected by the literature.

From the perspective of empirical studies, 2 out of 26 (8%) of the primary studies employed PMO efficiency concepts, presenting a possible model for measuring efficiency. The other 9 studies, as shown in Exhibit 8, used only "PMO efficiency" as a generic term to express a quantitative or qualitative measurement. Taking into consideration a rigorous conceptual approach, only the studies by Ko and Kim (2019) and Kim (2015) present a model that enables the measurement of PMO efficiency.

When analyzing the association rules, one issue noted from rules 4 and 5 was that, in 34.6% of the studies, $C13$ is 81.8% likely to exist when $C11$ is present. This rule consists of one of the most influential associations found here and indicates a consistent presence of PMO efficiency measured through project efficiency. These results are in line with previous indications of PMO efficiency results based on project efficiency results (Steyn, 2016).

From rules 15 and 16, the lift presents values close to one, which implies that there is no association between project efficiency classes and perceived efficiency and vice versa. The success criteria for measuring the efficiency of a project must be analyzed from a contingency perspective and is one of the most discussed topics in the area of project management, highlighting mainly the clear objective of the project to obtain an analysis of the final result of the project (Alves et al., 2013).

It is possible to identify that 69.2% of the studies are more susceptible when focused on the analysis of project efficiency alone. Likewise, the most relevant results identified in the study are still quite predictable. Project efficiency is the reference factor that represented the conclusions of the empirical studies on the results for organization efficiency as for PMO efficiency. Project efficiency turns out to be the main focus of analysis for definitions of efficiency in organizations and the PMO.

3.6 Conclusion

This paper sought to evaluate, through a systematic literature review, how PMO efficiency verification is performed, using the LGT (ERMEL et al., 2021) methodology. To this end, a corpus of analysis was defined consisting of both systematic reviews and empirical studies, based on rigorously designed research. Our results indicate a lack of conceptual rigor regarding the efficiency concepts employed in PMO evaluation. In this context, a significant portion of the empirical evaluation instruments found in the explored literature does not adequately address the concepts.

This study also contributes to reducing the gap in the literature on efficiency metrics related to the PMO topic. The first contribution identifies the strongest relationship of how the PMO is evaluated in organizations, where the project efficiency is identified as a reference for measuring the efficiency of the PMO. The second contribution is related to the cross-tabulation of the identified efficiencies (PMO efficiency, project efficiency, organization efficiency, portfolio efficiency, communication efficiency, Project Management efficiency, and perceived efficiency), looking for main correlations.

This research highlights a critical element of the PMO and proposes a conceptual basis for its evaluation. By synthesizing the literature on evaluation tools and defining the efficiency of a PMO, the authors aim to establish a common body of knowledge for future applications in the field of project management system evaluation. From a management perspective, this research expands the practical understanding of the inputs and mechanisms employed to achieve desired outcomes.

Expert authors are identified in this field, with important publications in this context, as well as the journals that have published the most on this subject. This shows that research on PMO still offers theoretical gaps and may generate opportunities for new studies, especially when it is directed to the efficiency of the PMO. Thus, when we refer to "most-cited authors," Monique Aubry and Brian Hobbs are the ones who appear as highlights with the highest citations, and these are highlighted in the references of "authors who have published the most."

By presenting correlation structures, the research demonstrated which combined items from the literature concerning PMO efficiency have been applied as efficiency metrics. With an emphasis on the relationship of the efficiency of projects, which pointed to greater relevance of the relationships of these variables to the efficiency of the PMO. One interpretation of the strength of this trend, besides proving the relative importance of having valid indicators to measure the efficiency of a project, is to attest that there is a difference between efficiency and effectiveness and this needs to be clear in companies that use the PMO as a project management tool. And there remains a question for future work on this topic: If a project is not efficient, is the PMO not efficient, respectively?

The state of the art could be classified into three stages that are built along with the analysis: an initial stage that presents articles that address conceptual and technical themes for PMO; an intermediate stage that allows deepening the knowledge of some studies related to specific methods and techniques; and a stage that can be called current in which it is possible to verify that the literature has emphasized, especially, the efficiency of projects as a result for the organization.

The research has contributed to the theory with a model of well-defined concepts from the review of existing literature on PMO. Through this study, it is possible to evaluate the relationships between efficiencies and identify how science and practice have been measuring and analyzing the efficiency of a PMO. On the other hand, it is noticeable that the study also contributed to the practice, because the study presents the ways that organizations measure their PMO and can be used as a support for decision making when considering the implementation and measurement of a PMO, according to the efficiencies that relate more strongly since the research identified and pointed out the degree to which the conceptual aspects of the literature influence the efficiency of the PMO in practice.

We suggest, for future research, PMO themes in complex organizations with rapidly changing scenarios and portfolios, a theme limited to the primary studies of this systematic review. In addition, an emerging theme for the application of the PMO is the measurement of its efficiency. Few studies report on measuring PMO efficiency in organizations.

3.6.1 Implications for Engineering Managers

The project management team is an area of engineering that is part of and complements industrial engineering, and the results presented in this study are relevant to engineering managers.

Organizations' managers should entrust their Project Management responsibilities to the PMO, including this body to project portfolios where standardization and prioritization of financial and time execution is required. The PMO has the ability to interact more easily with lessons learned and knowledge management within organizations. The efficiency of the PMO is related to a proactive leadership and culture that permeates all areas of the project in order to acquire knowledge and success in its execution, but giving autonomy in the progress and development of each project. The PMO must have the freedom to interact with all areas of the organization in order to achieve project success and, consequently, efficiency. This will allow the organization to evolve in the area of projects and, at the same time, manage a portfolio where new ventures are constantly being added. As the organization matures, the PMO is able to have more influence on the project portfolio and on realistic planning.

From this study, it can be seen that the PMO directly influences the results of the projects and the organization, and this has contributed to good engineering management. Furthermore, we can state that there is a field of study for this subject and that many companies can still apply and measure the efficiency of the PMO in their organization.

This study can support engineering managers in making decisions regarding the implementation of a PMO, its benefits, how much the efficiency of the PMO influences the organization's results, and to what extent the PMO can influence the organization's strategic results.

4 ARTICLE 2 – PROJECT MANAGEMENT EFFICIENCY MEASUREMENT WITH DATA ENVELOPMENT ANALYSIS: A CASE IN A PETROCHEMICAL COMPANY

Abstract: The research question this study poses is how to measure the efficiency of project management activities. The purpose of this article is to quantify the efficiency of the execution of a project portfolio managed by a project management office (PMO) structure. The research subject is a PMO operating within a petrochemical manufacturing company in southern Brazil. The research method is quantitative modeling. The study employed data envelopment analysis (DEA) to calculate the relative efficiencies of projects in three classes according to complexity over a period of four years. Each project is a decision-making unit (DMU), as required by the DEA procedure. One novelty is the calculation of cost- and time-weighted efficiency values, which slightly differ from the average. The main results indicate that the average efficiency for classes of projects roughly stands between 40 and 80%. The results also indicate a learning process guided by the PMO, as the average efficiency increased over three years in two classes of projects, according to the prioritization imposed by the office. The study also pointed out that the most influential variables in determining project efficiency are accuracy in meeting deadlines and the time planned for completion. The most important implication is that, from now on, the company has a theoretical foundation to justify focusing further efforts on reducing and controlling time to completion, not only cost and scope conformity, to increase overall project efficiency. Future research should prioritize investigating management techniques that increase the likelihood of completing projects within their deadlines.

Keywords: project management; project management office (PMO); efficiency; data envelopment analysis (DEA); petrochemical industry

4.1 Introduction

One crucial facet of effective project management involves quantifying efficiency in attaining goals (Taher et al., 2021). Achieving this objective often demands adept management of intermediate project stages and milestones, encompassing inter-team communication, task scheduling, resource utilization efficiency, compliance, and the conformity of results (Sun et al., 2020).

Project management (PM) activities aim to minimize unexpected impacts associated with typical management uncertainties, exploit opportunities for lower costs, expedite critical tasks, and ensure adherence to deadlines and scope, all while staying within the established budget (Yeganeh; Zegordi, 2020). Handling multiple factors is a multifaceted and intricate undertaking, given the inherent uncertainty, the array of adverse factors that can impede task progress, and, especially in the context of advanced manufacturing systems, the rapid technological changes that can influence pivotal decisions, making it challenging to establish a repository of historical data (Hansen et al., 2021). One of PM's core objectives is to effectively steer projects while aligning them with the company's operational strategy (Viglioni; Cunha; Moura, 2016).

Manufacturing companies engaged in complex projects often establish a dedicated organizational unit solely focused on project management, known as the Project Management Office (PMO). The PMO's primary role encompasses critical project functions, including defining governance protocols, resource allocation planning, and assessing interim and overall outcomes (Le; Van; Nomo, 2015). Additionally, the PMO is responsible for adhering to business constraints (Oliveira; Martins, 2018) and ensuring alignment with the operational strategy (Philbin; Kaur, 2020). Companies that adopt a PMO-type structure tend to achieve heightened efficiency in project execution (Khoori et al., 2022).

Authors like (Oliveira; Martins, 2018, 2020; Linde; Steyn, 2016; Favoretto; Carvalho, 2021) delve into aspects related to project efficiency. Assessing a project's efficiency involves considering the resources employed during execution and the outcomes achieved upon completion compared to the optimal utilization of resources and the maximal output generation benchmark. However, such comparative assessments encounter limitations because benchmarking analyses are typically external, involving comparisons with similar projects carried out by competitors (Piran et al., 2023). An appealing alternative is internal benchmarking, where projects executed by the same organization are compared (Carpinetti; Melo, 2002). In internal benchmarking, each project led by the Project Management Office (PMO) is a decision-making unit (DMU) for comparisons with other projects sharing similar attributes, either over time or longitudinally. Data Envelopment Analysis (DEA) evaluates a DMU, such as companies or projects, by employing multiple inputs and outputs, which facilitates the identification of best practices and promotes organizational learning (Desouza; Evaristo, 2006).

A Scopus database search in October 2023 yielded 5935 articles, published between 2017 and 2023, containing the phrase “project management efficiency” in both the title and as a keyword. Subsequently, a second search identified only three articles during the same period in the same database, featuring “project management efficiency” in the title and the keyword “efficiency.” These findings suggest that examining efficiency in project execution within the domain of PM still needs to be explored in existing research. This is the research gap the study aims to bridge. The research question posed is how to measure the efficiency of PM activities. The purpose of this article is to quantify the efficiency of the execution of a project portfolio managed by a project management office (PMO) structure. The research subject is a PMO operating within a petrochemical manufacturing company in southern Brazil. The research method is quantitative modeling.

The remainder of this article is structured as follows: it begins with a comprehensive review of theoretical perspectives on efficiency assessments, followed by an explanation of the methodological procedures employed. Subsequently, the article presents the results, discusses the findings, and concludes with final remarks.

4.2 Efficiency in PM: The PMO

The PMO is an organizational unit responsible for centralized and coordinated project management that carries out distinct functions and performs specific roles in PM (Wood; Rodgers; Hai, 2022), adapting its structure to the overall organizational framework (Bredillet; Tywoniak; Tootoonchy, 2018). Refs (Braun, 2018; Patanakul, 2022) shed light on the evolving roles and changing responsibilities of PMOs over time. Additionally, (Tshuma; Steyn; Van Waveren, 2022) emphasizes the PMO's crucial role in facilitating knowledge transfer among similar projects. By operating centrally, the PMO plays a pivotal role in fostering the exchange of insights among stakeholders. According to (Müller et al., 2013) a PMO model can take on different forms, serving as a service provider, a control center, or a management partner. In summary, the PMO can be categorized as an entity that offers various services, ranging from maintaining standardization systems to resource management, all with the overarching objective of supporting executive management and bolstering the project portfolio (Kutsch et al., 2015).

According to (Dai; Wells, 2004), the earliest implementations of PMO in companies date back to the early 1990s. Kutsch et al. (2015) point out that the majority, approximately 65%, of the implementations encountered during the study occurred after the 2000s. Consequently, uncertainties persist regarding the methods and techniques available for centralizing PM activities (Yesica et al., 2023). Centralized PM activities in PMO-type entities can be a critical success factor in projects, given their ability to standardize procedures and focus on objectives linked to deadlines, costs, and scope compliance. Another critical success factor in PM is the PMO's position in the organizational structure, which must be autonomous and cross-functional to be effective (Khoori; Hamid, 2022).

Assessing and managing the efficiency of PMOs can play a pivotal role in enhancing project outcomes. PMOs with a higher efficiency index yield improved compliance with deadlines, costs, and scope, enhancing overall project effectiveness (Ko; Park; Kim, 2015). When strategically positioned, the PMO enhances results (Aubry; Hobbs; Thuillier, 2007) and fosters organizational learning (Wiewiora; Chang; Smidt, 2020). This improvement results from acquiring superior knowledge, implementing standardized processes, and enhancing training. As Tsaturyan and Müller (2015) emphasized, there should be seamless integration between success factors and governance. Despite the acknowledged necessity of efficiency control, the existing literature, according to Paton and Andrew (2019), has predominantly focused on PMO functionalities rather than tangible outcomes. Another gap in the literature pertains to uncertainties surrounding the significance of

PMOs (Hobbs; Aubry; Thuillier, 2008) and the integration of multiple roles (Aubry; Müller; Glückler, 2011). A recent gap relates to the ambiguity surrounding the decision-making processes within PMOs (Wood; Rodgers; Hai, 2022).

To characterize the evaluation variables of a PMO, one must first discern how the PMO operates within each organization (Oliveira; Martins, 2018). By establishing measurable parameters and metrics, the PMO can showcase its efficiency (Spalek, 2013), overseeing performance in every activity and project phase. With a comprehensive view of project management, the PMO can pinpoint efficiencies at various process stages. Practical and significant results, considering both internal and external environmental variables, can contribute to managing the PMO's efficiency. Internal variables can be managed within the system's control, while external variables, often referred to as natural states, remain beyond management's influence and are contingent upon external forces, such as market dynamics and economic growth (Ko; Kim, 2019). Typically, a PMO succeeds in reducing project duration and costs while simultaneously maintaining scope and expected quality (Grandage, 2021). It also advances project management maturity within organizations (Anantatmula; Rad, 2018). Assessing a PMO's impact on project efficiency can deliver quantitative and qualitative benefits, which requires comprehension of the context in which the PMO operates and its evolving maturity level. This understanding helps define how a PMO engages in projects, consequently affecting its efficiency and, by extension, the project's efficiency (Aubry; Richer; Lavoie-Tremblay, 2014).

In the context of PM, the literature highlights efficiency in several areas, such as execution, organization, PMO functions, portfolio, and communication efficiency. In particular, it is feasible to identify a correlation between the PMO and the efficiency of the project portfolio. As a company's portfolio expands, its management extends its involvement in projects, and the PMO can offer support in defining objectives and delivering results about efficiency (Ko; Kim, 2019). For example, Oliveira and Martins (2020), Ko and Kim (2019), and Unger, Gemünden and Aubry (2012) evaluate project efficiency and show benefits such as return on investment, cost reduction, and increased accuracy.

There are various PMO typologies and functionalities, encompassing practical and theoretical approaches that involve implementing project management procedures and standards for practices and documents (Aubry; Müller; Glückler, 2011). Adhering to such standards contributes significantly to project success (Yessica et al., 2023). Table 24 outlines and synthesizes the PMO's multiple expected roles and functionalities retrieved from the literature reviewed.

Table 24 - Expected roles and functionalities of a PMO.

Functionalities of A PMO	**References**
Administrative support, information and knowledge management, and training.	Desouza and Evaristo (2006) and Pemsel and Wiewiora (2013)
Monitoring and controlling project efficiency, developing skills and methodologies, managing multiple projects, strategic management, and organizational learning.	Hobbs and Aubry (2007)
Service, control, and partnership management.	Müller et al. (2013) and Anantatmula and Rad (2018)
Development of project management methodologies, tools, software, knowledge, and lessons learned; training and development of PM skills; mentoring and coaching in PM; human resources governance and development; project monitoring and control; portfolio management, information regarding strategic planning; customers, suppliers, and contract management interfaces.	Jalal and Koosha (2015)
Provide functions and services, maintenance of the standardization system, resource use management, support for execution, and project portfolio management.	Kutsch et al. (2015)
Be a center of excellence in PM and implement practices, methodologies, and strategic choices.	Tywoniak, Tootoonchy and Bredillet (2015)
Support and control of project execution	Grandage (2021)
Develop and implement global PM methodologies, policies, standards, and reports for the company.	Müller, Drouin and Sankaran (2019)
PMOs enhance the achievement of strategic plans.	Sandhu, Ameri and Wikström (2019)
Organizational structure to support PM, establish standardization, and manage efficiency in PM, delivering value and quality and meeting customer expectations.	Oliveira e Martins (2020)
Coordination and boosting innovation and change in PM, and identification of innovation opportunities for PM efficiency.	Sergeeva and Ali (2020)
Facilitator for generating and sharing learning in projects.	Wiewiora, Chang and Smidt (2020)

Functionalities of A PMO	References
Improve the knowledge management infrastructure with regard to practice management and technical support.	Arbabi, Salehi-Taleshi and Ghods (2020)
Define the direction and objective of the flow of knowledge and governance, and act within and among three hierarchical levels: operational, PMO, and management.	Hadi, Liu and Li (2022)
Classify the functions into three groups: benchmarking best practices, project management compliance, and project governance.	Ershadi et al. (2021)
Knowledge intermediary between and among projects.	Tshuma, Steyn and Van Waveren (2022)
Intermediary functions in knowledge transactions within and among different organizational levels.	Wood, Rodgers and Hai (2022)
Optimize activities, processes, procedures, and documentation; support the PM database; and manage projects, providing resources and experience.	Kustsch et al. (2015) and Khoori and Hamid (2022)
Identify 60 roles within the seven functions of the PMO: knowledge management, support, strategic, project performance, governance, innovation, and organization performance enabler.	Ichsan et al. (2023)

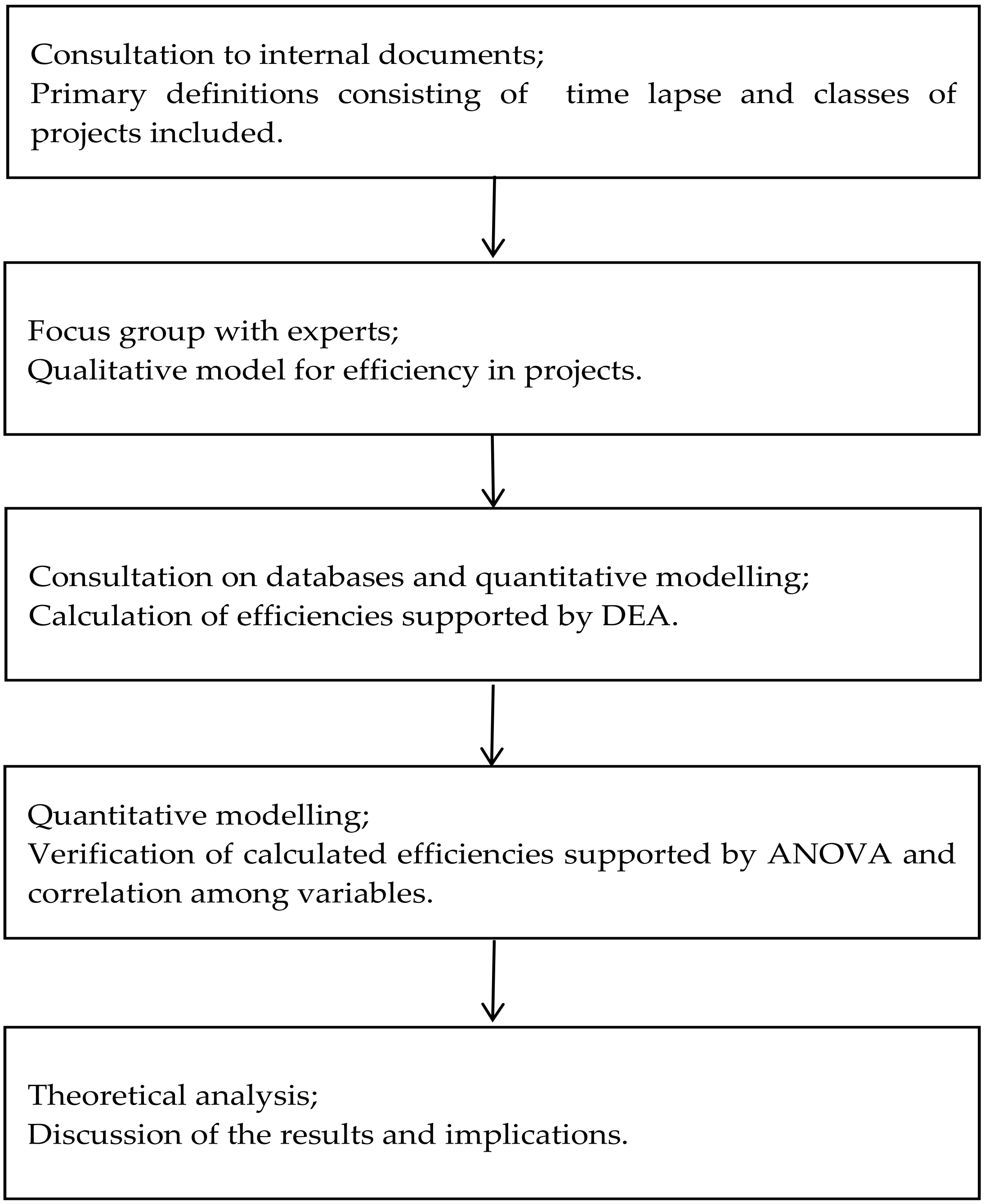
Source: Prepared by the author.

4.3 Methodology

The research method was quantitative modeling (Lacerda et al., 2013). The research object focused on the project portfolio of a petrochemical company located in southern Brazil over the past seven years. Longitudinal analyses are a necessary condition for the application of internal benchmarking (Bruwer et al., 2022). The company boasts more than 8000 employees, 36 industrial units (29 in Brazil, 5 in the United States, and two in Germany), and offices and commercial bases across the Americas, Europe, and Asia. The annual revenue is USD 5 billion (USD 1 = BR$ 4.89, the Brazilian currency, on 3 November 2023). On average, the company maintains a project portfolio of USD 105 million. Since 2018, a tactical and operational PMO for PM has been in place within the company. Tactical PMO refers to the processes and methods of implementation, while operational PMO pertains to project results (Müller; Drouin; Sankaran, 2019). Based on the level of PMO performance, measurable parameters and criteria in the form of metrics can be established to identify the influence of the PMO on project efficiency (Hadi; Liu; Li, 2022).

Figure 23 presents the methodology and the outcomes of each stage.

Figure 23 - Methodology



Source: Prepared by the author.

The projects range from class I to IV, depending on the complexity (class I embraces the less complex projects, according to the value and number of agents involved; the more agents, the greater the complexity). The research considered class II, III, and IV projects, as no class I or V projects were concluded during the period. The company also classifies the projects into SHE (safety, health, and environment), PI (profitability increase), and RM (reliability management). SHE projects focus mainly on managing safety issues on the shop floor (Nara et al., 2019), energy recovery and renewable energy sources, and the reuse and exchange of materials and energy among companies (Sellitto; Murakami, 2018). PI projects focus mainly on profitability increases through new sources of revenue and cost reductions in processes (Ichsan; Hamsal, 2019). RM projects focus mainly on retrofitting (Edwards; Holt, 2009) and overhauling critical equipment (Kosztyán; Pribojszki-Németh; Szalkai, 2019).

The intensity of involvement of the PMO depends on the project classification: the higher the class, the greater the number of deliverables. Each level of maturity requires specific documents and analyses according to their complexity, size, and characteristics. Deliverables are mandatory documents released by the PMO. In addition, the PMO is also responsible for communicating about investments, adjustments, and improvements to the investment management software, planning the project portfolio, and closing the qualitative and quantitative results of completed projects, among others. Table 25 displays the number of deliverables according to class and degree of project maturity.

Table 25 - Deliverables according to class and maturity.

		Maturity		
Class	**I**	**II**	**III**	**Total**
II		1		1
III		6		6
IV	1	6	1	8

Source: Prepared by the author.

4.3.1 The DEA Model

Each project is a DMU, which includes 49 class II, 54 class III, and 25 class IV projects, totaling 128 DMUs. Individual variable data per project for the DEA was retrieved from the project management system database between January 2015 and December 2021. The type of DEA was constant returns to scale (CRS) with output orientation. The efficiency levels were estimated assuming constant returns to scale (CRS), given the comparability of projects in terms of size. This is inherent in internal benchmarking. In an output-oriented approach, the emphasis is placed on optimizing output levels given a set of inputs. Consequently, this analysis provides insights into the extent to which the project management office (PMO) should have enhanced the performance of each project. Such an approach should produce internal benchmarks for any project. The specific project characteristics determine the extent to which inputs can be modified, which often leaves little room for input adjustments. Therefore, opting for Constant Returns to Scale (CRS) is the more effective strategy for improving performance by enhancing outcomes without compromising income. The model follows Equations (A)–(C) of Equation 3.

Equation 3 - CRS model equation

$$Min\ h_0 = \frac{\sum_{i=1}^{n} v_i\ x_{i0}}{\sum_{j=1}^{m} u_j\ y_{j0}} \qquad \text{(A)}$$

subject to:

$$\frac{\sum_{i=1}^{n} v_i\, x_{i\mathrm{k}}}{\sum_{j=1}^{m} u_j\, y_{j\mathrm{k}}} \geq 1, \forall k \qquad \text{(B)}$$

$$uj \geq 0, \forall j$$
$$vi \geq 0, \forall i$$

where:

$$h_0 = 1/eff0 \qquad \text{(C)}$$

v_i = weight calculated for the input *i*, *i* = 1, ... *n*.

u_j = weight calculated for the output *j*, *j* = 1, ... *m*.

x_{i0} = quantity of the input *i* for the DMU under analysis.

y_{j0} = quantity of the output *j* for the DMU under analysis.

x_{ik} = quantity of the input *i* for DMU *k*, *k* = 1, ... *N*.

y_{jk} = quantity of the output *j* for DMU *k*, *k* = 1, ... *N*.

N = number of DMUs under analysis.

n = number of inputs.

m = number of outputs.

The professionals listed in Table 26 supported the development of the DEA model.

Table 26 - Professionals' qualifications.

Function	**Years in the Company**	**Degree of Study**
Planning Analyst	15	Administration
Enterprise Engineer	4	Mechanical engineering
Enterprise Engineer	4	Mechanical engineering
Portfolio Engineer	12	Mechanical engineering
Venture Coordinator	22	Mechanical engineering
Portfolio and PMO Coordinator	16	Oil and gas engineering
Venture Manager	20	Electrical engineering

Source: Prepared by the author.

The model was developed through two focus group sessions conducted by one of the researchers at the company's headquarters. During the first session, the researcher gathered comments and feedback from the participants and then compiled the results. In the second session, the researcher presented the model to the participants, who accepted it and confirmed that there was enough data to proceed with the research. As inputs to the model, participants emphasized the importance of the cost and time expected to complete the project (input01 and input03) and the complexity indicated by the number of agents who must interact (input02 and input04). As outputs of the model, participants pointed out cost compliance (output01), the success rate in meeting deadlines (output02), and the absolute time until the end of projects (output03). Table 27 showcases the model.

Table 27 - The DEA model

Tag	Variable	Description	Unit	Reference
Input01	Project value	FID (Final Investment Decision) approval	USD	Oliveira and Martins (2020) and Barbalho, Toledo and Farias (2021)
Input02	Number of interfaces	Maintenance, Operation Automation, Logistics, Laboratory, Enterprise, SHE, Process	Number	Oliveira and Martins (2020), Dai and Wells (2004) and Aubry and Hobbs (2011)
Input03	Project time	Number of days from project opening to delivery to the area responsible	Mounts	Aubry and Hobbs (2011) and Barbalho et al. (2014)
Input04	Number of specialties	Electrical, Civil, Mechanical, Piping Instrumentation, Automation, Process	Number	Aubry, Richer and Lavoie-Tremblay (2014), Aubry and Hobbs (2011) and Otra-Aho et al. (2018)
Output01	Cost adherence	Difference from the planned FID	USD	Ko, Park and Kim (2015), Lacruz and Cunha (2018) and Beste and Klakegg (2022)
Output02	Projects on time	Difference between actual and planned completion	Days	Spalek (2013) and Duarte et al. (2019)
Output03	Time to completion	Number of days from start to completion	Days	Spalek (2013) and Duarte et al. (2019)

Source: Prepared by the author.

4.4 Results

Table 28 shows the efficiencies calculated by the free software SAGEPE for the entire set of projects (one project, one DMU). The analysis discarded projects finished before 2018, as the PMO was not fully activated, and many projects were conducted by a different method. Appendix A shows the gains for the variables of all the DMUs.

Table 28 - Relative efficiency of projects

	Class II			Class III			Class IV	
DMU	**Year**	**Efficiency**	**DMU #**	**Year**	**Efficiency**	**DMU #**	**Year**	**Efficiency**
1	2017	-	1	2015	-	1	2018	100%

	Class II			Class III			Class IV	
DMU	Year	Efficiency	DMU #	Year	Efficiency	DMU #	Year	Efficiency
2	2017	-	2	2017	-	2	2018	36%
3	2018	8%	3	2018	32%	3	2018	3%
4	2018	4%	4	2018	6%	4	2018	100%
5	2018	100%	5	2018	17%	5	2018	60%
6	2018	39%	6	2018	84%	6	2018	40%
7	2018	44%	7	2018	100%	7	2018	39%
8	2018	57%	8	2018	100%	8	2019	24%
9	2019	11%	9	2018	16%	9	2019	88%
10	2019	100%	10	2018	34%	10	2019	43%
11	2019	78%	11	2018	0%	11	2019	100%
12	2019	23%	12	2019	43%	12	2019	30%
13	2019	71%	13	2019	21%	13	2019	100%
14	2019	32%	14	2019	42%	14	2019	100%
15	2019	50%	15	2019	24%	15	2020	14%
16	2019	100%	16	2019	26%	16	2020	100%
17	2019	58%	17	2019	100%	17	2020	100%
18	2019	100%	18	2019	62%	18	2020	100%
19	2019	100%	19	2019	13%	19	2020	100%
20	2019	69%	20	2019	83%	20	2020	100%
21	2019	100%	21	2019	92%	21	2020	58%
22	2019	81%	22	2019	28%	22	2020	59%
23	2019	41%	23	2019	13%	23	2021	32%
24	2019	12%	24	2019	59%	24	2021	100%
25	2020	100%	25	2019	20%	25	2021	52%
26	2020	68%	26	2019	100%			
27	2020	68%	27	2019	51%			
28	2020	100%	28	2019	23%			
29	2020	46%	29	2019	27%			
30	2020	69%	30	2020	8%			
31	2020	46%	31	2020	33%			
32	2020	39%	32	2020	49%			
33	2020	100%	33	2020	100%			
34	2020	100%	34	2020	24%			
35	2021	18%	35	2020	34%			
36	2021	6%	36	2020	12%			
37	2021	13%	37	2020	39%			
38	2021	4%	38	2020	73%			
39	2021	100%	39	2020	100%			
40	2021	83%	40	2020	16%			
41	2021	67%	41	2020	38%			
42	2021	100%	42	2020	7%			
43	2021	57%	43	2021	31%			
44	2021	45%	44	2021	2%			
45	2021	87%	45	2021	6%			
46	2021	100%	46	2021	100%			

	Class II			Class III			Class IV	
DMU	**Year**	**Efficiency**	**DMU #**	**Year**	**Efficiency**	**DMU #**	**Year**	**Efficiency**
47	2021	100%	47	2021	4%			
48	2021	23%	48	2021	19%			
49	2021	31%	49	2021	100%			
			50	2021	22%			
			51	2021	100%			
			52	2021	61%			
			53	2021	100%			
			54	2021	55%			
Average		61%			45%			67%

Source: Prepared by the author.

An Analysis of Variance (ANOVA) test is useful to determine if there are significant differences in the average efficiencies, which can also be useful in project management (Lalic et al., 2022; Ibrahim; Hanna; Kievet, 2020; Sweis; Jaradat, 2020). This test involves multiple comparisons among treatment groups to ascertain whether the set of samples exhibits significant differences in means. Since Fcritical < Fscore and p-value < 0.05, there is at least one significant difference among the average efficiencies, which supports the statement that efficiency varies according to the service provided by the PMO. Table 29 shows the ANOVA test.

Table 29 - ANOVA test for average project efficiency.

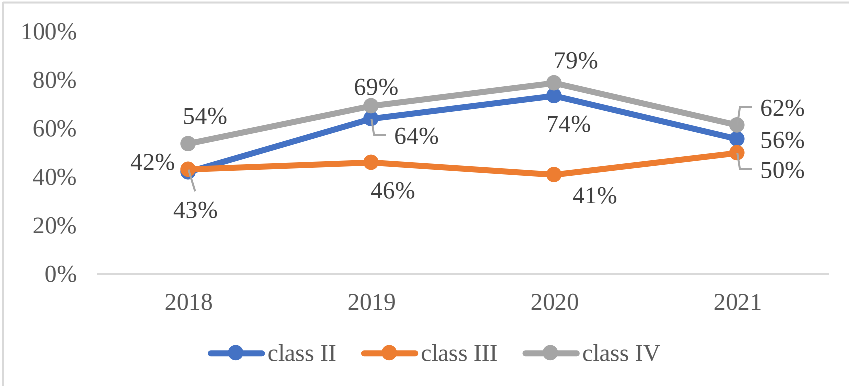
Source of Variation	**SS**	**df**	**MS**	**Fscore**	**P-Value**	**Fcritical**
Among groups	1.09	2	0.54	4.68	0.011	3.07
Within groups	14.6	125	0.12			
Total	15.7	127				

SS = sum of squares; *df* = degrees of freedom; *MS* = mean squared.

Source: Prepared by the author.

Figure 24 highlights average project efficiencies by year and by class.

Figure 24 - Average efficiencies by classes over the years.



Source: Prepared by the author.

The efficiency increased until 2020 for classes II and IV but not for class III, reflecting the strategic choices of the PMO. The class II projects are simple and require less managerial effort, while failure in the more challenging class IV projects could jeopardize future revenues. Therefore, the PMO focuses on expediting simple projects and does not take risks with expensive or revenue-focused projects. Given the wrong results in class III, by the end of 2020, the PMO management had decided to prioritize such a class, which was reflected in the 2021 results.

To assess the appropriateness of average efficiency in project control, this study also computed efficiencies weighted by cost and time. The rationale behind employing weighted indicators lies in the fact that maintaining cost efficiency, often associated with low-cost projects, holds less significance than achieving an intermediate efficiency level in high-cost projects. The same principle applies to project completion time. While a short, high-efficiency project can help mitigate resource idleness in critical areas, a large project with intermediate efficiency has the potential to reduce more idle hours. Hence, considering both cost and project completion time may be relevant in evaluating the implications of efficient management. Equations (4) and (5) below depict cost and time efficiency, respectively.

Equation 4 - Cost Efficiency

$$Eff_{cw} = \frac{\sum eff_i \, . \, C_i}{\sum C_i}$$

Equation 5 - Time Efficiency

$$Eff_{tw} = \frac{\sum eff_i . T_i}{\sum T_i}$$

where:

Eff_{cw} and $Efft_w$ = cost- and time-weighted efficiencies; C_i and T_i = cost and time to completion of the i_{th} project;

$\sum C_i$ and $\sum T_i$ = total cost and total time to completion of all the projects.

Table 30 presents the weighted and average efficiencies for the different classes.

Table 30 - Comparison among efficiencies -

Class	**Average Efficiency**	**Cost-Weighted Efficiency**	**Time-Weighted Efficiency**	**Differences (Percentage Points)**	
II	61%	55.8%	63.3%	4.8	−2.3
III	45%	43.6%	43.2%	1.5	2.0
IV	67%	76.5%	65.2%	−9.5	1.9

Source: Prepared by the author.

Notably, Class II and IV exhibited a major disparity between average and cost-weighted efficiency. In Class II, projects with higher costs received lower priority, leading to a 4.8 percentage point difference below the average. Conversely, in Class IV, the PMO prioritized projects with larger budgets, resulting in a positive difference of 9.5 percentage points, which was an outcome that made sense. Appendix B shows the entire calculation for weighted efficiencies.

Table 31 presents the partial success rate of projects by class, showing the absolute number and the percentage of projects that finished on time and at the expected cost.

Table 31 - Projects on time and at the expected cost

Class	Average Value (USD M)	Total	Projects On-Time		At Expected Cost	
II	1743	9	5	(51%)	34	(69%)
III	4598	4	6	(66%)	30	(55%)
IV	8121	5	7	(68%)	14	(56%)

Source: Prepared by the author.

It is interesting to note that the greater the class (and the value), the greater the percentage on time, which reflects the initial prioritization given by PMO to class IV projects. The low accuracy in cost in class IV projects highlights that on-time performance is achieved, jeopardizing cost. Regarding the cost, class II is significantly more accurate than the other classes due to such projects' low complexity and uncertainty.

Another issue is the relationship between the type and class of the project and its efficiency. Table 32 shows the characteristics of the class II projects located in the lower and upper quartiles (LQ and UQ) of efficiency (respectively under 25% and above 75% thresholds).

Table 32 - Number of projects in LQ and UQ of efficiency according to the type of project

Class	SHE Projects		PI Projects		RM Projects	
	LQ	UQ	LQ	UQ	LQ	UQ
I	3	4	0	4	4	9
II	4	2	3	7	6	4
II	4	5	5	1	2	5

Source: Prepared by the author.

Class II has no PI projects in the lower quartile, while nine of the twelve projects (75%) regard RM. This result may be associated with organizational strategy since projects to increase profitability require significant investments, usually more than USD 10 million. Such projects add financial resources, requiring detailed financial analysis and more rigorous monitoring, which implies more care from the PMO. Additionally, the PMO supports the publication of financial results, analyzes the results achieved throughout the project's life cycle, and calculates the financial performance, balancing benefits and investment. As the projects are more straightforward, the PMO succeeds in managing them. In the upper quartile, there are four RM projects, developed mainly to be implemented during the shutdown of the industrial plant for regular maintenance. As the fulfillment of the downtime is crucial for the plant's productivity, these projects resulted in high efficiency given the strict control exercised by the PMO. SHE projects a swing between the lower and upper quartiles. In class III, many PI projects (70%) lie in the upper quartile for the same reason: the need for stricter control by the PMO. As the complexity and the need for control increase, 30% of projects are less efficient. The four high-efficiency RM projects are also linked to plant shutdowns for maintenance, which forces more accurate time control. In class IV, SHE projects present a balance between high and low efficiency. PI projects are situated more in the low-efficiency quartile. The increasing complexity forces the PMO to make riskier decisions and deal with more uncertainty, reflecting lower efficiency. Finally, RM projects have higher than average efficiency in this class. The reason is that, in this range of high investment value, a large part of the projects is linked to purchasing new equipment, which requires more management efforts, as they can be reflected in the loss of new revenue opportunities.

Table 33 presents correlation analyses for each class of projects, which is a useful tool for performance evaluation (Barbalho et al., 2017). Bold highlights indicate moderate or strong correlations, while underlined highlights point to weak or very weak correlations with efficiency.

Table 33 - Correlation analysis

Class		**Efficiency**	**Input 01**	**Input 02**	**Input 03**	**Input 04**	**Output 01**	**Output 02**
II	Input01	<u>−0.174</u>						
	Input02	<u>−0.131</u>	−0.002					
	Input03	<u>0.117</u>	0.188	−0.083				
	Input04	<u>0.006</u>	0.021	0.54	0.005			
	Output01	0.295	0.017	−0.126	0.176	0.004		
	Output02	**0.394**	0.171	−0.183	0.302	0.135	−0.076	
	Output03	**0.346**	0.272	0.098	0.029	−0.044	0.116	−0.01
III	Input01	<u>−0.088</u>						
	Input02	<u>0.014</u>	−0.045					
	Input03	<u>−0.151</u>	0.105	−0.213				

Class		Efficiency	Input 01	Input 02	Input 03	Input 04	Output 01	Output 02
	Input04	−0.029	−0.111	0.736	−0.176			
	Output01	0.314	0.339	−0.053	0.26	−0.074		
	Output02	0.208	0.126	−0.221	0.078	−0.264	0.017	
	Output03	**0.620**	−0.075	0.236	−0.224	0.252	0.079	−0.397
IV	Input01	0.220						
	Input02	0.011	0.131					
	Input03	0.046	0.079	−0.072				
	Input04	−0.174	0.106	0.640	−0.191			
	Output01	0.280	0.319	0.007	0.406	−0.121		
	Output02	**0.492**	0.045	−0.125	0.199	−0.135	−0.069	
	Output03	**0.623**	0.263	0.204	−0.033	0.154	0.059	0.20

Source: Prepared by the author.

Correlation and benchmark analysis complement each other. The second one highlights the key variables that have the greatest impact on efficiency, while the first identifies the DMUs that should serve as a reference for guiding future initiatives. The two reference variables for the three classes are Output02 and Output03, respectively, the disparity between the project’s actual and initially planned completion date and the planned period required for the project. Synthesizing, the variables with the most significant positive influence on efficiency are Output2 and Output3. Hence, forthcoming initiatives should concurrently emphasize greater accuracy in meeting deadlines and reducing the estimated time to completion.

4.5 Conclusions

This research contributes to knowledge by examining PM efficiency. This discussion holds significance for project managers as it aids in the identification of variables that exhibit a stronger correlation with project efficiency. These identified variables can then be the focal point of future improvement initiatives in PM practices.

Within the academic domain, this research enhances our comprehension of project portfolio management processes. Unlike many existing studies that primarily concentrate on factors such as costs, time-to-completion, and adherence to project scope, this study delves into the intricacies of project complexity. Moreover, it is outstanding for investigating the interplay between project performance, PMO strategic decisions, project classifications, and complexity. To the best of our knowledge, based on a review of recent literature, no prior research has established a correlation between efficiency outcomes and the complexity of projects in conjunction with the PMO's activities.

Comparing the conclusions drawn in this study with findings from existing literature yields insights. Barbalho et al. (2017) examined the role of active PMOs in 35 companies, specifically in relation to project performance metrics encompassing time, cost, and scope. The study revealed that the attainment of targets in these dimensions (time, cost, and scope) was less dependent on the PMO's activities. Instead, the research suggested that PMOs wielded a more pronounced influence on project maturity, portfolio value, and the achievement of strategic objectives. Viglioni, Cunha and Moura (2016) introduced a model for assessing PMO efficiency within the software industry, employing a multicriteria approach. The study scrutinized project efficiency while interlinking it with PMO activities. It is worth noting that this study relied solely on practitioners' viewpoints, thus introducing a degree of uncertainty into the analysis.

From a theoretical perspective, this research offers a valuable contribution by presenting an evaluation model that encompasses novel variables, extending beyond the conventional aspects of scope, cost, and time. Notably, it factors in parameters such as the number of interfaces and specialties involved. The outcomes of this study pinpoint the most proficient DMUs, serving as internal benchmarks to guide the management of forthcoming projects and shape strategies for enhancement. It is worth highlighting that the analysis highlights 35 out of 124 benchmark projects, underscoring the company's substantial pool of high-performing projects that can provide valuable insights for strategic decision-making in future endeavors.

From a managerial perspective, this research supplies pertinent information concerning the efficiency outcomes of each project. This evaluation takes into account the PMO's performance in relation to the project's maturity level, class, and distinctive characteristics. Consequently, it facilitates the formulation of a strategy centered around benchmark projects and project efficiency. This, in turn, empowers the PMO to make informed decisions and take targeted actions in areas where further improvement is required, ultimately ensuring superior project outcomes.

The results confirm that Class IV projects, characterized by their extensive scope, increased deliverables, and heightened demand for PMO engagement, consistently yield superior efficiency averages throughout the entire study period. Notably, projects aimed at reducing equipment downtime and value-adding projects exhibit enhanced efficiency. This enhancement is attributed to the PMO's dual role as a standardizer and advisor, directly impacting deliverables across project classes. Enhanced efficiency is particularly pronounced when the PMO takes a more active role and collaborates closely with project teams, as observed in Class IV projects. In summary, the strategic decisions made by the PMO have a positive impact on project outcomes throughout their lifecycle, resulting in improved efficiency.

The primary limitations of this study include: (i) focusing only on a single industrial plant, which precluded replication of results across different international industrial facilities; and (ii) excluding routine maintenance projects and projects involving simple purchases (class I). Such an omission could potentially impact and skew the results of the DEA model. For further research, it would be beneficial to replicate the evaluation using the internal benchmarking method employed in this study. Additionally, external benchmarking could be conducted across various international industrial facilities within the company under examination. Such an approach could help in identifying best practices that would positively influence the PMO's effectiveness. Finally, future research should prioritize investigating management techniques that increase the likelihood of completing projects within their specified deadlines.

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Conflicts of Interest: The authors declare no conflicts of interest.

Appendices article 2

Appendix A

Table A1 - Gains for Class II projects

DMU	Input01	Input02	Input03	Input04	Output01	Output02	Output03
1	-	-	-	-	-	-	-
2	-	-	-	-	-	-	-
3	0	0	0	0	5.77	−49.46	−0.04
4	0	0	0	0	0	0	0
5	0	571.75	0	35.28	1246.99	−8415.89	216.19
6	0	0	0	0	0	0	0
7	1.50	38.63	0	68.85	501.26	−842.20	122.19
8	0	0	1.67	0	3699.62	−401.51	37.98
9	1.36	466.13	0	0	1034.80	−1501.66	300.78
10	0	0	0	0	0	0	0
11	1.00	0	0	172.15	1.625.46	−1945.41	96.49
12	2.36	0	0	0	1560.01	−1083.43	89.33
13	0.50	584.06	0	110.05	2150.24	−7184.99	212.97
14	0	0	0	0	1406.77	−17.63	0
15	0	0	0	0	2135.29	0	0
16	0	289.24	1.93	0	240.36	−17,328.95	0
17	0	0	0	32.37	2196.42	−1055.73	0.96
18	0	0	0.81	0	781.24	−6786.10	114.40
19	0	0	0	0	0	0	0
20	0	1380.59	0.15	0	4082.66	−2510.22	262.08
21	1.00	251.79	0	111.09	2214.93	−4365.94	142.80
22	0	0	0.52	0	2313.48	−464.06	170.21
23	0.27	0	0	0	3137.11	−4430.64	8.19
24	0	0	0	0	2062.92	−170.48	0
25	0	320.22	2.54	0	1548.27	−11,592.41	134.84
26	0	0	0	0	0	0	0
27	0	0	0	0	3682.39	−73.74	34.41
28	0	0	0	0	0	0	0
29	0	0	0	0	2145.66	0.55	44.77
30	0	0	0	0	1345.51	−67.30	19.44
31	0	0	0	0	1903.05	−1341.03	3.44
32	1.67	0	1.84	0	1200.07	−2548.64	78.71
33	0	0	0	0	0	0	0
34	0.70	194.10	0	1.62	810.07	−5905.01	90.35
35	0	0	0	0	0	0	0
36	0	0	0	0	0	0	0
37	0	111.86	0.27	0	1178.82	−319.25	91.74
38	0.31	136.74	1.34	0	128.41	−289.35	8.55
39	1.53	0	3.24	24.06	1026.76	−9039.35	71.75
40	0	0	0	19.74	2688.52	−1444.51	81.02
41	0	0	0	0	2129.94	−86.60	11.30
42	0	261.00	1.04	0	426.04	−5028.66	15.27
43	1.50	0	0	87.53	336.05	−987.47	38.37
44	0	0	0.65	0	2874.74	−561.43	196.39
45	0	422.79	1.55	0	1835.61	−2571.77	89.04

DMU	Input01	Input02	Input03	Input04	Output01	Output02	Output03
46	0	1056.74	0	16.35	0	−6297.24	1.09
47	0	0	0	0	0	0	0
48	0	0	0	0	2546.70	−2505.49	95.90
49	0	0	0	0	2419.11	−234.68	46.48

Source: Prepared by the author.

Table A2 **-** Gains for Class III projects

DMU	Input01	Input02	Input03	Input04	Output01	Output02	Output03
1	-	-	-	-	-	-	-
2	-	-	-	-	-	-	-
3	0	0.42	3018.99	0	−1153.23	−103.66	113.94
4	6835.88	0.46	0	1.25	−3985.28	−711.51	746.03
5	0	0	0	0	839.02	−2114.01	503.34
6	7682.83	4.91	0	3.83	−1401.25	−182.12	0
7	0	0	0	0	0	0	0
8	0	0	0	0	0	0	0
9	2749.39	0.98	0	0	−550.77	−313.23	302.11
10	0	1.72	888.29	0.53	−1226.74	−390.47	229.33
11	0	0	0	0	NA	NA	NA
12	0	3.26	39.97	0.50	−4190.59	−58.68	4.15
13	0	3.19	849.17	3.89	−839.32	−504.36	368.91
14	3048.72	2.35	0	0.04	−524.55	−488.89	300.92
15	0	2.93	739.97	2.64	−1359.73	−538.79	380.95
16	7537.61	3.14	0	2.59	−7834.91	−83.98	4.21
17	0	4.78	407.61	5.78	−3443.28	−170.23	0
18	0	2.03	283.74	0.83	−837.22	−349.30	35.61
19	286.12	1.85	0	1.65	−830.85	−375.95	345.43
20	0	3.19	461.99	3.94	0	−330.77	0
21	0	0	0	0	18.38	−25.78	41.47
22	2601.86	0.37	0	0.12	−952.90	−460.57	358.25
23	0	0	0	0	−4436.82	0	273.82
24	0	0	0	0	−320.82	0	137.58
25	0	2.97	332.71	0.90	−813.84	−171.02	123.29
26	5658.11	0.32	0	0	−4554.50	0	195.12
27	0	2.29	2583.57	1.20	−1776.73	−273.23	30.38
28	0	3.73	944.60	2.58	−180.68	−256.72	161.69
29	1560.17	0	579.89	0	−1470.07	−289.94	250.50
30	448.81	1.32	0	2.05	−2332.93	−614.48	612.90
31	0	1.52	705.96	1.66	−4684.83	−332.24	122.58
32	8547.82	1.25	0	0.09	−2224.91	−608.94	308.89
33	0	0	0	0	0	0	0
34	8973.58	2.88	0	1.93	−2422.78	−173.96	28.63
35	9925.02	1.40	0	0.10	−860.21	−423.79	349.88
36	1406.75	2.56	0	1.79	−4329.26	−96.41	92.98
37	0	0	0	0	−526.45	−27.71	247.72
38	0	1.31	129.04	0.17	−956.46	−286.47	16.35
39	0	0	0	0	−19,835.8	−48.40	246.69
40	3919.24	1.80	0	2.12	−3959.68	−209.44	3.50
41	0	2.10	270.75	1.06	−709.23	−315.71	0
42	0	4.99	692.97	2.96	−1237.72	−153.73	124.62
43	1528.40	1.35	0	2.99	−1435.26	−643.34	465.90

DMU	Input01	Input02	Input03	Input04	Output01	Output02	Output03
44	0	3.55	874.87	3.93	−5433.56	−54.29	96.29
45	0	0	0	0	−0.34	−191.41	427.00
46	0	0	0	0	0	0	0
47	0	1.91	279.38	0.65	−1645.34	−527.99	549.42
48	936.68	1.27	0	2.28	−2448.52	−237.73	178.59
49	0	0	0	0	148.50	−460.96	192.65
50	0	0	0	0	−1895.18	−56.15	404.31
51	0	0	0	0	−261.92	−1094.77	410.80
52	8760.07	1.60	0	0.36	−1497.24	−309.97	167.68
53	0	0	0	0	231.07	−1739.67	624.21
54	0	2.31	804.37	4.11	−208.77	−311.72	82.82

Source: Prepared by the author.

Table A3 - Gains for Class IV projects

DMU	Input01	Input02	Input03	Input04	Output01	Output02	Output03
1	0	0	0	0	0	0	0
2	0	0	0	0	−240.39	0	373.44
3	0	0	0	0	−4358.58	0	535.83
4	0	0	0	0	27.76	−28.64	43.00
5	0	0	0	0	40.51	0	246.86
6	0	0	0	0	0	0	274.54
7	0	0	0	0	0	0	196.61
8	0	0	0	0	−65.34	0	213.74
9	0	0	0	0	−13.79	0	35.87
10	0	0	0	0	−1842.23	0	244.98
11	0	0	0	0	0	0	0
12	0	0	0	0	0	0	598.75
13	0	0	0	0	0	0	0
14	0	0	0	0	0	0	0
15	0	0	1180.47	0	−0.01	−24.47	719.58
16	0	0	0	0	−59.84	−64.07	73.72
17	0	0	0	0	0	0	0
18	0	0	0	0	−2177.17	69.43	237.59
19	0	0	0	0	0	0	0
20	0	0	0	0	0	0	0
21	0	0	0	2.06	−146.62	−232.34	13.56
22	0	0	0	0	−428.24	0	246.19
23	0	0	0	0	−223.86	−166.01	288.18
24	0	0	0	0	−13035.16	0	319.57
25	9800.40	0	0	3.44	−591.99	−86.16	169.02

Source: Prepared by the author.

Appendix B

Table A4 - Average and weighted efficiencies for class II projects

DMU	Eff	Cost (USD M)	Eff.C_i	Time (Days)	Eff.T_i
1	-	-	-	-	-

DMU	**Eff**	**Cost (USD M)**	**Eff.C_i**	**Time (Days)**	**Eff.T_i**
2	-	-	-	-	-
3	7.6%	1870	142	264	0.46
4	4.4%	3163	140	820	0.22
5	100.0%	1583	1583	1525	4.00
6	39.4%	3174	1252	718	1.18
7	44.5%	1213	539	703	1.33
8	57.0%	471	269	685	2.28
9	11.5%	2690	309	1505	0.57
10	100.0%	1933	1933	898	4.00
11	77.6%	1429	1110	903	3.11
12	22.8%	1200	273	769	1.14
13	71.4%	1463	1045	1843	3.57
14	31.7%	1037	329	295	1.27
15	50.1%	3042	1523	734	3.00
16	100.0%	1693	1693	600	6.00
17	57.8%	3312	1915	963	2.89
18	100.0%	1065	1065	564	3.00
19	100.0%	2110	2110	292	5.00
20	69.1%	184	127	2892	2.76
21	100.0%	202	202	1095	4.00
22	81.3%	245	199	1.03	1.63
23	40.6%	1586	644	779	2.44
24	11.6%	1016	118	518	0.46
25	99.8%	1204	1202	1120	4.99
26	67.5%	3856	2604	594	2.03
27	68.4%	1498	1024	659	4.10
28	100.0%	1282	1282	490	2.00
29	45.8%	1198	549	463	1.83
30	69.3%	1799	1246	414	4.16
31	46.3%	1659	768	808	1.39
32	38.5%	198	76	485	1.54
33	100.0%	3783	3783	1499	3.00
34	100.0%	91	91	408	3.00
35	17.9%	3206	572	2466	0.36
36	6.0%	2932	176	456	0.18
37	12.9%	2105	272	1035	0.39
38	4.4%	2447	107	537	0.13
39	100.0%	232	232	261	5.00
40	83.3%	503	420	937	2.50
41	66.8%	1697	1134	663	2.00
42	100.0%	443	443	499	2.00
43	57.4%	1169	671	426	1.72
44	45.2%	1215	549	1594	1.81
45	86.8%	1577	1369	1987	4.34
46	100.0%	3302	3302	2288	4.00
47	100.0%	3060	3060	1637	2.00
48	23.3%	1461	340	775	1.16
49	31.4%	1997	627	939	1.26
Effic.	60.6%		55.8%		63.3%

Source: Prepared by the author.

Table A5 - Average and weighted efficiencies for class III projects

DMU	Eff	Cost (USD M)	Eff.C_i	Time (Days)	Eff.T_i
1	-	-	-	-	-
2	-	-	-	-	-
3	31.9%	1490	475	3572	1139
4	5.8%	12,1	699	1492	86
5	16.8%	1990	334	2519	423
6	83.6%	8711	7285	303	253
7	100.0%	4472	4472	471	471
8	100.0%	34	34	846	846
9	15.7%	3928	615	439	69
10	34.3%	1955	670	1478	507
11	0.0%	5273	0	3268	0
12	43.3%	3151	1364	799	346
13	21.3%	1942	414	1471	314
14	41.6%	4599	1912	523	217
15	24.3%	2361	573	1473	357
16	25.7%	14,0	3624	1597	411
17	100.0%	1878	1878	911	911
18	61.6%	1468	905	744	458
19	13.3%	1961	260	518	69
20	82.8%	619	512	736	609
21	92.1%	1524	1404	633	583
22	28.4%	4643	1318	632	179
23	13.1%	1582	207	1385	181
24	59.5%	6018	3579	470	279
25	19.9%	1014	202	629	125
26	100.0%	8716	8716	930	930
27	50.6%	1879	951	3119	1578
28	23.3%	707	165	1187	277
29	27.5%	4006	1101	1275	350
30	8.1%	3928	316	1025	83
31	33.3%	4962	1655	1987	663
32	48.7%	13,0	6343	1255	611
33	100.0%	801	801	875	875
34	23.7%	11,	2629	550	130
35	33.6%	11,	3872	534	179
36	11.9%	5429	643	1001	119
37	39.4%	12,1	4799	1319	519
38	72.9%	1488	1084	575	419
39	100.0%	12,7	12,7	3063	3063
40	16.3%	8400	1367	1089	177
41	38.3%	1045	400	565	217
42	6.7%	1252	83	1041	69
43	30.5%	4169	1272	834	254
44	1.6%	5331	84	2172	34
45	6.5%	6931	449	1452	94
46	100.0%	4827	4827	902	902
47	4.1%	2629	108	1074	44
48	19.2%	3646	700	724	139

DMU	Eff	Cost (USD M)	Eff.C_i	Time (Days)	Eff.T_i
49	100.0%	6246	6246	3864	3864
50	21.8%	1993	434	943	205
51	100.0%	1904	1904	1133	1133
51	61.3%	10,5	6471	562	344
53	100.0%	1665	1665	923	923
54	54.6%	1002	547	1141	623
Effic.	45.2%		43.6%		43.2%

Source: Prepared by the author.

Table A6 - Average and weighted efficiencies for class IV projects

DMU	Eff	Cost (USD M)	Eff.C_i	Time (Days)	Eff.T_i
1	100.0%	17,	17,3	1500	1500
2	35.5%	4596	1634	1000	355
3	2.6%	1833	47	1582	41
4	100.0%	15,7	15,7	1811	1811
5	59.8%	3876	2317	1305	780
6	40.1%	2910	1167	765	307
7	38.7%	1086	420	751	291
8	24.5%	1475	361	603	148
9	88.3%	1876	1656	519	458
10	43.3%	18,5	8047	1239	537
11	100.0%	11,8	11,8	858	858
12	29.7%	10,7	3189	630	187
13	100.0%	1939	1939	1633	1633
14	100.0%	13,3	13,3	706	706
15	14.1%	8583	1207	2307	324
16	100.0%	1428	1428	1125	1125
17	100.0%	1820	1820	842	842
18	100.0%	38,0	38,0	479	479
19	100.0%	753	753	678	678
20	100.0%	180	180	153	153
21	57.6%	5998	3458	849	489
22	59.1%	3793	2243	621	367
23	32.4%	1546	501	1271	412
24	100.0%	19,1	19,1	2272	2272
25	52.3%	14,6	7660	1014	530
Effic.	67.1%		76.5%		65.2%

Source: Prepared by the author.

5 ARTICLE 3 - LONGITUDINAL ANALYSIS OF THE EFFICIENCY OF A PROJECT MANAGEMENT OFFICE

Abstract: The Project Management Office (PMO) plays a crucial role in organizations, supporting project management and becoming a source of documentation, guidance, and metrics related to project management and execution. The PMO becomes a competitive differentiator, allowing companies to achieve ever higher levels of quality and added value to their processes by standardizing processes and selecting and prioritizing the simplest to the most complex projects. By implementing a PMO, organizations can enjoy better governance, standardization of project management processes, and easier sharing of resources, resulting in greater efficiency and cost savings. However, PMO efficiency is still a topic that has yet to be explored in the literature, and there is a need to develop models that allow for a more accurate assessment. This study aims to measure PMO efficiency based on the management of a project portfolio in a petrochemical company, seeking to identify the variables that have the most significant impact on the PMO's technical efficiency. Using Artificial Neural Networks, it was possible to identify the prevalent variables contributing to the increase in technical efficiency, finding that the cost of the PMO, the value of the portfolio, and the volume of projects managed impacted technical efficiency.

Keywords: Projet; Project Management Office (PMO); Efficiency; Data Envelopment Analysis (DEA); Benchmarking

5.1 Introduction

The Project Management Office (PMO) can influence project efficiency, business performance, and project management maturity, making it essential for organizations (Velásquez et al., 2022). Including the PMO in the organizational structure and its responsibilities are critical factors for project success (Khoori; Hamid, 2022). Therefore, they become a competitive differentiator, enabling companies to achieve increasing levels of quality and add value to their processes.

In addition, they provide value for projects and their assets and the delivery of the product or service by strengthening planning and control practices. By implementing the PMO, organizations can obtain benefits such as improvements in the governance process, standardization of project processes, and easier sharing of resources, which increases project efficiency and reduces costs (Kalman; Rathet, 2021).

The literature presents the PMO's characteristics, objectives, functions, and expected results and discusses factors that influence its efficiency. There are studies about the complex PMO for organizations (Bredillet et al., 2018) and adverse implementation factors such as culture and technological diversity (Hansen et al., 2021). Oliveira and Martins (2018) report that staff training improves PMO efficiency. The body of studies on PMO efficiency in organizations still shows a gap in understanding PMO efficiency. Ko, Park, and Kim (2015) present a specific model that uses DEA to measure PMO efficiency in large-scale information systems (IS) projects. The choice of variables is timely and contributes to advancing research into DEA in projects. However, the analyses are based only on qualitative perceptions, i.e., evaluation using people in managerial positions reporting their perceptions. Another critical issue that should have been chosen to evaluate efficiency is variables relating to project delivery, such as on-time, off-time, and cost.

Thus, efficiency analysis in companies is a critical factor in designing appropriate theories and policies (Piran et al., 2018). Coelho et al. (2023) analyze the influence of the PMO on project efficiency, but analyzing the efficiency of the PMO itself still needs to be addressed. Although published studies contribute to a better understanding of the effects of the PMO on a portfolio or organization, they are based on subjective metrics and the perceptions of the PMO team (KO; KIM, 2019).

In this context, this study aims to analyze a PMO's efficiency, considering the company's project portfolio in the petrochemical segment through the use of Data Envelopment Analysis (DEA), identifying the prevalent variables on PMO efficiency through artificial neural networks (ANN). The main contribution of this article is to measure the efficiency of the PMO in a project portfolio with classifications and values. Finally, the results observed in the company's project portfolio are discussed.

This article is organized as follows: Section two presents a theoretical overview of PMO efficiency evaluations and a review of efficiency studies applied to the PMO. Section three describes the methodological procedures for planning and carrying out this research. The results are presented in section four and discussed in section five. Finally, the conclusions, limitations, and suggestions for future research are described in section six.

5.2 Background

5.2.1 Project Management Offices (PMO)

Project offices, or PMOs (Project Management Offices), are organizational units responsible for planning, coordinating, and controlling organizational projects (PMI, 2023). They help standardize and improve project management practices, ensure the implementation of efficient processes, monitor project performance, and support project managers by adapting and implementing methodologies, tools, and techniques (PMBOK®, 2021).

Project management offices can play different roles, depending on the company's needs and organizational structure. Some PMOs act as centers of excellence in project management, providing guidance, best practices, and training for project managers (Dwianti et al., 2023). Others may be responsible for selecting and prioritizing projects, ensuring that resources are allocated efficiently to meet the organization's strategic objectives (Aubry; Hobbs, 2011).

Müller et al. (2013) defined a PMO model with three primary functions: service, control, and partnership. For Desouza and Evaristo (2006), there are four types of PMO: support, information management, knowledge management, and training. Hobbs and Aubry (2007) outlined five functions for the PMO: monitoring and controlling project efficiency, developing project management skills and methodologies, managing multiple projects, strategic management, and organizational learning. Thus, it is possible to classify PMOs as an organization that provides functions and services ranging from maintaining the standardization system to managing people and resources to support executive management and the project portfolio (Kutsch et al., 2015).

The five functions highlighted by Hobbs and Aubry (2007) that point to high-level PMO activities can be detailed as shown in Table 34.

Table 34 - High-level activities carried out by the PMO

	High-Level Activity	Activity breakdown
1	Monitoring and controlling project efficiency	• Reporting project status to senior management • Monitoring and controlling project efficiency • Implementing and operating a project information system • Developing and maintaining a project evaluation panel
2	Development of project management skills and methodologies	• Develop and implement a standardized methodology • Promote project management within the organization • Developing people skills, including training • Provide guidance for project managers • Provide a set of tools for standardization
3	Managing multiple projects	• Coordinating between projects • Identify, select, and prioritize new projects • Managing one or more portfolios • Managing one or more programs • Allocate resources between projects
4	Strategic management	• Providing advice to senior management • Participating in strategic management • Generate a network of support and benefits
5	Organizational learning	• Monitoring and controlling the efficiency of the PMO • Managing project documentation files • Conducting post-project reviews • Conduct project audits • Implement and manage a lessons-learned database • Implement and manage a risk database

Source: Hobbs and Aubry (2007) .

Philbin (2016) defined the Project Management Office (PMO) as an organizational unit that aims to standardize project management. Among the expected results, PMOs can be responsible for increasing the reduction of duration and budget while maintaining the established scope and quality. Thus, PMOs have been considered by organizations to be a competitive weapon insofar as they enable clients to achieve increasing levels of quality and add value to their interests, providing organizations with control over costs and changes and delivering the product or service within the agreed timeframe. However, for this to happen, it is necessary to understand the context in which this PMO is inserted and the evolution of this context within the organization (Aubry; Richer; Lavoie-Tremblay, 2014).

Recent studies in the United Arab Emirates have categorized the PMO into support, control, and management. The type of PMO has a direct impact on the functioning of the project cycle. The PMO performs several functions, including providing project support, training, maintaining lessons learned, supporting project management tools and software, controlling projects, communicating between projects, managing shared resources, and making decisions. A PMO plans for future resource needs, anticipates strategic planning, and assigns the right resources to suitable projects at the correct times (Khoori; Hamid, 2022).

5.2.2 Analysis of PMO effects

The main effects of the PMO on projects are related to the standardization of processes, improvement in the quality of projects, acting as an increment in reducing delivery times, reducing budgets and maintaining the scope and quality established, as well as increasing efficiency through the optimization of resources, greater visibility and control of the plan (Dwianti et al., 2023). Being responsible for managing the resources available for projects, such as people, materials, and tools, it is possible to monitor the use of these resources and allow for better allocation, ensuring that all projects are developed in a balanced way and that there are no conflicts due to a lack of resources (Liu; Yetton, 2007).

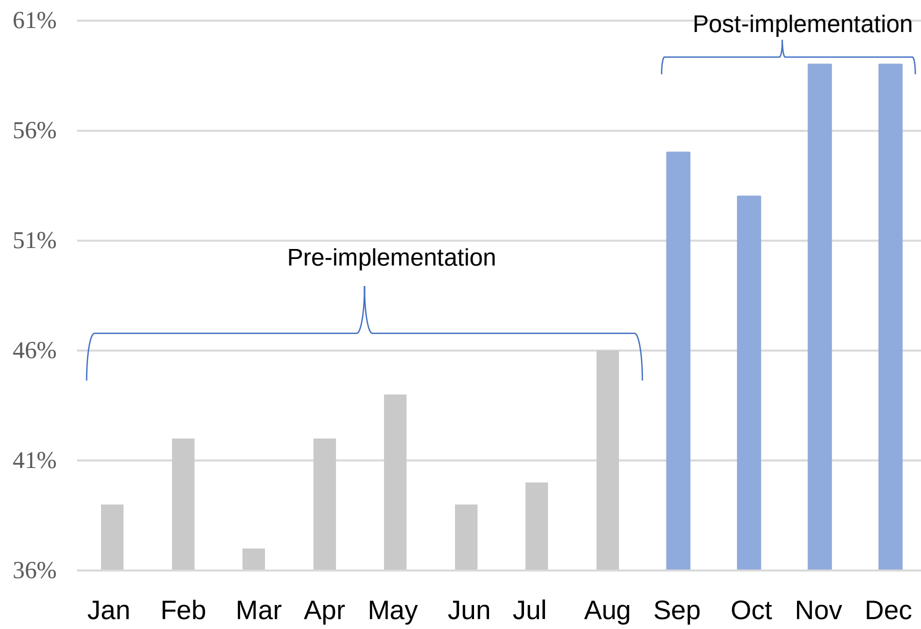
A project office can bring several benefits to an organization, such as greater consistency in project management, sharing resources and knowledge, improved communication, and alignment with strategic objectives (Philbin, 2016). However, it is essential to note that project offices must be tailored to the specific needs of each organization and can vary in terms of scope and complexity (Aubry et al., 2011), with a need to delve deeper into how they can work in organizations by providing integrated management of a project portfolio (Ershadi et al., 2023). According to Khoori and Hamid (2022), the PMO's position in the organizational structure and professional responsibilities are critical for project success.

The PMO allows for better control, problem identification, and more informed decision-making by managers, as it monitors all the organization's projects and provides a global view of ongoing initiatives (Philbin; Kaur, 2020). In addition, it can offer training related to project management, which contributes to developing team skills and improving practices adopted in projects, contributing to strategic alignment in the organization (Lavoie-Tremblay et al., 2017). This ensures that projects are developed according to the company's needs and priorities, generating more relevant and impactful results. A common characteristic of companies operating with a PMO is organizational leverage by increasing efficiency and delivering value and quality to clients (Oliveira; Martins, 2020).

In addition, the PMO seeks to identify ways of improving project efficiency, eliminating redundancies, and automating repetitive tasks (Kutsch et al., 2015). This allows teams to focus on the most critical activities and deliver projects on time and within budget (Hobbs; Aubry, 2010). Measuring the efficiency of PMOs can add even more to project results. PMOs with a higher efficiency index result in greater compliance with deadlines, cost compliance, and integration of resources, which results in increased project efficiency (Ko et al., 2015). Most scientific research has focused on revisions and applications of models aimed at PMO functions (Velásquez et al., 2022) and their responsibilities in organizations. However, the results of their operations are neglected (Paton; Andrew, 2019). A critical gap identified in the literature is the decision-making process of the PMO function in the organization. In order to achieve project success, it is necessary to identify the role of each team in the project management process (Hadi et al., 2022).

A study by Carmo and Albuquerque (2014) identified the increase in productivity, mapped over twelve months, with the automation of the PMO and can be seen in illustrative format in Figure 25.

Figure 25 - Productivity with PMO automation in a case study



Source: Carmo and Albuquerque (2014).

This study by Carmo and Albuquerque (2014)) represents an increase in productivity by analyzing it over a year and comparing project delivery times. The results show that after the implementation of the PMO, there was a higher rate of on-time project delivery, which was reflected in productivity for this organization. It is important to note that, in this study, the increase in productivity is directly reflected in the time efficiency of projects, i.e., it only evaluates projects on time without looking at relevant variables such as maturity and level of complexity (Crawford et al., 2012).

The study by Crawford et al. (2012) evaluates the maturity of the PMO versus the efficiency of projects in organizations. PMOs with high maturity are rare. The efficiency measure is evaluated using self-report within a qualitative investigation of an organization from 2007 to 2012. It shows that the increase in maturity of some processes is related to efficiency.

Oliveira and Martins (2018) evaluate PMO efficiency using constructs linked to PMO management: "implementation strategy," "staff training and capacity building," and "control of the project operations environment." This study reports that staff training contributes to the efficiency of PMOs. Although the research is significant for the academic and business areas, it must assess whether the PMO is efficient. However, it only highlights factors influencing the PMO's efficiency. From this perspective, this research develops a model that makes it possible to evaluate the efficiency of PMOs, considering variables related to cost, time, and quality used in project operations.

Barbalho and Toledo (2017) analyzed the role of PMOs in project performance indicators, time, cost, and scope in 35 companies that have an active PMO in their management. They also found that the success of time, cost, and scope results are separate from the activities carried out by the PMO. Barbalho and Toledo (2017) suggest evaluating the PMO's performance through management indicators, such as project management indicators, maturity, portfolio value, and strategic level. Corroborating this, this research involves management indicators in its analysis of PMO efficiency. Portfolio value and project value are part of the object of study.

Viglioni, Cunha, and Moura (2016) propose a PMO efficiency evaluation model for the software industry based on a multi-criteria approach. This makes a relevant contribution to the academic and operational areas. However, it uses the perception of managers, which can bring a risk to the results since the client is not in this analysis, compromising the analysis. In this context, this research analyzes the efficiency of the PMO from the perspective of statistical results and integrates the perspective of the client and the company.

Ko and Kim (2019) use DEA to measure the efficiency of PMOs but through a qualitative analysis of results on a Likert scale with an evaluation of management levels. Although the research makes significant contributions, concluding results based on perceptions can compromise the validity of the research results, especially when combined with the perceptions of leaders who, in some cases, are far removed from the project team. Evaluating efficiency only from the perspective of project or portfolio managers can create risks, as the service can be efficient for the manager and inefficient for the client. To overcome these shortcomings, this paper analyzes PMO efficiency from the perspective of statistical results and the perspective of the integrated client and company.

Ko, Park, and Kim (2015) evaluate the efficiency of PMOs in Information Systems projects using DEA for evaluation. This study uses five input variables: practice management, infrastructure management, resource integration, technical support, and business alignment. As outputs, four variables are mapped: project efficiency, meeting deadlines, meeting costs, and sufficiency of requirements. The choice of variables is an opportunity to contribute to advancing DEA research in projects. However, once again, the analyses are not based on observable data. Another critical issue is that variables relating to the quality of delivery should have been chosen to assess efficiency.

So, in order to consolidate the existing studies evaluating PMO efficiency, it is possible to identify in Appendix 1 the line of research of each study, the objective, the result achieved and reported in each study, as well as the variables and their respective metrics, the approach aligned with the DEA method and the nature of each study.

Thus, studies aimed at evaluating i) PMO efficiency and ii) variables that influence the increase in efficiency are considered relevant. The following section describes the context of this research, its main characteristics, the methodological procedures adopted, and the techniques applied.

5.3 Methodological procedures

This study was conducted using the following methods: (i) definition of the case study, (ii) two-stage DEA modeling, (iii) definition of the Neural Network (ANN) typology, and (iv) data analysis and statistics. Two-stage DEA analysis studies institutional, demographic, and management factors that can impact efficiency (Camanho, Silva, et al., 2023). Table 35 shows the detailed development of this work.

Table 35 - Study method

Activity	Detailed information
DEA modeling	• Determining the scenario and period of analysis • Survey of variables and data collected in the research through internal processes • Selection of the variables to be used in the conceptual model with the help of the experts • Drawing up the conceptual model based on the company's strategic and management scenario • Validation of the conceptual model with experts • Validation of the variables
Data analysis	• Quantitative testing of the model through statistical analysis • Selection of the statistical data analysis technique • Statistical analysis of the data (normality and non-parametric tests) • Data analysis
ANN	• Definition of the ANN model • Training the ANN
Data collecting	• Data collection • Data processing
Data analysis	• Quantitative model testing • Selection of the statistical data analysis technique • Data analysis
Prepare a report	• Discussion of results • Discussion of the contribution of the research • Analysis of the scope of the results • Analysis of the study's limitations • Suggestions for future research

Source: Prepared by the author.

5.3.1 Case study definition

The study was carried out at a Brazilian petrochemical company with more than 8,000 employees, 36 industrial units (29 in Brazil, 5 in the United States, and two in Germany), and offices and commercial bases in the Americas, Europe, and Asia, with an annual turnover of US$ 4 billion. The company has a project portfolio of up to US$ 100 million. The company has a tactical/operational PMO to support Project Management, operating in the project lifecycle since 2018. The PMO at the tactical level refers to the processes and methods of implementing projects, and the operational level refers to the results of projects (Müller et al., 2019). Based on the

PMO's level of operation, it is possible to establish measurable parameters and criteria in the form of metrics to identify the PMO's efficiency and its influence on project efficiency and thus identify the benefits for organizations (Hadi et al., 2021).

The company under study is a petrochemical industry with international operations. The company uses a tactical and operational PMO, i.e., that focuses on processes and methodology but monitors project results (Oliveira; Martins, 2018). The selection of the company is supported by the importance of measuring the efficiency of the PMO to make processes efficient and the benefits that efficiency can bring to these organizations (Ko; Kim, 2019). In addition, the company was chosen due to the possibility of access to information that allows knowledge and development of the analysis model, such as project life cycle data, in addition to providing access to practical information from the PMO and project management team, the way of working and interacting with the PMO active in the company, in addition to providing a precise analysis of the efficiency of the PMO in the company.

The data used for the analysis refers to four years (2018-2021). Using the data for 2022 and 2023 was not possible because there is still qualification for the projects after the annual closure. Therefore, the 2022 data ends selectivity at the end of 2023 and qualifies until June 2024. The model comprises the number of days above plan and the amount budgeted above plan. These variables would not yet be available for the analysis.

The company's projects are organized into classes I, II, III, IV and V. This definition is internal to the company in order to separate all projects according to size and complexity. The research considered class II, III, and IV projects in its analysis, as there was not enough data for the class I and V groups that closed during the analysis period. Class IV projects are more complex projects (in terms of value and specialties involved) and have greater PMO involvement in most processes and deliveries. According to its business strategy, the organization adopts a score from 1 to 6, depending on their importance to the company's results, with 1 being the least important score and six the most important. For the nature (X) of the projects, a score is established on a scale of 1 to 6. For the calculation item value (Y), the project is classified into five levels, with the highest score being for projects with the most significant value in US$, which the company classifies as special projects and has differentiated and more robust planning practices. As for the complexity (Z) of the project, six questions are given weights according to the degree of involvement of the team, the risks, the scope, the execution, and the complexity of the project itself. All the score values are inserted into Equation 6.

Equation 6 - Calculation of project classification

$$Class = x + \mathrm{y} + \frac{(\sum \mathrm{Z})\ \mathrm{X}\ 2}{6}$$

$$x = project\ nature$$
$$\mathrm{y} = value$$
$$\mathrm{Z} = complexity$$

The project manager (technical manager) is responsible for monitoring the project's life cycle and management using the company's project portfolio management software. Once the nature, value, and complexity have been answered, the projects are classified according to the result of Equation 6, as shown in Table 36.

Table 36 - Project classification values

Classe (#)	Range
I	# ≤5
II	>5 # <8,5
III	8,5 ≤ # ≤ 10
IV	# > 10

Source: Prepared by the author.

According to the classification of each project, there is a level of PMO involvement. The higher the class, the greater the project, the greater the deliverables and these deliverables require support, a degree of involvement or dedication from the PMO. The deliverables by class for the highest maturity phase (FEL3) can be found in the APPENDIX The PMO contributes to projects through deliverables by maturity phase (the company under study uses the FEL methodology for project evolution and maturity) and according to the project class. For each maturity phase there are specific documents and analyses according to its complexity, size and characteristics. The PMO contributes to projects through deliverables per maturity phase and according to the project class. Each maturity phase has specific documents and analyses according to its complexity, size, and characteristics. The PMO of the company analyzed acts in a tactical/operational capacity, which is directly related to the deliverables of each phase. Table 37 shows the number of deliverables in which the PMO is active in supporting and finalizing deliveries.

Table 37 - Quantity of PMO deliverables

	Maturity I	Maturity II	Maturity III	**Total**
Class II		1		**1**
Class III		6		**6**
Class IV	1	6	1	**8**

Source: Prepared by the author.

These deliverables are mandatory documents for projects to evolve in their maturity. In addition to these mandatory deliverables, the PMO is responsible for communicating investments externally and internally, adapting/improving the company's investment management software, planning the project portfolio, and closing the qualitative and quantitative results of closed projects, among other things.

5.3.2 DEA model design and definition

The DEA analysis model was developed with the support of a group of company experts. This model makes it possible to analyze a non-parametric method for comparatively measuring the efficiency of Decision Making Units (DMUs), based on best practices through the analysis of the data obtained. The set of DMUs must be homogeneous and share the same inputs and outputs.

To this end, unstructured conversations were held with the experts to carry out preliminary alignments related to the definition of the variables and the data collection and processing process. Table 38 shows each professional's role, participation in this study stage, the time they have worked at the company, and their academic background.

Table 38 - Professionals consulted

Role	Participation in this study	Time at the company	Formation
Planning analyst	Support in model definition, process data collection, and data interpretation	15 years	Administration
Venture engineer	Support in model definition and data interpretation	4 years	Mechanical Engineering
Venture engineer	Support in model definition and data interpretation	4 years	Mechanical Engineering
Portfolio Engineer	Support in model definition and data interpretation	12 years	Mechanical Engineering
Venture Coordinator	Support in model definition, model validation and data interpretation	22 years	Mechanical Engineering
Portfolio and PMO Coordinator	Support in model definition, model validation and data interpretation	16 years	Oil and Gas Engineering
Venture Manager	Model validation	20 years	Electric Engineering

Source: Prepared by the author.

Together with the experts, each project was defined as a DMU (R. Marques et al., 2022). The analyses included 48 DMUs. The selection of variables for this study is based on a literature review and internal analysis of the company's processes. The purpose of the literature review was to identify the inputs and outputs currently used in DEA research in the area of projects. The search for support in the literature to define the variables of the DEA model reinforces the rigor of the modeling carried out by the research (Piran, 2021). The research at the company aimed to provide practical variables to complement the model, taking into account the specificities of the case being assessed. Table 39 shows the list of variables and their references used in the DEA model, with their input definitions, which consider the total cost of the PMO for the organization, and the outputs, which are the volume of projects managed class II, Volume of projects managed class III, Volume of projects managed class IV, Value of projects managed class II, Value of projects managed class III, Value of projects managed class IV, Total days in arrears class II, Total days in arrears class III and Total days in arrears class IV.

Table 39 - DEA model variables

Input/Output	Variable	Description/Definition	Unit of measurement
Input01	Overall total cost	Total cost that the PMO uses to have its actions and services rendered in the company	US$
Output01	Volume of managed class II projects	Number of projects managed by the PMO in the month, class II	Unit
Output02	Volume of class III managed projects	Number of projects managed by the PMO in the month, class III	Unit
Output03	Volume of managed class IV projects	Number of projects managed by the PMO in the month, class IV	Unit
Output04	Value of class II managed projects	Total value of projects managed by the PMO in the month, class II	US$
Output05	Value of class III managed projects	Total value of projects managed by the PMO in the month, class III	US$
Output06	Value of class IV managed projects	Total value of projects managed by the PMO in the month, class IIV	US$
Output07	Total days in arrears class II	Total days the project was overdue in class II	Days
Output08	Total days in arrears class III	Total number of days the project was overdue in class III	Days
Output09	Total days in arrears class IV	Total days the project was overdue for class IV	Days
Output10	Value above budget class II	Amount over budget after closure of class II project	US$
Output11	Value above budget class III	Amount over budget after closure of class III project	US$
Output12	Value above budget class IV	Amount over budget after closure of class IV project	US$

Source: Prepared by the author.

A CRS model was defined because it is an internal benchmarking, i.e., an internal comparative analysis (Piran et al., 2021). Therefore, the scale of the variables chosen is similar between the DMUs, indicating the use of the CRS model. As for orientation, this study is output-oriented, seeking to maximize the PMO's results. The equations of the output-oriented CRS model are (A), (B) and (C) of Equation 7. It should be noted that the equations presented are fractional programming mathematical models. The efficiency of product-oriented models is calculated by the inverse of the objective function, i.e., efficiency (ho) = 1/E. This mathematical model defines the relationship between inputs and outputs.

Equation 7 - Output-oriented CRS model

$$Min\ h_0 = \frac{\sum_{i=1}^{n} v_i \ x_{i0}}{\sum_{j=1}^{m} u_j \ y_{j0}} \quad \text{(A)}$$

subject to:

$$\frac{\sum_{i=1}^{n} v_i \, x_{ik}}{\sum_{j=1}^{m} u_j \, y_{jk}} \leq 1, \forall k \quad \text{(B)}$$

$$uj \ \geq 0, \forall j$$

$$vi \geq 0, \forall i \quad \text{(C)}$$

where:

h_0 = 1/ $eff0$

v_i = weight calculated for the input i, i=1, ...n

u_j = weight calculated for the output j, j=1, ...n

x_{i0} = quantity of the input i for the DMU under analysis

y_{j0} = quantity of the output j for the DMU under analysis

x_{ik} = quantity of the input i for DMU k, k=1, ...n

y_{jk} = quantity of the output j for DMU k, k=1, ...n

k = number of DMUs under analysis

n = number of inputs

m = number of outputs

The data was collected directly from the project management system software (PPM) database used to monitor the portfolio and portfolio indicators. It refers to a total period of four consecutive years, from January 2018 to December 2021.

Data was collected directly from the company's planning database, which monitors portfolio indicators. An evaluation of the available data was carried out together with the company's managers and engineers. This assessment confirmed the quality of the data. Table 40 shows descriptive statistics by project class for all the variables. The values shown are annual averages, but the values obtained for each project class and variable were applied in the DEA analysis.

Table 40 - Statistical analysis of data collection

	Average			**Standard Deviation**		
Total PMO Value (US$mil)	117,53			30,14		
	Class II	Class III	Class IV	Class II	Class III	Class IV
Volume of Projects Managed	354,15	110,58	79,75	63,78	16,62	16,08
Total Value of Projects Managed	27.169,31	20.566,78	86.225,61	17.296,15	12.579,50	41.341,33
Days overdue	1.681,13	1.655,69	1.689,38	93,84	166,40	72,30
Value over budget (US$mil)	565,57	543,95	526,31	15,64	47,88	92,58

*** Dollar reference R$4,93**

Source: Prepared by the author.

For variable data equal to or less than zero, negative values or values equal to zero were adjusted to values smaller in magnitude than the positive values for the data analyzed (Bowlin, 1998). This step is necessary because there are positivity requirements for the basic DEA models, which work with data sets that preferably contain positive values. This technique allows DEA models to be applied to a broader set of data, making them more flexible and comprehensive (Sarkis, 2007).

In addition, the literature points to the possibility of incorporating an undesirable output IDD into the model using the additive inverse principle (-$y$undesirable). For example, in cost overrun evaluations, the higher the value, the lower the performance. To do this, the highest IDD value found in the data set was identified, and a value was added to create a sufficiently large number. This data treatment is used in the literature and provides results that allow for better interpretation (Camanho et al., 2023).

Therefore, this work aims to analyze the efficiency of the PMO by DMUs and, consequently, the impact of PMO efficiency during the analysis period for each class of project. Experts from the company were consulted to review and validate the use of the chosen model.

5.3.3 Data analysis and statistics

After collecting the data, the process of evaluating it began. The data obtained was organized into a calculation table to assess the efficiency of each DMU using the free software SAGEPE (Sistema de Análise e Gestão de Produtividade e Eficiência) available at <http://www.sagepe.com.br>. Initially, the technical efficiency is analyzed over the defined period, using the technical efficiency data to calculate the minimum, maximum, average, and standard deviation values. This analysis showed a variation in efficiency according to project class.

In addition, there are two tests for statistical analysis of data: parametric and non-parametric. Parametric tests are used when we assume that the data follows a specific distribution, usually the normal distribution (Hair et al., 2005). These tests are based on population parameters, such as the mean and standard deviation. Non-parametric tests are used when it is impossible to assume a specific distribution for the data or when it is measured on an ordinal scale. These tests are based on order or rank statistics.

In this study, to statistically identify the normality of the data, the efficiency scores were grouped by year (2018-2021). The Shapiro-Wilk test was applied using the Minitab software (Minitab, 2021) to assess the normality of the data, where it was found that the data did not constitute a normal distribution. A non-parametric Wilcoxon test was then used to compare the medians in a data group.

The Wilcoxon non-parametric test is used to compare two groups of data, comparing the difference between two independent samples (Hair et al., 2005). This test is used to test whether the difference between the medians of the two groups is significant (Piran et al., 2021). In this study, this test helps to test hypotheses by comparing the median for each year with the volume of projects and the value of the investment. Chapter four discusses the results obtained, highlighting this research's theoretical and practical contributions.

5.3.4 Artificial Neural Networks (ANNs)

The quantitative method used to identify the prevalent variables was the Artificial Neural Network (ANN), as it allows the variables to interact without having a relationship between them, has no assumptions about the distribution of the dependent and independent variables, and the sample size does not interfere with the result of the analysis (A. Marques et al., 2014). ANNs belong to the artificial intelligence (AI) layer to replicate the functional structure of human brain neurons to solve problems and establish relationships, with the capacity to organize and process agilely (Simon Haykin, 2001). Thus, ANNs identify the prevalent variables that have a preponderance on the efficiency of the PMO.

After analyzing efficiency using the DEA model, the prevalent variables on the effect of the PMO's efficiency were identified using ANN, which consists of a set of input variables classified according to their characteristics (Barbosa et al., 2017). IBM SPSS Statistics software was used for this analysis. The conceptual model of the ANNs was defined as follows: multilayer perceptron type and backpropagation training algorithm. This type of artificial neural network is the most widely used due to its ability to map input and output layers using historical data to capture data characteristics (A. Marques et al., 2014).

The ideal training rate is obtained heuristically and experimentally. Thus, there are varying training rates for artificial neural networks according to each test. In this analysis, the rate used was 75% of the data rate for training and 25% for testing, obtaining a relative error of 14.1%. The complete data used in the analysis and the detailed results of the artificial neural networks designed for this study are available in Appendix 2 and 3, respectively. The following section presents the analysis and discussion of the results.

5.4 Results

5.4.1 PMO efficiency by Project class

Table 41 shows technical efficiency using DEA. The DMUs are segregated into four groups, by year: referring to the periods from 2018 to 2021. The full results are available in Appendix 4.

Table 41 - PMO efficiency per year

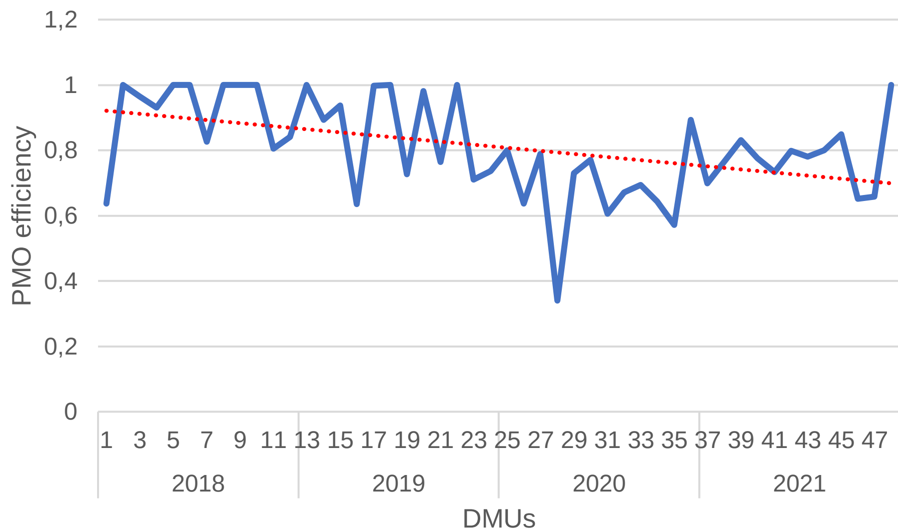
	2018	**2019**	**2020**	**2021**
Minimum	0,6377	0,6344	0,3399	0,6522
Maximum	1	1	0,8933	1
Median	0,9827	0,9151	0,6826	0,7780

Source: Prepared by the author.

Regarding the efficiency of the PMOs, the DMUs with the best performance in the series analyzed were the DMUs in 2018. In 2018, the period's most portfolios in value (US mil) were analyzed. DMU 28 shows the worst efficiency result in the entire time series. This DMU is part of the 2020 analysis group, which has the worst efficiency results compared to the other years and is one of the years with the most extensive portfolio in values (US$mil). In 2018, 75% of the DMUs were 100% efficient. In 2019, 25% of DMUs were 100% efficient. None of the DMUs in the 2020 group are 100% efficient. In 2021, one DMU was 100% efficient.

The results are presented in graph form in Figure 26 to make it easier to understand the longitudinal efficiency. This format makes it possible to visualize the trend in the PMO's efficiency over the time series.

Figure 26 - Efficiency over the time series

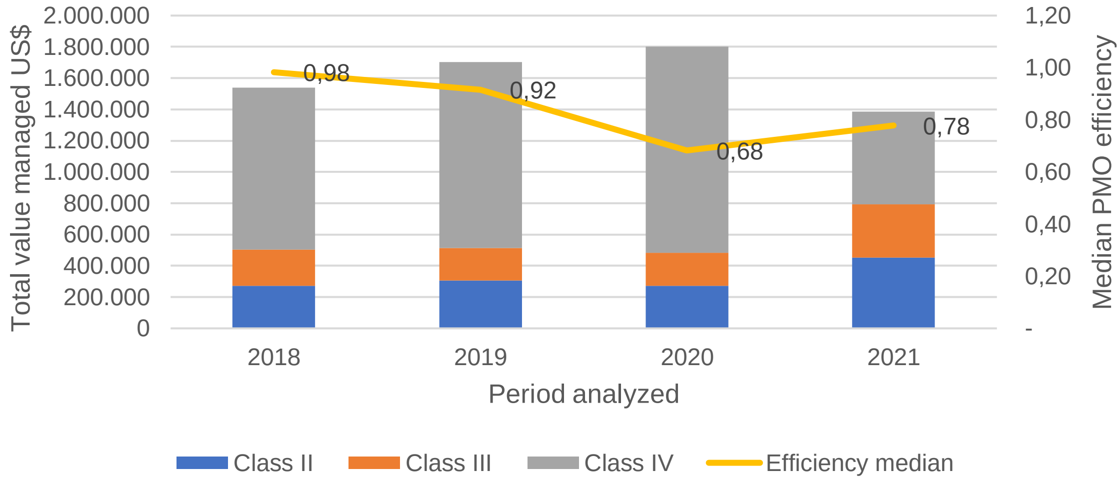


Source: Prepared by the author.

It can be seen that the trend over the period is declining throughout the series (red line), with a variation throughout the analysis. There are 10 100% efficient DMUs. The highest efficiency index is found in the 2018 group, with the lowest volume of projects managed and the lowest portfolio value over the period analyzed.

In order to understand the effects that led to these different results over the years, the engineers and coordinators of the area were involved in the evaluation. In addition, according to the organization's internal procedures and ways of working, class IV projects are more complex (in terms of value and specialties involved) and require greater PMO involvement for most processes and deliveries. Figure 27 shows how much project' value can influence the PMO's efficiency.

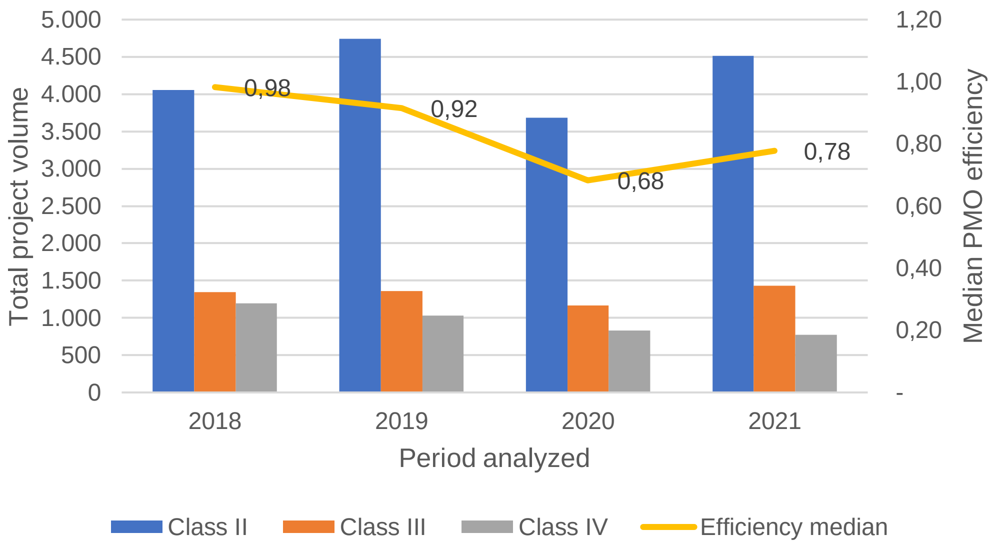
Figure 27 - Value of projects by class versus PMO efficiency



Source: Prepared by the author.

In this time analysis, the PMO maintained the number of people on the team. However, the higher the project value, the lower the efficiency (red line). 2020 saw the most significant investment portfolio and, consequently, the lowest efficiency of all the years analyzed. The year 2018, where there is 98% efficiency, was one of the years with the lowest investment value. Figure 28 also shows the volume of projects managed throughout the analysis. An additional factor that cannot be overlooked is the COVID-19 pandemic that directly affected the organization in 2020 and, to a lesser extent, 2021.

Figure 28 - Project volume by class versus PMO efficiency



Source: Prepared by the author.

In addition to the value of the projects, a comparative analysis can be made of the volume of projects managed per year. In 2018, regarding the overall volume of projects, it had the second-most-minor portfolio of the years analyzed and, consequently, the best PMO efficiency.

In order to identify and confirm the factors that most influence the PMO's efficiency, the analyses were carried out using ANNs. Table 42 shows the factors and their level of importance on efficiency.

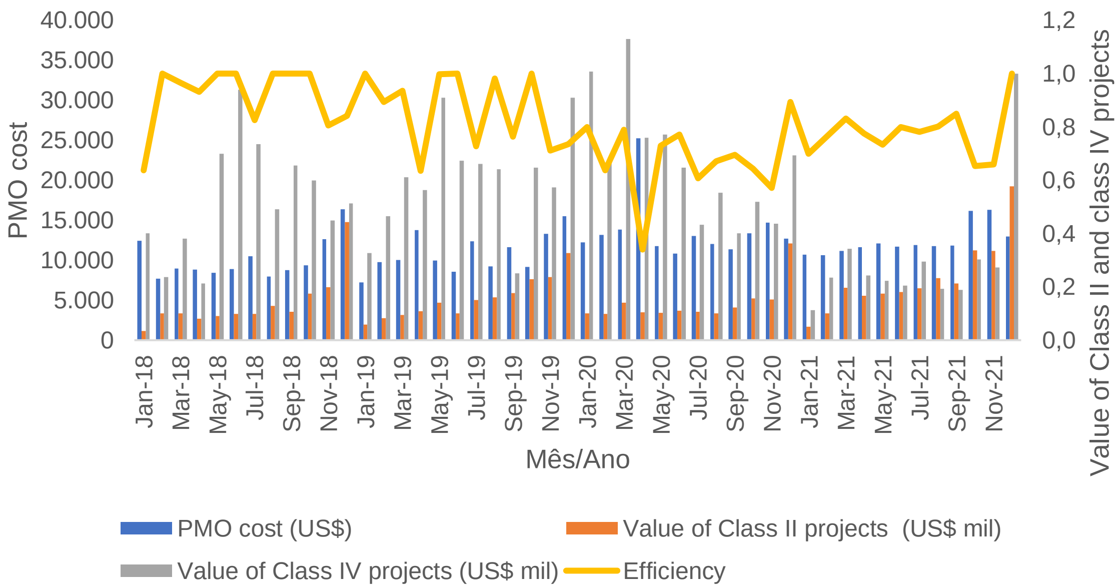
RNA Variable	Model variable	Model importance (%)	Relative error
VAR00001	**Total PMO cost**	**31,2**	**14,1%**
VAR00005	**Value of Class II projects (USD M)**	**13,4**	
VAR00007	**Value of Class IV projects (USD M)**	**10,4**	
VAR00003	**Volume of Class III projects**	**10,3**	
VAR00006	**Value of Class III projects (USD M)**	**7,4**	
VAR00004	**Volume of Class IV projects**	**5,6**	
VAR00009	**Delayed days Class III**	**5,3**	
VAR00002	**Volume of Class II projects**	**5,1**	
VAR00012	**Above budget Class III (USD M)**	**4,7**	
VAR00010	**Days behind schedule Class IV**	**4,1**	
VAR00008	**Days overdue Class II**	**1,7**	
VAR00011	**Above budget Class II (USD M)**	**0,9**	

Table 42 - Variáveis prevalentes sobre a eficiência do PMO

Source: Prepared by the author.

For the company under study, to determine the efficiency of the PMO, the total cost of the PMO is the variable that has the most significant impact on the efficiency of the PMO. Another representative variable in the ANN analysis is the value of class II and IV projects. These results are fundamental factors for process improvements to qualify and improve the efficiency of the PMO in the study organization. Figure 29 shows the analysis of the two variables prevalent in PMO efficiency to compare these variables with PMO efficiency.

Figure 29 - Prevailing variables on PMO efficiency



* For scaling purposes PMO cost divided by 10

Source: Prepared by the author.

In April 2020, there was a drop in efficiency (the lowest in the period analyzed), where the cost of the PMO was one of the highest among the years analyzed. Analyzing the statement of this PMO cost shows an increase in people-related amounts in this month. This increase is related to specific bonuses for this period, additional staff transfers, overtime, and the pandemic. This year saw one of the largest portfolios (in value) of all the years analyzed. This may justify the increase in the PMO's cost due to the team working overtime and investing in digital technologies for more efficient processes. In addition, this month refers to a month after the start of the pandemic (which began in March 2020). People had to adapt to the home office and new working methods during this period.

In 2018, when efficiency was high, the portfolio's value was lower than in the other years analyzed. In addition, it has one of the lowest volumes of projects managed over the years. In addition, drawing a trend line between PMO cost and PMO efficiency shows that while PMO cost increases, efficiency decreases. Thus, the prevalent variables of class II and IV projects can help improve and adjust the efficiency of the company's PMO, particularly. Adjusting the cost, volume of projects managed, and portfolio cost can significantly benefit the company and increase the PMO's efficiency.

5.5 Discussions

This research contributes to the advancement of knowledge about the role of the PMO and project portfolio, showing that having an active PMO in projects and organizations results in significant efficiency improvements and identifying factors that promote PMO efficiency in the study organization. Although several studies explore the relationship between efficiency and the PMO, presenting the results obtained in organizations or individual projects (Aubry, 2015; Coelho et al., 2023; Viglioni et al., 2016), few studies specifically analyze the efficiency of the PMO in a project portfolio.

The results obtained in this research provide empirical evidence of the benefits a PMO can bring to a project portfolio and the organization. These benefits can be seen as a boost to project management and, consequently, to PMO efficiency, and are in line with the findings of Ko and Kim (2019), who identified that PMO efficiency is influenced by the importance of the project to the organization, the strategic plans and the complexity of the projects.

The literature on PMOs suggests that companies should implement PMOs to optimize project management processes, improve organizational performance, and maintain competitiveness (Aubry; Hobbs, 2011). Therefore, the results of this research emphasize the importance of maintaining an active and competitive PMO in projects and highlighting the need for an efficient PMO that acts on key aspects to improve the life cycle of projects and the organization's performance. These identified benefits help to fill some of the gaps in the literature.

Barbalho et al. (2017) suggest evaluating the PMO's performance by analyzing management indicators, such as project management indicators, maturity, portfolio value, and strategic level. This research makes it possible to identify these factors by including project value, portfolio value, and project complexity in the analysis.

Analyzing the data and the results of the PMO's efficiency allows us to broaden our view of portfolio management and identify that the variation in efficiency is directly related to variables such as the volume of projects managed and the portfolio value by project class. In addition, the class of project influences efficiency since class IV projects, i.e., more complex projects, require more extraordinary dedication from the PMO team (Coelho et al., 2023).

In addition, this study can help identify the ideal productivity for a PMO to be 100% efficient and thus increase the efficiency of projects by identifying factors that prevail over the PMO's efficiency. The PMO's cost, the investment's value, and the volume of projects managed all impact the PMO's efficiency.

Analyzing a company over time, even by comparing it with itself, can gain valuable insights that reveal the potential for improvement and identify important variables for increasing PMO efficiency. These results prove that DEA (Data Envelopment Analysis) can be successfully applied to a single company, overcoming the limitation pointed out in the literature that its use requires a large sample of comparable companies and that the efficiency of the PMO is the efficiency of the projects. This approach, carried out in this study, allows for a more precise and efficient analysis, providing opportunities for improvement in the company.

From a business perspective, this study can be used as a driver to improve PMO and project portfolio efficiency strategies, especially by enabling the identification of possible optimal portfolio planning combinations that lead to better performance results. From a management point of view, analyzing efficiency levels over time, combined with using technology to quantify the impact of management interventions and external events, can bring significant benefits. The results suggested by this analysis were considered valuable for guiding future improvement actions. The ANNs improved the efficiency comparison of the company under study over time. In such cases, it is possible to understand why a specific year shows better results than another and how it would be possible to design a portfolio in which the PMO is more efficient.

5.6 Conclusion

This research aims to analyze the PMO's efficiency, considering a company's project portfolio in the petrochemical segment, through a longitudinal case study over four years (2018-2021) using Data Envelopment Analysis (DEA) in two stages. In addition, ANN analysis was used to identify the prevalent variables of the proposed model. The results show that the volume of projects managed and the value of the investment can impact PMO efficiency. The variation in project volume and portfolio value is generally recurrent over the years in the company studied. Therefore, a prior analysis before approving the portfolio is recommended in order to improve the efficiency of the PMO, in order to create opportunities for better efficiency or alternatives to maximize the efficiency of the PMO.

The data analyzed is from two atypical years, when the pandemic occurred. The drop in efficiency in these years can be attributed to the pandemic, as they were years in which it was necessary to work differently, in the face of an unknown scenario and atypical techniques for the company analyzed. The portfolio for these two years of the pandemic was high compared to the years before and after the pandemic. It is therefore possible that this pandemic situation had a direct impact on the results analyzed.

The main contribution of this article is to measure PMO efficiency. In addition, it may be one of the first studies to calculate PMO efficiency by analyzing improvement strategies using two-stage DEA. This may provide possibilities for expanding future studies on PMO efficiency in Project Management organizations.

The results show that the PMO is efficient according to its cost to the company, the volume of projects it manages and the total value of the investment portfolio.

The main limitations of this work were: by considering one industrial plant it was not possible to replicate the results for other international industrial facilities; and the class I group, i.e. simple purchases, and the special projects group were not considered in the data analysis. Class I projects and special projects could influence and distort the results of the DEA model. In addition to not analyzing the PMO team, which in this longitudinal scenario remained constant over the four years and would not have made any difference to the analysis.

As a suggestion for future studies, it would be important to carry out the same analysis carried out in this study, but considering the current years. This addition to the data could reaffirm whether or not the pandemic has had an impact on the company studied.

Appendices article 3

Appendix I

	Author	Title	Objective	Results	Variables	Metrics	Nature	*DEA*
1	Ko & Kim (2019)	The Effects of Maturity of Project Portfolio Management and Business Alignment on PMO Efficienc	To analyze the efficiency of project management offices (PMOs) using data envelopment analysis (DEA).	The efficiency of the PMO was positively influenced by the maturity of project portfolio management and the degree of strategic alignment with business objectives.	- Practice management - Infrastructure management - Resource integration - Technical support - Business alignment - PMO efficiency	Seven-point Likert scale	Basic	Yes
2	Oliveira and Martins, (2018)	Strategy, People and Operations as influencing agents of the Project Management Office performance: an analysis through Structural Equation Modeling	To evaluate the efficiency of the Project Management Office based on the constructs: "implementation strategies," "staff training and qualification," and "control of the project operations environment."	The results showed the degree of influence of the constructs on the performance of the Project Management Office, with people being the most significant predictor, followed by strategies and, finally, operations.	- Strategy - People - Operations - Efficiency	Non-comparative Likert scale on a balanced scale with a neutral point	Basic	No
3	Barbalho et al. (2017)	The impact analysis of functions of	Analyze the functions of the PMO through	The results suggest that PMOs should be more	- Perception of better programming - Cost	Score from 5 to 1, high effort to	Basic	No

	Author	Title	Objective	Results	Variables	Metrics	Nature	*DEA*
		Project Management Office on performance of triple constraint of new-product development projects	performance indicators related to the triple constraints of projects.	focused on activities that deliver project success in terms of time, cost, or scope.	- Scope - Support for higher levels - Support for Project Managers and their teams - Projects, Programs and Portfolio Management	very low effort, respectively		
4	Viglioni et al. (2016)	A Performance Evaluation Model for Project Management Office based on a Multicriteria Approach	It proposes an efficiency evaluation model for PMOs in the software industry based on a multi-criteria approach to involve all stakeholders in this process.	Development of a model using software applied to a business segment presents strengths and weaknesses in the efficiency of a PMO, as well as the priority for improvement according to a vision shared by all stakeholders.	- Value of human resources - Training and development - Moral about the personal project - Conflict resolution and the search for cohesion - Quality of output - Information and communication management - Stability in processes - Control - Profit - Productivity - Planning - Efficiency - Growth - Flexibility / adaptation / innovation in project management - Evaluation by external bodies - Links with the external environment - Responsiveness	Score from 4 to 1, 4 was considered good and 3 was considered neutral	Applied	No

	Author	Title	Objective	Results	Variables	Metrics	Nature	*DEA*
5	Aubry (2015)	Project Management Office Transformations: Direct and Moderating Effects That Enhance Performance and Maturity	It seeks to show that the organizational context, change management, and changes in coordination, control, or service orientation mechanisms drive the efficiency of a PMO.	Increasing the PMO's support role improves commercial performance and project management maturity. On the other hand, increasing the PMO's control role does not improve project performance.	- Project management performance - Business performance - Project management maturity	9-point Likert scale	Basic	No
6	Ko et al. (2015)	Efficiency Analysis of Project Management Offices for Large-scale Information System Projects: Insights for Construction Megaprojects	In this study, the efficiencies of PMOs in large-scale information systems projects are addressed using DEA analysis. In addition, the potential levels of improvement for each input and output factor of inefficient PMOs are examined. The effects of the performance levels of PMO functions on project outcomes and	The result shows that twenty-four PMOs are considered efficient out of forty-nine analyzed. As a result of the analysis of the impact of efficiency on project performance depending on the functional levels of the organizations, the groups with a high degree of efficiency show higher results compared to the groups with a low degree of efficiency.	- Practical management,- Infrastructure administration - Integration of resources, technical support - Commercial alignment - Meeting deadlines - Cost compliance - Sufficiency of requirements - Project performance	7-point Likert scale	Basic	Yes

	Author	Title	Objective	Results	Variables	Metrics	Nature	*DEA*
			efficiency levels are also analyzed.					
7	Kutsch et al. (2015)	The Contribution of the Project Management Office: A Balanced Scorecard Perspective	The article provides new insights into the success and failure of PMOs and provides the rationale and framework for a holistic approach to establishing and sustaining a PMO.	The results were structured using strategy maps. In general, strategy maps do not provide an overview of the	- What value do you expect to receive from the PMO? - What value do you expect to deliver? - How satisfied are you with the value you receive?	- Not currently provided and no plans - Need to develop smaller activities - Not satisfactory; needs improvement - Service is satisfactory - Planned for the future	Applied	No
8	Aubry et al. (2011)	Pluralism in PMO Performance: The Case of a PMO Dedicated to a Major Organizational Transformation	The focus of the study is the PMO's contribution to organizational performance. It explores the particular case of a PMO dedicated to a significant organizational transformation within a Canadian university hospital.	The perceptions of the two groups were analyzed within a framework of competing values, allowing for a combination of four different conceptions of performance. The results show certain similarities in the barriers to PMO performance but, more importantly, reveal that there is a paradox regarding what is valued in	- Human Relations - Internal Processes - Open System - Rational Objective - Role of the PMO - PMO Implementation - Impact on the PMO	Underlying axes: - Flexibility versus Control - Internal versus external focus	Applied	No

	Author	Title	Objective	Results	Variables	Metrics	Nature	*DEA*
				PMO performance between the two groups.				
9	Aubry and Hobbs (2011)	A Fresh Look at the Contribution of Project Management to Organizational Performance	The aim is to understand better the contribution of project management in general and of PMOs to organizational performance.	The empirical results contribute to a better understanding of the role of project management in general and of PMOs. They present this structure's usefulness for studying project management's contribution to organizational performance.	- Human Relations - Internal Processes - Open System - Rational Goal	5-point Likert scale, where 1 was not at all important and 5 was very important	Basic	No
10	Bettin et al. (2010)	A PMO Installation for TI Project Management in a R&D Institution	To observe, through a case study, whether there has been an increase in project management process compliance rates with the installation of the PMO.	The actions taken to structure the PMO were observed and documented, as was the correlation of process compliance data from two years of developed projects, proving the impact of PMO performance on project results.	- Number of projects - PMO implementation	- Compliance rate	Applied	No

Appendix II

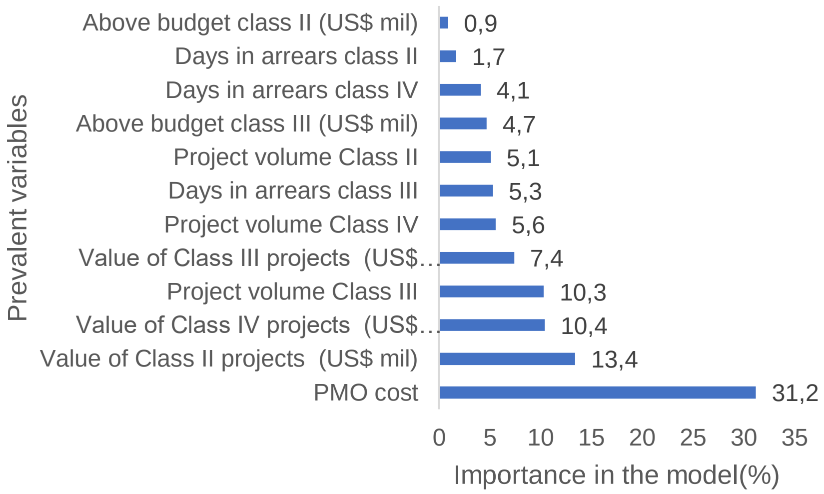
*** Reference dollar R$4.93**

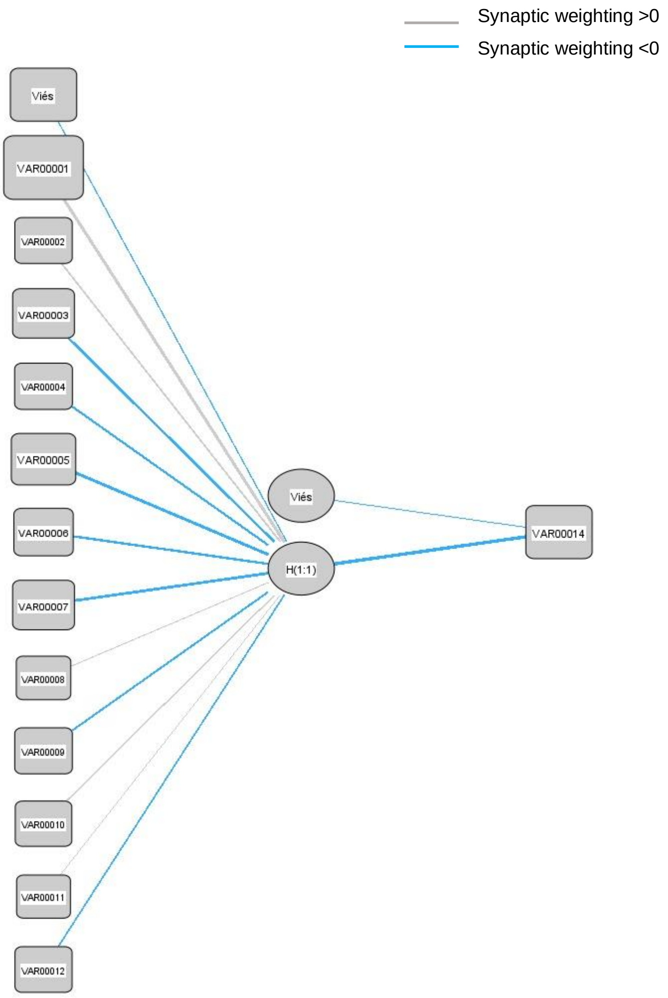
Variables	Independents													Dependent
ANN	**VAR00001**	**VAR00002**	**VAR00003**	**VAR00004**	**VAR00005**	**VAR00006**	**VAR00007**	**VAR00008**	**VAR00009**	**VAR00010**	**VAR00011**	**VAR00012**	**VAR00013**	**VAR00014**
Month	**PMO cost**	**Class II volume**	**Class III volume**	**Class IV volume**	**Value of Class II projects (US$ thousand)**	**Value of Class III projects (US$ thousand)**	**Value of Class IV projects (US$ thousand)**	**Days late Class II**	**Days late Class III**	**Days late Class IV**	**Above budget Class II (US$ thousand)**	**Above budget Class III (US$ thousand)**	**Above budget Class IV (US$ thousand)**	**Efficiency**
DMU1	123.987,50	254,00	81,00	100,00	1.121,40	1.751,74	13.354,37	1.712,00	1.712,00	1.712,00	572,89	572,89	572,89	0,79
DMU2	77.065,84	259,00	94,00	90,00	3.368,63	2.272,04	7.911,53	1.712,00	1.712,00	1.518,00	572,89	572,89	298,16	1,00
DMU3	89.707,33	274,00	94,00	92,00	3.336,06	4.164,79	12.696,75	1.712,00	1.712,00	1.712,00	572,89	572,89	572,89	1,00
DMU4	88.463,68	290,00	103,00	82,00	2.687,70	3.306,02	7.067,64	1.712,00	1.712,00	1.712,00	566,23	566,23	566,12	1,00
DMU5	84.563,91	277,00	101,00	87,00	2.997,96	3.304,57	23.324,26	1.712,00	1.000,00	1.712,00	560,76	501,49	412,27	1,00
DMU6	89.196,00	311,00	90,00	84,00	3.307,75	3.373,42	31.318,35	1.712,00	1.712,00	1.712,00	572,89	572,89	572,89	1,00
DMU7	105.247,26	327,00	106,00	95,00	3.258,07	2.934,87	24.519,83	1.712,00	1.712,00	1.712,00	572,89	566,35	566,35	0,86
DMU8	79.482,19	359,00	117,00	107,00	4.272,47	4.611,43	16.370,24	1.477,00	1.712,00	1.712,00	571,81	455,33	455,33	1,00
DMU9	87.279,99	354,00	118,00	108,00	3.559,24	4.692,98	21.855,65	1.712,00	1.712,00	1.712,00	558,70	558,70	558,70	1,00
DMU10	93.332,41	425,00	135,00	122,00	5.814,72	3.600,94	19.993,53	1.707,00	1.712,00	1.712,00	572,89	572,89	572,89	1,00
DMU11	126.543,31	415,00	146,00	104,00	6.627,97	4.489,57	14.972,98	1.712,00	1.712,00	1.712,00	572,89	572,89	572,89	0,85
DMU12	163.557,78	509,00	162,00	124,00	14.756,60	8.359,46	17.085,09	1.712,00	1.712,00	1.712,00	572,89	523,17	523,17	1,00
DMU13	72.327,58	305,00	102,00	89,00	1.927,41	672,81	10.914,62	1.712,00	1.712,00	1.712,00	572,47	572,47	572,47	1,00
DMU14	97.415,99	361,00	127,00	98,00	2.760,23	2.233,01	15.496,18	1.712,00	1.712,00	1.712,00	572,89	444,47	444,47	0,90
DMU15	99.987,78	432,00	121,00	89,00	3.126,43	1.695,87	20.377,76	1.712,00	1.712,00	1.712,00	572,89	562,67	562,67	0,93
DMU16	137.464,08	391,00	122,00	85,00	3.598,45	2.116,05	18.763,98	1.712,00	1.712,00	1.712,00	522,66	487,92	487,92	0,7
DMU17	99.363,01	395,00	110,00	79,00	4.658,86	2.846,65	30.341,94	1.712,00	1.712,00	1.712,00	572,89	572,89	572,89	1,00
DMU18	85.569,49	382,00	111,00	78,00	3.375,11	2.881,01	22.451,54	1.712,00	1.712,00	1.712,00	567,88	564,15	564,15	0,99
DMU19	123.786,46	396,00	116,00	87,00	5.038,53	3.258,79	22.025,56	1.712,00	1.712,00	1.712,00	572,89	569,64	569,64	0,79
DMU20	92.074,72	397,00	111,00	81,00	5.355,26	2.166,47	21.370,66	1.712,00	1.712,00	1.712,00	572,89	572,89	572,89	0,98

Variables	Independents													Dependent
ANN	**VAR00001**	**VAR00002**	**VAR00003**	**VAR00004**	**VAR00005**	**VAR00006**	**VAR00007**	**VAR00008**	**VAR00009**	**VAR00010**	**VAR00011**	**VAR00012**	**VAR00013**	**VAR00014**
Month	**PMO cost**	**Class II volume**	**Class III volume**	**Class IV volume**	**Value of Class II projects (US$ thousand)**	**Value of Class III projects (US$ thousand)**	**Value of Class IV projects (US$ thousand)**	**Days late Class II**	**Days late Class III**	**Days late Class IV**	**Above budget Class II (US$ thousand)**	**Above budget Class III (US$ thousand)**	**Above budget Class IV (US$ thousand)**	**Efficiency**
DMU21	116.578,33	407,00	102,00	83,00	5.866,96	3.594,18	8.362,23	1.712,00	1.681,00	1.413,00	568,29	568,29	568,29	0,83
DMU22	91.586,57	435,00	112,00	88,00	7.608,16	6.909,16	21.553,41	1.712,00	1.515,00	1.403,00	572,89	572,89	530,70	1,00
DMU23	132.789,59	392,00	107,00	76,00	7.910,21	5.716,80	19.124,66	1.712,00	1.695,00	1.712,00	560,80	560,80	560,80	0,69
DMU24	154.863,13	450,00	116,00	97,00	10.906,16	7.790,87	30.322,61	1.432,00	1.712,00	1.712,00	557,06	413,09	43,04	0,76
DMU25	122.398,40	296,00	84,00	72,00	3.356,55	4.313,04	33.559,29	1.698,00	1.712,00	1.712,00	560,81	560,81	560,81	0,74
DMU26	131.542,66	281,00	92,00	68,00	3.258,45	2.844,86	22.483,38	1.712,00	1.640,00	1.712,00	572,89	472,49	472,49	0,62
DMU27	138.012,60	321,00	94,00	70,00	4.718,47	4.244,15	37.642,71	1.710,00	1.711,00	1.692,00	547,35	547,01	543,89	0,74
DMU28	252.282,04	290,00	95,00	63,00	3.514,07	2.507,58	25.330,43	1.712,00	1.241,00	1.712,00	572,89	540,87	540,87	0,31
DMU29	117.526,78	261,00	83,00	67,00	3.413,99	1.557,68	25.724,33	1.712,00	1.712,00	1.712,00	572,89	572,89	572,89	0,69
DMU30	108.546,37	271,00	93,00	68,00	3.657,09	2.487,30	21.606,65	1.712,00	1.695,00	1.712,00	572,89	521,30	521,30	0,73
DMU31	130.294,86	297,00	96,00	72,00	3.542,63	2.174,48	14.434,98	1.712,00	1.712,00	1.712,00	572,89	572,89	572,89	0,63
DMU32	120.600,67	280,00	97,00	66,00	3.361,04	2.006,06	18.451,12	1.712,00	1.712,00	1.712,00	572,89	572,89	572,89	0,66
DMU33	113.731,98	304,00	100,00	68,00	4.113,31	2.874,16	13.376,77	1.254,00	1.712,00	1.712,00	541,25	465,07	465,07	0,68
DMU34	133.497,74	314,00	99,00	69,00	5.239,72	3.901,88	17.318,57	1.697,00	1.712,00	1.712,00	572,54	572,54	572,54	0,6
DMU35	146.733,88	346,00	112,00	72,00	5.100,45	2.771,90	14.547,99	1.702,00	1.076,00	1.712,00	526,32	375,20	375,20	0,59
DMU36	127.038,87	424,00	125,00	73,00	12.066,63	10.686,25	23.096,31	1.703,00	1.188,00	1.712,00	553,59	536,52	536,52	0,90
DMU37	106.924,95	302,00	106,00	59,00	1.666,86	375,22	3.769,36	1.712,00	1.712,00	1.501,00	570,76	570,76	516,74	0,7
DMU38	106.420,49	282,00	105,00	68,00	3.370,29	2.902,16	7.802,07	1.712,00	1.712,00	1.712,00	572,89	572,89	572,89	0,76
DMU39	111.513,18	377,00	112,00	65,00	6.536,18	5.517,24	11.461,40	1.570,00	1.702,00	1.712,00	572,89	572,89	572,89	0,81
DMU40	115.980,53	355,00	111,00	65,00	5.560,71	5.706,82	8.071,92	1.709,00	1.710,00	1.659,00	494,17	482,18	469,27	0,76
DMU41	120.859,63	371,00	114,00	62,00	5.807,63	4.508,04	7.391,49	1.403,00	1.699,00	1.712,00	572,89	572,89	572,89	0,73
DMU42	116.672,21	350,00	120,00	63,00	6.044,99	5.975,52	6.826,52	1.712,00	1.712,00	1.712,00	560,18	560,18	560,18	0,77
DMU43	118.758,62	369,00	121,00	63,00	6.463,58	6.243,09	9.834,99	1.712,00	1.712,00	1.712,00	572,89	531,99	531,99	0,76

Variables	Independents													Dependent
ANN	VAR00001	VAR00002	VAR00003	VAR00004	VAR00005	VAR00006	VAR00007	VAR00008	VAR00009	VAR00010	VAR00011	VAR00012	VAR00013	VAR00014
Month	PMO cost	Class II volume	Class III volume	Class IV volume	Value of Class II projects (US$ thousand)	Value of Class III projects (US$ thousand)	Value of Class IV projects (US$ thousand)	Days late Class II	Days late Class III	Days late Class IV	Above budget Class II (US$ thousand)	Above budget Class III (US$ thousand)	Above budget Class IV (US$ thousand)	Efficiency
DMU44	117.305,88	378,00	118,00	65,00	7.742,97	5.683,03	6.446,24	1.712,00	1.712,00	1.712,00	572,89	572,89	572,89	0,78
DMU45	118.195,54	414,00	131,00	64,00	7.094,88	7.100,41	6.271,94	1.712,00	1.712,00	1.712,00	572,89	572,89	572,89	0,83
DMU46	161.820,89	408,00	128,00	67,00	11.233,36	3.686,99	10.104,99	1.712,00	1.712,00	1.712,00	572,89	572,89	572,89	0,62
DMU47	162.726,37	440,00	131,00	65,00	11.158,97	7.338,43	9.091,87	1.712,00	1.712,00	1.712,00	572,89	572,89	572,89	0,65
DMU48	129.824,14	471,00	137,00	69,00	19.265,58	14.094,67	33.298,46	1.712,00	1.712,00	1.712,00	572,89	572,89	572,89	1,00

APPENDIX III





Hidden layer activation function: Hyperbolic tangent
Output layer activation function: Identity

APPENDIX IV

Month/Year	DMU	Efficiency
Jan/2018	DMU1	0,6377
Feb/2018	DMU2	1,0000
Mar/2018	DMU3	0,9654
Apr/2018	DMU4	0,9314
May/2018	DMU5	1,0000
Jun/2018	DMU6	1,0000
Jul/2018	DMU7	0,8260
Aug/2018	DMU8	1,0000
Sep/2018	DMU9	1,0000
Oct/2018	DMU10	1,0000
Nov/2018	DMU11	0,8055
Dec/2018	DMU12	0,8408
Jan/2019	DMU13	1,0000
Feb/2019	DMU14	0,8936
Mar/2019	DMU15	0,9365
Apr/2019	DMU16	0,6344
May/2019	DMU17	0,9983
Jun/2019	DMU18	1,0000
Jul/2019	DMU19	0,7272
Aug/2019	DMU20	0,9816
Sep/2019	DMU21	0,7643
Oct/2019	DMU22	1,0000
Nov/2019	DMU23	0,7103
Dec/2019	DMU24	0,7362
Jan/2020	DMU25	0,7999
Feb/2020	DMU26	0,6363
Mar/2020	DMU27	0,7888
Apr/2020	DMU28	0,3399
May/2020	DMU29	0,7299
Jun/2020	DMU30	0,7707
Jul/2020	DMU31	0,6062
Aug/2020	DMU32	0,6705
Sep/2020	DMU33	0,6947
Oct/2020	DMU34	0,6437
Nov/2020	DMU35	0,5715
Dec/2020	DMU36	0,8933
Jan/2021	DMU37	0,6991
Feb/2021	DMU38	0,7660
Mar/2021	DMU39	0,8311
Apr/2021	DMU40	0,7749
May/2021	DMU41	0,7333

Month/Year	DMU	Efficiency
Jun/2021	DMU42	0,7988
Jul/2021	DMU43	0,7811
Aug/2021	DMU44	0,8005
Sep/2021	DMU45	0,8495
Oct/2021	DMU46	0,6522
Nov/2021	DMU47	0,6585
Dec/2021	DMU48	1,0000
	Median	**0,7993**
	Standard Deviation	**0,1509**

6 RESULTS

This study began with a content analysis that mapped the codes found in the selected articles and the studies in which the topic was present. Next, the types of efficiency related to the PMO theme were identified, such as project and organizational efficiency.

This analysis made it possible to identify researchers and their lines of research according to the topic covered. Kutsch et al. (2015) address the functionality of the PMO in organizations to improve project efficiency. In addition, they point out that even though the PMO is strategic for improving project deliveries, it needs to have adequate recognition and justification for its existence. To investigate how the PMO adds value, an exploratory study was carried out, using questionnaires for managers to identify what this value means from the perspective of project stakeholders. Kutsch et al. (2015) concluded that before setting up a PMO, it is necessary to define its role in the organization. With this, it can be highlighted and valued in organizations.

Another research group evaluates the main factors for assessing the efficiency of a PMO. Lavoie-Tremblay et al. (2018) present a unique opportunity to understand how a PMO facilitates the successful implementation of a project. This study by Lavoie-Tremblay et al. (2018) uses a case study and presents the main factors of an efficient PMO. These include developing a support model and providing rigorous project guidance (methods, evaluation, analysis, promotion of collaboration, support from dedicated experts, etc.); developing and providing rigorous and long-lasting tools and methods that are linked to continuity (data, evaluations, frequent process reviews, dashboards); providing or offering project management training; and introducing and using communication (Lavoie-Tremblay, Aubry, Richer, & Cyr, 2018).

Steyn (2016) indicates measuring portfolio efficiency or the organization's ability to execute its projects by pre-established indicators, such as the accuracy of capital expenditure forecasting. In addition, he suggests measuring a PMO quantitatively through these portfolio indicators.

Dai and Wells (2004) state that projects, even with the support of efficient management, still have errors and failures. The study suggests continuously exploring new process models and organizational structures to fuel strong project performance. An essential candidate for improving these results is project management offices

(PMOs). A regression analysis was carried out to achieve these results, which mainly demonstrated the increase in project efficiency through implementing the PMO.

Industrial efficiency is a topic with several lines of research that can be developed in different ways. The PMO can be one of the factors in developing this environment. To obtain satisfactory results, PMOs should be divided into short-term (up to one year) and long-term (two or more years). The effectiveness of operations in a multi-project environment is a crucial objective for professionals. This study was based on questionnaires with PMI members (Spalek, 2013). Analyzing the 503 articles from the database search, 26 articles related to the research topic of efficiency related to the PMO area were analyzed. With this corpus of analysis coded, a binary conversion was carried out for a more precise analysis of the frequency of these codes.

By analyzing the articles that address PMO efficiency, it is possible to identify the strong relationship between the study of this topic and portfolio efficiency, project efficiency, and perceived efficiency. As a company's portfolio increases, so does its ability to achieve its objectives, which can directly influence PMO efficiency (Ko; Kim, 2019). In addition, a project's efficiency level can be realized on time through the project milestones. The quality, budget, and schedule requirements can directly affect the efficiency of the PMO in cases where the company manages its portfolio through the PMO (Philbin; Kaur, 2020). Suppose the client's satisfaction and opinion evaluate a project's success. In that case, it is appropriate to evaluate that the perceived efficiency can impact the efficiency of the PMO (Ko; Kim, 2019).

Therefore, the influence of the PMO on project efficiency was analyzed. Identifying the variables that can be used as a reference to improve project efficiency is possible. One of the determining points for this efficiency result may be related to the PMO's involvement in each gate. Class IV projects stand out for having better results at the end of their life cycle, even though they involve more significant investments.

Another critical issue is the nature of the project according to its class. This analysis can support the result of closing the project cycle and justify or explain the efficiency of projects. When analyzing the nature of the project and highlighting the lower and upper quartile, it is possible to identify that the nature of the project can be directly related to project efficiency.

Through the correlation analysis, it was possible to identify the variable with the highest input/output correlation in each project class. This correlation analysis will complement the benchmark analysis, highlighting the DMUs that are a reference for the other DMUs and correlating them with the variable with the highest correlation. For class II projects, the benchmark DMUs will be presented with a comparison of the variable out of time. For class III projects, adherence to closure is the variable with the highest correlation that will be compared with the reference DMUs. Moreover, for class IV projects, the correlation variable is adherence to closure. For class IV projects, it will be possible to see how long the most efficient projects take to close, from release for operation to accounting closure. As these are large-scale projects, this analysis helps us know the timeframe in which efficient projects are closing and how future projects should account for closure in their planning to remain efficient.

With the benchmark analysis, it was possible to identify that the five reference DMUs for the least efficient DMUs take, on average, 418 days to close the project (operation). Similar to the analysis of class III projects, most projects close their lifecycle within the planned timeframe, making them a reference in the benchmark analysis.

Regarding PMO efficiency, the DMUs with the best performance in the series analyzed were the DMUs in 2018. In 2018, the period's most portfolios in value (US mil) were analyzed. DMU 28 shows the worst efficiency result in the entire time series. This DMU is part of the 2020 analysis group, which has the worst efficiency results compared to the other years and is one of the years with the most extensive portfolio in values (US$mil). In 2018, 75% of the DMUs were 100% efficient. In 2019, 25% of DMUs were 100% efficient. None of the DMUs in the 2020 group are 100% efficient. In 2021, one DMU was 100% efficient.

It was found that for the company under study, in determining PMO efficiency, the total cost of the PMO is the variable that has the most significant impact on PMO efficiency. Another representative variable in the ANN analysis is the value of class II and IV projects. These results are fundamental factors for process improvements to qualify and improve the efficiency of the PMO in the study organization.

In April 2020, there was a drop in efficiency (the lowest in the period analyzed), and the cost of the PMO was one of the highest among the years analyzed. Analyzing the statement of this PMO cost shows an increase in people-related amounts in this month. This increase is related to specific bonuses for this period, additional staff transfers, overtime, and the pandemic. This year saw one of the largest portfolios (in value) of all the years analyzed. This may justify the increase in the PMO's cost due to the team working overtime and investing in digital technologies for more efficient processes. In addition, this month refers to a month after the start of the pandemic (which began in March 2020). People had to adjust to the home office and new working methods during this period.

In 2018, when efficiency was high, the portfolio's value was lower than in the other years analyzed. It also has one of the lowest volumes of projects managed over the years. In addition, drawing a trend line between PMO cost and PMO efficiency shows that while PMO cost increases, efficiency decreases. Thus, the prevalent variables of class II and IV projects can help improve and adjust the efficiency of the company's PMO, particularly. Adjusting the cost, volume of projects managed, and portfolio cost can significantly benefit the company and increase the PMO's efficiency. The following section presents the discussions and conclusions.

7 RESEARCH DISCUSSIONS AND CONCLUSIONS

This research aims to conduct an exploratory analysis to identify the variables present in the PMO process, using Data Envelopment Analysis to evaluate the technical efficiency of operations. A case study was conducted with a longitudinal evaluation of a petrochemical company's project portfolio.

The work presents theoretical and practical contributions, as summarized in Table 43. These contributions help support the research's central thesis, which aims to use Data Envelopment Analysis as an approach for a broad assessment of the technical efficiency of the PMO in the company under study. Thus, the theoretical contributions refer to the extension of existing knowledge about evaluating technical efficiency using the concepts of Data Envelopment Analysis. The practical contributions refer to the empirical application of these concepts to evaluate technical efficiency in Project Management processes in the company studied.

Table 43 - Summary of the thesis' theoretical and practical contributions

Theoretical contributions	Practical contributions
A systematic literature review is carried out considering empirical evaluations of project and PMO efficiency. This literature review provides insights for researchers in the field;	It presents ways in which organizations can measure their PMO and which can be used in decision making when considering the implementation and measurement of a PMO, according to the efficiencies that are most strongly related, since the research identified and pointed out the degree of relationship with which the conceptual aspects of the literature influence the efficiency of the PMO in practice;
The opportunity to expand studies evaluating the technical efficiency of the PMO is identified;	Variables that have a stronger correlation with project efficiency are presented, and are focal variables for improvements in the company's Project Management and the actions of the coordinators;
It is identified that technical efficiency in DEA can be applied to a low sample of companies, negating the assumption of a large sample for this type of analysis;	An analysis of the PMO's influence on project efficiency is carried out. This analysis provides consistent results for the company under study in order to help in the decision making process for the multi-year planning of the project portfolio;
Promotes an investigation between the concepts of project efficiency and the strategic decisions of the PMO, classifying projects by complexity;	The ideal productivity for a PMO to be 100% efficient is identified, thus increasing the efficiency of the projects and its own efficiency, identifying factors that prevail over the efficiency of the PMO and contributing to

Theoretical contributions	Practical contributions
	the action of managers in the face of the prevalent variables of the RNA analysis;
An analysis of the role of the PMO and project portfolio is presented, showing that having an active PMO in both projects and organizations results in significant improvements in project efficiency, as well as identifying factors that promote PMO efficiency in the study organization.	It is possible to obtain valuable insights that reveal potential for improvement and identify important variables to increase the efficiency of the PMO through DEA.
	It is presented as a facilitator for improving PMO and project portfolio efficiency strategies, especially by enabling the identification of possible optimal portfolio planning combinations that lead to better performance results.

Source: Developed by the author.

To achieve the primary research objective, several specific procedures were defined and carried out. Firstly, a critical assessment was made of empirical studies that analyze technical efficiency with and without the use of DEA for projects and PMOs. The prevalence of classic DEA models (cost and time) was identified, and two-stage DEA analysis has been increasingly used in empirical applications. In addition, it was identified that researchers need to study PMOs to determine their efficiency for companies and, above all, their contribution to project management. It was also noted that studies use a project's efficiency to portray the PMO's efficiency. Other studies also disregard the assumption of the PMO's cost to the organization.

Secondly, an attempt was made to assess the impact of the PMO on project efficiency using the internal benchmarking approach. Large projects, i.e., projects in the class IV group, which require greater PMO involvement due to the number of deliverables, are the ones with the best average efficiency results. For example, projects that involve stopping operations are more efficient, i.e., strategic prioritization. In the company under study, the PMO has the role of standard-setter/guide/supporter in strategic decisions, which is directly related to the deliverables by project class. Thus, it is possible to observe that on issues where the PMO is more active and works closely with the team (such as class IV projects), there is greater project efficiency.

Thirdly, the study evaluated PMO efficiency using two-stage DEA with the application of ANNs to identify the variables that most influence PMO efficiency. The volume of projects managed, and the value of the investment can impact PMO efficiency. This is because the PMO was less efficient in the years when a more significant volume could have been more.

The work carried out has limitations. Considering one industrial plant, it was impossible to replicate the results for other international industrial facilities; the class I group, i.e., simple purchases, and the particular projects group (projects with a higher investment value) were not considered in the data analysis. Class I and special projects could influence and distort the results of the DEA model and not analyze the PMO team, which remained constant over the four years in this longitudinal scenario.

The external benchmarking carried out in this study could be evaluated for future work. In addition, external benchmarking could be carried out among other international industrial facilities of the company under study, thus developing the best suggested to look at the PMO in complex organizations with rapidly changing scenarios and portfolios, a topic limited to the primary studies in this systematic review.

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