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Project Management Efficiency Measurement with Data Envelopment Analysis: A Case in a Petrochemical Company

Marilia Botelho Coelho, Daniel Pacheco Lacerda, Fábio Antonio Sartori Piran, Débora Oliveira da Silva and Miguel Afonso Sellitto *

Production and Systems Graduate Program, University of Vale do Rio dos Sinos, Avenida Unisinos 950, São Leopoldo 93022-180, Brazil; mariliabotelho@outlook.com (M.B.C.); dlacerda@unisinos.br (D.P.L.); fpiran@unisinos.br (F.A.S.P.); deboraoliveira@unisinos.br (D.O.d.S.)

* Correspondence: sellitto@unisinos.br

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

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1. Introduction

One crucial facet of effective project management involves quantifying efficiency in attaining goals [1]. 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 [2].

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 [3]. 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 [4]. One of PM's core objectives is to effectively steer projects while aligning them with the company's operational strategy [5].

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 [6]. Additionally, the PMO is responsible for adhering to business constraints [7] and ensuring alignment with the operational strategy [8]. Companies that adopt a PMO-type structure tend to achieve heightened efficiency in project execution [9].

Authors like [7,10–12] 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 [13]. An appealing alternative is internal benchmarking, where projects executed by the same organization are compared [14]. 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 [15].

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.

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 [16], adapting its structure to the overall organizational framework [17]. Refs [18,19] shed light on the evolving roles and changing responsibilities of PMOs over time. Additionally, [20] 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 [21], 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 [22].

According to [23], the earliest implementations of PMO in companies date back to the early 1990s. [22] 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 [24]. 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 [25].

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 [26]. When strategically positioned, the PMO enhances results [27] and fosters organizational learning [28]. This improvement results from acquiring superior knowledge, implementing standardized processes, and enhancing training. As [29] emphasized, there should be seamless integration between success factors and governance. Despite the acknowledged necessity of efficiency control, the existing literature, according to [30], has predominantly focused on PMO functionalities rather than tangible outcomes. Another gap in the literature pertains to uncertainties surrounding the significance of PMOs [31] and the integration of multiple roles [32]. A recent gap relates to the ambiguity surrounding the decision-making processes within PMOs [16].

To characterize the evaluation variables of a PMO, one must first discern how the PMO operates within each organization [7]. By establishing measurable parameters and metrics, the PMO can showcase its efficiency [33], 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 [34]. Typically, a PMO succeeds in reducing project duration and costs while simultaneously maintaining scope and expected quality [35]. It also advances project management maturity within organizations [36]. 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 [37].

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 [34]. For example, [10,34,38] 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 [32]. Adhering to such standards contributes significantly to project success [24]. Table 1 outlines and synthesizes the PMO's multiple expected roles and functionalities retrieved from the literature reviewed.

Table 1. Expected roles and functionalities of a PMO.

Functionalities of A PMO	References
Administrative support, information and knowledge management, and training.	[15,39]
Monitoring and controlling project efficiency, developing skills and methodologies, managing multiple projects, strategic management, and organizational learning.	[40]
Service, control, and partnership management.	[21,36]
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.	[41]
Provide functions and services, maintenance of the standardization system, resource use management, support for execution, and project portfolio management.	[22]
Be a center of excellence in PM and implement practices, methodologies, and strategic choices.	[42]

Table 1. *Cont.*

Functionalities of A PMO	References
Support and control of project execution	[35]
Develop and implement global PM methodologies, policies, standards, and reports for the company.	[43]
PMOs enhance the achievement of strategic plans.	[44]
Organizational structure to support PM, establish standardization, and manage efficiency in PM, delivering value and quality and meeting customer expectations.	[11]
Coordination and boosting innovation and change in PM, and identification of innovation opportunities for PM efficiency.	[45]
Facilitator for generating and sharing learning in projects.	[28]
Improve the knowledge management infrastructure with regard to practice management and technical support.	[46]
Define the direction and objective of the flow of knowledge and governance, and act within and among three hierarchical levels: operational, PMO, and management.	[47]
Classify the functions into three groups: benchmarking best practices, project management compliance, and project governance.	[48]
Knowledge intermediary between and among projects.	[20]
Intermediary functions in knowledge transactions within and among different organizational levels.	[16]
Optimize activities, processes, procedures, and documentation; support the PM database; and manage projects, providing resources and experience.	[22,25]
Identify 60 roles within the seven functions of the PMO: knowledge management, support, strategic, project performance, governance, innovation, and organization performance enabler.	[49]

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 [50]. 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 [43]. 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 [47].

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 [51], energy recovery and renewable energy sources, and the reuse and exchange of materials and energy among companies [52]. PI projects focus mainly on profitability increases through new sources of revenue and cost reductions in processes [53]. RM projects focus mainly on retrofitting [54] and overhauling critical equipment [55].

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 2 displays the number of deliverables according to class and degree of project maturity.

Figure 1 presents the methodology and the outcomes of each stage.

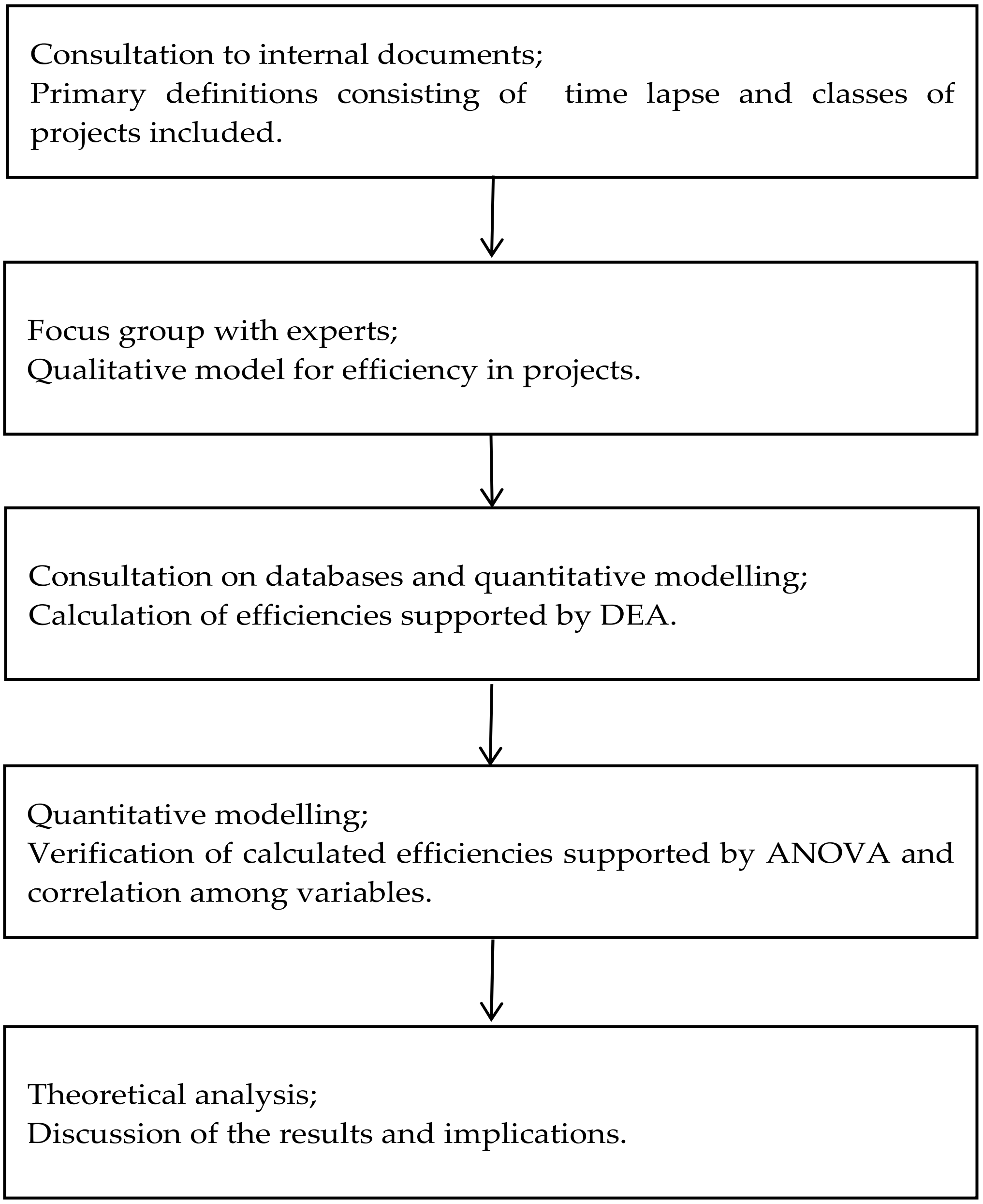

Figure 1. Methodology.

Table 2. Deliverables according to class and maturity.

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

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 (1)–(3).

$$Min\ h_0 = \frac{\sum_{i=1}^{n} v_i x_{i0}}{\sum_{j=1}^{m} u_j y_{j0}} \tag{1}$$

subject to:

$$\frac{\sum_{i=1}^{n} v_i x_{i\mathrm{k}}}{\sum_{j=1}^{m} u_j y_{j\mathrm{k}}} \geq 1, \forall k \tag{2}$$

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

$$h_0 = 1/eff0 \tag{3}$$

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.
$x_{i\mathrm{k}}$ = quantity of the input i for DMU k, k = 1, . . . N.
$y_{j\mathrm{k}}$ = 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 3 supported the development of the DEA model.

Table 3. 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

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 4 showcases the model.

Table 4. The DEA model.

Tag	Variable	Description	Unit	Reference
Input01	Project value	FID (Final Investment Decision) approval	BR$	[11,56]
Input02	Number of interfaces	Maintenance, Operation Automation, Logistics, Laboratory, Enterprise, SHE, Process	Number	[11,23,57];
Input03	Project time	Number of days from project opening to delivery to the area responsible	Mounts	[57,58];
Input04	Number of specialties	Electrical, Civil, Mechanical, Piping Instrumentation, Automation, Process	Number	[37,57,59];
Output01	Cost adherence	Difference from the planned FID	BR$	[26,60,61]
Output02	Projects on time	Difference between actual and planned completion	Days	[33,62]
Output03	Time to completion	Number of days from start to completion	Days	[33,62]

4. Results

Table 5 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 5. 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%
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%			

Table 5. *Cont.*

	Class II			Class III			Class IV	
DMU	**Year**	**Efficiency**	**DMU**	**Year**	**Efficiency**	**DMU**	**Year**	**Efficiency**
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%			
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%

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 [63–65]. 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 6 shows the ANOVA test.

Table 6. 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.

Figure 2 highlights average project efficiencies by year and by class.

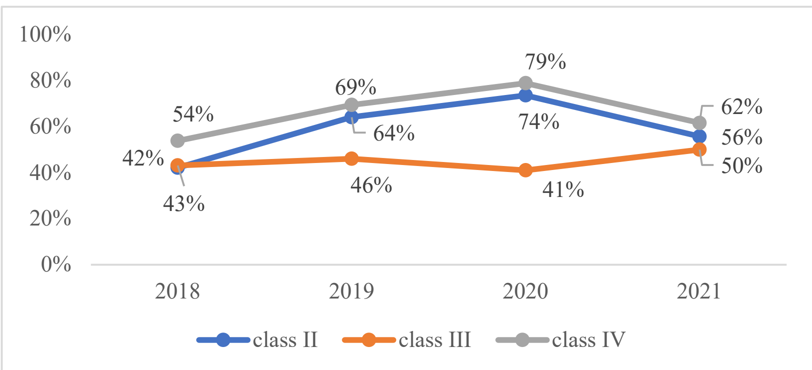

Figure 2. Average efficiencies by classes over the years.

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.

$$Eff_{cw} = \frac{\sum eff_i.C_i}{\sum C_i} \quad (4)$$

$$Eff_{tw} = \frac{\sum eff_i.T_i}{\sum T_i} \quad (5)$$

where:

Eff_{cw} and $Efft_w$ = cost- and time-weighted efficiencies;

C_i and T_i = cost and time to completion of the ith project;

ΣC_i and ΣT_i = total cost and total time to completion of all the projects.

Table 7 presents the weighted and average efficiencies for the different classes.

Table 7. 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

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 8 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 8. Projects on time and at the expected cost.

		Projects				
Class	Average Value (BR$M)	Total	On-Time		At Expected Cost	
II	1743	49	25	(51%)	34	(69%)
III	4598	54	36	(66%)	30	(55%)
IV	8121	25	17	(68%)	14	(56%)

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 9 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 9. 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

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 10 presents correlation analyses for each class of projects, which is a useful tool for performance evaluation [66]. Bold highlights indicate moderate or strong correlations, while underlined highlights point to weak or very weak correlations with efficiency.

Table 10. Correlation analysis.

Class		Efficiency	Input01	Input02	Input03	Input04	Output01	Output02
II	Input01	$\underline{-0.174}$						
	Input02	$\underline{-0.131}$	−0.002					
	Input03	$\underline{0.117}$	0.188	−0.083				
	Input04	$\underline{0.006}$	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	$\underline{-0.088}$						
	Input02	$\underline{0.014}$	−0.045					
	Input03	$\underline{-0.151}$	0.105	−0.213				
	Input04	$\underline{-0.029}$	−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

Table 10. *Cont.*

Class		Efficiency	Input01	Input02	Input03	Input04	Output01	Output02
IV	Input01	0.220						
	Input02	<u>0.011</u>	0.131					
	Input03	<u>0.046</u>	0.079	−0.072				
	Input04	<u>−0.174</u>	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

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.

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. Ref. [67] 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. Ref. [5] 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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Data Availability Statement: Data are contained within the article.

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

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

Table A1. *Cont.*

DMU	Input01	Input02	Input03	Input04	Output01	Output02	Output03
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
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

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	−19,835.83	−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
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

Table A2. *Cont.*

DMU	Input01	Input02	Input03	Input04	Output01	Output02	Output03
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

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	−13,035.16	0	319.57
25	9800.40	0	0	3.44	−591.99	−86.16	169.02

Appendix B

Table A4. Average and weighted efficiencies for class II projects.

DMU	Eff	Cost (R$M)	Eff.C_i	Time (Days)	Eff.T_i
1	-	-	-	-	-
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	1.034	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

Table A4. *Cont.*

DMU	Eff	Cost (R$M)	Eff.C_i	Time (Days)	Eff.T_i
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%

Table A5. Average and weighted efficiencies for class III projects.

DMU	Eff	Cost (R$M)	Eff.C_i	Time (Days)	Eff.T_i
1	-	-	-	-	-
2	-	-	-	-	-
3	31.9%	1490	475	3572	1139
4	5.8%	12,136	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%	14,079	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

Table A5. *Cont.*

DMU	Eff	Cost (R$M)	Eff.C_i	Time (Days)	Eff.T_i
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%	13,026	6343	1255	611
33	100.0%	801	801	875	875
34	23.7%	11,089	2629	550	130
35	33.6%	11,538	3872	534	179
36	11.9%	5429	643	1001	119
37	39.4%	12,190	4799	1319	519
38	72.9%	1488	1084	575	419
39	100.0%	12,714	12,714	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
49	100.0%	6246	6246	3864	3864
50	21.8%	1993	434	943	205
51	100.0%	1904	1904	1133	1133
51	61.3%	10,556	6471	562	344
53	100.0%	1665	1665	923	923
54	54.6%	1002	547	1141	623
Effic.	45.2%		43.6%		43.2%

Table A6. Average and weighted efficiencies for class IV projects.

DMU	Eff	Cost (R$M)	Eff.C_i	Time (Days)	Eff.T_i
1	100.0%	17,300	17,300	1500	1500
2	35.5%	4596	1634	1000	355
3	2.6%	1833	47	1582	41
4	100.0%	15,720	15,720	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

Table A6. *Cont.*

DMU	Eff	Cost (R$M)	Eff.C_i	Time (Days)	Eff.T_i
9	88.3%	1876	1656	519	458
10	43.3%	18,575	8047	1239	537
11	100.0%	11,800	11,800	858	858
12	29.7%	10,736	3189	630	187
13	100.0%	1939	1939	1633	1633
14	100.0%	13,383	13,383	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%	38,063	38,063	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%	19,116	19,116	2272	2272
25	52.3%	14,645	7660	1014	530
Effic.	67.1%		76.5%		65.2%

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