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Integrating the Work Breakdown Structure (WBS) With the Organizational Breakdown Structure (OBS) in Wind Farm Construction

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ABSTRACT
The construction of wind farms is increasingly becoming a viable and necessary solution to meet the growing demand for renewable and sustainable energy sources. In this context, effective project management is essential to ensure the success of these projects, which involve technical complexity, multiple stakeholders, and stringent regulatory requirements. The integration of the Analytical Project Structure (APS) with the Organizational Project Structure (OPS) has emerged as a fundamental strategy to optimize processes, improve communication among teams, and ensure the effective delivery of resources. This article explores this integration, highlighting its importance for project management in wind farm construction and the benefits that can be achieved through a structured and collaborative approach. This study employs a qualitative approach, which is fundamental to the scientific community, especially in complex and dynamic areas such as project management in wind farm construction. The research procedure utilized in this investigation was a literature review. The general objective of this research is to analyze the integration of the Analytical Project Structure (APS) with the Organizational Project Structure (OPS) in wind farm construction, aiming to enhance the efficiency and effectiveness of project management. It was evidenced that the development and implementation of best practices, combined with the use of management tools, position companies in the sector—both entrepreneurs and service providers—as key agents in promoting a more sustainable and competitive energy matrix.

Keywords*: Wind farms; Project management; Analytical Project Structure; Organizational Project Structure.*

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I. INTRODUCTION

The integration of the Analytical Project Structure (APS) with the Organizational Project Structure (OPS) in the construction of wind farms represents a critical advancement in project management practices within the renewable energy sector. As the demand for sustainable energy solutions continues to grow globally, wind energy has emerged as a leading option due to its environmental benefits and scalability potential.

However, the complexity of constructing wind farms, which involves multiple stakeholders, technical challenges, and regulatory requirements, necessitates a robust framework for effective project management. By aligning APS with OPS, project managers can enhance communication, streamline processes, and improve resource allocation throughout the project lifecycle. This integration is particularly significant in the context of wind energy projects, where timely execution and compliance with safety standards are paramount.

This study employs a qualitative approach, which is essential in the scientific realm, especially in complex and dynamic areas such as project management for wind farm construction. The research procedure utilized in this investigation was a literature review.

The general objective of this research is to analyze the integration of the Analytical Project Structure (APS) with the Organizational Project Structure (OPS) in the construction of wind farms, aiming to enhance the efficiency and effectiveness of project management. This study seeks to identify best practices and methodologies that facilitate this integration, thereby contributing to the successful delivery of wind energy projects while addressing the inherent challenges of their construction and operation. The outlined objectives are related as follows: to scientifically explain wind farm projects; to highlight the Analytical Project Structure (APS); to discuss the Organizational Project Structure (OPS); and to demonstrate the integration between APS and OPS – responsibility matrix.

This scientific article is organized into four sections. The first section is the introduction, which outlines the objectives of this research. The second section is dedicated to methodological procedures. The third section develops the theoretical framework, consisting of an extensive scientific discussion on the theme addressed herein. Finally, the fourth section presents the concluding remarks of this research, demonstrating all findings from this study and proposing directions for future research.

II. MATERIAL AND METHODS

This study employs a qualitative approach, which is fundamental to the scientific realm, especially in complex and dynamic areas such as project management for wind farm construction. Qualitative approaches allow for a deeper understanding of the phenomena under investigation, facilitating the exploration of contexts, meanings, and interactions that cannot be captured by quantitative methods.

This perspective is particularly valuable when studying the integration of the Analytical Project Structure (APS) with the Organizational Project Structure (OPS), as it enables a detailed analysis of practices, challenges, and relevant experiences of experts, thereby enriching understanding. The research procedure utilized in this investigation was a literature review. This method is essential in the scientific community because it allows for the collection and critical analysis of a wide range of existing sources on the topic in question.

The literature review provides a comprehensive overview of established theories, concepts, and practices, while also identifying knowledge gaps that can be explored in future research. As part of this study, a bibliographic review helped to identify best practices in the integration of APS and OPS in wind farm construction projects, contributing to the development of a solid theoretical framework that supports the discussions and conclusions presented throughout the article.

Thus, the combination of qualitative methods with a literature review process not only enriches the research but also enhances its academic and practical relevance, yielding profound and valuable insights for professionals and researchers in the field of project management.

III. THEORETICAL FRAMEWORK

Driven by the increasing awareness of climate change and the pursuit of renewable energy sources, the wind energy industry has experienced significant growth in recent decades both in Brazil and globally. In this context, wind farm projects represent complex undertakings that require effective management to integrate technical, organizational, and strategic aspects. One of the crucial challenges faced by managers of these projects lies in the integration between planning activities and the organizational structure responsible for their execution. Planning involves determining what needs to be done, by whom, and when, in order to fulfill a designated responsibility within a project. The term "scope" refers to the set of components that constitute the product and outcomes of the project. A project cannot be managed effectively without well-defined boundaries. The most recommended technique for identifying project activities is scope decomposition in the form of an Analytical Project Structure (APS) (Mattos, 2010; Espinha, 2024).

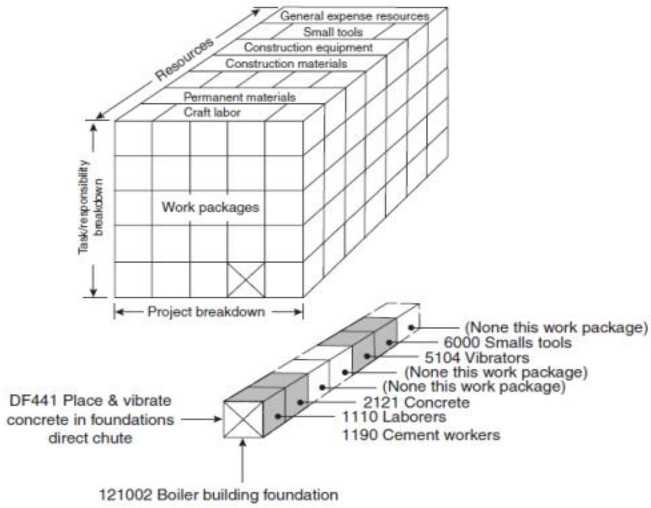
While the APS illustrates the project's deliverables, the responsible parties within the organization can similarly be represented hierarchically through the Organizational Project Structure (OPS). The OPS is organized according to existing departments, units, or teams within the organization, with project activities or work packages listed under each department (PMBOK, 2017).

To integrate the APS and OPS, a methodology similar to that presented by Halpin et al. (2017) was employed, which refers to a tripod: Analytical Project Structure (APS), Organizational Project Structure (OPS), and resources or cost structure. The cost structure or cost account is a level identified at a natural intersection point between the APS and OPS, where responsibility for the work is assigned (Halpin et al., 2017).

The work package is a crucial level for ensuring efficiency in project management. Defining who is responsible for executing the package can enhance resource allocation, optimize processes, improve communication and contract management, clarify responsibilities, and minimize conflicts.

Once the concepts described in Figure 1 were defined, data were collected from the company responsible for constructing wind farm projects in Brazil. To ensure the confidentiality of sensitive information, given that it is a privately held company, the data were summarized.

Figure 1. Three-dimensional visualization of cost control through APS, OPS, and cost structure.



Source: Halpin, & Senior (2009)

The objective is to integrate project activities with the organizational structure, ensuring that those responsible for production teams have a clearer understanding of their scopes and responsibilities during project execution.

3.1 Wind Farm Projects

The energy transition refers to the reduction in the use of polluting sources and fossil fuels in favor of alternatives that emit fewer greenhouse gases. The primary solution lies in the expansion of renewable energy production, such as wind and solar power.

According to Abeeólica (2024), Brazil has an electrical and energy matrix with a higher share of renewables than the global average. Brazil possesses some of the best wind conditions in the world for onshore energy generation. Wind energy is an important source of renewable energy, and its growth has contributed significantly to Brazil's energy matrix. Wind farm projects are complex undertakings, as they involve various engineering disciplines, different systems, and a wide range of equipment. To ensure better management of the implementation of a wind farm, projects are divided into Balance of Plant (BoP) components.

According to Bernardino (2024), Balance of Plant (BoP) refers to all auxiliary components and systems necessary for the efficient and safe operation of a power generation plant, excluding the main generator itself. In renewable energy projects, such as solar, wind, hydropower, and biomass, BoP is essential for the integration, control, and optimization of the efficient energy plant operations.

The company studied operates in the sector of constructing wind farm plants, specifically focusing on civil works for wind farms, or civil BoP, as well as electrical works for medium-voltage networks, or BoP RMT.

3.2 Analytical Project Structure (APS)

The APS aims to divide the project scope into activities or work packages that are hierarchically and progressively smaller, thereby organizing the work into more manageable parts (Mattos, 2010; Espinha, 2024). In wind farm projects, the civil Balance of Plant (BoP) and medium-voltage network BoP (BoP RMT) have different structures.

The civil BoP for wind farms encompasses all civil infrastructure works, from the construction of access roads to the execution of foundations and assembly platforms for wind turbines. The BoP RMT includes all electrical works related to the medium-voltage network, from the installation of electrical and data cables—either aerially using concrete poles and elevated cables or underground with buried cables—to the interconnection of each wind turbine to the park's electrical substation.

Although there is a variety of structures, the most common is the six-level indented structure (Kerzner, 2015): Management Levels: Program, project, and task. Technical Levels: Subtask, work package, and effort level. For this study, a summarized APS was developed outlining the main activities executed by the company in wind farms across the two previously mentioned BoPs.

Figure 2. Analytical Project Structure for Civil BoP and RMT.

Level 01	Level 02	Level	Level 04	Level 05
WIND FARMS	IMPLEMENTATION	CIVIL BOP	ENGINEERING	PROJECTS
			INFRASTRUCTURE	VEGETATION CLEARING
				EARTHWORK
				PAVING
			FOUNDATIONS	CONCRETE
				REINFORCEMENT
			QHSE	HEALTH
				QUALITY
				SAFETY
				ENVIRONMENT
		BOP RMT	ENGINEERING	PROJECTS
			INFRASTRUCTURE	VEGETATION CLEARING
				EARTHWORK
				RMT IMPLEMENTATION
			ELECTROMECHANICAL	EQUIPMENT
				COMMISSIONING
				ELECTRICAL AND DATA CABLING
			QSMS	QUALITY
				SAFETY
				ENVIRONMENT
				HEALTH

Source: Data from researchers

The WBS will serve as the foundation for various project management tools, such as the responsibility matrix, schedule, commercial budget, construction budget (cost), organizational structure (OBS), contract progress control, and project activity tracking.

3.3 Project Organizational Structure (POS)

The Project Organizational Structure (POS), often represented in the form of an organizational chart, aims to divide the project's organizational responsibilities into teams or departments that are progressively smaller and hierarchically structured. This allows for greater transparency and accountability for the work performed (Halpin et al., 2017).

The POS refers to the configuration of the organization responsible for executing a project. According to Hastak (2015), the POS represents a hierarchical division of the entities performing the work assigned to a specific organization. The primary function of the POS is to allocate the resources required to execute the project scope as defined in the Work Breakdown Structure (WBS). The POS must strike a balance between the complexity needed for effective control and the simplicity required for producing accurate reports (AACE, 2011).

The lowest level of a POS corresponds to the organizational entity responsible for executing a work package. Similar to the WBS, the level of decomposition is a balance between practicality and effectiveness. The organizational structure of the company under study can be characterized as projectized, organized by product (project). As an engineering service provider, the company's wind farm projects are typically located far from its headquarters and major urban centers.

Consequently, each project is supported by a robust structure to ensure autonomy in project management and the presence of necessary specialized professionals. The headquarters serves as a support hub for the projects, hosting departments essential for overall company management. The primary advantage of this organizational flow is that the project manager holds full line authority over the entire project. The manager not only assigns tasks but also conducts performance evaluations (Kerzner, 2013; Viola, 2019).

Figure 3. Project organizational structure for BoPs in civil and RMT.

GENERAL DIRECTOR

	MANAGER BOP CIVIL			MANAGER BOP RMT	
ENGINEERING	**PRODUCTION**	**SUPPORT**	**ENGINEERING**	**PRODUCTION**	**SUPPORT**
Projects	Earthworks	Quality Management	Projects	RMT Infrastructure	Quality Management
	Foundations	Safety and Health		RMT Launching	Safety and Health
		Environment			Environment

Source: Researchers' Data

3.4 Integration Between WBS and OBS – Responsibility Matrix

According to Kerzner (2013), the successful implementation of both the contract and corporate objectives requires a plan that defines the total effort to be expended, assigns responsibility to a specifically identified organizational element, and establishes schedules and budgets for task completion. One way to represent the integration between project activities (Work Breakdown Structure, WBS) and the organizational entity responsible for their execution and management (Organizational Breakdown Structure, OBS) is through a Responsibility Matrix. A Responsibility Matrix (RM) illustrates the project resources allocated to each work package (PMBOK, 2017).

The matrix format displays all activities associated with a person and all individuals linked to an activity. It also ensures that only one person is accountable for each task, thereby avoiding confusion regarding who ultimately holds authority or responsibility for the work. An example of an RM is a RACI chart (Responsible for execution, Accountable for approval, Consulted, and Informed) (PMBOK, 2017).

Considering the WBS on the vertical axis and the OBS on the horizontal axis, the integrative RACI Responsibility Matrix for the company under study, by Business Operating Plan (BoP), is as follows:

Figure 4. RACI Responsibility Matrix for civil BoP.

			BOP CIVIL							SEDE
			ENGENHARIA	PRODUÇÃO		APOIO			GESTÃO	
Nível 03	**Nível 04**	**Nível 05**	PROJETOS	TERRAPLENAGEM	FUNDAÇÕES	GESTÃO DE QUALIDADE	SEGURANÇA E SAÚDE	MEIO AMBIENTE	GERENTE BOP CIVIL	DIRETORIA
BOP CIVIL	ENGENHARIA	PROJETOS	R	C	C	I	I	I	A	I
	INFRAESTRUTURA	SUPRESSÃO VEGETAL	I	R	I	C	C	C	A	I
		TERRAPLENAGEM	I	R	I	C	C	C	A	I
		PAVIMENTAÇÃO	I	R	I	C	C	C	A	I
	FUNDAÇÕES	ARMAÇÃO	I	I	R	C	C	C	A	I
		CONCRETO	I	I	R	C	C	C	A	I
	QSMS	QUALIDADE	I	C	C	R	I	I	A	I
		SEGURANÇA	I	C	C	I	R	I	A	I
		MEIO AMBIENTE	I	C	C	I	I	R	A	I
		SAÚDE	I	C	C	I	R	I	A	I

RACI		
	R	Responsável
	A	Aprova
	C	Consultado
	I	Informado

Source: Researchers' Data

For Civil BoP, in the RACI Responsibility Matrix, allocating an OBS manager to each WBS item indicates that the production teams bear the greatest responsibilities. Being a company with quality, safety, and environmental certifications, the QSMS teams also play a prominent role, as they directly influence activities as consultants and manage critical processes described in the WBS. The contract manager plays a key role as an integrator of all sectors, acting as the approver of activities and interacting across all areas.

The information generated from the RACI Responsibility Matrix can also be utilized for other important purposes within the project, such as: communication matrix, project budget by sector, cost control by sector, quality control by sector, resource control by sector, among others.

The company's board of directors is kept informed of all project activities and may intervene when necessary or requested. Management and control tools can be developed for those responsible, aligning with goals established by the board and managed by the project manager.

Figure 5. RACI Responsibility Matrix for BoP RMT.

			BOP RMT							SEDE
			ENGENHARIA	PRODUÇÃO		APOIO			GESTÃO	
Nível 03	**Nível 04**	**Nível 05**	PROJETOS	INFRAESTRUTURA DE RMT	LANÇAMENTO DE RMT	GESTÃO DE QUALIDADE	SEGURANÇA E SAÚDE	MEIO AMBIENTE	GERENTE E BOP RMT	DIRETORIA
BOP RMT	ENGENHARIA	PROJETOS	R	C	C	I	I	I	A	I
	INFRAESTRUTURA	SUPRESSÃO VEGETAL	I	R	I	C	C	C	A	I
		TERRAPLENAGEM	I	R	I	C	C	C	A	I
		IMPLANTAÇÃO DE RMT	I	R	I	C	C	C	A	I
	ELETROMECÂNICA	CABEAMENTO ELÉTRICO E DADOS	I	I	R	C	C	C	A	I
		EQUIPAMENTOS	I	I	R	C	C	C	A	I
		COMISSIONAMENTO	I	I	R	C	C	C	A	I
	QSMS	QUALIDADE	I	C	C	R	I	I	A	I
		SEGURANÇA	I	C	C	I	R	I	A	I
		MEIO AMBIENTE	I	C	C	I	I	R	A	I
		SAÚDE	I	C	C	I	R	I	A	I

RACI		
	R	Responsável
	A	Aprova
	C	Consultado
	I	Informado

Source: Researchers' Data

For the BoP RMT, similar to the previously presented RACI Matrix for the Civil BoP, the production OBS includes the majority of WBS activities. This is an expected characteristic for engineering projects. In this type of project, materials play a crucial role. The RACI Matrix supports management in the enterprise's supply chain sector by defining responsibilities for procurement, inventory control, and distribution within the project.

When integrating the WBS and OBS from both BoPs of the company, the result is a robust RACI Matrix. For this analysis, the breakdown of structures (WBS and OBS) was simplified for convenience, but in a more detailed effort, the result would be an extensive matrix with multiple functionalities for the company. The RACI Matrix will serve as a valuable source of data for the efficient management of wind farm projects.

Figure 6. Integrative RACI Matrix for WBS and OBS of wind farms.

					BOP CIVIL							BOP RMT							SEDE
					ENGENHARIA	PRODUÇÃO		APOIO			GESTÃO	ENGENHARIA	PRODUÇÃO		APOIO			GESTÃO	
Nível 01	Nível 02	Nível 03	Nível 04	Nível 05	PROJETOS	TERRAPLENAGEM	FUNDAÇÕES	GESTÃO DE QUALIDADE	SEGURANÇA E SAÚDE	MEIO AMBIENTE	GERENTE BOP CIVIL	PROJETOS	INFRAESTRUTURA DE RMT	LANÇAMENTO DE RMT	GESTÃO DE QUALIDADE	SEGURANÇA E SAÚDE	MEIO AMBIENTE	GERENTE BOP RMT	DIRETORIA
PARQUES EÓLICOS	IMPLANTAÇÃO	BOP CIVIL	ENGENHARIA	PROJETOS	R	C	C	I	I	I	A								I
			INFRAESTRUTURA	SUPRESSÃO VEGETAL	I	R	I	C	C	C	A								I
				TERRAPLENAGEM	I	R	I	C	C	C	A								I
				PAVIMENTAÇÃO	I	R	I	C	C	C	A								I
			FUNDAÇÕES	ARMAÇÃO	I	I	R	C	C	C	A								I
				CONCRETO	I	I	R	C	C	C	A								I
			QSMS	QUALIDADE	I	C	C	R	I	I	A								I
				SEGURANÇA	I	C	C	I	R	I	A								I
				MEIO AMBIENTE	I	C	C	I	I	R	A								I
				SAÚDE	I	C	C	I	R	I	A								I
		BOP RMT	ENGENHARIA	PROJETOS								R	C	C	I	I	I	A	I
			INFRAESTRUTURA	SUPRESSÃO VEGETAL								I	R	I	C	C	C	A	I
				TERRAPLENAGEM								I	R	I	C	C	C	A	I
				IMPLANTAÇÃO DE RMT								I	R	I	C	C	C	A	I
			ELETROMECÂNICA	CABEAMENTO ELÉTRICO E DADOS								I	I	R	C	C	C	A	I
				EQUIPAMENTOS								I	I	R	C	C	C	A	I
				COMISSIONAMENTO								I	I	R	C	C	C	A	I
			QSMS	QUALIDADE								I	C	C	R	I	I	A	I
				SEGURANÇA								I	C	C	I	R	I	A	I
				MEIO AMBIENTE								I	C	C	I	I	R	A	I
				SAÚDE								I	C	C	I	R	I	A	I

RACI		
	R	Responsável
	A	Aprova
	C	Consultado
	I	Informado

Source: Researchers' Data

IV. DISCUSSION AND CONCLUSION

The data presented in this study underscores the complexity of wind farm implementation projects, demonstrating the need for integrated management of technical, organizational, and strategic aspects. The use of structures such as the WBS (Work Breakdown Structure) and OBS (Organizational Breakdown Structure) proves essential for organizing scopes, assigning responsibilities, and ensuring an efficient interface between the project's sectors and teams.

The integration of these structures through a RACI Matrix stands out as an efficient tool to enhance communication, resource management, and accountability within the project scope. The use of the RACI chart in both Civil and RMT BoPs has proven to be a robust solution for aligning deliverables with responsible parties, ensuring that all stakeholders are aware of their roles and activities.

The application of this methodology by the company studied highlights the relevance of customizing management tools according to the specific needs of its projects and its area of expertise. It is recommended that the WBS and OBS be broken down into more manageable levels, contributing directly to efficient project planning and production control by enabling the preparation of reliable schedules, meeting deadlines, creating detailed budgets, cost control, supply plans, quality management, assertive safety actions, and environmental control measures.

Expanding the RACI Matrix to other project management disciplines can yield additional benefits, such as improved communication management, resource management, risk management, maintenance management, human resource evaluation, among others. The WBS and OBS also serve to standardize project data, acting as an integrative source for assembling electronic dashboards in software, keeping information readily accessible to project managers.

Data generated from completed projects can turn into lessons learned and input for new ventures. In conclusion, effective management of wind farm projects plays a vital role in Brazil's energy transition. The development and implementation of best practices, combined with the use of management tools, position companies in the sector—both entrepreneurs and service providers—as key players in promoting a more sustainable and competitive energy matrix. These practices highlight the importance of investing in new methodologies and training professionals to manage more complex and dynamic projects in the renewable energy sector.

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