


# Analyzing the Logistics of the Brazilian Book and Teaching Material Program: a sociotechnical strategy to inform optimization

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**Abstract:** The National Book and Teaching Material Program, formulated and executed by the Brazilian Ministry of Education and the National Education Development Fund, aims to ensure that students and teachers in Brazilian public schools have the constitutional right to access teaching materials. The program's logistics are complex, requiring the timely and cost-effective delivery of thousands of tons of teaching materials to public schools across thousands of Brazilian municipalities. A sociotechnical analysis is essential to comprehend the logistics challenges of such a program, as it enables considering social, normative, and technical aspects in a comprehensive and integrated manner. This article presents a qualitative analysis of the program logistics by applying different sociotechnical artifacts. The findings reveal a complex problem involving diverse processes and stakeholders who must adhere to several norms, adopt different computer systems, and rely on a direct and intense communication culture. Identifying key attention points and acknowledging the unique Brazilian context, the article argues that a sociotechnical perspective is crucial for understanding the problem's complexity and informing the design of solutions to optimize the program's logistics.

**Keywords:** Sociotechnical Analysis, Logistics, Book and Teaching Material, Public Education

## 1 Introduction

The National Book and Teaching Material Program (PNLD<sup>1</sup>) is developed and implemented by the Ministry of Education (MEC<sup>2</sup>) and the National Education Development Fund (FNDE<sup>3</sup>) to ensure that students and teachers in Brazilian public schools have access to teaching materials, as mandated by the constitution [Brazil, 2017]. To participate in the program, state and municipal education networks and those with agreements with public authorities (e.g., philanthropic non-profit institutions) must indicate their interest via pre-established memberships.

PNLD is a complex program that covers around 130 thousand schools and distributes approximately 153 million books yearly [FNDE, 2023]. It encompasses different stages, including the publication of notices, validation, material selection by schools, acquisition from publishers, distribution, and monitoring deliveries. Since 1995, the delivery of PNLD books and materials has been managed by Correios, the public posting organization [Cassiano, 2007].

Given the sociotechnical nature of PNLD, investigating and optimizing the program's logistics is challenging. On the social front, the program plays a vital role in ensuring access to quality teaching materials for all public schools in Brazil, a vast and diverse country marked by structural inequalities. On the technical side, the PNLD constitutes a significant portion of the Brazilian publishing market, and its logistics pose a large-scale optimization for the delivery of 12 to 17 million orders annually, organized into roughly 280 thousand pallets [FNDE, 2023].

In 2020, AgênciaBrasil [2020] reported that PNLD distributed approximately 80 thousand tons of books to students across 5,570 municipalities. The logistics for this substantial volume of books have high complexity and operational peculiarities. Brazil is the fifth-largest country in territorial extension, and the logistics operation spans the entire national territory, including remote counties. Deliveries are strategically concentrated within a predefined timeframe according to the school calendar, ensuring that schools receive materials before the classes have started. Notably, book production and delivery follow the annual period schools select their materials, typically between July and August.

Additional factors increase the logistics complexity:

<sup>1</sup>“Programa Nacional do Livro e do Material Didático”, in Portuguese.

<sup>2</sup>“Ministério da Educação”, in Portuguese.

<sup>3</sup>“Fundo Nacional de Desenvolvimento da Educação”, in Portuguese.

schools and teachers can choose teaching materials from an extensive catalog, creating orders tailored to their specific needs and preferences. Consequently, each school, whether in urban centers or remote rural areas, compiles orders of books produced by various publishers, potentially from different regions. Therefore, ensuring that books reach every student before classes have started is a logistical challenge and, more importantly, a social imperative. This perspective aligns with Oliveira and Santos [2015], who advocate broadening traditional criteria in state contracting to implement public policies by incorporating elements that consider the social impact of these contracts.

The current logistics of PNLD are robust and decentralized and operate on different systems with diverse domain rules and stakeholders. The distributor (i.e., Correios) has developed infrastructure tailored to the demands and characteristics of the program. The knowledge encompassing the entire PNLD process has evolved and refined over 85 years. Due to the program's high complexity and substantial practical and theoretical significance, a thorough examination involving modeling, heuristics, and optimization algorithms is necessary, as demonstrated in the study by Dereniewicz *et al.* [2023]. However, for a comprehensive understanding of the problem and optimization efforts to align with social responsibility, such work must be guided by sociotechnical knowledge. This knowledge must explicitly consider the program's purpose, social nature, diverse stakeholders, core processes, and insights gained from decades of running the program.

Recognizing the sociotechnical nature of the PNLD logistics, we have conducted qualitative research to comprehend and analyze the logistics and inform possible improvements for the program. This research involves scrutinizing historical data, indicators, legal documentation, technical specifications, and processes derived from the extensive experience of stakeholders in the program execution.

In this article, we present the findings of the PNLD logistics analysis, recognizing the need for a sociotechnical approach that encompasses technical, formal, and social aspects in an integrated manner [Stamper *et al.*, 2000]. This approach entails considering the norms and technological infrastructure in use, the interdependencies among the involved parties, and the particularities of the Brazilian context. Without a sociotechnical perspective, there is a risk of overlooking critical aspects that define the social nature of the problem and adopting a restricted technical perspective. These aspects reveal the types and forms of plausible interventions that could be implemented and contribute to the overall purpose that justifies the program's existence.

Building upon the results and discussions presented in Castellano *et al.* [2023], this article further explores how the extensive diversity of stakeholders, concepts, processes, systems, and norms renders PNLD logistics a complex problem, underscoring the necessity for a prevailing social perspective over an inherently technical one. The apparent duality between a social and a technical perspective in PNLD logistics must be viewed in terms of focus and priority. Addressing the PNLD logistics requires a sociotechnical approach that cohesively considers human, social, organizational, and technical aspects [Baxter and Sommerville, 2011]. Even when these aspects are approached systematically and

integratively, prioritizing technical and formal aspects first may lead to their dominance, potentially overshadowing the actual needs that technical and formal solutions should address. Instead, the approach should start by comprehending the social world and its complexity, progressing toward understanding and defining the formal and technical dimensions [Pereira and Baranauskas, 2017].

The subsequent sections of this article are organized as follows: Section 2 presents some relevant related works and briefly describes the main events in the PNLD evolution, and Section 3 outlines the research method and materials employed for this research. Section 4 provides an overview of the results derived from the stakeholder analysis; Section 5 synthesizes the key concepts that define and operationalize PNLD logistics; Section 6 summarizes the various norms and rules identified; and Section 7 maps the logistics process, illustrating its breadth and complexity. Finally, Section 8 outlines some points of attention derived from the previous sections, and Section 9 concludes with final remarks.

## 2 Related Work and Milestones

Although we have found no directly related work, several works relate to or inform different aspects of our research, mainly regarding the studied domain, the purpose of our study, the adopted methods, or the theoretical ground.

Capella [2011] analyzes the evolution of Brazilian public administration, emphasizing electronic government policy, over the last decade. Using government sources and national and international bibliographic reviews, the author highlighted the scarcity of academic reflection on the topic and the difficulties public managers face in implementing actions in this field, including challenges for advancing electronic government policies in Brazil.

Analyzing the transformation of postal services in the face of the Internet and new ICTs, Silva *et al.* [2022] highlighted that post services were revitalized by logistics and online commerce, boosting the sector's revenues. However, despite the significant increase in orders worldwide, unequal access to services persists, especially in less developed countries. Correios, the current distributor of PNLD plays crucial social roles in the Brazilian context, although issues about costs and lack of competition persist. The study by Silva *et al.* [2022] seeks to understand the PNLD's logistical process, suggesting improvements in the distribution of educational materials in Brazil and recognizing the importance of Correios in this process. Although the private logistics market is expanding, Correios continues to be the largest logistics operator in Brazil, reaching all regions of the country, including the most remote ones. Alternative solutions, such as consortiums of companies, can be considered, but it is necessary to carefully evaluate their implications for managing PNLD distribution.

Rodrigues [2022] addresses the implementation of PNLD, highlighting its complexity and importance for public education. Based on the author's experience as an educator and participant in the PNLD since 2009, the study seeks to understand the participation of state agents in the program cycle, identify challenges, and propose improvements. Santos *et al.* [2017], in turn, present a case study of the postal service

focusing on the logistics challenges of PNLD. The study recognizes the PNLD's logistical efficiency and highlights the importance of strategic planning, indicating that investments in ICT are necessary to overcome challenges such as precarious infrastructure and to improve the stages of posting and distributing teaching materials continuously.

The study by Lima [2018] highlights the unique challenges faced by logistics in the Amazon region, especially in the distribution of textbooks, and suggests several strategies to improve this process. Among the challenges, the importance of exploring and implementing new ideas and technologies, investing in information systems and warehouse management, and ensuring adequate training for the employees involved stands out. Similar challenges were highlighted by Mathias [2015], who sought to optimize the Correios operational flow management model for the distribution of PNLD orders. Analyzing existing processes and identifying opportunities for improvement, the author identified points of rupture, such as the lack of systematized management and the need to improve the information systems used in the logistics processes.

The studies by Silva *et al.* [2022], Rodrigues [2022], Santos *et al.* [2017], Lima [2018], and Mathias [2015] explore the theme of PNLD logistics in different aspects that confirm and complement each other. These studies bring into discussion different issues related to the technical, formal, or social aspects of PNLD that must be discussed in an integrated way.

A theoretical and methodological ground must be explicitly adopted and explained for such an integrated sociotechnical analysis to add to the debate. In the Information Systems field, Stamper *et al.* [2000] Organizational Semiotics is one of the most relevant foundations for sociotechnical analysis. It understands society as a social system governed by norms and accounts for its informal, formal, and technical information systems. Drawing on Organizational Semiotics and a phenomenological understanding of the human-technology-society relation, Baranauskas *et al.* [2024] have developed and applied a framework she named Socially Aware Design, proposing methods and design practices that ally systems design with social activities with the interested parties.

Drawing on Baranauskas' foundations, Piccolo and Pereira [2019] analyze how technology impacts culture and propose strategies for culturally informed design, exemplified by case studies in Brazil. The study highlights the relevance of cultural factors and presents some key issues to consider, such as stakeholders' diversity, behavioral patterns, interests, and values. Other studies have conducted sociotechnical analysis grounded on Stamper's ideas in different domains. Ferrari *et al.* [2020] used artifacts and practices to identify requirements for a voice-based game to support speech therapy exercises; Miranda *et al.* [2010] investigated and developed adjustable interactive rings to support inclusive interaction with Digital TV; and Buchdid *et al.* [2019], in turn, worked in the situated context of a TV broadcast company and proposed the Pro-iDTV model, a design process based on sociotechnical principles for developing applications for interactive TV.

While the studies from Silva *et al.* [2022], Rodrigues [2022], Santos *et al.* [2017], Lima [2018], and Mathias [2015] suggest the need to look at PNLD logistics more broadly, the studies from Buchdid *et al.* [2019], Miranda

*et al.* [2010], Ferrari *et al.* [2020], and Piccolo and Pereira [2019] explore the foundation brought by Stamper and Baranauskas, showing the viability to conduct sociotechnical analysis in different scenarios. Methods and artifacts, such as stakeholder and norm analysis adopted in our research, are exemplified in these studies and combined with other artifacts to help organize the informal, formal, and social levels relevant to understanding an organization and its situated problem.

## 2.1 The PNLD History

The current PNLD model had its roots in the programs initiated since the National Book Institute was founded in 1937 [Rodrigues, 2022]. From a historical perspective, the early initiative to establish the PNLD dates back to Decree-Law No 93, issued on December 21, 1937. Originally named the National Book Institute, the program was created to publish rare or valuable works that held significant cultural importance for the country, expanding the publication of books nationwide and fostering importation. The initiative also aimed to establish and upkeep public libraries, contributing to the country's cultural development [Brazil, 1937].

After establishing the National Book Institute, different decrees shaped the book policies in Brazil. Decree-Law No 1,006 created the National Textbook Commission and marked a comprehensive policy for textbook production, importation, and use [Brazil, 1938], consolidated by 1945's Decree-Law No 8460. Notably, Article 5 of this decree imposed restrictions on teachers, limiting their autonomy in choosing the books to be used with students [Brazil, 1945].

The Technical Book and Textbook Commission, established by Decree No 59,355 in 1966, stemmed from an agreement between the MEC and the North American Agency for International Development. The commission's primary purpose was to foster, guide, coordinate, and execute activities related to the production, editing, enhancement, and distribution of books under the MEC's supervision [Brazil, 1966]. This agreement ensured sufficient resources for MEC, enabling the distribution of 51 million books free of charge over three years. The continuity of the program was guaranteed by government public financing.

In 1970, the National Book Institute assumed administrative and financial management responsibilities and co-editing books with national publishers started. Simultaneously, the Textbook Program for Elementary Education began to function. However, Decree No 77,107 later closed the National Book Institute, transferring the implementation of the textbook program to the National School Material Foundation. However, due to insufficient resources, most municipal schools were excluded from the program [Brazil, 1976]. Later, Decree No 91,542 implemented the National Textbook Program, introducing several modifications: 1. teachers at each school were now responsible for selecting textbooks, considering regional issues and needs; 2. the quality of materials used in book manufacturing and finishing was improved, promoting increased durability and facilitating textbook banks for reusing the materials; and 3. the scope of book distribution expanded to include 1st and 2nd-grade students in public and community schools [Brazil, 1985].

In 1993, the significance of textbooks in school education was underscored with the Ten-Year Education for All Plan<sup>4</sup> [Gusso, 1993]. This plan marked a big change as the distribution of textbooks gradually expanded to reach all students in Brazil's public school system. Simultaneously, a collaborative effort involving MEC, the Student Assistance Foundation, and UNESCO resulted in the definition of criteria for assessing textbooks [FNDE, 2023]. The plan promoted expansions and improvements in the PNLD, which can be highlighted through some of the program's milestones [FNDE, 2023]:

- 1997: PNLD was expanded with the continuous acquisition of textbooks of literacy, Portuguese language, mathematics, science, social studies, history, and geography for all 1 to 8-grade students in grades of public elementary school.
- 2000: Portuguese dictionaries started to be delivered to 1 to 4-grade elementary school students. For the first time in the program's history, textbooks were delivered a year ahead of their intended use.
- 2001: Services for visually impaired students in regular public schools, offering textbooks in Braille. Presently, students with disabilities also receive books in Libras, enlarged characters, and the MecDaisy version — a program enabling users to convert any text format on the computer into audio.
- 2003: The National Textbook Program for Secondary Education started, and Portuguese and mathematics books were procured for 1st-year students in the North and Northeast regions.
- 2009: The program included the National Textbook Program for Youth and Adult Education, a special modality for adults who have not received basic education at the expected age.
- 2010: The first complete distribution of books for High School and Youth and Adult Education. This year marked the initial instance where books on Foreign Languages, Sociology, and Philosophy were distributed.

Therefore, in pursuit of their social objectives, national book provision programs have undergone transformative processes that have established a formal and technical infrastructure, resulting in one of the world's most extensive educational materials programs. The activities involving acquiring and distributing textbooks and literary books, formerly managed separately by the National Textbook Program and the National School Library Program, were consolidated through Decree No 9,099 [Brazil, 2017], resulting in the current PNLD. The expanded scope and integration allowed for the inclusion of various materials to support educational practices beyond didactic and literary works. These additions encompass pedagogical works, educational software and games, materials for reinforcement and correction, training materials, and resources intended for school management.

### 3 Materials and Methods

To conduct the sociotechnical analysis, seven documents provided by the FNDE, which specify and regulate the logistics of the PNLD, were considered. These documents include [COLED, 2017], [SEI/FNDE, 2017], [SEI/FNDE, 2021], and [Valente, 2021]. Five primary activities were conducted:

1. *Identification of Stakeholders*: A documentary analysis was conducted to identify individuals involved in logistics, supported by analysis and visualization using the Stakeholder Diagram from the Organizational Semiotics [Stamper et al., 2000].
2. *Conceptual Analysis*: A mapping of concepts characterizing the distribution problem was carried out, representing them in a Unified Modeling Language (UML) Conceptual Model [Sommerville, 2011].
3. *Identification of Norms and Rules*: The rules governing PNLD logistics were mapped, and part of them were analyzed utilizing the Organizational Semiotics' Norm Analysis Method [Stamper et al., 2000] to enhance their representation.
4. *Process Mapping*: Subprocesses and activities constituting PNLD logistics were identified, and the Business Process Model and Notation (BPMN<sup>5</sup>) [White, 2004] notation revealed promising to represent the process.
5. *Identification of Points of Attention*: From the four previous activities, points of attention regarding the logistics were identified to inform its improvement and further interventions.

To execute the five activities, analysis and study practices with different artifacts and techniques were aligned with workshops involving researchers and FNDE representatives to validate preliminary results and solve emerging doubts. The initiative started in February 2022 and produced a technical report by February 2023. Following the publication of preliminary results at WCGE 2023 [Castellano et al., 2023], the work progressed to conceptual analysis, norms identification and analysis, and the logistics process mapping, as detailed in Sections 4, 5, and 6, respectively.

The documentation provided by FNDE and the outcomes of preceding activities were used as input to the next ones. Three researchers individually analyzed each document to i) identify stakeholders involved in logistics; ii) map terms indicating potentially relevant concepts for describing or characterizing the problem; iii) identify and structure norms that specify and govern PNLD logistics; and iv) map stages, processes, and activities constituting the PNLD logistics process.

Next, the information collected by each researcher was revised by two additional researchers. When discrepancies in conclusions arose, discussions were held to arrive at a consensus and construct a joint understanding. This collaborative approach may be considered a kind of triangulation based on the researcher's interpretation, which helps to ensure a robust and thorough analysis.

<sup>4</sup>"Plano Decenal de Educação para Todos, 1993-2003", in Portuguese.

<sup>5</sup>Object Management Group (OMG), BPMN 2.0: <https://www.omg.org/spec/BPMN/2.0>.

Over the months, seven workshops (four remote, one in person in Curitiba, and two in person at the FNDE in Brasília) were conducted: after the workshops, a diary was produced and summarized with observations to inform and refine the analysis. The work was completed by four researchers and discussed/validated with two other project researchers; two FNDE representatives participated in all workshops with the researchers, validating the results presented. More than a dozen people from the research group and FNDE participated in different workshops to learn about the project and contribute with suggestions and questions.

## 4 Analysis of Stakeholders

The documentation served as input for the stakeholder analysis, and three researchers independently analyzed each document to map potential stakeholders. Drawing on Stakeholder Theory [Donaldson and Preston, 1995] and Organizational Semiotics [Stamper *et al.*, 2000], any individual, organization, or entity with an interest in the problem under analysis and the potential to be affected directly or indirectly by the problem or its (non) solution was considered a candidate stakeholder. Utilizing the Stakeholder Diagram [Stamper *et al.*, 2000], Figure 1 illustrates about 40 stakeholders distributed across different layers of the diagram. Based on the Stakeholder Theory [Donaldson and Preston, 1995], the diagram represents different types of entities that exert influence or are influenced by the PNLD logistics problem.

In Figure 1, the central layer, labeled “Operation”, signifies the core problem being analyzed: the logistics for book distribution. In the “Contribution” layer, numerous stakeholders play key roles in the planning and direct execution of book distribution. These stakeholders work to ensure that the program effectively achieves its objectives.

The “Source” layer reveals several stakeholders and encompasses at least five computer systems responsible for storing, processing, and disseminating data at various process stages. Additionally, diverse stakeholders are associated with the Distributor and Publishers (producers), both essential to the distribution process. Within this layer, stakeholders labeled “Centralizers” and “Distribution Centers” underscore the need for centralization in operationalizing the book distribution process, highlighting that the stakeholder responsible for the delivery of books must not only ensure effective distribution but also manage the handling and storage of substantial quantities of objects, requiring robust infrastructure and high logistical capacity.

In the “Market” layer, the support of Education Departments at the municipal (SEMED, Municipal Secretary of Education) and state (SEDUC, State Secretary of Education)<sup>6</sup> levels are indispensable for delivering books and managing exceptions. These departments ensure the existence of a broad network of stakeholders capable of receiving books and directing them to their final destinations when direct delivery is not possible (e.g., for Rural Schools). These agents are also key to monitoring the successful delivery and use of books.

In the most external layer, “Community”, various stakeholders act as regulators or supervisors, influencing the logistics and contributing to its configuration and execution. Additionally, while not directly receiving books or actively participating in the distribution process, stakeholders such as Rural Schools, Students, and Teachers benefit from its execution and bear the consequences of failures. This layer underscores the diverse range of stakeholders that impact or are impacted by PNLD logistics, even without direct involvement.

The Stakeholder Diagram provides valuable insights, revealing a substantial number of individuals involved in PNLD logistics and the considerable diversity of stakeholders with different levels of influence. This diversity underscores the complexity of the problem, which requires the management of participation, demands, interests, resources, and risks across an extensive network of stakeholders.

When looking at the distribution of stakeholders across layers, it is evident that students and teachers occupy the outermost layer, constituting the *raison d’être* of the program. Therefore, the emphasis on the social perspective for the PNLD’s purpose renders the logistics problem inherently relevant and must be explicit. Otherwise, external analyses may inadvertently adopt an essentially technical perspective focused on minimizing operational costs — which may compromise the program’s ability to fulfill its purpose. If a technical perspective comes first, primary stakeholders — schools, students, and teachers — risk becoming secondary stakeholders, with their needs sent to the background due to an appealing drive for cost reduction imposed by control and financing bodies.

### 4.1 Grouping Stakeholders

During the documentation analysis, it became apparent that standardizing nomenclature and obtaining more detailed information about specific stakeholders was necessary. These details cover the definition and roles played by stakeholders and explain the functioning of various technical systems, information flows, responsibilities, and rules each stakeholder must adhere to at different stages or activities of the distribution process. Standardizing stakeholders’ names and mapping their basic relationships is the first step toward a better understanding.

Figure 2 represents straightforward connections indicating that a stakeholder “is a type of” or “is part of” another stakeholder or a specific class of stakeholders. This representation serves to visualize the multitude of interested parties and a grouping relationship based on similarity. For instance:

- Within the FNDE’s structure, there are units (e.g., DIFIN<sup>7</sup> and Coled<sup>8</sup>) dedicated to logistics and distribution and different computer systems that support parts of the distribution process.
- Regulatory and monitoring bodies also play a role, defining rules and inspecting results, guiding and restricting PNLD activities (e.g., MEC).

<sup>6</sup>Portuguese acronyms for “*Secretaria Municipal de Educação*” and “*Secretaria Estadual de Educação*.”

<sup>7</sup>Portuguese acronym for Financial Board.

<sup>8</sup>Portuguese acronym for Logistics and Distribution Coordination.

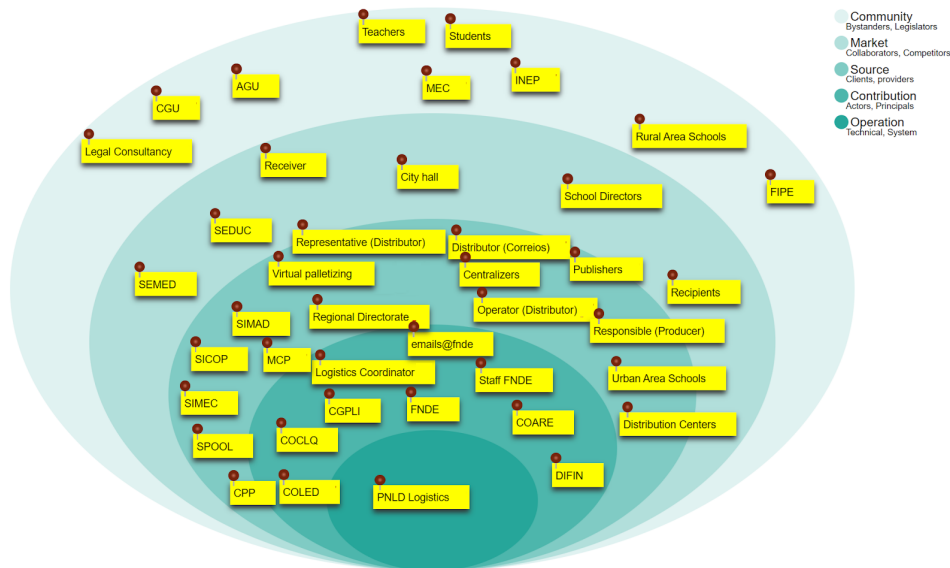


Figure 1. Stakeholder Diagram represented in the DSC Tool [Silva et al., 2016].

- Producers (i.e., publishers) and the Distributor (i.e., the Correios) stand out as critical stakeholders in the production and distribution chain, each having associated stakeholders and often being referred to by different names.
- Various stakeholders can act as receivers of book orders and collaborate to ensure that the target audience is effectively attended (e.g., rural and urban schools, SEMED, SEDUC).
- Different systems support PNLD distribution activities, starting when books are selected and finishing when delivery is complete, and distributor and producers are paid.
- The target audience is students, teachers, and school directors. The distribution and the entire PNLD program are conceived for them.

Understanding more substantial relationships, particularly those indicating dependencies between stakeholders, also helps understand the distribution complexity. In the Enterprise Resource Planning (ERP) systems realm, Maglyas and Smolander [2014] have identified relationships between stakeholders that can be valuable to map and analyze in PNLD logistics. Adapting the types of relationships proposed by the authors, the following may be beneficial to map onto the identified stakeholders: collaboration, cooperation, supply, monitoring, and control.

**Collaboration:** Both stakeholders, A and B, act together for mutual benefit to fulfill an objective, perform a task, and achieve some specific result of common interest. This relationship is characterized by a relatively high level of openness on both sides. Example: SEDUCs, SEMEDs, and City Halls collaborate with rural schools in receiving and sending book orders, enabling students and teachers to receive teaching materials before classes start.

**Cooperation:** Both stakeholders, A and B, work for their benefit but collaborate to achieve synergy for a common goal. A low level of openness on both sides characterizes this relationship. Example: Producers and the Distributor cooperate

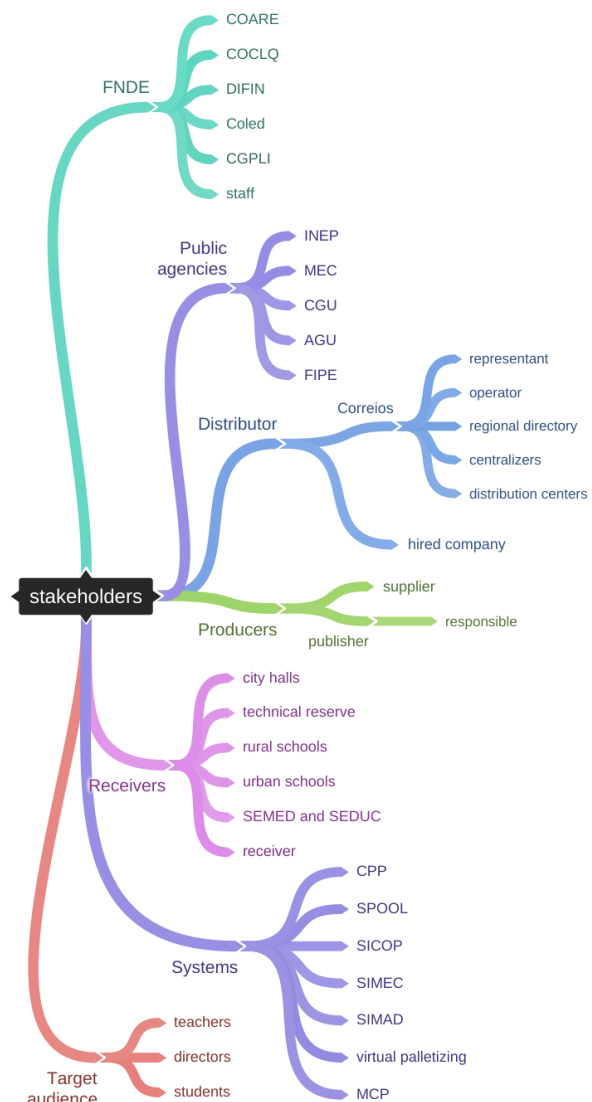


Figure 2. Grouping related Stakeholders.

in scheduling and loading book orders at the Producers' or the Distributor's depots. These stakeholders also cooperate by providing data and receipts to each other, enabling the payment for services.

**Supply:** Stakeholder A provides inputs (e.g., data, objects, resources, expertise) to stakeholder B. This relationship is characterized by a dependency, not necessarily exclusive, of stakeholder B on stakeholder A. Example: FNDE provides each Producer with a file containing the virtual palletization of the orders it must produce and group. Producers depend on the file sent by the FNDE to know how their orders should be palletized.

**Monitoring:** Stakeholder A assesses the situation of an activity or event under the responsibility of stakeholder B and reports the results. This relationship is characterized by a power or responsibility of stakeholder A over stakeholder B. Example: FNDE technicians monitor the conditions of production and delivery of materials in the Producers' depots. Conditions refer to the characteristics of materials and pallets and the posting conditions (i.e., loading pallets onto the Distributor's trucks).

**Control:** Stakeholder A exercises the role of (not) authorizing the execution of some action or task by stakeholder B under specific conditions or situations. This relationship is characterized by a normative power of stakeholder A over stakeholder B. Example: When the weight variation of an order exceeds the tolerated limit, the Producer must request authorization from FNDE to send the product with the new weight. Otherwise, the Distributor is not authorized by FNDE to receive and transport the books. Therefore, the Producer and the Distributor depend on FNDE authorization to proceed with the order posting.

**Delegation:** Stakeholder A delegates to stakeholder B the execution of an action or task within its responsibility. This relationship is characterized by a dependency of stakeholder A on stakeholder B. Example: The FNDE delegates to the Distributor the task of routing the orders, recommending prioritizing orders to more distant destinations. The FNDE adopts strategies to ensure this prioritization, such as sending data for orders to more distant destinations first for production but without directly interfering with the routing process carried out by the Distributor.

Mapping stakeholder relations resulted in 75 relationships initially identified, which were then consolidated into 29 central relationships. This relevant amount of relationships supports Valente [2021] claims that the PNLD's complexity stems from its ambitious objective and the necessary interaction between various public administration bodies.

Figure 3 depicts the quantity of each relationship type: Delegation (34.5%, 10 relationships), Control (17.2%, 5 relationships), Supply (17.2%, 5 relationships), and 3 relationships (10.3%) each for Monitoring, Collaboration, and Cooperation. Although Supply relationships are not the majority, they are more complex, involving logistics execution and representing more activities, dependencies, data transfer, and systems' data updates. Conversely, delegation relationships appear in higher numbers because they are specific and tied to particular activities.

Stakeholders like MEC, Schools, Students, and Teachers, located in the outermost layer of Figure 1, naturally have

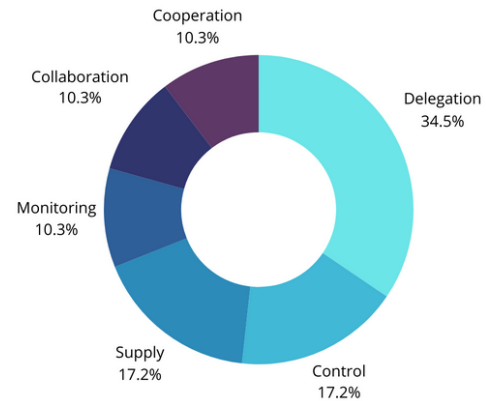


Figure 3. Mapped Relationships among the Stakeholders.

fewer relationships as they are distant from logistics operations. However, this community layer is where stakeholders must directly benefit from successful distribution.

On the other hand, FNDE, Distributor, and Producers play central roles in PNLD Distribution and exhibit the highest number of relationships. FNDE serves as the orchestrator of PNLD with 28 relationships, underscoring its key role in logistics — from providing data and controlling the process to delegating responsibilities and monitoring activities and outcomes. The Distributor ranks second with 14 relationships, engaging with various stakeholders to execute logistics and material delivery — from monitoring and cooperating with producers to collaborating with SEMED and SEDUC to deliver books to their final destinations. Producers also maintain many relationships (11) since they rely on information from other stakeholders to organize material production, palletization, and effective delivery.

In line with the understanding that community stakeholders are the primary focus of logistics, the mapped relationships emphasize that the success of logistics hinges on strong interaction among FNDE, Distributor, and Producer. For instance, Valente [2021] underscores that failing to distribute teaching materials to 0.5% of students in 2002 would mean neglecting 163 thousand students. The interaction among these three stakeholders requires direct, swift, and effective communication to ensure a 100% successful delivery.

The stable nature of these stakeholders facilitates efficient communication, their clear understanding of responsibilities, and evident commitment to logistics execution — a result of repeated interactions over the years and the continuity of these relationships. Both the Distributor and the Producers establish dedicated structures for PNLD, with Producers aiming at the extensive market represented by PNLD and the Distributor as a public company, handling delivery and storing the technical reserve of materials. The stability of these three stakeholders and the public nature of FNDE and Distributor are critical to the overall success of logistics.

## 5 Concept Mapping and Model

In a complex problem like PNLD logistics, numerous concepts are essential to represent the problem and facilitate its understanding (see Figure 4).

The documentation analysis revealed over fifty concepts,

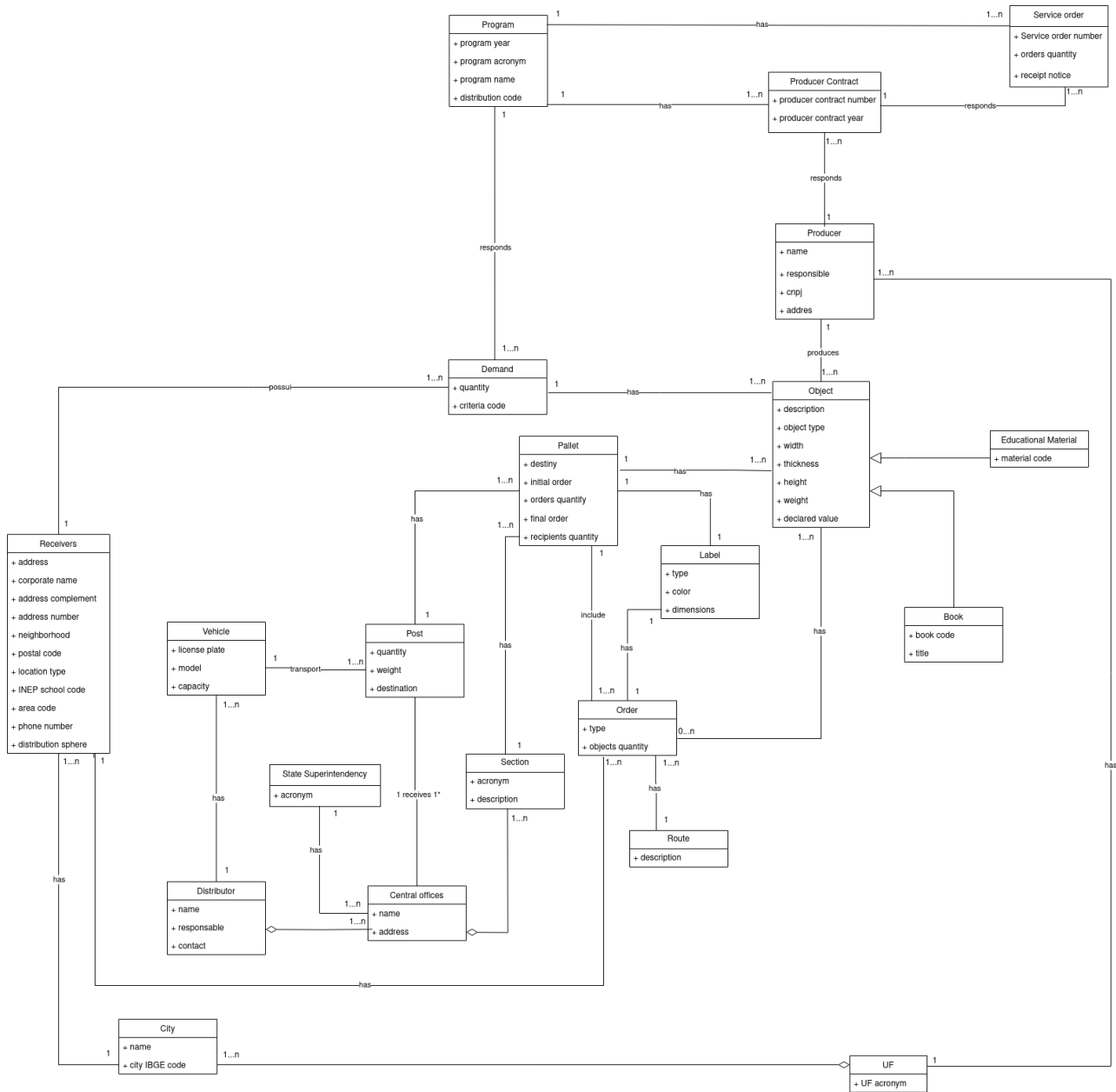


Figure 4. Conceptual Model for the PNLD Distribution.



most commonly relating to materials, processes, stakeholders, and activities. During the study, several problems were identified and resolved, such as different names for the same stakeholder — e.g., Correios, Distributor, and Contracted Company refer to the same stakeholder responsible for receiving and managing orders and delivering books to schools — and inconsistencies in specifications: concepts that appear with identical names but are detailed with different properties or specifications. Such inconsistencies could trigger ambiguity problems and hinder technical interoperability between systems.

After identifying and clarifying concepts solving ambiguities and inconsistencies, they were analyzed regarding their relationships and properties: 21 concepts had their relationships and properties mapped and depicted in the Conceptual Model, as illustrated in Figure 4. Reinforcing the results from the stakeholder analysis, four prominent stakeholders emerge when grouping these concepts by their association with mapped stakeholders: FNDE, Producer, Distributor, and Receivers.

The concepts directly associated with FNDE relate to the resources utilized to sustain PNLD and outline its role as the orchestrator and facilitator of the entire program. Concepts related to the Producer present operational specifics necessary for the production and delivery of educational materials adhering to the norms defined by FNDE. Concepts linked to the Distributor reveal an extensive logistics infrastructure capable of handling the complexity of the distribution problem. Utilizing central offices and sectors, the Distributor established its extensive infrastructure with a large-scale capacity for book distribution to meet PNLD distribution's needs. Concepts about the Receivers underscore the multi-organizational nature of distribution, which is crucial for ensuring successful material delivery even in exceptional circumstances or conditions.

Beyond quantity and diversity, the interrelationships among concepts and the attributes that characterize them serve as another indicator of the complexity within a domain. The relationships between concepts and their essential attributes must be explicit for a thorough and organized understanding of the distribution problem. This knowledge informs the conceptual modeling of the distribution problem, which serves as a communication tool among stakeholders, particularly those engaged and invested in proposing solutions to the problem.

Starting from the Producer, the Conceptual Model reveals that a producer makes one or more objects, such as books, educational materials, or any other educational resource. These objects are associated with one or more orders. Each order possesses a label, is grouped on a pallet, and has a route. The relationship between objects, books, and educational materials raised questions and underscored the necessity of specifying and documenting rules for transporting educational materials other than books. These rules likely already exist but are currently undocumented.

Examining the concepts in isolation reveals that the Producer's task concludes upon delivery to the Distributor, and the Distributor's task ends when materials reach schools or an alternative receiver. In contrast, FNDE's work extends until the book is accessed by its target audience: students

and teachers. Therefore, looking at these concepts in an integrated manner is necessary as the logistics success results from each stakeholder having completed its tasks and responsibilities.

The Conceptual Model, with its concepts and relationships, helps to demonstrate the distribution robustness and to inform the design of technologies and systems to support the logistics process. The conceptual model represents the PNLD logistics problem domain, aiding in comprehending how the logistics system operates. This model is valuable for maintaining interoperability among existing systems, facilitating the evolution of legacy systems, and creating new ones. Additionally, it can mediate communication and understanding among various stakeholders, particularly those who may be less familiar with the logistics operations, such as stakeholders from the market or the community layers.

## 6 Norms Analysis

Adopting a sociotechnical approach to comprehend the PNLD logistics problem involves acknowledging that this problem exists and holds significance within a social system composed of informal, formal, and technical information systems [Stamper *et al.*, 2000]. Information technology (i.e., computational/technical systems) is limited in capturing, storing, transmitting, processing, and presenting data. Encompassing all information technology are numerous norms — rules, prescriptions, directives, and recommendations — aimed at ensuring PNLD's logistics and distribution fulfill the objective of timely delivering quality teaching materials to its target audience across all regions of the country. However, these norms only operate within the social and human context where they hold meaning, influenced by the dynamics of the social world and the capability of individuals and their organizations to comprehend and manage these norms and systems.

Therefore, another relevant step to delineating the operation (and complexity) of PNLD logistics is mapping and elucidating its norms, understanding the context that assigns meaning to them, and discerning the technical and social systems underpinning their execution. Consistent with Stamper *et al.* [2000] definition, norms reflect regularities in the behavior of members of an organization, facilitating coordinated actions so that all organized behavior is governed by some type of norm.

To systematize and standardize the norms governing PNLD logistics, we identified and extracted the norms from the logistic documents provided by FNDE, and categorized them according to the taxonomy introduced by Von Wright [1963]. Based on the explanations of Pereira *et al.* [2015], four types of norms stand out as particularly relevant for the PNLD context (Figure 5): 1. Rules, 2. Prescriptions, 3. Directives, and 4. Ideal rules.

1. *Rules* encompass regulations or principles governing conduct within the logistics, akin to game rules, grammar, or logic principles. Rules delineate how activities within PNLD logistics should be conducted.
2. *Prescriptions* function as commands, permissions, or prohibitions, comparable to state laws dictating what

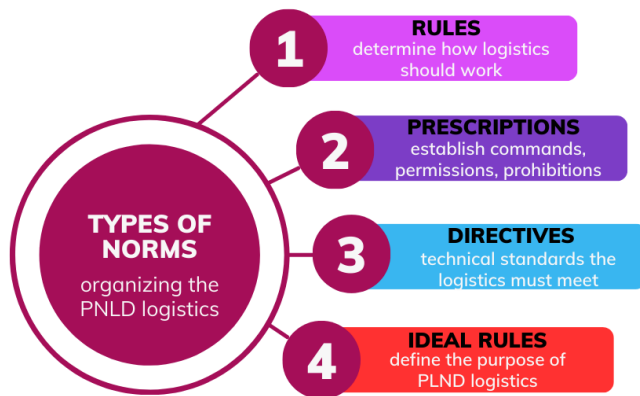


Figure 5. Types or groups of norms that specify PNLD logistics.

stakeholders can or cannot, should or should not do in distributing teaching materials. Prescriptions operate as standards determining the actions permitted or required from stakeholders.

3. *Directives* in PNLD logistics are akin to technical standards, specifying the means to achieve a particular end. Examples include directives outlining the dimensions and characteristics of pallets, detailing label creation, and providing instructions on how books must be accommodated in packaging.
4. *Ideal rules*, in turn, constitute a distinct type of norm in PNLD logistics: in contrast to the preceding three types, which prescribe actions, ideal rules qualify and define the characteristics of what is considered good and desirable in logistics and distribution. For instance, ideal rules in PNLD logistics delineate the objectives of delivering materials quickly and at the lowest possible cost, providing quality materials to the target audience, and ensuring equal-quality service across all regions of the country.

As expected, the documentation analysis identified over four hundred norms about processes, activities, specifications describing a concept or object, stakeholder responsibilities, conditions under which operations must occur, etc. For instance SEI/FNDE [2017]:

- Rules for payment of services: “*Payment for the distribution service occurs per order.*”
- Prescriptions for Producer postings: “*All postings must be previously agreed with the distributor.*”
- Directives for order formation: “*Standard Order - up to 8 kilograms or 16 cm thick. The same pallet may contain books for different destinations, sometimes in multiple municipalities.*”
- Ideal rules for routing: “*Posting for the most distant locations must be prioritized.*”

The identified norms exist in various levels of detail and formality. In certain instances, it becomes challenging to precisely explain the conditions under which a norm should/must be applied and to identify the stakeholder responsible for its implementation, adherence, or verification. Variations in detail and formality may introduce inconsistencies, conflicts, ambiguities, or other issues within these norms, potentially affecting the logistics — or, at least, making its understanding and operation more difficult.

Therefore, in addition to categorizing PNLD norms into these groups, we employed the Norm Analysis Method Stamper *et al.* [2000] to structure all norms categorized as Prescriptions, yielding a comprehensive set of 174 structured norms. Prescriptions are more directly related to behavioral patterns that stakeholders are expected to follow and, therefore, can be specified in the format proposed by [Stamper *et al.*, 2000], which improves their formality and facilitates their audit and automation:

**Whenever** <condition>  
**if** <state>  
**then** <agent>  
**is** <deontic operator>  
**to** <action>

For instance, when considering the prescription “Posts must be carried out in a covered location” we observe that it lacks two crucial elements for ensuring its execution: the condition and the responsible agent or stakeholder. Consequently, this norm must be analyzed within its application context to be correctly understood, as essential information is missing for proper execution. When represented in the structure proposed by the Norm Analysis Method, this norm can be formulated as:

**Whenever** *the posting of pallets occurs,*  
**if** *this posting takes place on the Producer’s premises,*  
**then** *the Producer*  
**is** *obligated (must)*  
**to** *ship the pallets in a covered location.*

In this structure, norms present the necessary elements to ensure that the stakeholder responsible for their execution possesses the required information about the action to be taken and under what conditions.

The description of norms in this format requires considering nuances of their application in the actual context of logistics. For instance, consider the norm prescribing the expected response from the Distributor upon receiving the orders addressing data from the FNDE. The current norm stipulates that “*Within seven business days after receipt, the contracted company will send FNDE a digital file containing information about the composition of orders and the logical palletization of the cargo for distribution of materials.*”

To maintain coherence with the identification of stakeholders and concepts in previous sections, the term “contracted company” is replaced with “Distributor”. Additionally, the norm could be structured as follows: “*Whenever there is a new distribution, if the Distributor receives addressing data for order formation from the FNDE, then the Distributor is obliged to (must) send the digital file containing the virtual palletization to the FNDE within 7 working days.*” In this formulation, the Distributor is in a passive state, and the FNDE is implicitly in charge of guaranteeing that the file was received by the Distributor. Consequently, any delay in confirmation or data transmission issues will directly affect the deadline (e.g., the person responsible for confirming may forget or miss the notification message).

Alternatively, the norm can be specified as follows: “Whenever there is a new distribution, if FNDE sends data for addressing and order formation to the Distributor, then the Distributor must send the digital file containing the virtual palletization to the FNDE within 7 working days.” In this second formulation, the condition triggering the response time count is no longer the receipt of data by the Distributor but rather their transmission by the FNDE. The alteration in the norm condition carries practical implications for logistics: whereas the first formulation implies a responsibility for the FNDE to confirm the transmission of data, the second formulation implies a responsibility for the Distributor to confirm receipt.

The interrelationships between norms are crucial, as one norm can indeed influence the condition, state, or action of another. For instance, a rule specifies that only a legally capable person can certify the receipt of a delivery, and a prescription dictates that orders must be delivered to the ground floor of the receiving institution. When these norms are examined in isolation, it might be challenging to perceive that the first norm significantly impacts the state of the second, given that a qualified individual must be present to receive a delivery. Therefore, the structured norm would be:

**Whenever** there is an attempt to deliver an order,  
**if** a legally able person receives it,  
**then** the Distributor  
**is allowed (should)**  
**to deliver the order on the ground floor of the receiving institution.**

This norm version is more complete and precise than the original one, illustrating that recognizing and analyzing such interdependencies helps to understand the normative framework.

Understanding norms allows for the deduction of their information requirements, as norms typically follow a general format: if <CONDITION>, then <CONSEQUENCE>. The condition part outlines the necessary information for stakeholders to meet the norm, while the consequence part generates information for other stakeholders, either directly or indirectly, through the production and transmission of data. Identifying stakeholders and mapping the norms they must adhere to enables the deduction of their information needs and the information they generate for each other.

As illustrated in this section, the identification and systematization of the norms governing PNLD logistics enable the analysis and standardization of their structure and specifications, which may offer several benefits: i) enhanced precision in specification documents, facilitating comprehension and mitigating issues of ambiguities and inconsistencies; ii) facilitation of checklist development for monitoring and verifying compliance with these norms; and iii) increased possibilities for automation, as certain aspects of these norms are already automated by computer systems or are amenable to automation.

The full set of identified norms is available for online con-



Figure 6. The twelve main stages of the PNLD.

sultation<sup>9</sup> and download.

## 7 PNLD Logistics Process

To comprehensively map and comprehend the PNLD logistics and distribution process, gaining a macro view of the program’s stages or phases is essential. The examination of documents has allowed us to delineate twelve stages, outlined in Figure 6. From stages 1 to 5, the program is announced, and producers submit their book proposals, subject to validation. Transitioning to stages 6 to 9, schools make selections based on their needs and preferences, and FNDE enters into contracts with producers for production. The subsequent stages, from 10 to 12, encompass the logistical processes, which include posting, processing, and ultimately delivering books and teaching materials to schools.

Each stage encompasses distinct processes and activities. From Stage 10 onwards, distribution-related processes and activities come into play, requiring considering decisions, constraints, and regulations from preceding stages. Numerous monitoring and evaluation activities are initiated during this stage until the books reach their designated schools (Stage 12). Distribution tasks involve various stakeholders, are supported by diverse computer systems, and must adhere to many rules and constraints. The distribution process must ensure the logistics and delivery are of the utmost quality, ensuring that books and educational materials are delivered on time and in optimal conditions for all schools nationwide.

The PNLD logistics across the distribution stages comprise five primary activities: 1. Virtual Palletizing, 2. Preparation and Posting, 3. Order Processing and Routing, 4. Delivery, and 5. Monitoring.

1. *Virtual Palletizing* is one of the most crucial activities, meeting diverse criteria such as the number of orders, weight, book type, receiver type, pallet size, and more. In this activ-

<sup>9</sup>[https://docs.google.com/spreadsheets/d/12d6DNtsz4fGy4GQQjaavC\\_RT0xQsSUcB0JD0axGylCY/edit?usp=sharing](https://docs.google.com/spreadsheets/d/12d6DNtsz4fGy4GQQjaavC_RT0xQsSUcB0JD0axGylCY/edit?usp=sharing)

ity, data from book orders placed by schools are utilized to virtually palletize the load to distribute materials. Each pallet contains orders for the same book, often destined for different receivers. The three main stakeholders are FNDE, the Distributor, and the Producers. The FNDE supplies the data for the Distributor to generate virtual palletization. This palletization is then validated by the FNDE and forwarded to Producers. Other stakeholders are engaged in processing the data, validating the work, and monitoring its execution. Additionally, schools, teachers, and students are impacted by virtual palletizing: to meet delivery deadlines with the required quality, the FNDE determines that orders from more distant destinations should be prioritized. This prioritization informs virtual palletizing, influencing the formation of pallets and determining which orders should be palletized and grouped first.

2. *Posting* refers to the logistics and delivery of books from the Producers to the Distributor, encompassing load scheduling, validations, loading (when performed at the Producer's facilities), or delivery (when carried out at the Distributor's facilities). This stage signifies the transition of responsibility from the Producer to the Distributor, who assumes accountability for the quality of orders until the delivery process is concluded. This shift in responsibility establishes a monitoring relationship between the Producer and the Distributor, underscoring the significance of logistics being managed by a public company. While the Producer strives to expedite order delivery for timely compensation, the Distributor must ensure it receives accurate orders produced according to FNDE contracts, adhering to quality specifications.

Posting also underscores the essential requirement for a Distributor equipped with infrastructure capable of handling substantial load collections from various Producers, storing these significant quantities, and executing deliveries to diverse destinations. In the book production process, each Producer organizes its production system to fulfill all orders for each book at a time. This strategy enables speed and cost-effectiveness by minimizing unnecessary changes and reconfigurations in the production chain. Consequently, the Producer dispatches pallets comprising orders for the same type of book destined for different receivers. The Distributor, in turn, must efficiently receive these pallets and then direct the orders to their final school destinations. Because each school's orders may encompass different books potentially produced by distinct producers, the Distributor must manage the orders to deliver all ordered books for each school as quickly and cheaply as possible. This process demands not only logistical capability but also significant storage capacity. Therefore, an effective Distributor requires infrastructure (physical, personnel, computing) capable of handling a substantial volume of objects to be delivered to diverse regions nationwide.

3. *Order Processing and Routing* occur at the Distributor's centralizers, where two operational and computational activities are conducted to facilitate delivery to the final recipients: cargo sorting and batch formation by route. In the sorting, orders destined for the same receiver or nearby receivers are identified, facilitating routing and the creation of batches for delivery. Some practical issues significantly impact the optimization of PNLD logistics and distribution. For

instance, Producers are geographically dispersed across different country regions. As book production advances, these producers must schedule the shipment of loads to the Distributor. These loads are predetermined in the virtual palletizing process, aiming to streamline the distributor's workflow, which involves transferring the loads to their centralizers and organizing the orders for swift and efficient delivery to destinations across the country.

Processing and routing orders involve adhering to different norms and restrictions, including limitations on pallet and transport vehicle capacities, maximum load storage capacities for Producers and Centralizers, and temporal constraints (e.g., deadlines, order production time, and delivery duration). Therefore, Virtual Palletizing and Order Routing are strongly related activities demanding dedicated analysis that will benefit from the outcomes of this sociotechnical analysis, as shown by Derenievicz *et al.* [2023]. However, since the Distributor exclusively performs the routing process, the algorithm and parameters for routing are undisclosed, making them challenging to compare and analyze.

4. *Delivery* in the PNLD distribution involves transporting orders from the Distributor's centralizing facilities to a designated receiver. Typically, the receiver is the school for urban locations or another assigned receiver for rural areas or situations where the school cannot receive the books. In such cases, an alternative receiver accepts the orders and assumes responsibility for their delivery to their final destination (i.e., the school). The orders must be delivered to a legally capable person who verifies the received orders and acknowledges the delivery by signing a receipt. If delivery to the specified address fails, three attempts must be made, and if unsuccessful, an alternative address is considered. Collaboration with municipal and state education departments is vital in handling exceptional cases directly between the FNDE and the Distributor. Receipts for the delivery service, necessary for Distributor payment, are sent in monthly batches by contractual agreements.

5. *Monitoring* is integral across all Posting, Order Processing, and Delivery activities. Monitoring actions aim to ensure that all activities align with the established norms governing distribution. Key areas for monitoring include book production, packaging procedures, order integrity, labels for orders and pallets, book handling conditions, pallet formation, cargo loading and unloading at the post, operation of computer systems, control of posting lists, and exchanging digital files between different stakeholders. Monitoring follows the norms orchestrating logistics and distribution, emphasizing the responsibilities and attributes essential for smooth distribution functioning. Specific checklists guide stakeholders responsible for monitoring these norms.

The mapping of PNLD logistics phases, spanning Stages 10 to 12 of the program, has unveiled over fifty activities across various processes. More than twenty stakeholders play roles ranging from Virtual Palletizing to Posting and Delivery, and at least ten monitoring activities are conducted by different stakeholders, particularly FNDE staff or representatives of the Producer and Distributor. With numerous responsibilities across various stakeholders, dependencies, information production, and a complex workflow, it is necessary to elaborate on the logistics process concerning its activ-

ities, the stakeholders participating in each activity, and the norms stakeholders must obey.

Therefore, depicting the PNLD logistics and distribution process regarding its norms and the stakeholders accountable for adhering to them may enable a coherent and auditable representation of the process (e.g., utilizing BPMN notation). Such a representation paves the way for analyses to optimize the process and propose new computing solutions beyond Virtual Palletizing and Routing, such as solutions that support monitoring the progress of activities and compliance with norms.

## 8 Points of Attention

The findings from the activities discussed in the preceding sections have allowed us to map stakeholders and identify concepts, processes, norms, ambiguities, incompleteness, problems, and risks. These outcomes illustrate the complexity of PNLD distribution and bring attention to aspects that require deeper analysis: some aspects are related to the analyzed documentation, while others are related to the distribution process and their norms. Figure 7 presents an overview of the main points of attention derived from the analysis.

1. *Implicit Roles and Responsibilities*: The PNLD logistics and distribution involve numerous stakeholders, and their roles and responsibilities are challenging to map due to their implicit nature or dispersion across various documents. Making these roles and responsibilities explicit and capable of being verified and audited is necessary. Stakeholder identification and their relations presented in Section 4 show the diversity of stakeholders and can support updating the PNLD documentation.

2. *Operational Bottlenecks in Email Requests*: Important communications (e.g., notifications, change requests, etc.) are sent to email addresses specified in different documents, which presents a flexible approach to address diverse demands as they arise. However, this communication is susceptible to operational bottlenecks, such as lost messages, delayed responses, outdated email addresses, an overload of requests during increased demand for deliveries, and other challenges.

While email-centered communication allows for a direct and responsive interaction between stakeholders, it can encounter limitations if the number of Producers increases or when distribution involves multiple entities. This communication style can be effective as long as the scale is manageable and there is a sufficiently sized and experienced team to handle these demands. Yet, with growth or complexity, alternative approaches should be considered to ensure timely and efficient responses, such as anticipating situations in which the FNDE's analysis, authorization, or intervention will be necessary.

3. *Formality and Completeness of Norms*: results revealed that specifications, restrictions, and regulations exist at varying levels of detail and formality. This variability sometimes makes it challenging to discern the conditions under which a norm applies and identify the stakeholder responsible for its execution, compliance, or verification. As discussed in Section 6, the absence of essential elements, such as clear con-

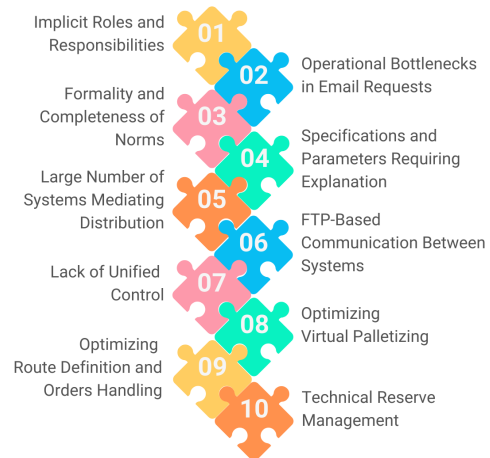


Figure 7. Ten Points of Attention derived from sociotechnical analysis.

ditions and accountable stakeholders, may impede the understanding and adherence to these norms. Therefore, an analysis and standardization effort in the structure and specification of these norms can bring precision to the documents, enable the creation of checklists for monitoring and verifying distribution, and expand possibilities for process automation. The Norm Analysis Method was employed over prescriptive norms to address this concern partially. A comprehensive analysis report detailing the outcomes and a spreadsheet containing the structured norms were provided as part of this action and exemplify the advantages of such an analysis. Expanding the study to other types of norms would help advance the norm's standardization.

4. *Specifications and Parameters Requiring Explanation*: Decades of operational experience and accumulated knowledge within the PNLD have played a crucial role in shaping logistics capable of timely and high-quality delivery of books and teaching materials from source to destination. This success has been achieved by establishing and refining various specifications, continually adjusted based on practical distribution experiences and in-depth studies. Illustrative examples of such specifications include:

- Size and Weight of Orders:
  - Standard Order: Max weight of 8 kg or max height of 16 cm.
  - Order by Weight: Max weight of 30 kg.
  - Transfer Order: Ten copies of the student book and five of the Teacher's Manual.
- Pallet Size and Material:
  - Dimensions: 980x1120mm, with a capacity ranging from 700 to 1,000 kg.
  - Pallet composition uses various sizes and configurations of wood, nails, staples, and cardboard.
- Minimum Quantity of Orders for Collection by the Distributor:
  - Minimum weight is 20,000 kg.

These specifications have been defined considering orders' handling, storage, and transport capacity, ensuring delivery without compromising physical quality or making direct human action impractical. However, explaining these

parameters' rationale would benefit the distribution's continuous improvement as they impact logistics efficiency (e.g., order formation, palletization, routing, and delivery). Simulations should also be conducted to analyze potential parameter variations, considering their impact on logistics efficiency. Therefore, the recommended actions for addressing this concern involve elucidating the knowledge supporting the established parameters and conducting simulations for a comprehensive impact analysis.

5. *Large Number of Systems Mediating Distribution*: The Stakeholder Diagram (Figure 1) derived from the analysis in Section 4 reveals the involvement of different systems in the distribution process, posing potential operational bottlenecks and challenges in maintaining consistent and up-to-date data. System maintenance issues further introduce risks that can impact the process, making testing and ensuring correct operation complex.

Exploring the feasibility of an integrative solution seems necessary — one capable of supporting all PNLD stages illustrated in Figure 6, from the initial stages involving announcement preparation and publication to the confirmation of book delivery to their target audience. Any proposed solution for supporting PNLD processes must align with the sociotechnical understanding outlined in this paper, reflecting a deep comprehension of the program's purpose: ensuring timely access to quality teaching materials for students and teachers across the country.

The results from activities presented in the previous sections support designing solutions that are aligned with the PNLD's objectives by considering the diverse stakeholders involved, understanding the key concepts characterizing the problem, and complying with the rules governing the distribution.

6. *FTP-Based Communication Between Systems*: The lack of direct integration among different systems necessitates manual import and export of files by technical staff, introducing vulnerabilities to operational issues, hindering real-time information access, and posing risks to data integrity. Additionally, knowledge regarding import processes, utilized files, and the workflow (including information about which files are imported into which systems) relies on the technical team and is susceptible to the impact of staff changes or unavailability. An integrated computing solution is necessary to address this point — one that comprehensively supports the entire process or, at the very least, automates communication between systems, enhancing the speed and security of data exchange.

Additionally, documenting and specifying the existing workflow is imperative. This documentation should outline which files are exported/imported by/to different systems, enabling a detailed analysis of potential risks and informing the development of an integrated solution.

7. *Lack of Unified Control*: As mentioned in the previous points, the absence of unified control in the PNLD distribution process stems from the involvement of multiple systems exchanging data and adhering to various formal and informal technical standards. A workflow tightly connected to the responsible stakeholders and a checklist outlining essential points for guaranteeing, monitoring, and adhering to standards is necessary. Such a system would facilitate

monitoring actions and reporting problems or identified non-conformities. In response to this point, two key actions are necessary:

- I. Process Specification using BPMN Notation: Specify the distribution process utilizing BPMN notation, which can be cross-referenced with the norms that stakeholders must meet at each activity.
- II. Interactive Workflow: investigating the feasibility of an interactive workflow to support navigating through the distribution stages, offering insights into the process and participant responsibilities.

8. *Optimizing Virtual Palletizing*: The current virtual palletizing activity in the PNLD distribution relies on the Distributor and involves validation by the FNDE technical team and data transmission to Producers. This activity's efficiency depends on the availability and expertise of FNDE technical personnel. The parameters for palletization must be more explicit and studied to investigate whether there are alternative and viable forms of palletization.

Likewise, the effects of virtual palletizing on the efficiency of order routing, batch processing, and other stages of the distribution process are not explicit. This point requires in-depth analysis and can benefit from studies from a Computer Science perspective, such as the Pallet Loading Problem and the Vehicle Routing Problem, as explored by Derenievich *et al.* [2023].

9. *Optimizing Route Definition and Order Handling*: The Distributor defines routes, handles parcels, forms batches, and determines routing strategies. While recommendations exist to ensure cost-effective delivery to all schools, this entire Distributor-led process poses auditing and analysis challenges. To address this point, the following actions are recommended:

- I. Conduct a thorough analysis of the routing definition and order handling activities, identifying existing challenges, dependencies, and areas for improvement. This analysis should examine the current workflow, constraints, and decision-making criteria.
- II. Utilize concepts from Computer Science, notably the Vehicle Routing Problem (VRP), to study and optimize route definition. VRP involves determining the most efficient way to deliver orders to a set of locations, aligning to minimize costs while meeting delivery requirements.
- III. Integrate insights from the Packing Problem (loading vehicles) and the Pallet Loading Problem (palletizing) to improve order handling and enhance the overall distribution process.
- IV. Apply mathematical modeling techniques and optimization strategies to address route definition and order handling complexities. This includes developing models considering several factors, such as distance, delivery times, and cost constraints.
- V. Throughout the optimization work, maintain the focus on achieving improvements within the scope and purpose of PNLD distribution: ensuring timely and cost-effective delivery of books and teaching materials to all schools before classes start. No exceptions.

These actions can enhance the PNLD distribution process's efficiency, reduce logistics time, and optimize cost-effectiveness while ensuring its effectiveness in fulfilling its core purpose.

*10. Technical Reserve Management:* Within Annex III of the postal contract [COLED, 2017], specific roles regarding the management of the technical reserve of books are presented. A comprehensive analysis of these roles is necessary as it represents an additional responsibility for the Distributor: more than conventional delivery tasks, the Distributor is responsible for the delivery, storage, and oversight of materials designated for the technical reserve.

Therefore, the Distributor assumes a “dual role” by providing the necessary infrastructure for storage and management, effectively serving as a repository for FNDE. This dual role ensures that the conditions for delivering technical reserve materials align seamlessly with standard deliveries in terms of both time and cost considerations. Additionally, it reinforces the importance of the public interest alignment of the stakeholders in charge of the PNLD distribution. While a private company needs to put its economic interests and needs first, a public company aims to serve society as its primary reason for existence.

Other points of attention have been identified and documented, including discovering outdated email addresses in the documentation, name variations for the same stakeholder, potential specification inconsistencies, implicit dependencies, and more. Each point requires specific actions and presents opportunities for future work. For the present research, subsequent analyses will unfold, encompassing optimization assessments, BPMN process modeling, and the development of an instrument aimed at presenting the general requirements for the distribution. These actions will be informed by the findings and the sociotechnical perspective presented in this paper.

## 9 Final Remarks

This study aimed to analyze the PNLD book distribution problem through a sociotechnical lens. The approach involved examining documentation and engaging in discussions with representatives from FNDE, facilitated by a team of four researchers. The process employed a triangulation method with activities discussed and validated by three researchers and two FNDE representatives. The primary outcomes are:

1. Identify stakeholders and their interrelationships;
2. Mapping of concepts that represent the distribution problem;
3. Analysis of norms governing the distribution;
4. Mapping the key activities within the logistics process;
5. Identify critical points for attention in PNLD logistics and suggestions for future work.

The sociotechnical approach to stakeholder analysis has emphasized that, despite not being explicitly featured in norms and documentation, the schools, students, and teachers constitute the book distribution's target audience and ultimate beneficiaries. The effectiveness of PNLD logistics is

measured by its ability to meet the diverse needs and expectations of these stakeholders in various contexts. This study successfully mapped over 40 stakeholders directly or indirectly linked to logistics, identified numerous concepts representing the problem, delineated diverse processes comprising dozens of activities, and scrutinized more than a hundred prescriptions detailing logistics conditions and stakeholder responsibilities.

Therefore, in addition to the evident high complexity of the PNLD logistics problem, the results show that the current structure exists to enable its operation and, thus, meet the general purpose of the PNLD. For logistics not to lose its essence, any study to understand and optimize PNLD logistics needs to adopt a sociotechnical perspective that considers social, normative, and technical issues in an integrated way — with social issues guiding and giving meaning to others.

The current distribution process has successfully ensured the fulfillment of its purpose. This success is attributed to the commitment and effective communication among the three primary stakeholders responsible for executing logistics — FNDE, Distributor, and Producers. The effectiveness heavily depends on qualified personnel who conduct and monitor the execution. The dual role of the Distributor, which involves both processing and storing orders and their subsequent delivery, is another crucial aspect of the current solution as it facilitates the timely delivery of educational materials to all regions of the country and prevents additional costs associated with storing technical reserve orders. Centralizing the solution with a single distributor is also necessary as it enables a uniform pricing strategy for deliveries across the country — something crucial to prevent more distant regions from being uncovered. Moreover, the organization and execution of all logistics by two public institutions, FNDE and Distributor, are central to the program's success in achieving its social objectives.

Finally, we reinforce the need to comprehend PNLD's logistics from a social perspective: optimizing logistics and improving its quality and efficiency aim to guarantee the timely delivery of books to all students and teachers in public schools across all regions of Brazil before classes have started. This must be achieved with the lowest possible operational cost, emphasizing the transfer of social considerations to technical aspects and not the opposite.

As the research next steps, the results presented in this paper will inform the work toward addressing the main points of attention presented. Specific analyses and modeling, aiming to optimize and represent the logistics process, will benefit directly from the results presented in this paper. Projects and research dedicated to investigating and developing new technical solutions to support the PNLD logistics may also use the sociotechnical understanding raised in this paper to inform their design decisions.

## Declarations

## Research Ethics

The data analyzed in this research is public and does not compromise privacy or have the potential to cause harm to third

parties. Its authors conducted and reported the study, so all people involved in significant work activities also signed the article. Other professionals who participated in meetings did so as part of their professional activities without any costs or losses. Due to the public nature of the funding and the object of study of this research, all data produced is made available for open access.

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## Authors’ Contributions

RP contributed to the Conceptualization, Investigation, Methodology, Formal Analysis, Supervision, Visualization, and Writing of this study. AS contributed to Data curation, Formal Analysis, Validation and Writing, and Investigation with Normal Analysis. KM contributed to Data Curation, Formal Analysis, Validation, Visualization and Writing, and Investigation with Conceptual Model. PC contributed to Data Curation, Formal Analysis, Validation, and Writing of the original paper and review of the current paper. LMP contributed to Conceptualization and Methodology. GD contributed to Formal Analysis, Investigation, and Validation. MC contributed to Conceptualization, Funding acquisition, Project administration, Resources, and Supervision. NR contributed to Data curation, Funding acquisition, Resources, Validation, and Writing. SC contributed to Data curation, Resources, and Validation.

## Competing interests

The authors declare no competing interests.

## Availability of data and materials

Document with the analyzed norms available at: <https://drive.google.com/file/d/1QrLcKrKb2zV76r12fdhKNTW1KEVQUVkkq/view?usp=sharing>. Access on 01 May 2024.

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