

THE APPLICABILITY OF COMPLEXITY THEORY IN THE MANAGEMENT OF NON-REFUNDABLE FUNDED PROJECTS

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ABSTRACT

This paper explores the applicability of Complexity Theory to the management of non-refundable funded projects, with a particular focus on the public administration sector. Based on the premise that such projects function as complex, dynamic systems-marked by nonlinearity, emergence, interdependence, and sensitivity to initial conditions-the research aims to highlight the limitations of traditional project management models and the potential of an alternative, complexity-informed approach. The adopted methodology aligns with the qualitative paradigm and employs a case study-the construction of the Cluj-Napoca metro line-as a representative example. Documentary analysis enabled the identification of dysfunctions generated by linear management logic and brought to light the advantages of a more flexible conceptual framework, capable of navigating the uncertainties and multi-actor interactions characteristic of the public sector. The findings suggest a need to reconceptualize public project governance by integrating principles of Complexity Theory, thereby offering an innovative and adaptive perspective on decision-making and implementation processes.

KEYWORDS: *complexity theory, project management, non-refundable funding, public administration, case study, uncertainty, complex systems, dynamic environment.*

JEL CLASSIFICATION: H43, O22, D73

1. INTRODUCTION

1.1. Complexity Theory - An alternative conceptual framework for the Management of Non-Refundable Funded Projects.

The management of projects funded through non-refundable sources has traditionally relied on predictable and rigid models such as the *waterfall approach* or *Gantt chart planning*. These methods are based on sequential structuring, detailed upfront planning, and the assumption of control over risks and deviations. However, in practice, projects unfold within environments

shaped by uncertainty, legislative instability, institutional constraints, complex stakeholder interactions, and unpredictable external factors.

In such contexts, classical approaches often prove insufficient in addressing the real-world dynamics of project implementation. *Complexity Theory* offers an alternative perspective by conceptualizing projects as *adaptive systems*, sensitive to initial conditions and capable of *self-organization and emergent behavior*. In contrast to linear methodologies, this perspective promotes flexibility, adaptability, and distributed decision-making within an interactive and collaborative framework.

Compared to conventional models, Complexity Theory proposes an *evolutionary approach*—one that embraces uncertainty and treats risk not as a disruptive element but as a source of valuable information. Thus, the aim is not to reject traditional methods outright but to *complement them* with adaptive mechanisms that more accurately reflect the volatile realities of public sector projects.

1.2. Contribution of the Study to the Existing Literature

Although the applicability of Complexity Theory has been explored across various domains—such as organizational management, economic processes, and private-sector projects—research focused directly on publicly funded projects within public administration remains limited. The specialized literature is still predominantly centered on classical methodologies or case studies from construction and corporate sectors, often overlooking the specific structural and institutional challenges inherent to public sector projects.

This study seeks to expand that theoretical framework by directly examining the potential of complexity thinking to enhance the processes of design, implementation, and sustainability in public projects. Furthermore, it offers a comparative analysis between traditional approaches and those rooted in complexity theory, illustrating—through an applied case study—the benefits of adopting an adaptive paradigm in the face of methodological rigidity.

Accordingly, the study's main contribution lies in proposing an alternative theoretical and practical framework, applicable in real-world contexts, one that can support public authorities in avoiding administrative deadlocks and in improving the effective use of non-refundable funding resources.

2. NON-REFUNDABLE FUNDED PROJECTS AS COMPLEX SYSTEMS: THEORETICAL FOUNDATIONS AND APPLICABILITY

Over the past few decades, Complexity Theory has emerged as an increasingly influential analytical framework for understanding systems characterized by dynamics, interdependence, and

emergent behaviors. Initially developed in fields such as ecology, mathematics, and systems physics, the theory has since been integrated into the social sciences, including the study of organizations and decision-making processes. Its ability to explain phenomena that cannot be anticipated through linear or hierarchical models makes it particularly relevant for analyzing projects financed by non-refundable funds, especially within the public sector.

2.1. Public Projects – A Dynamic and Unpredictable Reality

Projects implemented in public administration typically involve a complex organizational architecture: multiple stakeholders, institutional interactions, rigid regulations, and fluctuating external influences. From the drafting of funding proposals to final reporting, each stage is exposed to the pressures of a constantly evolving legal and political environment. Under such conditions, treating a project as a mechanistic system governed by a fixed and predictable plan often leads to bottlenecks, delays, and unnecessary rigidity.

Complexity Theory, by contrast, proposes understanding the project as an *adaptive system*, characterized by *self-organization*, *nonlinearity*, *continuous feedback*, and *sensitivity to initial conditions*. From this perspective, small variations in the early phases can lead to disproportionately large effects throughout the project's lifecycle—a phenomenon equivalent to the “*butterfly effect*” described by Lorenz (1963) in chaos theory.

2.2. Core Principles of Complexity Theory and Their Application in Project Management

The scholarly literature (e.g., Mason, 2007) identifies five core features of complex systems that are directly applicable to project management:

- Nonlinearity – system responses are not proportional to stimuli;
- Emergence – outcomes result from interactions, not from centralized planning;
- Feedback – information circulates continuously and influences real-time decision-making;
- Self-organization – the system adjusts internally without direct external command;
- Adaptability – the capacity to respond to unforeseen external changes.

These principles form the foundation of a *new paradigm* for managing non-refundable funded projects—one that shifts the focus from control to learning, and from fixed planning to ongoing adaptation.

2.3. Advantages of the Complexity-Informed Approach in Public Projects

Implementing a vision inspired by Complexity Theory brings a range of concrete benefits:

- Integration of uncertainty as a functional, not disruptive, element – e.g., the system's ability to quickly adapt to legislative or economic changes during implementation;
- Iterative decision-making, based on continuous feedback – decisions are not static but evolve in response to the project's ongoing development;
- Modular and flexible organization – project activities can be reconfigured without disrupting the entire implementation flow;
- Organizational learning – insights gained from past experiences are applied in real-time to improve ongoing processes;
- Cross-sectoral collaboration – the relationships between stakeholders (beneficiaries, funders, partners) are viewed as *dynamic and interdependent*, serving as a source of innovation rather than mere hierarchical reporting lines.

This perspective strengthens *organizational resilience* and helps avoid the systemic blockages often generated by rigid application of traditional methodologies. As such, *Complexity Theory* serves not only as an abstract theoretical framework, but also as a *practical and necessary guide* for efficient and sustainable public sector project management.

3. RESEARCH METHODOLOGY

This study is situated within the *qualitative research paradigm*, characterized by an *exploratory and interpretative approach*. Its aim is to assess to what extent *Complexity Theory* can provide a relevant conceptual framework for the management of non-refundable funded projects in public administration. The chosen method is the *case study*, deemed appropriate for the in-depth investigation of a singular phenomenon within a real-world and complex context.

3.1. Case Study – The Cluj-Napoca Metro Project

The analysis focuses on a large-scale public initiative: the *construction of the Cluj-Napoca metro*, partially financed through non-refundable funding mechanisms. The selection of this case reflects the *intrinsic complexity of public projects*, which typically involve numerous institutional actors, extensive bureaucratic procedures, and high exposure to external variables.

The research methodology relies primarily on *documentary analysis* as the main tool for data collection. Information was sourced from official public platforms (institutional websites, technical documentation, city council resolutions, etc.) and complemented by documents obtained through a formal request submitted to the Cluj-Napoca City Hall.

This approach enabled the reconstruction of the *decision-making process* and the identification of key moments where the traditional project management model proved rigid or inefficient. Special attention was paid to situations in which linear planning models led to bottlenecks, delays, or coordination issues—thus illustrating the need for *adaptive mechanisms* and a *complexity-informed perspective*.

3.2. Methodological Justification

The case study provides an ideal framework for testing the applicability of Complexity Theory, as it allows direct observation of institutional interactions, organizational responses, and the influence of exogenous factors on project implementation. This method is particularly suited to contexts where *quantitative analysis would fail to capture* critical variables such as actor relationships, contextual dynamics, or the decision-making adaptability that are central to the logic of complex systems.

4. CASE STUDY ANALYSIS: THE CLUJ-NAPOCA METRO PROJECT

The construction of the Cluj-Napoca metro serves as a *relevant case study* of a public initiative partially supported by non-refundable funds, exemplifying several features of *complex systems*. Due to its technical scale, the number of institutions involved, and its high level of exposure to external uncertainties, this project reveals a series of *organizational and structural challenges* typical of large-scale initiatives managed within the Romanian public sector.

4.1. Institutional Blockages and Dysfunctionality

The documentary analysis highlighted several recurring dysfunctions, which can be grouped into four major categories:

- **Administrative Fragmentation:** The involvement of multiple decision-making bodies (local authorities, ministries, regulatory agencies) resulted in significant delays in project phase approvals. The absence of a coherent inter-institutional coordination mechanism amplified the rigidity of the decision-making process.
- **Overlapping Competencies and Decision-Making Ambiguity:** Responsibilities among the involved authorities were not clearly delineated, leading to ambiguity, duplication of roles,

and a lack of accountability during critical phases of the project.

- Lack of a Risk Management Mechanism: The traditional approach relied on rigid planning, poorly adapted to the project's dynamic realities. The absence of a functional risk anticipation and mitigation system resulted in delayed responses to unforeseen developments.
- Poorly Defined Responsibilities Within Project Teams: The absence of a flexible team structure, based on adaptive competencies, led to discontinuities in decision-making and communication breakdowns in operational processes.

These issues are not isolated to this specific case; rather, they reflect *systemic patterns in Romanian public administration*, where *structural fragmentation and excessive bureaucratization* often hinder the effective coordination of complex public projects.

4.2. Interpretation through the Lens of Complexity Theory

From the perspective of *Complexity Theory*, these institutional blockages reflect the behavior of an *underdeveloped adaptive system*, in which the absence of feedback loops and real-time adjustment capabilities undermines overall functionality. The metro project operates in an environment characterized by *interdependencies, contextual instability, and emergent decision-making*, all of which are inherently incompatible with rigid, linear planning.

For instance, *overlapping decision-making structures* can be interpreted as a consequence of lacking self-organizing mechanisms, while *administrative fragmentation* reveals systemic deficiencies in interconnectivity. In the absence of iterative institutional learning and continuous adaptation mechanisms, the project becomes highly vulnerable to *unexpected risks* and *systemic delays*.

An approach inspired by Complexity Theory would have entailed:

- Establishing a flexible and distributed governance framework;
- Creating institutional feedback mechanisms between the involved actors;
- Implementing an active system for managing emergent risks;
- Promoting adaptive leadership, capable of recognizing and addressing contextual instability.

The absence of these elements led to delays and structural dysfunctions—issues that could have been at least partially prevented through a *complexity-aware and adaptive managerial vision*.

5. CONCLUSIONS AND FUTURE DIRECTIONS

This study has highlighted the *relevance of Complexity Theory* as both a conceptual and operational tool for rethinking the management of publicly funded projects. Using the Cluj-Napoca Metro Line I project as a case study, the research demonstrated that *strategic infrastructure initiatives*, developed under conditions of institutional instability and interdependence, are more appropriately understood as *adaptive complex systems*.

The proposed theoretical approach was grounded in key concepts such as *nonlinearity, emergence, self-organization, and iterative feedback*—principles that naturally occur in the dynamics of public projects, yet are rarely recognized or leveraged within current governance practices. The research emphasized the need to move beyond a traditional, rigid, and hierarchical paradigm toward one that is *flexible, collaborative, and centered on continuous learning*.

The case analysis brought to light a series of *structural dysfunctions*—including fragmented decision-making, the absence of effective risk management mechanisms, and poorly defined responsibilities—which reflect the public system's *inability to function adaptively*. Despite formal compliance with technical funding requirements, the project suffered from delays and missed financial opportunities due to the lack of a dynamic governance framework.

From this standpoint, the study offers not only a theoretical demonstration of the applicability of Complexity Theory but also outlines a *practical path for reform*, in which public administrations may enhance their *resilience and effectiveness* through the integration of feedback mechanisms, organizational reconfiguration, and distributed governance models.

While the study acknowledges its limitations—such as its reliance solely on document analysis and focus on a single case—these constraints serve as *starting points for future research*. Further studies could involve *comparative inter-regional analysis, qualitative investigation of institutional networks, or the integration of digital tools* to simulate and anticipate the behavior of complex public projects.

In conclusion, this research calls for a *paradigm shift*: from control to adaptation, from hierarchy to network, from bureaucratic compliance to *organizational resilience*. Far from being a theoretical abstraction, Complexity Theory emerges as a *necessary and applicable framework* for modernizing the way public projects are designed, coordinated, and evaluated within an administrative landscape undergoing accelerated transformation.

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