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Adaptive planning: a proposal to manage nanotechnology projects

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Abstract

Purpose – Research, development and innovation (RD&I) projects involving nanotechnology are complex, requiring an agile mindset and approaches capable of adapting to new discoveries, yet alternative project management (PM) approaches are still mainly limited to software development. This study aims to fill part of this gap by developing and evaluating the use of an adaptive planning model to contribute to PM in nanotechnology.

Design/methodology/approach – The approaches of “process tracing” and complexity dimensions were combined in an in-depth case study to identify events and build a real-time map of the complexities of a collaborative RD&I project involving nanotechnology, prominent in the national context.

Findings – The systematization of the case in question resulted in the proposal of an adaptive and replicable model with implementation guidelines capable of contributing in real time to managers’ understanding of complexities and decision-making in complex projects.

Research limitations/implications – This study’s limitations included the limited number of informants and the focus on a single case. However, this can serve as a starting point for further investigation aiming to advance the application of adaptive approaches to PM in RD&I projects involving nanotechnology.

Originality/value – The study fills a knowledge gap in the field of adaptive planning for environments beyond software development and creates an opportunity for discussions on PM approaches in hard science contexts.

Keywords Complex RD&I projects, Adaptive planning, Nanotechnology

Paper type Research paper

1. Introduction

RD&I collaborations between University and Industry (U-I) are focused on the development of new products and occur mainly in projects using disruptive technologies (D’Este, Amara & Olmos-Peñuela, 2016), such as in the fields of advanced materials and nanotechnology. Both are classified as “converging and enabling technologies”; they hold systemic relevance and enable the innovation of processes, goods, and services across different markets. These technologies, identified as a priority by many national governments, are knowledge-intensive as they are associated with high levels of RD&I and rapid innovation cycles (MCTI, 2021).

Projects using these technologies are considered complex and, at the outset, they do not allow for complete planning or control (Loch & Sommer, 2019). This complexity is associated with various factors, such as the lack of knowledge due to the novelty they propose (Pich, Loch & Meyer, 2002; Nachbagauer, 2021), unpredictability, uncertainties, interdependencies,



dynamic behaviors, nonlinearity, and unique local conditions (Vidal & Marle, 2008; Bakhshi, Ireland & Gorod, 2016; Guerra, 2023).

Project management (PM) is the application of knowledge, skills, tools, and techniques to design activities and meet project requirements (Guide, 2001; Vidal & Marle, 2008). In the field of PM, complexities are viewed as a key independent (contingent) variable, impacting many decisions (Rezende, Blackwell & Pessanha Gonçalves, 2018). In the scope of this study, they are directed towards RD&I and refer to the project's characteristic that causes the inability to fully understand, predict, and control its behavior (Vidal & Marle, 2008).

In PM literature, complexities have been investigated through two general research approaches: “complexity in projects,” which studies complexity through different theoretical lenses, and “complexity of projects,” which focuses on identifying the characteristics of complex projects and how individuals and organizations respond to them (Gerald, Maylor & Williams, 2011; Bakhshi *et al.*, 2016).

The failure of complex RD&I projects has been mainly associated with management challenges, considering both the lack of PM tools capable of dealing with unpredictability and the understanding of complexities (D'Este *et al.*, 2016; Guerra, 2023). Scholars in the PM field also highlight the need for managers to better understand such complexities (Gerald *et al.*, 2011; D'Este *et al.*, 2016; Rezende *et al.*, 2018; Elia, Margherita & Secundo, 2020). According to Gerald *et al.* (2011), complexities can work as a starting point for an analysis on the challenges a project faces or will face and to identify and define strategies to address them. Guerra (2023) further emphasizes the need for strategies to better understand the origin of complexity in projects, thus providing a common ground to support managers in PM.

Unlike traditional PM methodologies, adaptive approaches accept change as an integral part of the project, given the recurring unpredictabilities of its lifecycle (Matos, Romão, Sarmiento & Abaladas, 2019; Cooper & Soomer, 2016, 2018). Therefore, it is necessary to adopt new PM approaches that can contribute in identifying and interpreting complexities and decision-making within dynamic and unpredictable environments. Vidal and Marle (2008) suggest the use of adaptive approaches, as they accept that change is an integral part of the project and complete planning is impossible.

Adaptive approaches are mainly used in software development (Elia *et al.*, 2020), while hybrid models combine such approaches with traditional PM tools, focusing on the development of physical products associated with innovation (Cooper & Soomer, 2016, 2018). Thus, PM studies have trodden different paths when proposing management tools capable of handling high-tech RD&I projects, which are of growing social and economic importance. Therefore, this lack of specific focus indicates a gap in the PM field for this type of project.

Given the above, this work aims to fill part of this PM gap by proposing an adaptive model to support managers' decision-making by mapping the complexities of RD&I projects in nanotechnology. To this end, two approaches were combined to investigate real-time complexities at the project level in an RD&I project using nanotechnology: “process tracing” (Heise, 2022; Beach, 2020; Langley, 1999) and dimensions (Gerald *et al.*, 2011; Rezende *et al.*, 2018; Elia *et al.*, 2020).

2. Theoretical foundation

2.1 Complexities in RD&I projects

The Project Management Institute (PMI) defines a project as a temporary effort to create value through a unique product, service, or result (Guide, 2001). It consists of a set of interdependent and planned activities with defined objectives. Various factors connect these activities and require efficient management to ensure the competitiveness and survival of organizations (Elia *et al.*, 2020).

In the literature, the term “exploratory projects” (Loch & Sommer, 2019; Lenfle, Midler & Hällgren, 2019) is also used to refer to complex RD&I projects, which begin in an early phase described as chaotic, difficult to predict, and structure (McGrath & MacMillan, 1995). Thus,

even though complex projects are designed to achieve well-defined results, they lack the clarity to fully describe the objectives or the means to achieve them at the outset. As a result, as they progress, they are subject to constant changes and adjustments (Loch & Sommer, 2019; McGrath & MacMillan, 1995; Guerra, 2023).

In the PM field, Geraldi *et al.* (2011) proposed using the dimensions approach to investigate the effect of complexities based on conceptual patterns mapped from different authors' perspectives, due to structural, dynamic, pace, sociopolitical, uncertainty (Geraldi *et al.*, 2011), and regulatory issues (Rezende *et al.*, 2018).

Table 1 presents a synthesis of the complexity dimensions, considering the bibliometric studies by Geraldi *et al.* (2011) and Rezende *et al.* (2018), in addition to the categories of uncertainties anticipated in RD&I projects according to Meyer, Loch, and Pich (2002). These approaches were applied to understand and identify the complexities in the investigated project.

Table 1. Summary of the dimensions of complex elements present in projects

| Dimension | Definition | Attributes | Categories | Examples of indicators |
|----------------|---|--|---|---|
| Structural | Set of interrelated elements and entities that must be considered in the decision-making process of a project | Size or number Variety Interdependence | Size (or number) of... Variety of... Interdependence of... | Scope Types of knowledge Team sizes X Types of knowledge required Scope changes |
| Dynamic | Changes in any of the other dimensions and their impact on the project | Changes: variability and dynamism | Changes in... | Scope changes |
| Pacing | Rate at which projects must be delivered, considering a defined optimal level of measurement | Pacing | Speed of... | Market changes that impact the speed at which activities are completed |
| Sociopolitical | Refers to human actors (agents) involved in the project, as well as all interactions between them | Importance Support for (the project) or from (stakeholders) Adjustment/convergence Transparency | Importance of... Support for... or from... Adjustment/convergence with... Transparency of... | Stakeholder commitment Conflict resolution Alignment between project objectives and organizational strategy Hidden agendas among stakeholders Need for fundamental changes in project structure |
| Uncertainties | Uncertainties related to tasks, project typology, and technological scope | Novelty Experience Availability of information | Chaos or turbulence Unforeseen uncertainties Variations Predicted uncertainties | Side effects different from those predicted in a new drug Underestimated activity time Side effects of new drugs |

Source(s): Adapted from Geraldi *et al.* (2011)

Elia *et al.* (2020), Rezende *et al.* (2018), and Guerra (2023) consider the dimensions approach to complexities as a promising strategy for identifying and understanding complexities in projects. Guerra (2023) highlights opportunities for progress in the field of RD&I project management (PM), including studies on the identification of complexities during the implementation of these projects, as well as understanding the use of complexity dimensions in project analysis.

2.2 Managing complexities in projects

Unlike traditional managers, those involved in complex projects face events that are difficult to predict or interpret and they must make choices in dynamic and unstable environments (Cristóbal, Carral & Fraguela, 2018). These professionals also deal with perceived complexity, as they cannot fully grasp or manage a project's reality and complexity (Vidal & Marle, 2008). Thus, each professional assimilates and interprets complexity individually based on their experiences, backgrounds, and mental models (Jaafari, 2003).

Numerous factors hinder the management of complex RD&I projects. Scholars in the field (Cristóbal *et al.*, 2018; Rezende *et al.*, 2018; Loch & Sommer, 2019; Elia *et al.*, 2020; Guerra, 2023) emphasize the need for management models that are unlike traditional ones in order to reduce the failure rate in these projects. These new models need to contribute both to the identification and understanding of complexities and to the definition of strategies to manage them. According to Baccarini (1996), Geraldi *et al.* (2011), and Rezende *et al.* (2018), understanding complexity is essential because it impacts decision-making and influences project planning, objectives, schedule, costs, and the quality of project deliverables.

The literature describes some management tools that contribute to the identification of complexities in projects, such as the goals and methods matrix by Turner and Cochrane (1993), Stacey's matrix (1996), which assesses project complexity along two dimensions: uncertainty and agreement; Williams and Hilson's model (2002), an extension of Baccarini (1996), which assesses complexity based on the number of elements and the interdependencies between them; and the Cynefin framework by Snowden and Boone (2007), which addresses complexities as new opportunities from different perspectives. However, depending on the product category, between 40% and 90% of innovation projects still fail partially or completely, mainly due to management challenges (D'Este *et al.*, 2016). According to Guerra (2023), this failure is related to the need for specific solutions for the dynamic environment in which RD&I projects characterized by uncertainty are found. Therefore, the need for new tools to manage complexities in projects becomes evident, as traditional management models prove insufficient.

2.2.1 Adaptive approaches in PM. Unlike traditional methodologies, adaptive approaches accept change as a fundamental part of the project. They can thrive in the presence of change by focusing on constant evolution through adaptive planning, carried out in the short term (Elia *et al.*, 2020).

Although mainly disseminated in software development, the literature describes adaptations of these methodologies for the development of innovative physical products in the manufacturing industry. Commonly known as hybrid approaches, these models were developed by integrating agile methods with traditional approaches (e.g. stage-gate) to provide greater adaptability to PM (Cooper & Sommer, 2016, 2018). Other approaches incorporate elements of flexibility, contingency, and adaptation, such as the diamond model by Shenhar and Dvir (1996), or models focused on high-uncertainty environments, such as the Learning Plan (Rice, Mark & O'Connor, 2008) and the Milestone Plan (Meyer, Loch, & Pich, 2002). However, these models focus on uncertainties within a limited set of dimensions, disregarding other complexities arising from RD&I projects.

According to Conforto and Amaral (2010), the implementation of hybrid approaches in RD&I projects still faces challenges related to the difficulty of planning an unpredictable scope, the inflexibility of organizational structures, and risk management during innovation development. As highlighted by Elia *et al.* (2020) and Guerra (2023), identifying and

exploring underlying complexities is essential for the success of PM in this context. Authors like [Baccarini \(1996\)](#) and [Rezende et al. \(2018\)](#) agree and emphasize the need for managers to understand how to manage complexity, given its influence on decision-making.

3. Method

The objective of this study was to develop and evaluate the use of an adaptive/flexible approach to contribute, in real time, to the management of complex RD&I projects in the field of nanotechnology. An in-depth single case study was conducted using the process tracing approach ([Heise, 2022](#); [Beach, 2020](#)). The method was selected with an explanatory focus, aiming not only to describe the case but also to infer causalities and identify patterns in the elements of complexity and their dimensions ([Freitas, de Melo, Salerno, Bagno, & Brasil, 2021](#)) as the project progressed.

Process tracing was used to map the events based on the unfolding of the actors' actions in a complex RD&I project involving nanotechnology. In the context of this research, events refer to the actions of a particular agent on a specific object at a given point in time ([Heise & Durig, 1997](#); [Melo, Salerno, Freitas, Bagno, & Brasil, 2021](#)). They include decisions, meetings, and interactions relevant to the context carried out among the actors ([Langley, 1999](#)).

3.1 Object of analysis

The study setting was the Nanomaterials and Graphene Technology Center of the Federal University of Minas Gerais (CTNano/UFGM), a Science and Technology Institution (STI) focused on developing processes and services using nanotechnology to enhance industrial competitiveness. More specifically, the investigated case was an RD&I project executed through a partnership between the center and a multinational company to develop a new high-performance material with industrial applications. The investigation scope covered the period from the pre-development phase to the laboratory scale-up (ESCLAB).

The case was selected due to the innovative aspects inherent to the use of nanotechnology in an RD&I project, the organizational arrangement, the ease of access to informants, and the project's development status. These aspects allowed for a preliminary analysis of issues (unpredictable and complex) with a high probability of failure, thus highlighting the value of the approach to be developed.

3.2 Data collection and structuring

Over a period of two years, data were collected and structured on a recurring basis from key informants, through document research (archive of documents and emails), participant observation, and semi-structured interviews with support to conduct the event framework ([Heise & Durig 1997](#)) – see [Table 2](#). Additionally, for validation purposes, two other

Table 2. Event framework adapted for semi-structured interviews and event coding

| Elements | Definitions |
|------------|---|
| Agent | The instigator of an event |
| Action | The merging of the elements of the “event framework” into an occurrence |
| Object | The entity that is moved or changed, such that the repetition of the occurrence requires the replacement of the entity. People can be objects |
| Instrument | An entity used by the agent to causally advance the occurrence without being significantly changed by the occurrence. People, social organizations, and verbalizations can be instruments |
| Product | An entity that comes into existence as a result of an occurrence and that enables or disables subsequent occurrences |

Source(s): [Freitas, de Melo, Salerno, Bagno, and Brasil \(2021\)](#)

informants involved in the project (Coordinator and Supervisor) were also interviewed in both formal and informal settings, using semi-structured and unstructured formats. During this period, field notes were taken and more than 20 semi-structured interviews were conducted, each lasting about 2 hours.

Participant observation by the researcher complemented the data collection and made it easier to describe and interpret the relationship between events, allowing for real-time monitoring of the phases of technological development (TD) and ESCLAB, as well as promoting bi-weekly interactions with the project team. Thus, when appropriate, discussions and questions regarding the project's reality were encouraged.

3.3 Data analysis

With the event framework, a results-oriented narrative (Melo *et al.*, 2021; Lerman, Mmbaga & Smith, 2022; Langley, 2007) was constructed and validated periodically with informants, both individually and in group meetings. The pattern-matching approach was adopted to facilitate the chronological analysis of empirical data (Reay & Jones, 2016), using as an "ideal type" model the Product Development Process (PDP) applied by the Center for PM (Resende & Bagno, 2017), focusing up to the pilot phase. As the project progressed, it is important to note that data collection, analysis, and narrative construction occurred simultaneously.

4. Results

Of the 62 events mapped, only 49 (Table 3) were considered for understanding the case study in question. A more detailed table about the events is available in Supplementary File 1.

4.1 Complexity map

By combining the dimensions approach with iterative data collection through process tracing to obtain the event framework, it was possible to build and validate the complexity map across multiple dimensions in real-time and with the informants, as the project progressed. As shown in Figure 1, complexities were mapped in four dimensions: sociopolitical, structural, uncertainties, and pace.

In the pre-development phase, the events were mapped retrospectively. They were related to the ideation process, construction, and project proposal approval, considering the technological challenge posed by the contracting company. The mapped complexities presented sociopolitical indicators (importance, convergence, and transparency), uncertainties (chaos or turbulence and unforeseen), and structural aspects identified in the events.

During the technological development (TD) phase, events were mapped in real-time and were associated with rescheduling and a series of experimental activities focused on enabling the application of the technology to the product, as predicted by Coad, Segarra-Blasco, and Teruel (2021). The mapped complexities presented sociopolitical indicators (support and convergence), uncertainties (unforeseen, variations, predicted, and chaos or turbulence), and structural aspects. Understanding these complexities provided greater clarity to the informants regarding the need to adapt the initial plan and the knowledge exchange between the CTNano/UFGM team (nanotechnology) and the multinational's industrial specialists, which was not initially anticipated.

During the ESCLAB phase, the map was constructed in real-time, and events related to the replicability and proof of concept of the technology at a larger scale, were identified still within the laboratory. As predicted in the literature (Snowden, 2002; Williams & Hillson, 2002; Loch & Sommer, 2019; Lenfle *et al.*, 2019), this phase could not be fully planned and specified due to the pioneering nature of the technology under development. Therefore, the mapped complexities presented uncertainty indicators (chaos or turbulence, predicted and unforeseen), sociopolitical (convergence and support), structural, and pace-related complexities due to the COVID-19 pandemic.

Table 3. Events (49) considered in the case study

| No | Events | No | Events |
|----|--|----|---|
| 1 | Multinational proposal: technological demand | 26 | Partial technical report |
| 2 | Solution discussion | 27 | Workshop: field challenge discussions |
| 3 | Project proposal (PP): construction | 28 | Workshop: partial results |
| 4 | PP: submission/approval | 29 | Reproduction: production process and composition of TED |
| 5 | Alignment of technical scope (TS) of PP | 30 | Evaluation: characterization of TED |
| 6 | Expansion: TS | 31 | Identification: RMQ of TAE |
| 7 | Detailing: expanded TS | 32 | Definition: RMQ of TED |
| 8 | Validation: detailed TS | 33 | Internal alignment: partial results |
| 9 | Follow-up for hiring | 34 | Supplier for TED production |
| 10 | Hiring procedures | 35 | Supplier formalization |
| 11 | Confidentiality agreement | 36 | Evaluation: feasibility of partnership |
| 12 | Hiring: technical team | 37 | Technical report: partial |
| 13 | Workshop: alignment of challenges and expectations | 38 | Workshop: partial results |
| 14 | Detailing: TS and schedule | 39 | Partnership for pilot production of TED |
| 15 | Internal alignment: center team | 40 | Prior search |
| 16 | Access to currently employed technology (TAE) | 41 | Patent writing |
| 17 | Redefinition: TAE characterization strategy | 42 | Patent filing |
| 18 | Rescheduling: TAE characterization timeline | 43 | ESCLAB of TED |
| 19 | Characterization of TAE | 44 | Evaluation of ESCLAB success |
| 20 | Identification of minimum quality requirements (RMQ) for TAE | 45 | Proof of concept (POC) methodology |
| 21 | Definition of raw materials for technology under development (TED) | 46 | POC in the laboratory |
| 22 | Definition: TED production process | 47 | Internal alignment: final results |
| 23 | Evaluation/characterization: TED | 48 | Technical report: final |
| 24 | Identification: main field challenges | 49 | Delivery of report: project completion Phase I |
| 25 | Internal alignment: partial results | | |

Source(s): Authors' own work

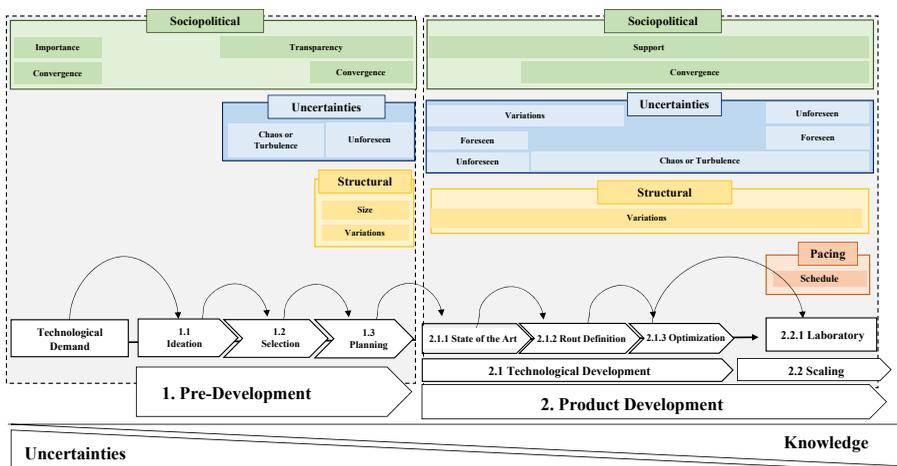


Figure 1. Complexity map identified in the RD&I project. Source: Authors' own work

4.2 Proposed adaptive model for managing complex projects

By grounding the case study experience in the literature on complexity dimensions and adaptive PM approaches, a prescriptive model of adaptive planning is proposed, as shown in Figure 2. When applied on a recurring basis, as the project progresses, the model allows for the construction of an event framework to dynamically map complexities, providing a clearer view of the project’s reality. This view served as a support for discussing complexities and identifying the necessary adjustments to the initial project plan. This strategy indicated feasibility for application in similar contexts, if tests and adjustments are made.

(1) Data collection

The combination of process tracing and pattern matching approaches allows for the chronological organization of data as it is collected, according to the phases of the organization’s PM model. The collection must be conducted retrospectively in the pre-development phase using document research. This allows the manager to access the history of negotiations, better understand the context of the partnership between organizations, and connect with the informants and decision-makers involved in the project.

During the product development (PD) phase, it is recommended to collect data regularly, at bi-weekly intervals, as the project progresses, through participant observation and semi-structured interviews using the event framework in collaboration with the person primarily responsible for project development (technical leader).

(2) Event coding

After the data collection, it is crucial to code and structure the data using the key elements of the event framework to obtain a visual scheme that illustrates the events resulting from the actions of agents on a specific object at a given time. During the PD phase, event coding should continuously and temporally evolve to reflect the project’s real-time situation.

Simultaneously, it is recommended to use the synthesis framework (Table 1) to identify the complexity dimensions of the events (Gerald et al., 2011). These may present complexity indicators across more than one dimension, which need to be considered based on their potential impact on the current and subsequent project phases.

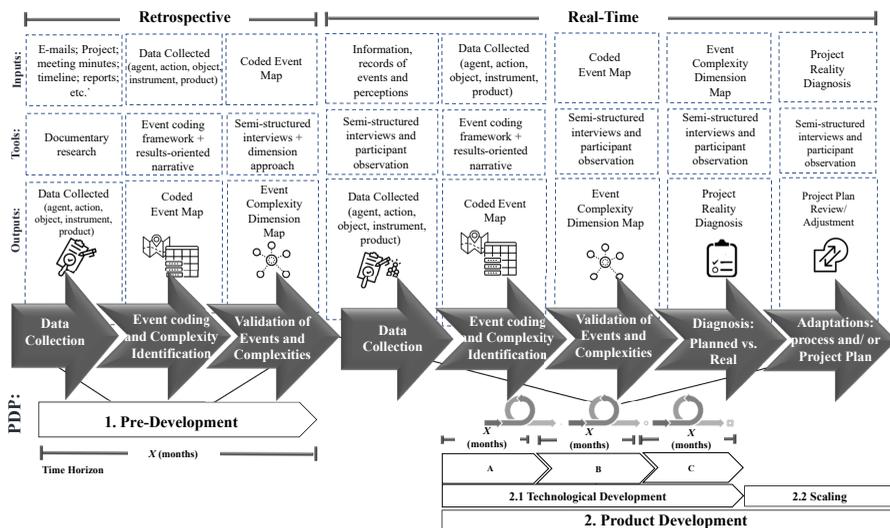


Figure 2. Proposed adaptive model for managing complex projects. Source: Authors’ own work

(3) *Validation of events and identified complexities*

It is recommended that the manager validate the event map with complexity dimensions alongside the technical leader and other informants during semi-structured interviews, formal/informal meetings, individually and/or in groups. This map serves as a visual element that simplifies the view of the project plan, thus enabling better understanding and discussions about the challenges faced at the project level. These discussions should focus on project planning, considering the identified complexities and the strategies needed to overcome them over time.

During the PD phase, it is suggested that recurring interviews take place at bi-weekly intervals to update data and construct a real-time view of the project's reality. It is also recommended for interactions for data collection and validation of events containing complexities alternate at average bi-weekly intervals.

(4) *Diagnosis: planned vs real*

At this stage, the manager needs to diagnose the project's status by comparing the initial plan with the identified temporal scenarios, considering the event framework and the complexity map. This strategy will allow the manager and the technical leader to assess the need for adjustments in the subsequent project phases based on the current identified scenario. It is further recommended that the diagnosis be conducted at each subphase of development, according to the organization's management model. Moreover, the diagnosis can serve as a decision gate to determine whether to adjust the project plan or proceed to the subsequent phases.

(5) *Adaptation of the process and/or project plan*

After assessing the need for adjustments and adaptations in either the process or the initial project plan, the project itself should be adjusted according to the identified reality, considering the complexity map. If necessary, adaptations in the process and project plan should be carried out by the manager, together with the technical leader, after the diagnosis is concluded, which is considered as the decision gate for proceeding to the subsequent phases.

5. Discussions

5.1 Theoretical implications

Unlike adaptive models described in the literature, which focus on the development of hardware/innovative physical products (mainly associated with Scrum) (Cooper & Sommer, 2016, 2018), the model proposed here considers the complexity dimensions as key contingencies for managing complex projects using nanotechnology. In addition to providing greater agility and adaptability in development, it acknowledges that the complexity dimensions must guide project plan adjustments. Thus, it becomes possible to consider complexity as a condition and understand its temporal evolution status, allowing it to be dynamically addressed in the project through convergence patterns, given uncertain, dynamic, pace, and sociopolitical issues.

From the perspective of research implications for the broader debate on managing complex projects, the model proposes an adaptive approach to support managers in identifying and understanding the complexities of a project over time and dynamically managing them. More specifically, this adaptive model, which includes the real-time contribution of the event framework (process tracing) and the complexity dimensions map, provides RD&I project management, especially in nanotechnology, with the ability to adapt in unpredictable and complex environments. This is a significant contribution, considering that current models do not take into account the impact of complexity dimensions and do not allow for the construction of a dynamic and in-depth view of the challenges faced at the project level.

5.2 Practical implications

From a practical perspective, the research experience has outlined recommendations that can be useful and applicable to RD&I project management in other contexts, if adjustments are made.

From an organizational structure perspective, the presence of a professional (either dedicated or part-time) playing the role of a “complexity facilitator” is recommended to enhance the use of the model. This person should have know-how in managing complex projects and be familiar with process tracing approaches and complexity dimensions. Given their external analytical position (excluded from operational routine), they can support the technical leader by generating alerts and insights for replanning, which can be crucial for course correction in one or more projects. Furthermore, this professional’s involvement in other projects can generate interproject insights, support benchmarking of new projects, encourage more robust initial planning, and help align new team members.

From the perspective of project management professionals, the flexible nature of the model can assist project managers and researchers in the field of nanotechnology in adjusting the course and plans of ongoing projects as identified needs arise. As a general approach, the model proposed here showed potential for application in RD&I projects using nanotechnology, carried out in partnership between STIs and industry, and it can also serve as a foundation for other studies focused on enabling the application of adaptive planning approaches in complex RD&I projects in other fields.

6. Conclusions

This study focused on developing and evaluating an adaptive planning approach capable of supporting project managers dealing with RD&I projects using nanotechnology. As seen in the events related to replanning, the model’s application allowed for the recognition of the need and the implementation of adjustments to the initial project plan as it evolved over time.

From the perspective of research implications for the broader debate on managing complex projects, unlike hybrid approaches, the proposed model considers the complexity dimensions as an essential contingency for managing RD&I projects using nanotechnology. Thus, the adjustments resulting from the project’s evolution are guided by the complexities identified in a real-time event map created by combining process tracing and complexity dimension approaches.

A limitation of this study was that the results obtained were based on the perceptions of a limited number of informants. While this strategy was appropriate for identifying the complexity elements in the RD&I project in question, there is still much to be explored in project management. Suggestions for future research focus on applying this model in different contexts for managing RD&I projects or developing frameworks focused on nanotechnology.

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Supplementary material

The supplementary material for this article can be found online.

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