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Causes of failures in project management: Analysis and inductive evidence based on case study research

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Abstract

The goal of this study is to examine the causes of project-level failure. In particular, the paper suggests typologies of failure in phases of project management associated with limited information and bounded rationality by organizations to achieve difficult goals and face environmental turbulence (increasing complexity and dynamism leading to increasing uncertainty). The main case study clarifies theoretical conceptualization, describing determinants of failure in project management of antibody drugs for Alzheimer's disease, Mars Climate Orbiter, Boeing 737-MAX, bridge and building collapses and finally in the ICT industry (e.g., in streaming platform, a cloud-streaming gaming console, etc.). Two basic strategies to face failure in project management are suggested: the first is Strategic Learning with Argyris' approach of a) single-loop learning in organizations that detects minor errors in the phases of project development and changes the actions to minimize deviations and difference between expected and obtained objectives/results, maintaining the design intent and current routines in organization; b) double-loop learning in the presence of major errors to support radical change in organizational and managerial behaviour to re-design project management to be effective to achieve goals. The second approach is strategic adaptation when an organization learns how to adapt when it is continuously subjected to internal and/or environmental change, such that it increases the ability to maintain its efficiency under different conditions. This study clarifies factors determining failure in project management to support

> best practices directed more effectiveness in achieving intermediate objectives and final goals for the competitive advantage of firms.

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1. Introduction of failure in project management

Goal setting in innovation projects is one of the basic aspects of strategic change directed to increase organizational performance, take advantage of main opportunities or cope with environmental threats (Teece et al., 1997). However, in turbulent environments, the risk of goal failure in innovation projects has a high probability and can plague many corporations in different industries, generating negative consequences on the organization, such as wasted investments, missed commercial opportunities, sales below expectations, costs exceeding expectations, etc. (Cooper, 1975; Taylor, 2021). Studies show that setting and failing high and specific goals in projects can be damaging to organizational and managerial behaviour (Arnold and Artz, 2015; Höpfner and Keith, 2021). Management studies of innovation failure analyze different aspects. Starbuck and Hedberg (2001) examine the effects of successes and failures on organizational learning and technological development by considering partnerships between firms. Cannon and Edmondson (2005) show that organizations can learn from failures and suggest a strategy to support learning processes in projects (cf., Coccia, 2012, 2017; Denrell, 2003; Desai, 2015). Danneels and Vestal (2020) propose two organizational approaches to failure analysis in organizations: normalizing failure (i.e., accepting the failure as a necessary aspect of innovation processes) and analyzing failure (i.e., convert failure experiences into learning processes that increase organizational knowledge to achieve next strategic goals). A normalizing approach does not improve project management, unlike the in-depth analysis of project failures (e.g., by using Fault Tree Analysis, cf., Ruijters and Stoelinga, 2014). Edmondson (2011) argues that many executives consider all failure events negatively, but this approach can impoverish organizational learning. Eggers (2012) analyzes investments in a losing technology because can provide positive learning effects for the development of inter-related technologies in the portfolio of organizations (cf., Coccia and Watts, 2020; Magazzini et al., 2012; Rhaiem and Amara, 2019), the choice of less risky and difficult goals in projects or the entry in markets after a reduction of technological and environmental uncertainty (Fleming, 2001; Ferreira et al., 2020). Velikova et al. (2018) analyze driving factors in failure in order to recommend the exploration of alternative paths to escape from well-known or rare causes of failure. Instead, Maslach (2016) shows that a flop in the development of incremental innovation leads the organization to a strategy of persistence in the same technological trajectory, whereas a flop in the development of radical innovation generates a change in innovation pathways and also of partnership. Dana et al. (2021) argue that a lot of failures in innovation projects are often neglected, leading to a loss of knowledge for improving learning processes and applying corrective actions to achieve the next goals and important opportunities in markets (cf., Gioia and Chittipeddi, 1991; Välikangas et al., 2009).

Despite the scientific attention that innovation failure has received and is receiving in management studies, different terms of failure refer to the same thing and the same term is used to indicate different things, as well as ambiguity is present in determining general drivers of failure (missing goals) in innovation projects (specifically innovation here is the creation, application and diffusion of new ways of doing things, Coccia, 2021). To gain a better understanding of these vital topics, an appropriate conceptual framework about the systemic structure of factors determining innovation failure in the R&D process is needed. The present research aims to develop and systematize the conceptual structure of underlying categories of determinants leading to failure in innovation can provide critical implications for improving decision-making and strategic management in organizations. Multiple-case study research verifies proposed concepts and categories of factors determining innovation failure in different sectors from pharmaceutical, aircraft and aerospace sectors to transportation and building engineering. Findings here can help R&D managers, designers, analysts, etc. to detect and analyze the types of error leading to failure in innovation projects for appropriate strategies of problem-solving that improve organizational and managerial behaviour towards the achievement of the next designed goals in turbulent contexts.

2. Theoretical framework

In order to propose a conceptual framework of failure in innovation projects with a systems approach (Ackoff, 1971), the theoretical framework here is given by goal-setting theory and the concept of target difficulty (Locke and Latham, 1990, 2002; Wood and Locke, 1990), by strategic model of Pich et al. (2002), by typological theory of Shenhar and Dvir (2004), and finally by normal accident theory of Perrow (1984).

The first approach is goal setting in project management can support decision-making in strategic planning, coordination, and resource allocation (Hansen and Van der Stede, 2004; Widener, 2007). Goal-setting theory analyses and indicates the effects of goal setting and achieving on organizational performance (Locke and Latham, 1990). Locke (1982) suggests that the basic elements of goal setting are: clarity and specificity, challenging new directions, commitment and collaboration, expertise to deal with complexity and constructive feedback. The setting of difficult and specific goals in projects plays a main role in organizations to take advantage of important opportunities or to cope with environmental threats (Shields et al., 2000). Empirical evidence shows that the relation between goal difficulty and organizational performance is still contradictory. Some studies suggest that setting difficult and specific goals in projects can increase organizational performance compared to easy or ambiguous goals (Locke and Latham, 1990, 2002, 2006; Simons, 1988; Webb et al., 2010), whereas other researchers do not find a significant association (Hansen and Van der Stede, 2004;

Hirst and Lowy, 1990) or even find a negative impact (Webb et al., 2013). This ambiguity in the relation can be due to manifold endogenous factors in organizational behaviour and different exogenous elements of environmental turbulence (Perrow, 1984; Pich et al., 2002). Organization in the presence of internal and external changes can revise goals in projects (Indjejikian and Matějka, 2006; Leone and Rock, 2002) and analyze how the consequential adjustments affect the performance (Anderson et al., 2010; Bouwens and Kroos, 2011; Murphy, 2001). Revisions of difficult goals may lead to higher flexibility of organizational behaviour in target setting (Arnold and Artz, 2015; Milgrom and Roberts, 1992). However, goal difficulty and flexibility may also increase the costs of project management (Weitzman, 1980). Locke and Latham (1990, p. 349) maintain that high and specific goals lead to about 10 % of positive achievements that improve organizational performance (Locke et al., 1989; Latham and Locke, 1991; Latham and Seijts, 1999; Welsh and Ordóñez, 2014; Welsh et al., 2019), whereas 90% of projects fail the goals with main consequences (Carver and Scheier, 1990; Dweck and Leggett, 1988; Judge and Kammeyer-Mueller, 2004). To our knowledge, there are no studies that integrate goal-setting theory and concepts of difficulty in a consistent framework of failure in innovation projects.

The second approach, forming the theoretical background of the study here, analyzes the ambiguity between complexity and uncertainty in the execution of innovative projects (Mihm et al., 2003). Pich et al. (2002) argue that when projects increase in complexity, also the ambiguity of information that may influence project development increases. In complex projects, Pich et al. (2002) maintain that engineers cannot afford to wait for complete information to develop them and often continue the lifecycle of projects using preliminary and ambiguous information. Pich et al. (2002) also show that in the presence of insufficient information and complex problems, “selections” and learning processes can be necessary actions of problem-solving in project management to cope with new events.

The third approach for theoretical framework here is by Shenhar (1998) that suggests a model of “Diamond Typology” in project management based on four dimensions: the *novelty* that has an impact on the definition of project requirements and market-related activities; the *technology* used that affects project design, development, and technical skills needed; the *complexity* that influences the positioning of the project and related coordination and organization, and finally the pace of project affects available timeframe of project development in the environment. These four elements assess the tasks, the environment, and the level of risk to support optimal project management.

Finally, some scholars analyze proximate causes and proximate consequences of project failures to discuss preliminary inter-related events (Vantine, 1998). Perrow (1984) argues that organizational accidents leading to system failures in space missions and nuclear power projects, having difficult and challenging goals, are due to tight coupling and complex interactions. In these projects, while the complexity cannot be adequately understood and can lead to failure systems, the coupling is a result of the design process or operating environment, and efforts can be made to de-couple critical systems and reduce the likelihood of a system failure. Perrow (1984) suggests efforts to control complexly interactive and tightly coupled systems may lead to a growing risk of failure in projects.

3. Conceptualization of failure in project management

3.1. Proposed conceptual framework based on concepts and specific terminology for innovation failure

Different studies about innovation failure focus on organizational and managerial aspects, such as learning from failure (Cannon and Edmondson, 2005; Edmondson, 2011), uncertainty in innovation failure (Eggers, 2012), failure of new industrial products (Cooper, 1975; Kono and Lynn, 2007; Ferreira et al., 2020), financial issues in failure of innovation projects (García-Quevedo et al., 2018), etc. Failure is also a topic of scientific investigation in computer science that suggests specific concepts, such as fault-tolerant computing (Laprie, 1995), the taxonomy of failure in unmanned ground vehicles (Carlson and Murphy, 2005), fault taxonomy based on the relation between faults in autonomous robot systems and dependability (Stainbauer, 2013), etc. In the context of computer and robotics research, a failure is a divergence from a specified service, the error is a specific state within the system that can generate a failure, finally, a fault leads the system to enter a state of error (Laprie, 1995; Carlson and Murphy, 2005; Pangione et al., 2020). This theoretical background of flops in physical components, just mentioned, can be applied to propose here, in analogy, new concepts to analyze the structure of innovation failure in management science. The proposed conceptual framework of innovation failure here is also underpinned by goal-setting theory (Locke, 1982; Locke and Latham, 2002, 2006), concepts of complexity and uncertainty (Perrow, 1984; Pich et al., 2022; Shenhar, 1998) and relationships describing the goal-seeking behaviour of organizations to achieve and sustain innovation (cf., Ackoff, 1971). The following definitions and terminology are basic to design a conceptual framework that clarifies the different types of elements underlying failure in innovation. The failure, with a systemic perspective, can be conceptualized as a set including different sub-sets and related elements. In particular:

Failure (F) is when an organizational system misses the goal of a designed project at time *t* or in a specific period (*t*, *t*+*n*). Goal (*G*) ={objective-*1*, objective-*2*, …, objective-*i*, …, objective-*n*}, where objectives are specific and measurable actions supporting the accomplishment of the main goal in projects (Frost, 2000; Ittner and Larcker, 2003). Failure is caused by a set of errors that leads to miss principal goal designed:

Failure = {*err*1, *err*2, …, *err*j, …, *err* m}, $F = \sum_{j=1}^{m} err_j$

In turn, *error (err)* is a set of faults that changes or alters the objectives within a project, decreasing the expected results of the main goal: Error (*errj*) ={*flt*1, *flt*2, …, *flti*, …, *flt* n}, $errj = \sum_{i=1}^{n} flt_i$

Fault (flt) is a basic element that shapes errors and leads to failure. Fault is caused by misleading modes of cognition and action leading to errors.

Hence, $\sum_{i=1}^{n} fault_i \Rightarrow error\ j$, $\sum_{j=1}^{m} error_j \Rightarrow$ *Failure.*

Failure can be categorized as Total or Partial:

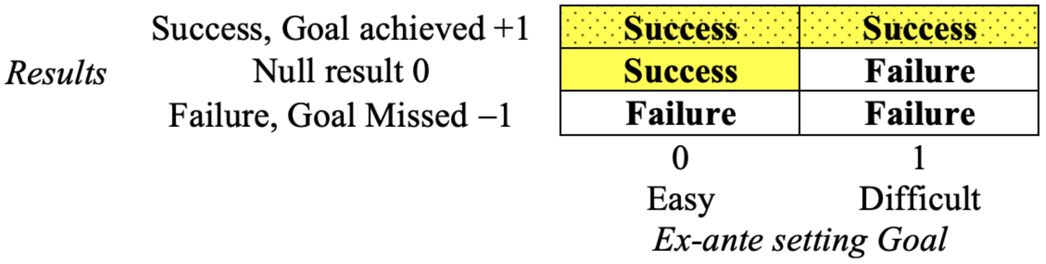
Total Failure means that all primary objectives of the designed principal goal are missed because of manifold and consequential errors in the system: Total Failure = *missing principal goal*

Partial Failure is the non-achievement of circumscribed and/or specific objectives of the principal goal because of some errors that reduce expected results and the overall effectiveness of the project. In the context of partial failure, the majority of objectives leading to the main goal are not achieved: Partial Failure = {*objective-1 achieved, objective-2 achieved, objective-i missed*, *objective-j missed*, …}, with objectives missed >objectives achieved in innovation project.

Of course, {Partial Failure } $\subseteq$ {Total Failure}

Total or partial failures can be due to goal difficulty, environmental complexity and uncertainty in the project management for endogenous and exogenous factors (Shenhar, 1998; Perrow, 1984; Pich et al, 2002;).

Moreover, if Failure (*F*) and Success (*S*) are two sets in a space of events. The complement (**C**) of *F* is *S* (all objectives are achieved), given by the set of elements not in *F* (i.e., $S=F^{C}$). The space of events can include Failures (Fs), Successes (Ss) and Inconclusive Results (Is), when there is a balance between objectives achieved and missed such that the project cannot be categorized as success (full achievement of the principal goal) or failure (missing main goal). The concepts and terminology of failure are used to design a matrix of failure underpinned in goal-setting theory by Locke (1982) and goal difficulty (Hirst and Lowy, 1990) in contexts of environmental complexity and uncertainty (Perrow, 1984; Pich et al., 2022; Shenhar, 1998). In a simplified model, a player (e.g., organization) can choose to establish, *ex ante*, for an innovation project as principal goal 1 (a difficult goal that maximizes the payoff) or 0 (an easy goal that minimizes the payoff). Of course, goal setting in the organization is assumed to generate payoffs ≥0, i.e., organizations cannot set ex-ante negative results leading to failure of projects (negative payoff). The corresponding environmental results for the organization in this game can be 1 (goal achieved, success), 0 (null or inconclusive result), or -1 (goal missed, failure) as represented in Figure 1:



Results	0 Easy	1 Difficult
Success, Goal achieved +1	**Success**	**Success**
Null result 0	**Success**	**Failure**
Failure, Goal Missed −1	**Failure**	**Failure**

Ex-ante setting Goal

Figure 1. Matrix of failure in innovation project

Note: horizontal axis indicates the ex-ante goal of the player/organization (1=difficult or 0=easy), of course by definition goal setting is ≥0, it has to be a non-negative payoff. Results indicated on a vertical axis can 1=goal achieved, 0=null result, -1=goal missed=failure.

Three main basic cases are:

- *Case 1 of easy goal setting=0.* If player (i.e., organization) A sets for an innovative project an easy goal equal to 0, the failure can be only the event -1 in the presence of triple outcomes in the matrix (-1,0,1 on vertical dimension of figure 1). The probability of errors and failure (Prf), using an equal-likelihood model[1], is Prf=1/3=0.33.
- *Case 2 with a difficult goal setting=1.* Player/organization B sets a difficult goal equal to 1 (one), max payoff in the

setting target (horizontal axis) given by two options 0 and 1, or this goal of 1 is the only useful outcome for the player in the presence of an environmental threat. The matrix in Figure 1 (vertical axis) shows that only one result is favorable to player B according to its goal-setting i.e., 1. The probability of errors and failure (Prf) is given by the total number of flops (two outcomes out of three: i.e., -1,0) divided by the total number of possible outcomes (i.e., three): Prf=2/3 = 0.667. Although the literature shows that setting difficult goals can increase organizational performance compared to easy ones (Locke and Latham, 2002, 2006), an in-depth analysis here also reveals that a difficult goal setting can lead to a double probability of failure. Moreover, if the goal setting of player B is 1, the max achievable payoff, and player B achieves the outcome 0 (that is not negative, but it is not the goal set), it can be affected by the Anna Karenina effect for main goal missed, ex-ante designed as 1 (max). To clarify this aspect, a short background can clarify the implications of the Anna Karenina effect in the proposed conceptual framework here of failure in the context of project management of innovation. The first sentence of Tolstoy's (1875–1877/2001) novel Anna Karenina is: “Happy families are all alike; every unhappy family is unhappy in its own way”. Tolstoy means that for a family to be happy, several key aspects must be given (e.g., good health of all family members, acceptable financial security, and mutual affection). If there is a deficiency in any one or more of these key aspects, the family will be unhappy in its own specific way. Diamond (1994, 1997) extended the principle behind Tolstoy’s first sentence of his novel in scientific research, calling it the Anna Karenina principle: for something to succeed, several key conditions must be fulfilled but the deficiency in any one of the factors or not achieving the designed main goal can lead to a perspective of failure, as in the case just described (Bornman and Marx, 2012).

- *Case 3 of a combination in goal setting given by 0-1.*The matrix of failure can change if player C established simultaneously as goal both 0 and 1 (two targets); in this case, the space of the event has 6 environmental situations and using an equal-likelihood model, the probability of errors and failure is, of course, lower and equal to Prf=2/6=0.33.

Appendix A shows, that using game theory, uncertainty in decision-making affects the best strategy to develop an innovation project by organizations.

Overall, then, failure of projects is when an organization has a clear goal that is not achieved: goal failure. Setting difficult and specific goals in projects can induce improvements in organizational performance compared to general and easy goals (Locke,1982; Locke and Latham, 2002, 2006). However, difficult goals in innovation projects increase the probability of errors and consequential failure with main consequences (Judge and Kammeyer-Mueller, 2008).

3.2. Proposed taxonomy to structure errors leading to failure in innovation projects

To gain a more complete conceptual framework, using the theoretical framework and concepts described in previous sections, the present research proposes here a structure of factors determining the failure in innovation projects, based on three main typologies or classes of error (Figure 2):

1. Design and planning errors that can lead to a flop of one or more objectives in an innovation project inducing a partial or total failure
2. Errors in execution/implementation

3. Errors in market orientation

These general types of error are due to a number of specific, internal and/or external causes. There are also latent causes of errors leading to failure that are less visible and tend to underlie or precede other causes, such as: *a)* deficient activities, done poorly or mistakenly omitted in the R&D process and *b)* deficient resources that are missing or insufficient in the organization but basic for innovation development (cf., Cooper, 1975; Newman, 2001; Zhang et al., 2022).

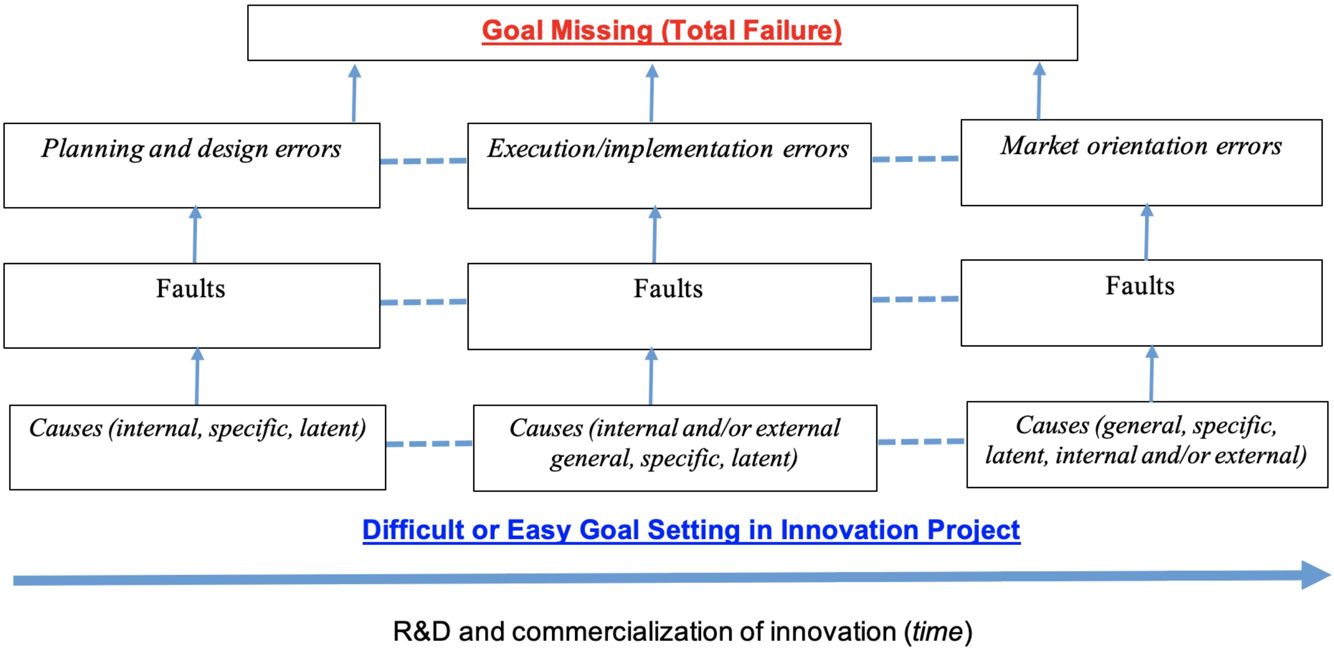


Figure 2. Structure of main types of errors leading to goal missing (failure) in innovation projects

The proposed structure of factors determining the failure in innovation projects, visualized in Figure 2, pinpoints that failure as a goal missing is due to errors in phases of planning and design, execution/implementation and/or market orientation of the project. The following description of proposed categories of errors clarifies the structure of factors determining the failure of innovation projects:

a. *Planning and design errors in innovation projects.*Errors lead to ineffective and inefficient planning and design in innovation development with partial failures in specific objectives or total failure in the overall goal of the project. Planning and design of innovation refers to moment-to-moment steps in taking actions in the correct time and scheme, from the starting to ending phase of project development, to achieve the designed objectives and consequential principal goal of innovation. Planning and design errors are due to defects in design theory that are difficult to find before the completion of the project and/or to verify the causes. The design theory defects can be due to the bounded rationality of the project team and/or the complexity of the project that reduces the understanding of the relations in the context of environmental uncertainty (Simon, 1962; Klaes and Sent, 2005). Hence, errors in this stage are due to making an incomplete and/or inefficient plan or design to face environmental complexity and uncertainty (Zhang et al., 2022). This class of design errors can be due to faults in the process of innovation development that generate one or more latent errors, which are activated when specific circumstances occur and create the conditions for partial or total failure (Laprie, 1995). This type of error in innovation projects is also due to a scenario that makes an organization unable to progress towards the designed main goals because of a poor loadout (a set of resources and abilities chosen by the organization before embarking on a strategic project of innovation). These types of errors and faults can be also associated with the specificity of technology, complexity, and pace of innovation in project management (Shenhar, 1998). Moreover, the level of criticality in design errors increases the risks of project failure in innovation development. From the perspective of Perrow (1984), this type of error affecting innovation projects can be due to complex systems that reach a point where all the possible interactions cannot be adequately understood or identified and controlled. As a consequence, complexity is one of the elements that can lead to this type of error in project development of innovation, which can alter objectives and the achievement of the final goal.

b. *Execution and implementation errors: when an organization does not succeed in something they had planned to do in the phase of design*

   Execution and implementation errors are when an organization is not able to finalize the correct ending phase of an innovation project. The bounded rationality of organizations in complex environments can generate errors in this stage as well as calculation errors, equipment operation mistakes, arbitrary change of the design scheme, implementation of works in project carried out in the wrong way, inadequate maintenance and management, etc. In addition, this type of error leading to the failure of the innovation project is also due to inadequate consideration of the boundary conditions, material defects, and unknown interaction of components and elements. Other factors determining this type of error can be due to poor ability to deal with the ambiguity between environmental uncertainty and structural complexity in the phase of implementation of the project (Mihm et al., 2003). Pich et al. (2002) argue that when projects increase in complexity, the consequential ambiguity of information may influence execution and implementation, and the capabilities of the team to successfully finalize the project with the achievement of intermediate objectives and principal goals. One of the determinants of this type of errors in complex projects is that designers, engineers, etc. cannot afford to wait for complete information before implementing the overall project and will often continue through the project development by using preliminary and ambiguous information that may increase the risk of errors in turbulent environments (Laprie, 1996; Pich et al., 2002).

c. *Market orientation errors: when an organization has for an innovation project sales and profit margins below expectations, and/or cost and investment exceeding expectations.*

   The general reason for the failure of innovation in markets is due to low profit margins, excessive development costs and excessive investment. This type of error can be due to management making poor assessments of complexity and misleading market forecasting with scarce strategic actions that do not reduce uncertainties in the new marketplace (Cooper, 1975). In particular, errors here are in misleading market analyzes that do not detect the role of competitors firmly entrenched in the market, creating higher difficulties in breaking into the market than expected, overestimation of potential users and technical deficiencies in the product. Moreover, “bad timing” is an important category of this type of error. One of the errors in this typology leading to innovation failure is that firms underestimated the innovation development expenditures in markets and erred in their estimates of the production facilities that would be required to manufacture new products. Errors in market orientation leading to failure of innovation can also be due to also to the lack of needed resources to undertake the venture of market penetration, lack of marketing research skills or people, followed by a lack of selling resources or skills (Cooper, 1975). Errors of market orientation are that management underestimates the strength of competitors, overestimates the number of potential users, and overestimates the price customers would pay for the innovation. These errors can be major causes of low sales and consequential failure of innovation in markets. Overall, errors of market orientation leading to failure of innovation can be due to deficiency in operational marketing given by the lack of structural actions to achieve the goals of an effective marketing plan. Hence, errors in market orientation are due to a lack of understanding of the marketplace, the customers, and the competition environment (Booz and Hamilton, 1965; Hlavacek, 1974; Konopa, 1968; O'Meara, 1961).

Finally, it is important to observe that a failure of the principal goal is also when a project has corrected planning and design, execution and implementation, but innovation does not solve the problem. Instead, errors in planning, design and implementation, and/or market orientation can lead to a failure of intermediate objectives and the consequential missing of the main goal in innovation projects at time *t* or at *t+n*.

4. Case study Research

The proposed conceptual framework of innovation failure is verified here with a case study research and examples that clarify the practical application in project management. Multiple-case study research plays a main role in supporting the process of inducting theory in new topic areas (Eisenhardt, 1989). The proposed conceptual framework here, supported by case study research, can be valid and consistent because of the linkage with empirical evidence. The evidence with case study research that will be described here has independence from prior literature and is particularly well-suited to these research areas in which existing theory about innovation failure is scarce. Eisenhardt and Graebner (2007) argue that theory building based on case study research can create a strong connection from qualitative evidence to deductive research. The study here substantiates the suggested conceptual framework and taxonomy of failure in innovation projects with main case studies from pharmaceutical sector where 90% of projects in clinical drug development fail (Sun et al., 2022), aircraft and aerospace sectors that record a lot of project failures (cf., Celikmih et al., 2000; Li and Hou, 2022; Fernández et al., 2022; Kaplan, 2022), traffic and transportation engineering with errors leading to bridge failure (Schultz et al., 2022; Zhang et al., 2022), construction industry with also errors leading to collapse of buildings and consequential projects failure (Baiburin, 2017; Tayeh et al., 2020) and finally failures of innovative projects in Information and Communication Technologies (Livescault, 2023; Cosmos Collective, 2023).

Information here is based on secondary data that play a vital role in scientific inquiry to provide evidence based on a case study research to support a new theoretical framework (Ansari et al., 2016; Kozinets, 2002).

5. Evidence from a case study for inductive implications of organizational behaviour

The proposed conceptual framework suggests that innovation projects fail when there is a goal missing, which can be due to three main typologies of errors: in planning and design, in execution and implementation and in market orientation

(Figure 2).

Table 1 shows a case study that is discussed to verify and explain the three general classes of errors in different stages of R&D and marketization leading to failure (i.e., goal missing) of innovation projects.

Table 1. Types of errors leading to goal failure in innovation projects.

Types of errors leading to failure	Case study of failure in innovation project	Error
Planning and design errors	▪ Pharmaceutical sector Antibody drugs for Alzheimer's disease	Targeting tau protein in drug design has resulted in ineffective
	▪ Aerospace sector Mars Climate Orbiter	Planning high economic and temporal constraints in the project life cycle leads to failure
	▪ Boeing 737-MAX	Design problems in sensors and other technical components generated accidents
	▪ Transportation engineering, bridge failure: -Tacoma Bridge (USA) -The I-35W Mississippi River bridge (USA) -Chirajara Bridge (Colombia) -FIU Bridge (Miami, FL, USA)	-Design errors to face high wind speeds for Tacoma bridge -High fatigue of truss bridge joints for the Minnesota I-35W bridge -Incorrect design of the bearing capacity of the lower beam of the bridge tower for Chirajara Bridge -Deck joint failed with the consequential collapse of FIU Bridge
Execution and implementation errors	▪ Transportation engineering, Bridge collapse: -Morava Bridge (Italy) -Rhine Bridge (Germany)	Problems in control processes during the construction of these bridges
	▪ construction industry, Building collapse in the construction stage	Poor soil compaction, expired materials, material or component failure, corroded or second-hand reinforcement steel

	Gwangju Hwajeong I-Park (South Korea)	
Markets orientation errors	▪ ICT sectors -Nintendo Virtual Boy	Overpriced piece of gaming hardware, a limited set of games for consumers
	-CNN+, streaming platform	The streaming market is investing in diversification of content, instead of focusing on just one type of content as CNN News
	-Google Stadia, a cloud-streaming gaming console	Google has a strong established business and did not create a new brand for this service, creating uncertainty in customers; moreover, Google did not correctly assess the target audience's behavior in the market

Case study of goal missing for planning and design errors.

- Pharmaceutical industries: failure of antibody drugs for Alzheimer's disease.

  Clinical drug discovery and development have a high risk of flops and about 90% of projects fail during the clinical trial phases (Sun et al., 2022). Clinical failures in the R&D process of drug discovery can be due to incorrect selection of the best drug candidate with optimal properties leading to: a lack of clinical efficacy (about 45%), higher toxicity (roughly 30%), poor drug-like properties (around 12%), and poor strategic planning 10% (Dowden and Munro, 2019; Harrison, 2016). These factors, just mentioned, are associated with errors in planning and design of drug discovery and development leading to missing the intermediate objectives and principal goal to treat the disease. The main case study is the *difficult* goal of Biogen (an American multinational biotechnology company) which endeavored to develop the anti-tau antibody gosuranemab drug—licensed from Bristol Myers Squibb in 2017— to treat Alzheimer's disease but it failed the objectives in the phase 2 trial and was rapidly dismissed (Taylor et al., 2022). The design error in the development of this drug is associated with targeting Tau, a protein that forms insoluble filaments and accumulates as neurofibrillary tangles in Alzheimer's disease patients and related tauopathies. As a result, the antibody gosuranemab focused on the microtubule-associated protein Tau to treat the complex Alzheimer's disease is ineffective, leading to a flop of the designed goal (Teng et al., 2022). Design errors in this drug development focused on anti-Tau can be due to the lack of comprehensive understanding of the complex mechanisms of this antibody drug in the human body (Lindkvist et al., 1996; Pich et al., 2002; Sauser et al., 2009). Targeting Tau is also a design error in other R&D processes to cure patients with progressive supranuclear palsy, a type of neurodegenerative disorder, because ineffective. In fact, poor results are similar for Roche and AC Immune's anti-tau antibody semorinemab in 2020. These drugs are unable to show an impact on tangles in the brain measured using Tau-PET scans, despite its impact on cerebrospinal fluid levels of the protein, which might give an explanation for scarce efficacy. Roche corporate has suggested design error is that it may be difficult to target Tau with a large molecule, such as an antibody, and if that assessment is correct, this insight can create problems for other Tau-targeting antibodies (Taylor et al., 2022).

- Aerospace industry: Failure of the innovative project of Mars Climate Orbiter and Boeing 737-MAX

  A case study of the project failure of NASA's Mars Climate Orbiter (MCO), lost in space after completing its nine-month journey to Mars, shows another case of errors in the planning and design of research projects having difficult goals (Sauser et al., 2009). In this case study the design errors leading to the failure are due to managerial behaviour. In particular, planning errors of management are due to strong economic and temporal constraints forced by the strategy of ‘better, faster, cheaper’ for developing the complex project that has generated its inevitable failure of difficult goal (Sauser et al., 2009). The errors in planning are that NASA management did not assess properly the level of environmental complexity and uncertainty, and the time pressures involved with the MCO project (Shenhar and Dvir, 2004). In fact, the errors in planning are that some innovative projects, having difficult goals, can be more uncertain, risky, or complex than others, and constraints in timing and economic resources may not work for every project (Henderson and Clark, 1990; Pich et al., 2002; Sauser et al., 2009). Shenhar and Dvir’s (2004) framework can clarify planning errors in this MCO project because of a misfit between project type and project management style considering dimensions of novelty, technology, and complexity. Pich et al. (2002) approach maintains that executives of MCO projects applied an incorrect strategy to face highly uncertain information and complex situations. In fact, Sauser et al. (2009) maintain that the wrong perception of MCO’s problems resulted in an improper managerial approach. The presence of errors in planning is based on the application, in the initial phase, of proper project management having the capability to predict potential problems in complex environments. In short, errors in planning and design for managing complex space projects, based on project constraints in the presence of high levels of risk can lead to failure, such as for MCO (Sauser et al., 2009), Space Shuttle Columbia in 2003 (Guthrie and Shayo, 2005; Hogeback, 2023) and numerous other innovative space projects (Newman, 2001).

In the aircraft industry, an interesting case study is the design error in the Boeing 737-MAX (an innovative project having an intermediate level of difficulty). Boeing’s 737-MAX aircraft was operational in 2016 but in 2018 some pilots had lost control of the aircraft because of the failure of a sensor and other technical problems of the aircraft’s systems. This new aircraft showed technical problems because of errors in the aircraft’s design concerning the signs of the angle-of-attack sensor and other instruments affecting the correct mode of operation in flight in the presence of different atmospheric instability, leading to a failure of the project (Calleam, 2023).

- Transportation engineering: bridge failures

  The construction of bridges can have an average or high level of difficulty (Schultz et al., 2022). Design error can lead to project failure with bridge collapses because of defects in design theory and bounded rationality of designers in the presence of complex and uncertain events in atmosphere, lithosphere, hydrosphere, etc. (Perrow, 1984; Schultz et al., 2022; Zhang et al., 2022). In fact, in the presence of complexity and uncertainty, some design errors can be latent and are difficult to discover before the completion of the bridge, or before structural tests and the occurrence of natural events (Lee et al., 2013). Hence, design errors are caused by the cognitive limitations of human beings in the presence of manifold and complex factors and a lack of sufficient understanding of the interaction of bridges with the surrounding environment (Zhang et al., 2022). For example, the collapse of the Tacoma Bridge in the U.S. state of Washington was due to an error design due to an insufficient understanding of the effects of wind speed on the motion of the bridge (Billah and Scanlan., 1991; Zhang et al., 2022). The collapse of the I-35W Mississippi River bridge downstream from Saint Anthony Falls in Minneapolis (Minnesota, United States) was due to a design error due to insufficient understanding of the fatigue of truss bridge joints and other calculation errors by designers (Salem and Helmy, 2014). The failure of the FIU Bridge in Miami (Figure 3) was due to design flaws in which the deck joint failed with consequential collapse (Architect, 2023; Shaolli, 2019). Another example is the collapse of the Chirajara Bridge in

Colombia during construction because of the incorrect design of the bearing capacity of the lower beam of the bridge tower (Pujol et al.,2019).

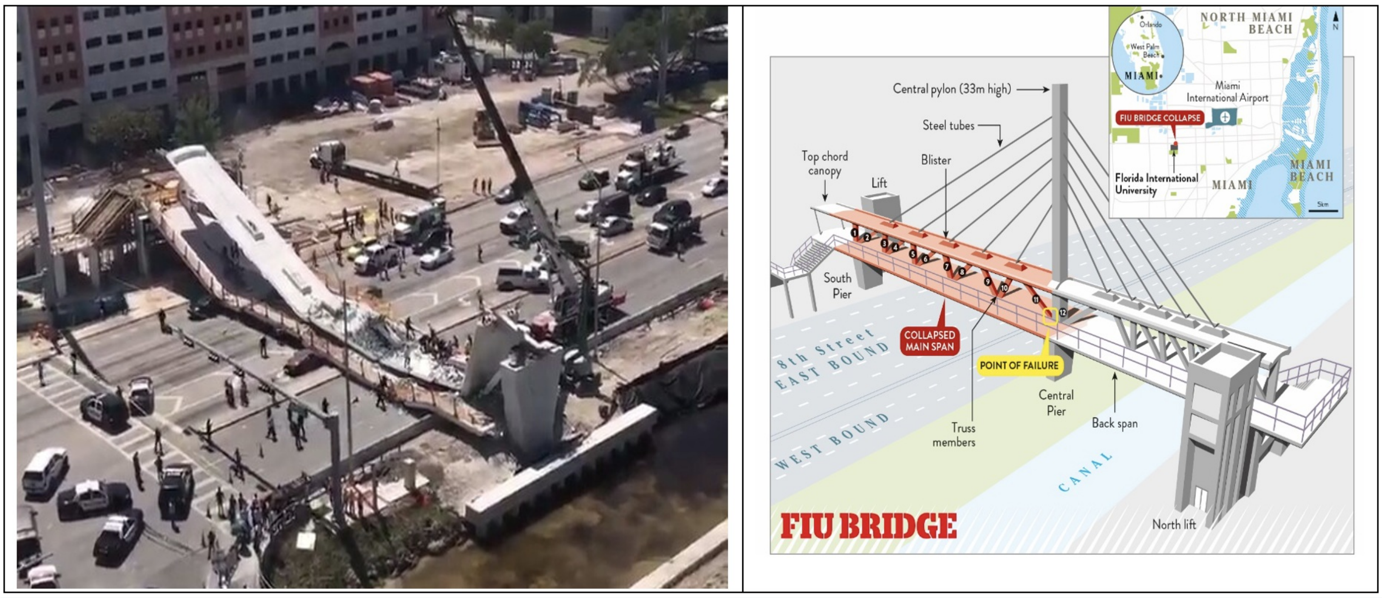


Figure 3. Bridge Collapse for Design Errors at Florida International University (Miami, USA) , 15 March 2018. Photo by Gabriela Colazo (Left) in Architect (2023). *Note*. The action calculation error in the member 11 and 12 deck joint is the connection that failed with consequential FIU bridge failure (cf., Brady Hwywood,2023; Photo in Shaolli, 2019).

Case study of goal missing for execution and implementation errors.

- Transportation engineering: bridge failures

  Studies show that some bridges collapsed during construction due to execution errors (Chan et al., 2022; Fu et al., 2013; Yi et al., 2015; Zhao et al., 2017). Execution errors in bridge construction can be due to equipment operation mistakes (Pereira et al., 2020; Zhao et al., 2017), changes in the construction scheme, making the construction work carried out in the wrong way and poor consideration of the boundary conditions, defects in alloys, binder or brackets used, structural instability of scaffolding during the construction of steel bridges, etc. (Zhang et al., 2002). Examples are the overall buckling failure of the compression chords, for execution errors of the project, in Morava Bridge (Italy), the buckling failure of a steel plate of compression flange in a steel box girder, for assembling errors, in Rhine Bridge (Germany), etc. In general, execution errors in innovation projects are due to problems in assembly and control processes, security management, experience, and expertise of technicians about mechanical characteristics of structures during the construction in different environmental conditions over time, etc. (Zhang et al., 2022).
- Civil engineering: flops in the construction stage of buildings

  The construction of buildings can also have an average or high level of difficulty (Tayeh et al., 2020). The execution errors at the stage of construction in buildings can be due to defects in construction and erection works, violation of operation rules, poor quality of materials, excess loads accidental external impacts, etc. (Baiburin, 2017). Tayeh et al. (2020) argue that execution errors are of great concern for the construction industry and increase costs. The study revealed the accurate analysis of some critical factors to avoid errors during the construction stage, such as:

construction materials, inspections, construction equipment, construction management, etc. In addition, some of the most important errors are the poor evaluation of soil compaction, exceeding the allowable limits of verticality of the structural elements, insufficient reinforcement concrete cover, owner's negligence of inspections, absence of an engineer in most of the construction phases, using expired material, material or component failure, using corroded or second-hand reinforcement steel, using materials not of acceptable quality and not conforming to the specifications or design and lack of required equipment. An example of this type of error is Gwangju Hwajeong I-Park (South Korea) on 11 January 2022, in which the wall of a 39-story apartment building under construction collapsed (Yonhap, 2022). The HDC Hyundai Industrial Development New Apartment Collapse Accident Investigation Committee determined that faulty construction methods and substandard building materials were responsible for the accident (HDC, 2023). In addition, unauthorized changes to the 39th floor of Building 201, making the slab of the floor 35 cm thick instead of the originally proposed 15 cm, have led to building collapse.

Case study of goal missing for errors in market orientation.

Nintendo (a Japanese multinational video game company) released in 1995, the Nintendo Virtual Boy, marketed as the first console capable of displaying stereoscopic 3D graphics. However, it was an overpriced piece of gaming hardware for the market. Moreover, it featured a difficult operating system for users and had a limited set of games for requests of consumers (Livescault, 2023). These market errors have generated a failure of this new product.

In March 2022, CNN (a U.S. corporate of multinational news channel and website) launched its own streaming service, called CNN+, with a huge investment, to be the first news-driven streaming platform. The estimation of potential users was about 2 million to justify a planned investment of $1 billion over 4 years. However, in April 2022 it was announced that CNN+ would be discontinued, having less than 10,000 active users. Errors in market orientation are that the streaming market is growing in the number of active players. All market players are investing in diversification of content, instead of focusing on just 1 type of content as CNN invested. These errors in market orientation are due to that CNN should have researched the effective dynamics of the streaming market, not just on the business side, but on the consumer expectation side as well (Cosmos Collective, 2023).

Finally, the Google Stadia by Google (an American multinational technology company) is a cloud-streaming gaming console that enables users to stream games from the Google Cloud directly onto their computer. Google assumed that the price of 129$ for a console with 12 games, would have been appropriate to attract customers to move from PlayStation, Xbox, or Nintendo consoles to this new platform. New customers also needed to purchase a subscription of approximately $10 per month in order to keep playing their Stadia games. The project Google Stadia failed in January 2023, less than 3 years after its launch. Google has made errors in market orientation because of having a strong established business and should have created a new brand for this innovative service in the market and evaluated with accuracy their target audience's behavior in the market before launching the new product (Cosmos Collective, 2023).

6. Theoretical and managerial implications

Failure is when organizations do not achieve the main goal of projects because of a set of errors. The proposed conceptual framework of failure in innovation projects clarifies the structure of factors determining goal failure with a categorization of main types of errors in stages of R&D and marketization process to improve strategic and project management in organizations. Results of study cases suggest the specificity of errors per type of innovation and industry, mainly associated with the bounded rationality of humans in the presence of increasing complexity and uncertainty (Chan et al., 2022; Mihm et al., 2003; O'Hare, 2000; Perrow, 1984; Pich et al., 2002; Simon, 1982, 1993). In general, errors determining the failure (goal missing) have to be appropriately contextualized to provide fruitful R&D management implications.

6.1. Implications of strategic management in the failure of innovation projects

In the presence of different types of errors leading to goal failure in innovation projects, organizations can apply two basic strategies to improve project management in the stage of R&D:

- Strategic *Learning*
- Strategic *Adaptation*

Learning. Learning from errors in planning and design, and execution leading to innovation failure can take place only when an organization has a choice among alternative modes of cognition and action in the R&D process. In particular, learning in this case is directed to increase the efficiency in new processes of project development (Levinthal and March, 1993; Madsen and Desai, 2010). Weick (1991) argues that organizational learning has mixed different concepts, such as change, learning, and adaptation. From a perspective of strategic management for dealing with errors in design and planning, and execution leading to failures of innovation projects, R&D managers and designers should consider learning as the: "the process within the organization by which knowledge about action-outcome relationships and the effect of the environment on these relationships is developed" (Duncan and Weiss 1979, p. 84, cf., Weick, 1991). Organizations, in the presence of errors and consequential goal missing (failure), have to change routines to cope with organizational deficiencies and environmental turbulence. In this context, the theory by Argyris (1976) proposes two learning approaches that can reduce, whenever possible, errors in R&D processes: organizational research and trial-and-error. Argyris (1976) argues that the sequence of trial-and-error approach in the development of innovation can foster changes in the organizational behaviour directed to learning processes to achieve expected objectives (cf., Nelson, 2008). In particular, the approach by Argyris (1976) can improve project management of innovations to avoid errors and consequential failure of principal goals with:

-- *Single-loop learning* in organizations detects minor errors in the phases of project development and changes the actions to minimize deviations and differences between expected and obtained objectives/results, maintaining the design intent and current routines in the organization.

--*Double-loop learning* can be necessary in the presence of major errors to support radical change in organizational and managerial behaviour to re-design project management to be effective in achieving goals.

A fruitful management of learning processes, in the presence of errors in R&D, can improve the strategic change of organizations to achieve new goals in the next innovation projects and to take advantage of main opportunities.

Adaptation is the strategy to face mainly errors of market orientation, but this approach can be also necessary for errors in the execution of projects when causes are due to external and specific factors. Adaptiveness as a strategy to cope with errors leading to goal missing is the ability of an organization to modify itself or its environment when either has changed to the organization's disadvantage so as to regain, whenever possible, at least some of its lost effectiveness, efficiency and performance. In fact, adaptation can generate a change in the internal state of an organization to improve market strategies to pursue one or more of its intermediate objectives leading to principal goals in innovation projects in the presence of high market competition (Locke, 1982, 1989; Locke and Latham, 1990, 2002, 2006). Ackoff (1971) states that a system (organization in our case) learns how to adapt when it is continuously subjected to internal and/or environmental change, such that it increases the ability to maintain its efficiency under different conditions. As a consequence, an adaptation strategy can be learned. In general, in the presence of errors in innovation projects leading to a failure (F) in achieving intermediate objectives and/or principal goal, an organization α has better adaptedness (A) than organization β in the environment (E), if and only if α is better able to react to failure F and learn than is β: α is better adapted to innovation F than β in E $\Leftrightarrow$ $A(\alpha, E)>A(\beta, E)$

Moreover, in the presence of turbulent environments, the difficulty of the decision-making process in the development of a new innovation project is due not only given by the uncertainty of the possible events but also to the ex-ante evaluation of expected results with different strategies (cf., Appendix A with a game theory approach). Overall, then, in the presence of environmental turbulence (increasing complexity and dynamism leading to increasing uncertainty), there is limited information and bounded rationality by organizations and

The decision-making concerning innovation projects, to avoid errors and consequential failure, has to assess with accuracy the quality of the information of all external factors.

6.2. Theoretical implications

The findings of the study can also provide theoretical implications from the proposed structure of factors determining the failure in innovation projects by using set theory.

Properties: elements and relations underlying the failure

- Failure (*F*) is the missing goal caused by a set of errors
- Errors (*err*) are caused by a set of faults (*flt*) associated with internal and external causes
- *Inclusion*: $\text{flt} \subseteq \text{err} \subseteq F$
- Error condition: $\text{flt} \Rightarrow \text{err}$ (fault is a necessary but not sufficient condition for an error in project development)
- Failure condition: $\text{err} \Rightarrow F$ (error is a necessary but not sufficient condition for project failure)

Property: strategy of adaptedness

- In the presence of a failure (F, goal missing), an organization α has better adaptedness (A) than organization β in the environment (E), if and only if α is better able to learn from errors and react to failure than is β:

α is better adapted to innovation F than β in E ⇔ A(α, E)>A(β, E)

Property: probability of failure with difficult goals and Anna Karenina effect

- Setting a difficult goal can double the probability of failure in projects compared to an easy goal
- Setting a difficult goal can generate the Anna Karenina effect when a player achieves a lower payoff than an ex-ante-designed goal
- Setting mixed goals, both difficult and easy, can minimize the probability of failure.
- Organizations should invest 33% of resources in projects with a difficult goal and 67% of economic resources in projects with easy goal setting (cf., Appendix A).

Hence, the proposed conceptual structure, based on errors determining consequential missing goals, can lead to improved strategic management and trigger learning and adaptation effects in new R&D processes, fostering *a creative failure for inducing new innovations or generative failure of new innovations* (Coccia, 2017, 2021; Sosna, 2010). Overall, then, the proposed systematization of errors can clarify factors determining failure in innovation projects and support best practices of strategic management that create new models of innovation with fewer errors in the R&D process and marketization and more effectiveness to achieve intermediate objectives and goals (Firestein, 2015; Schickore, 2021; Van der Panne, 2003).

7. Concluding remarks

Errors in the R&D process and innovation failures are basic elements of scientific and technological progress (Barwich, 2019; Borycki, 2013). Since organizational and managerial behaviour varies in the presence of innovation failures, it is important to discriminate different types of errors leading to the goal missing for improving upstream design and downstream applications in markets (Laprie, 1995). In fact, the understanding and systematization of errors leading to innovation failures are critical aspects of improving R&D and strategic change of organizations in environments with rapid changes (Rhaiem and Amara, 2021; Sosna et al., 2010; Starbuck and Hedberg, 2001). This paper suggests a new conceptual framework based on key concepts and a categorization of errors leading to failure in projects to identify the critical flaws in stages of R&D that can become frustrating and detrimental for further R&D projects, for organizational motivation and performance (Locke and Latham, 1990). In particular, this study defines failure as missing a goal in a project, driven mainly by errors in planning and design, execution and implementation, and market orientation associated with internal, external and/or specific or latent causes. The understanding of the type of error in a specific stage of innovation development provides critical information to guide managerial and organizational behaviour in order to avoid errors leading to missing intermediate objectives and principal goals in the next project (Webb et al., 2013). In fact, an in-depth analysis of errors leading to failure can support new business models in organizations directed to the next scientific and technological development (Barwich, 2019; Sosna et al., 2010). The insight of this study, verified in different industries and new products/processes, shows the temporary bounded rationality and limits of organizational behaviour in planning and design innovation in the presence of problems and/or uncertain environments (Newman, 2001; Pich et al., 2002). The error analysis in innovation projects can boost the organization's behaviour to extend the perspectives in the R&D process by exploring alternative technological pathways and/or new scientific and technological directions of investigation to solve problems, errors, and/or latent causes and as a consequence reduce the probability of failure in the presence of complexity and uncertainty (Perrow, 1984). In short, the identification of heterogenous typologies of error in innovative projects (e.g., in drug discovery processes, space missions, bridge failures, etc.) induces organizations to experiment with alternative paths and new modes of action and cognition to solve problems generated by internal and/or external causes and/or unforeseen environmental changes.

We envision that this conceptual framework and categorization of errors leading to failure in innovation projects can be used to clarify what general categories occur in different stages of the R&D process in the innovation model to better understand problematic phases and why an innovation project fails, considering the specificity of projects and industries (Petroski, 1985). The analysis of errors and failure in innovation projects, using the proposed conceptual framework, associated with other approaches (e.g., Fault Tree Analysis, cf., Hixenbaugh, 1968; Vesely et al., 1981, 2002), can also offer criticism of the overall development of specific innovations to improve strategic change (Pangione et al., 2020; Gioia and Chittipeddi, 1991; McGrath, 1999). Appropriate solutions to minimize project failures can be better guided with proposed classification based on accurate terms that clearly differentiate the types of errors expected and unexpected in different phases of the R&D process (Lampel et al., 2009; Pangione, 2020). The results of the research here are consistent with previous investigations about product and project failures in different settings (Cooper, 1975; Sun et al., 2022; Sauser et al., 2009; Zhang et al., 2022). However, the results proposed here go much further in identifying general categories of errors in the R&D process and related strategies of learning and adaptation relevant to different innovations and industries. Results show that in some sectors, firms' attention appears to be focused on product and its attributes, rather than on customers' needs leading to errors in market orientation. A main implication of strategic management is the adaptability of firms to balance R&D investments and marketing research expenditures to avoid errors in market penetration and expansion (Cooper, 1975).

Although the proposed conceptual framework and categorization of errors leading to project failure are useful for strategic management, it is important to be aware of the limitations. First, some categories of error are borderline between different phases of the R&D process in an innovation project. As a consequence, a better and extended categorization of errors should be pursued in future studies. Second, the use of the proposed classification of errors in the initial phases of innovation projects can avoid some faults and direct the projects in some directions, discarding interesting insights from other alternative directions. It is important to be flexible in using the proposed classification of errors in innovation projects to consider all possible technical and market alternatives for improving R&D and achieving the designed goals. Third, this study proposes a taxonomy and evidence based on a case study, but the next step should be data-driven evidence to confirm the results and implications of the proposed conceptual framework here.

Overall, then, the proposed taxonomy of errors in innovation projects here does not represent specific typologies but general classes for the vast spectrum of R&D projects across different innovations and sectors. Without taxonomies and a general framework, like this proposed here, R&D managers have to work harder and the chances of finding correct solutions to errors can be reduced (cf., Casey, 2105; Xhignesse, 2020). Types of errors leading to innovation failure have to be known, *ex-ante*, to be, when occur, accurately categorized for appropriate managerial solutions to minimize undesirable effects in organizations and improve project management directing resources and strategic activities towards effective directions. In fact, for organizations, the understanding of errors inducing goal failure has vital aspects for improving the R&D process that supports firm performance and competitive advantage. Hence, this study contributes to the theory of innovation management to elucidate different types of errors leading to goal missing and that can improve organizational and managerial behaviour, especially when different projects fail consecutively, and the organization has no resources, know-how and dynamic capabilities to counteract the negative effects with strategies of learning and adaptation in markets with rapid changes.

To conclude, organizations can support new innovation the strategic change to take advantage of important opportunities or to cope with competitive threats in turbulent markets, but they have to also know the types and characteristics of errors leading to failure in the R&D process to find appropriate managerial solutions for achieving all goals in new projects. In fact, as Bill Gates, co-founder of Microsoft Corporation properly says: “it is... important to heed the lessons of failure.”

Appendix A. A game theory approach to analyze failure in project management

Application of game theory to show uncertainty of decision-making in new innovation projects with different strategies (from difficult to easy) and different environmental events (failure, success and null results)

A player (e.g., corporate) has to develop an innovation project and can apply three different strategies in goal setting (i.e., possible plans):

Strategy 1. Difficult goal setting with the highest payoff and loss

Strategy 2. Mix with average payoff and loss of strategy 1(difficult goal) and 3 (easy goal)

Strategy 3. Easy goal setting with the lowest payoff and loss

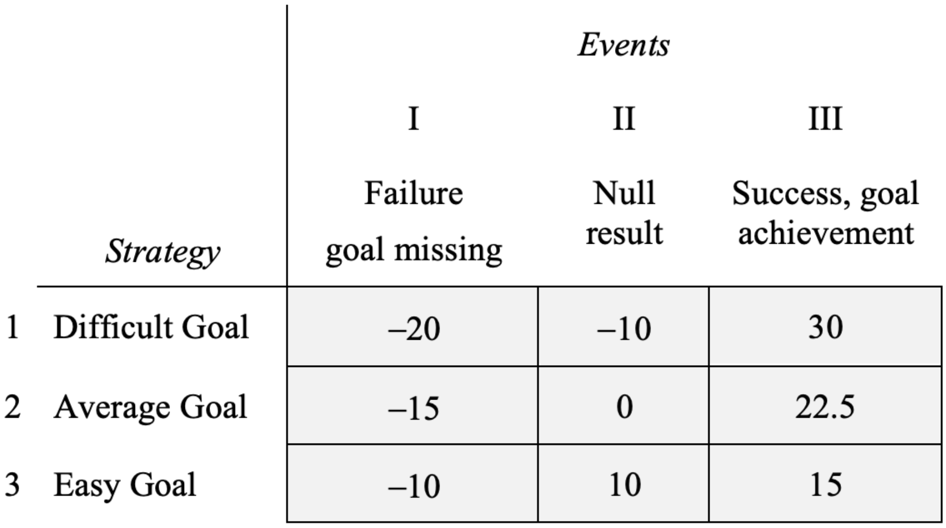
Suppose that the future events for the innovation project can be:

--Goal Missing leading to a failure with a loss that varies according to strategy 1, 2 or 3

--Null results that vary with strategy 1, 2 or 3 and can be positive or negative according to goal setting

--Goal Achieving with success having a payoff that varies with strategy 1, 2 or 3

A convenient way of describing the strategy spaces of the player (organization), having a finite number of strategies, is to draw a matrix (Table 1A). Each cell represents the payoff of the player for decision-making depending on goal setting with consequential pros and cons.



		Events		
		I	II	III
	Strategy	Failure goal missing	Null result	Success, goal achievement
1	Difficult Goal	–20	–10	30
2	Average Goal	–15	0	22.5
3	Easy Goal	–10	10	15

Table 1A. Matrix of payoff in decision-making of innovation projects.

Decision-making depends on manifold factors, such as perception of what may happen in the future, the firm's attitude towards risk and uncertainty, complexity of the projects, environmental turbulence, etc. (Pich et al., 2022).

- *Prudent player* focuses on easy goals and with a max-min strategy minimizes the loss with -10
- *Risk-taker player* focuses on difficult goals and with a max-max strategy maximizes the payoff with 30
- *Rational player* assesses the relative probability of events I, II and III considering that some events can have a higher or lower probability of occurring. If we assume that the probability of success is low 0.15, the null result is 0.50, and failure =0.35 (sum=1.00)

  Expected values are:

  Strategy 1 (difficult goal setting) = (-20)×0.35+(-10)×0.5+(30)×0.15=-7.5

  Strategy 2 (average goal setting) = 1.87

  Strategy 3 (easy goal setting) = 3.75

  The proper strategy is n. 3, in this case, the easy goal setting.
- *Approximate player* assesses the relative probability of events I, II and III with an equal-likelihood model considering that all events have equal probability of 0.333 to occur. The expected value of each strategy is:

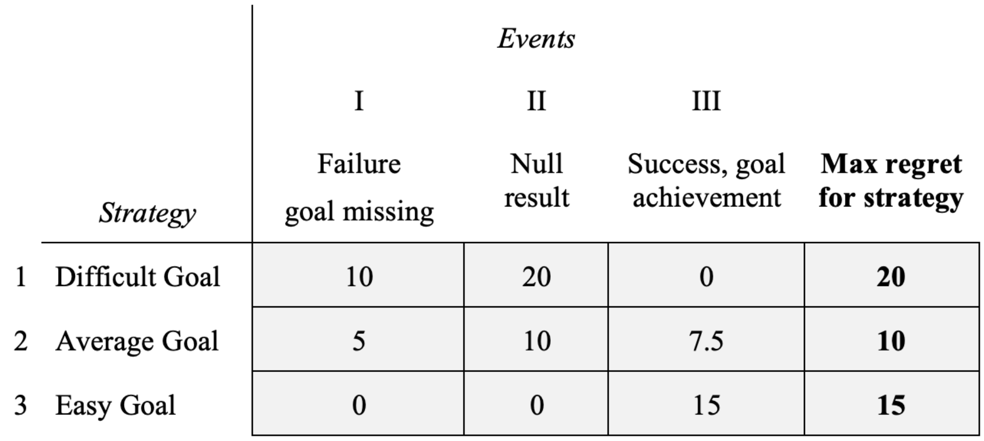
  Strategy 1 (difficult goal setting) = (-20)×0.333+(-10)×0.333+(30)×0.333=0

  Strategy 2 (average goal setting) = 2.48

  Strategy 3 (easy goal setting) = 6.6

  The proper strategy is also n. 3 with the easy goal setting.
- *Player without regret* in developing an innovation project assesses the regret of a decision with a concept similar to opportunity cost in economics. If the player applies strategy 3 (easy goal setting) and event III occurs, the payoff of decision-making is 15. But if he had known that event III would have occurred, he would have chosen strategy 1 (difficult goal setting): The difference between what was actually achieved as payoff (15) and what could have been achieved as payoff (30) is the measure of regret: i.e., 15. *Mutatis mutandis* for all the other decision-making values, the

regret matrix is in Table 2A.



		Events			
		I	II	III	
	Strategy	Failure goal missing	Null result	Success, goal achievement	**Max regret for strategy**
1	Difficult Goal	10	20	0	**20**
2	Average Goal	5	10	7.5	**10**
3	Easy Goal	0	0	15	**15**

Table 2A: Matrix of regret in decision-making of innovation projects (values are in modulus=non-negative values)

The max regret for each strategy is in the last column. This player applies the min-max strategy to select the lowest value of max regret, i.e., 10. The proper strategy is n. 2 with average goal setting.

Finally, players (organizations) can also make a combination of strategies for different innovation projects and for the sake of briefness, we assume only two events: failure or success. The payoffs of strategies can be placed on two vertical columns and be connected with a straight line as in Figure 1A. The most convenient combination of strategies is the lowest intersection point of the upper polyline: min-max solution.

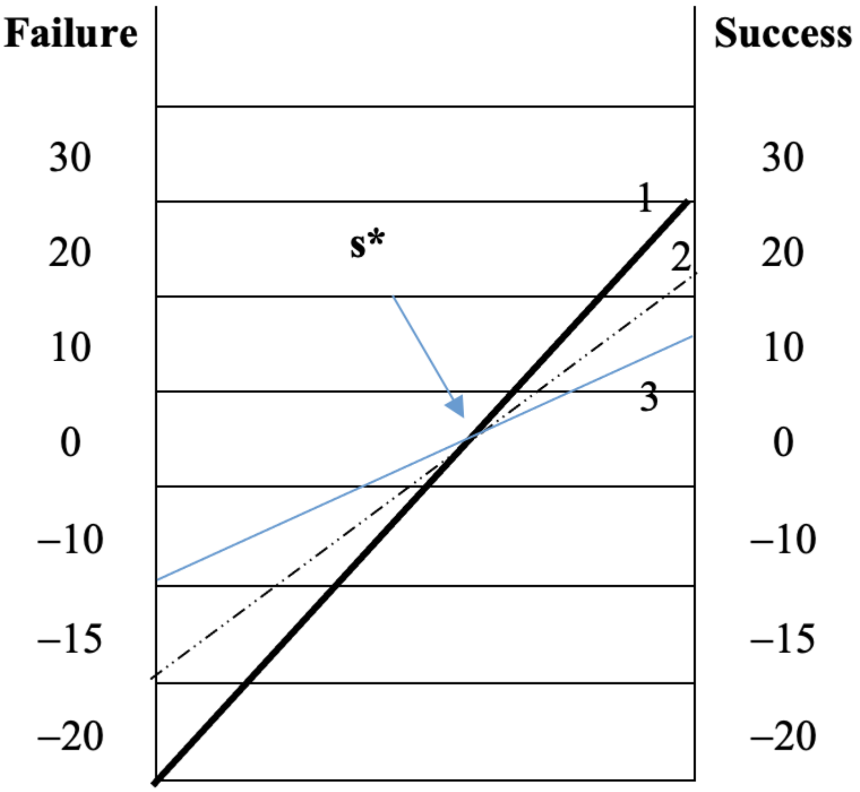
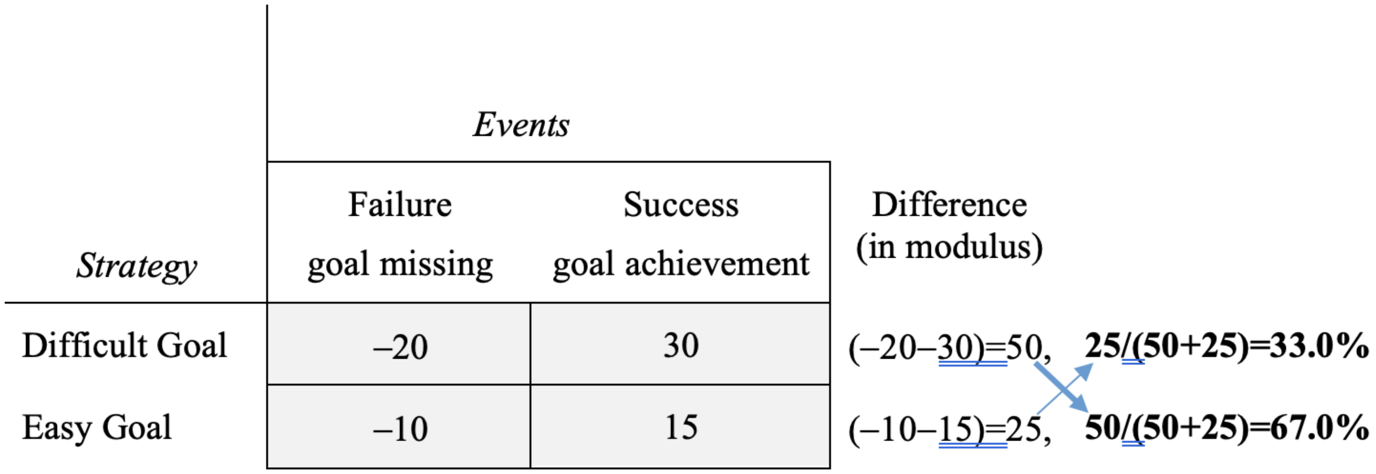


Figure 1A. Graphical solution of the problem about the most convenient strategy for different research projects. The most convenient combination of strategies (s*) is the lowest intersection point of the upper polyline.

The organizational resources for innovation projects can combine the strategies identified in Figure 1A with the percent proportions calculated in Table 3A.



	Events			
Strategy	Failure goal missing	Success goal achievement	Difference (in modulus)	
Difficult Goal	–20	30	(–20–30)=50,	**25/(50+25)=33.0%**
Easy Goal	–10	15	(–10–15)=25,	**50/(50+25)=67.0%**

Table 3A. Solution of the combination of strategies for the development of innovation projects.

The difference (in modulus) of one strategy is allocated to the other strategy because it is an indication of the loss of a wrong choice (opportunity cost). Results suggest that the organization should invest 33% of resources in projects with a difficult goal and 67% of economic resources in projects with easy goal setting.

Declaration of competing interest

The authors declare that he has no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper. No funding was received for this study.

Footnotes

[1] The equal-likelihood model is a based on a finite number of alternative outcomes, all of which have equal probability: 1 indicates the certainty, 0 indicates the impossible event.

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