Incremental Innovation versus Discontinuous Innovation: An Analysis of the Fuzzy Front End*

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ABSTRACT: Companies innovate to increase revenues or reduce costs. The literature identifies two types of innovation approaches: incremental innovation, when an enterprise uses and "exploits" its current competencies, and radical innovation, which points out a company's need to develop and "explore" new competencies. In product design and development through discontinuous innovation, fuzzy front end (ffe)—the most critical stage due to the difficulty of understanding and articulating the opportunities detected—has a decisive impact. Thus, through literature analysis, this reflective article allows a deeper understanding of ffe from two dimensions: i) Degree of innovation—incremental innovation vs. discontinuous innovation— and ii) Time—a project stage. To that end, we propose a framework of reference for ffe construct. The results enable academia to reduce the gap around the ffe construct and companies involved in innovation projects to better understand the nature of a project according to the degree of innovation of a new product, as well as how to proceed in order to reduce uncertainties; insights that could ultimately increase the chances of a new product becoming successful.

KEYWORDS: Fuzzy front end, discontinuous innovation, incremental innovation, product development, radical innovation.

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Introduction

Companies innovate to increase revenues or to reduce costs. Products lose competitiveness over time and so companies are forced to innovate in order to maintain a level of competitiveness (Salerno & Gomes, 2018). In this context, to facilitate innovation, company managers are interested in implementing the best product development practices that have already proved successful. These best practices are not fixed rules, but they are rather approaches considered beneficial in the context of the company, according to its degree of maturity (Oliveira & Kaminski, 2012).

The literature classifies the degree of product innovation according to technical or market novelty from incremental to radical innovation. Incremental innovation usually consists of improving products by using existing technologies and targeting existing markets (Reid & Brentani, 2004; Salerno & Gomes, 2018). This type of innovation involves changing some features of an existing product to extend its economic life, increase sales, or decrease costs. Based on this, companies undertake new product designs based on their current competences, which are linked to the concept of "exploitation" (Bessant *et al.*, 2014; Lavie *et al.*, 2010; March, 1991); under the incremental innovation paradigm, technical and market uncertainties are minimal (Salerno & Gomes, 2018; Unger & Eppinger, 2011).

In contrast to the above, there is the radical, disruptive, or discontinuous innovation paradigm, which could also take other names. Under this paradigm, a company is required to develop new skills to undertake new product designs, which are identified under the concept of "exploration" (Bessant *et al.*, 2014; Lavie *et al.*, 2010; March, 1991). Radical innovation focuses on obtaining products, processes or services that exhibit unprecedented performance features, or delivering known features that provide significant improvements in performance (or costs) and transform existing markets or create new ones (Leifer *et al.*, 2002). This innovation approach is about creating new and unique ideas and concepts with long-term value, which is the basis for building and mastering new markets (O'Connor & Rice, 2013). Salerno and Gomes (2018) indicate that radical innovation creates a technological or market disruption, i.e., an unknown or a known product, that creates a new market and is usually based on a new technology (cell phone) or an unprecedented combination of existing technologies (iPod). Despite the literature coverage of this construct, there is really no precise definition of radical innovation.

The term "disruptive innovation" was introduced by Christensen (1997), who defined this concept as emerging technologies that change product architecture by proposing different product attributes and meeting the needs of new markets, which finally surpass established technologies in the principal market. However, in the literature, the terms "disruptive" and "radical" innovation are usually taken as synonyms (Fernández & Valle, 2018).

Some studies indicate that companies can benefit from both contexts, i.e., incremental and radical innovation (Brun, 2016; Fernández & Valle, 2018; O'Reilly & Tushman, 2008, 2013; Zaragoza-Sáez *et al.*, 2020), since both types of innovation are important for companies and have different roles to play (Salerno & Gomes, 2018). In this respect, academia has shown an interest in ambidexterity, which is defined as firms' ability to simultaneously pursue incremental and radical innovation (Brun, 2016; O'Reilly & Tushman, 2008; Tushman & O'Reilly, 1996). Organizational ambidexterity relates to the concepts of exploitation and exploration, despite the existing tension between these (Lavie *et al.*, 2010; March, 1991).

Nevertheless, there is a spectrum of possibilities between incremental and radical innovation. Several authors identify radical innovation as an exceptional and sporadic event and propose an intermediate point

between both kinds of innovation (Garcia & Calantone, 2002; O'Connor *et al.*, 2008; Salerno & Gomes, 2018). For example, Garcia and Calantone (2002) mention a category knows as "really new innovation," while Salerno and Gomes (2018) proposed the construct "more radical innovation," and O'Connor *et al.* (2008) indicate "major innovation." This article focuses on product innovation and will use the term discontinuous innovation (DI) to refer to innovation, which is substantially greater than incremental innovation but does not meet the definitions or requirements to be considered radical innovation. A discussion and clarification of these terms can be found in the work by Salerno and Gomes (2018, p. 20).

An important point to remark is that DI, as indicated by Garcia and Calantone (2002), O'Connor *et al.* (2008), and Salerno and Gomes (2018), shares the same issues in the management of radical innovation: high uncertainties (mainly market and technology), multiple dimensions, difficulty to understand or articulate the opportunities with a company's current business, and difficulty to make economic evaluations, among others. These authors indicate that companies have consolidated processes for the realization of projects framed in the context of incremental innovation. However, they do not count on adequate practices for the DI context. The articles consulted in the present research on FFE that claim to be framed within a radical innovation perspective could, however, be classified as in DI from the presented concepts.

Researchers and company managers have identified that the phase preceding the beginning of a formal project is the most critical for new product development and has an important influence on its final result (Cooper, 1988; Hoonsopon & Puriwat, 2021; Khurana & Rosenthal, 1997; Koen *et al.*, 2001; Markham, 2013; Reinertsen & Smith, 1991; Seclen-Luna & López-Valladares, 2020; Tatikonda & Rosenthal, 2000). In their study, Hoonsopon and Puriwat (2021) find empirical evidence that relates the proper conduct of FFE with the efficiency and effectiveness of subsequent product development. In addition, other authors point out how during FFE technology ideas and work procedures are defined, and how subsequent concept changes add costs and time to the project, an approach that goes in line with established authors in product development (Kaminski, 2000; Mazaral *et al.*, 2004; Rozenfeld *et al.*, 2006).

The term *fuzzy front end* was introduced by Reinertsen and Smith (1991) and was defined as the period between the generation of an idea for a new product and the company's decision to invest in its development. Kim and Wilemon (2002) indicate that FFE begins when an opportunity suitable for ideation, exploration and evaluation arises, and ends when a company decides to invest in the idea. However, this definition has changed, as FFE is an evolving construct. FFE has been labeled under different names, definitions, scopes, and phases in the literature: innovation front end, new product front end, or pre-development (Costa & Toledo, 2016). In a broader sense, FFE could be defined as all the activities undertaken before the formal and structured process for the development of a new product begins.

FFE became a topic of study over the last three decades with an increasing relevance, as demonstrated by the growing number of publications on the subject in the last 15 years (Borgianni *et al.*, 2018; Costa & Toledo,

2016; Joachim & Spieth, 2020; Oliveira *et al*., 2022; Park *et al*., 2021; Takey & Carvalho, 2016); thus, research on FFE shows significant advances. From the late 1980s to the early 2000s, FFE research focus was on process, under the context of incremental innovation (Cooper, 1988; Khurana & Rosenthal, 1997; Reinertsen & Smith, 1991). According to Oliveira *et al*. (2022), between 2000 and 2010, the FFE construct was consolidated, and its influence verified. Since 2010, research on FFE has matured by focusing on deepening some topics and extending the frontiers of FFE to different forms of innovation, such as services and business models. In this period, papers addressing specific topics increased their relevance, e.g., studies addressing idea generation or creativity in FFE.

Research conducted in the last decade indicates gaps in knowledge about FFE. Based on this, Joachim and Spieth (2020) proposed five trends for future research on FFE, among which we highlight i) understanding the differences and similarities in FFE caused by different types of innovation, such as incremental and discontinuous innovation, service or eco-innovation, and ii) improve knowledge about creativity in FFE.

Grounded on the above, this reflection paper attempts to develop a deeper understanding of FFE from two dimensions: i) Degree of innovation—incremental innovation vs. discontinuous innovation—, and ii) Time—a project stage. It also synthesizes an initial FFE model specific to DI that helps to reduce the tension between exploitation and exploration, clarifying FFE in both contexts, i.e., incremental innovation and DI. Additionally, the proposed model makes it easier for companies to implement DI projects.

The rest of this article is structured as follows. First, the FFE construct is analyzed from the perspectives of relevant authors in the literature. Then, the FFE process is contrasted in the contexts of incremental innovation versus DI. Subsequently, the process of unstructured problem-solving is presented from the perspective of creativity, Finally, FFE models are analyzed based on the theoretical concepts presented and a general FFE model for incremental innovation and DI is synthesized.

Fuzzy front end

Product development is a topic of academic and business interest, given its importance for company growth and survival. Indeed, proposals on how to conduct projects for new products date back to the mid-twentieth century (Asimow, 1962; Evans, 1959). However, the number of product development process (PDP) studies and proposals has increased since the 1980s. Similarly, researchers and companies are giving greater relevance to what happens before the start of the formal project, which, in sum, represents the foundation of PDP. Some of these articles indicate the initial exploration of opportunities in FFE (Uribe-Ocampo *et al*., 2015), address FFE as the exploration and solution of a problem to synthesize a product concept (Frishammar *et al*., 2016; Vizioli, 2019), integrate support methodologies at FFE to conceive product concepts (Seclen-Luna & López-Valladares, 2020; Silva *et al*., 2020; Uribe-Ocampo & Kaminski, 2019a), or focus on the relevant aspects of FFE.

PDP and FFE: relationship and comparison

Authors focusing on pdp in their models propose phases or activities prior to product design. Although not all of them indicate ffe (Kaminski, 2000; Ulrich *et al.*, 2019; Uribe Ocampo & Kaminski, 2019), these authors recognize the relevance of the initial phases and suggest that the features of a product are defined in the first phases of product design, which require small investments but strongly influence the final features of a given product. Thus, a continuum between ffe and pdp is acknowledged, even though they are different processes.

By studying pdp models developed by some of the most prominent authors (Uribe-Ocampo & Kaminski, 2019b), it is possible to conclude that these methodological proposals, despite their different scopes and structures, share common features, such as i) the division of the design into phases and activities with decision points; ii) the idea of pdp as a business process and not just as an engineering procedure; iii) the integration of different areas of knowledge is essential in product development; iv) the important participatory role of senior management in the initial stages and in process evaluation; v) the tendency to attach importance to ffe by considering the company's technology and market strategy for key decision-making projects. According to Gassmann and Schweitzer (2014), in general terms, managers tend to be more familiar with the later development stages of innovation, during which activities are defined and processes and procedures exist.

Regarding the differences between ffe and the stages of development, table 1 presents a comparison in which it is possible to perceive how the different aspects move from the undetermined and flexible ffe to a determined and rigid development.

Table 1.

Differences between FFE and development.

Factor	FFE	Development
Idea status	Probable, diffuse, easy to change	Clear and specific, defined to develop, difficult to change
Nature of work	Experimental, chaotic, and difficult to plan	Structured, goal-oriented with a project plan
Nature of the information for decision	Qualitative, informal, and approximate	Quantitative, formal, and precise
Easiness to reject idea	Easy	Difficult
Degree of formalization	Low	High
Marketing date	Unpredictable	Definable
Billing expectation	Uncertain, it can be done as speculation	Can be estimated with some accuracy
Activities	Individual and in teams, to reduce risk	Multifunctional teams in development

Method of management	Unstructured, experimental, creativity required	Structured and systematic
Visible damage, if abandoned	Usually small	Substantial
CEO Committee	Small or non-existent	Usually large

Source: authors, based on Kim and Wilemon (2002) and Koen et al. (2001).

In sum, the development phase is characterized by its structure, formalism, and clear objectives. In contrast, FFE is characterized by its unstructured, informal, and not well-defined (fuzzy) objectives. When comparing the paradigms of incremental innovation and DI, uncertainties, ambiguities, and unpredictability appear to be more accentuated at the high innovation level, since there is not much previous information and knowledge.

FFE *models*

FFE is experimental, ambiguous, and at times chaotic and uncertain, in contrast to the structured and systematic development phase, which strives for efficiency and target orientation (Koen *et al.*, 2001). Different authors proposed activities and ways of relating them to structure FFE in the context of incremental innovation (Cooper, 1988; Khurana & Rosenthal, 1997, 1998; Riel *et al.*, 2013), at a higher level of innovation (Koen *et al.*, 2001, 2014; Vizioli, 2019), and for DI, by highlighting the research of authors such as Brentani and Reid (2012), Reid *et al.* (2014), Reid and Brentani (2004, 2010), Florén *et al.* (2017), and Frishammar *et al.* (2011, 2013, 2016). The latter propose FFE models with a clear separation into early FFE (problem identification and information gathering) and late FFE (idea generation and concept development). Other authors concurrently proposed models for specific contexts, such as software (Brem & Voigt, 2009) and Technology (Whitney, 2007).

Table 2 and figure 1 show the synthesis of FFE proposals chronologically organized into three groups, from incremental innovation to DI. Table 2 shows the main activities and features of these models, while figure 1 indicates their graphic representation. Models in figure 1 were placed to indicate their orientation with early or late FFE.

Table 2.

Summary of FFE models.

	Author	Activities	Key concepts	Comment
Group 1. Incremental innovation	Cooper (1988)	Idea generation, preliminary evaluation, concept definition	From idea to concept	Linear model, based on Stage Gate (SG). The author identifies the importance of technological and market evaluation
	Khurana and Rosenthal (1997)	Preliminary identification of opportunity, concept definition, product and plan definition	From opportunity identification to concept, product strategy during the process	Inspired by Cooper's (1988) existence of iterations. The authors identify problems in FFE based on case studies and literature review
	Riel *et al.* (2013)	Prerequisites, idea generation, idea selection	Generation, selection, and transfer of ideas, integrating internal and external stakeholders	Based on SG the model only focuses on the ideation process. Originated from case studies of the automotive sector and interviews with specialists
Group 2. Incremental innovation	Koen *et al.* (2001, 2014)	Opportunity identification, opportunities analysis, ideas genesis, idea selection, concept definition	Consideration of external influences, strategic business, top management and organizational culture; few details on how to operate the activities	Non-linear model based on interactions. In essence, it is an evolution of the models by Cooper and Khurana and Rosenthal. It emerges from a longitudinal study with 8 companies, later evaluation with 19 companies
	Vizioli (2019)	Plan: mental map, market research, patents and identification functions Informational project: interviews with users Conceptual design: brainstorm, testing and identification of intrinsic functions	Two cycles of divergence and convergence, focusing on the problem and on the solution, respectively; integrates design thinking and value analysis in FFE	Based on SG, with interactions, the model indicates DT and value analysis domains, resulting from literature analysis and academic applications
Group 3. Discontinuous innovation	Reid and Brentani (2004, 2010); Brentani and Reid (2012); Reid *et al.* (2014)	Boundary interface: detection and interpretation of unstructured opportunity by the individual Gatekeeping interface: the individual's step to organizing the most structured opportunity Project interface: from organization to formal project	Early FFE identification of the problem and gather information, late FFE generation of ideas and development of the concept	The authors are more interested in the inter-phases and the flow of information. Strictly theoretical, does not present practical results. Originated from a succession of studies on radical innovation
	Frishammar *et al.* (2011, 2012, 2016),	Mapping problems: customer analysis, values, culture, current	Part of users' understanding and their surroundings, to define	Based on studies of seven cases of radical innovation and previous longitudinal

	Florén *et al.* (2017)	situation, and external environment Problem creation: finding and formulating customers' problems, iterative steps Problem-solving: creating and refining ideas, iterative steps. Select the appropriate solution and develop the concept	the problem and proceed to its solution and development of the concept in successive phases	study of 4 years. No real application of the model

Source: authors.

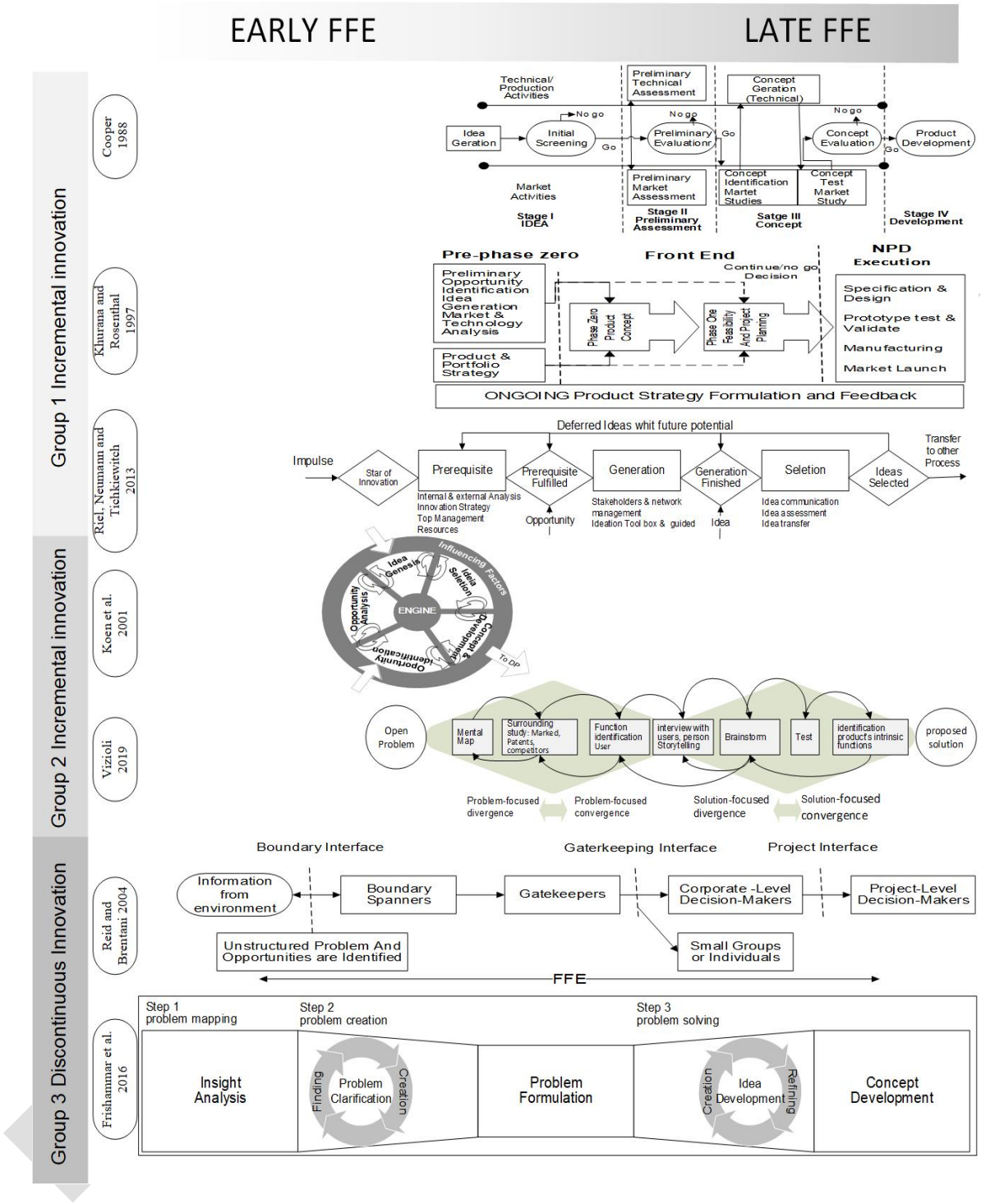

Figure 1. ffe models. **Source**: authors.

The boundary between the three groups is not chronological, but from their framing from incremental to discontinuous innovation. Group 1 starts with the authors who identified FFE and made it explicit as a process based on SG. Group 2 are models that are clearly proposing processes to conceive more innovative product

concepts than the first group, with a more iterative process. Finally, group 3 gathers model proposals that are synthesized from the analysis of real DI projects, thus integrating relevant issues in the DI context.

By analyzing these studied models, it is possible to observe how the proposals become more refined and include new elements, and that the essential theme has shifted from idea generation and selection (Cooper, 1988) to the detection of opportunities and ideation of these opportunities (Khurana & Rosenthal 1997, 1998), followed by the transfer of ideas and integrating internal and external stakeholders (Riel *et al*. 2013) in an SG-based process in the context of incremental innovation (group 1, table 2). In group 2, table 2, the essential subject of FFE are opportunity identification, opportunity analysis to concept definition, integrating external and internal influences, strategic business, top management, and organizational culture (Koen *et al*., 2001), cycles of problem understanding and problem solving (Vizioli, 2019). The last two models propose an iterative process in essence, and they do not show a clear separation between early and late FFE.

Finally, in DI (group 3, table 2), the models present a separation between early and late FFE (Frishammar *et al*., 2016; Reid & Brentani, 2004). However, this separation is not always explicit, so it can be inferred from the analysis of the models. In this way, Reid and Brentani (2004) propose a model based on information flows considering three levels: environmental, individual, and organizational. These authors have been more interested in how information flows in the process and interfaces than in FFE activities. On the other hand, Frishammar *et al*. (2016) propose a four-phase model (figure 1) comprised as follows: i) mapping problems, ii) problem creation (early FFE), iii) problem solving, and iv) concept development (late FFE).

The analysis also identified how FFE models went from being based on SG, in incremental innovation, and characterized by rigidity and decision gates as part of their essence, to more flexible models, in which, rather than activities and gates, they present elements and their connections to the process.

Some authors focus on specific aspects of FFE. For example, Riel *et al*. (2013) are centered in the generation and selection of ideas that integrate different stakeholders, pointing information flows and interfaces as essential elements. On the other hand, Vizioli (2019) proposes a methodology to solve the problem—late FFE— y integrating the value analysis and Design Thinking methodologies in order to understand the problem and to propose solutions in divergence and convergence cycles.

Similarly, Florén *et al*. (2017), Frishammar *et al*. (2011, 2013), and Koen *et al*. (2001) highlight the importance of the participation of senior management to legitimize, facilitate, and evaluate innovation-related initiatives. Specifically, Frishammar *et al*. (2016) indicate open and divergent thinking, flexibility, and market vision, i.e., the ability to identify and to capture gaps. Besides, Frishammar *et al*. (2016) and Koen *et al*. (2001) propose determining aspects such as culture, organizational climate, vision, resources, and leadership.

Degree of innovation, flexibility, and iteration

As discussed in the introduction, product innovation is a spectrum ranging from incremental to radical innovation (Garcia & Calantone, 2002; Salerno & Gomes, 2018). It was also stated that for FFE, and more specifically in DI, the process needs to be performed in a significantly different way than the structure of product development. This chapter discusses the degree of innovation in the FFE, the relationship of activities in the design process, and the creative process. These issues will serve as the basis for the analysis of FFE in the context of DI.

High degree innovation process

DI product development involves uncertainties, which in the context of product development correspond to lack of information or knowledge (Frishammar *et al.*, 2016), and generally are within the scope of technical or market uncertainties (Unger & Eppinger, 2011). For their part, O'Connor and Rice (2013) identify four categories of uncertainties: technical, market, organizational, and resource-based.

To reduce uncertainties, various ways of acting have been proposed from different areas of knowledge. In design theory, Buchanan (1992) indicates how the product design process, with its separate stages for analysis and synthesis, is not suitable; specifically, when it comes to social problems, it is not possible to separate the solution from the analysis. On the other hand, product engineering authors (e.g., Frishammar *et al.*, 2013; Heck *et al.*, 2016, 2020; Markham, 2013; Tatikonda & Rosenthal, 2000; Unger & Eppinger, 2011) have suggested trial and error and flexibility in the design process as ways of dealing with uncertainties during product design. Finally, organizational theory authors mention the most innovative and radical projects as presenting the greatest uncertainties and they also propose ways to approach them at organizational level (Bessant *et al.*, 2014; O'Connor *et al.*, 2008; O'Connor & Rice, 2013; Salerno & Gomes, 2018).

Cooper (2014) proposes a new SG process that becomes more flexible and adaptive by incorporating the concept of Spiral into the development process. On the other hand, Unger and Eppinger (2011), based on the degree of technical and market uncertainty, propose a reconfiguration of product design, which can be adjusted from a typical SG to a spiral structure, with the increase of technical and market uncertainties.

In sum, FFE models proposed for incremental innovation are based on SG (Cooper, 1988; Khurana & Rosenthal, 1997, 1998). In the DI context, the SG model is not adequate or it could require adjustments and special attention, particularly during the early stages (Bessant *et al.*, 2014; Cagan & Vogel, 2002; Unger & Eppinger, 2011), due to the rigidity and linearity of the SG process, which implies making important decisions in the early stages of product development, where information is insufficient.

Flexibility and iterations in product development

In order to understand flexibility and iterations in product development, the possible relationships of activities in this process are illustrated in figure 2. There can be three types of relationships: i) dependence, i.e., task B requires information from task A by demanding serial organization; ii) independence, tasks A and B have no information relationship and can be executed in parallel; and iii) interdependence, task B requires information from task A and this, in turn, requires information from task B to be completed. Therefore, these sets of tasks must be executed iteratively, with successive advances of both A and B with communication between them (Eppinger *et al*., 1994).

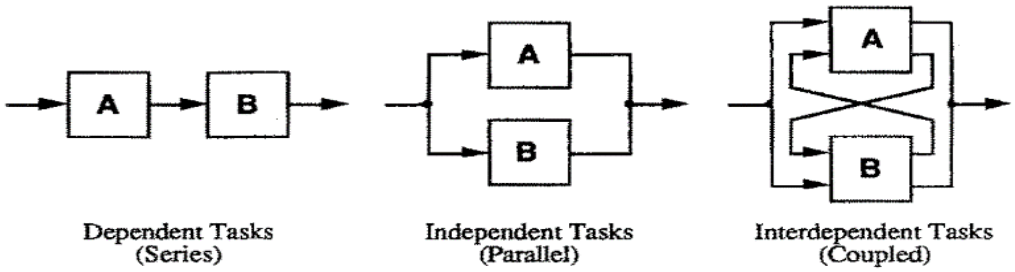

Figure 2. Relationships of activities in product development. **Source**: Eppinger et al. (1994).

Interdependency or dependency relationships may be weak when the information needed for task *A* can be estimated with an adequate level of accuracy to complete task *B*, or the information has little impact on the subsequent task. The relationship may be strong if the information from task *A* has a high impact on the subsequent task and it is not possible to estimate this information with the degree of accuracy necessary to complement task *B*. Thus, the relationship or independence, as well as the intensity of this relationship, determines whether the activities need to be performed sequentially, in parallel, or iteratively.

In FFE, the more innovative the product, the less prior information is expected to be available, thus implying greater uncertainty. This lack of knowledge causes situations that cannot be controlled by the development team. As a result, activities tend to have greater dependence or interdependence. In contrast, to develop a less innovative product, some relevant information is already known or can be estimated with sufficient precision to continue design, so that activities can be more independent and the process defined with activities in series or in parallel. In other words, the increase in the degree of innovation determines the level of FFE un-structuredness.

This is essentially the theoretical basis for the requirement of greater flexibility in the project, as a function of the increased degree of innovation. Flexibility of the design process consists of the iteration between activities and even between phases, characterized by the number and length of iterations; that is, iterations between adjacent activities or between distant activities (Unger & Eppinger, 2011). Thus, an iterative SG is more suitable for short and few iterations. However, when the project progress requires constant

iterations, both short and long, the spiral structure may be more convenient due to its flexible nature, which proposes constant iterations, as shown in figure 3 (Unger & Eppinger, 2011).

The spiral scheme has been proposed for the engineering area by Evans (1959) and Kaminski (2000) and for software development by Boehm (1988). This concept has different interpretations, in the version by Boehm (1988), which consists of the idea that each spiral run passes through different phases, the radius represents the resources of time and money invested, and the angle traveled represents the accumulation of knowledge. Based on the results of the previous run, with each subsequent run the project is taken to a higher level. Its high interactivity allows the project to be understood as a successive advance of several aspects, but it becomes difficult to manage due to the high level of flexibility (Unger & Eppinger, 2011). Figure 3 shows the project structure from the ideal and linear SG to highly interactive SG with the spiral.

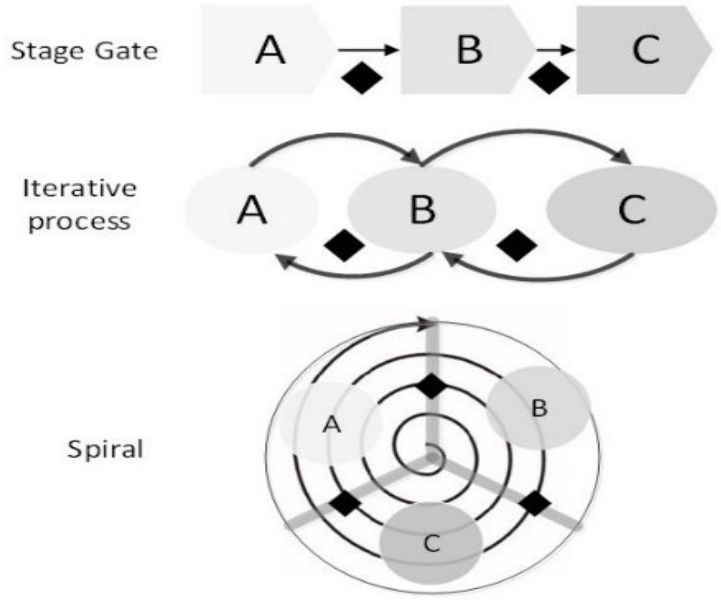

Figure 3. Activity relationship according to flexibility. **Source**: authors.

Creative process

As explained above, the FFE is uncertain in nature, in the sense that there is insufficient information and prior knowledge. FFE is also ambiguous, since the root problem is not completely defined and has different forms of understanding, and unstructured, in the sense that solution pathway cannot be determined previously. Creativity is a starting point for innovation, which is considered as the successful implementation of an idea in the context of the organization. Consequently, creativity and innovation are part of the same process (Amabile & Pratt, 2016). Thus, different authors place importance on creativity in FFE (Huang *et al.*, 2020; Olszewski, 2022; Ummar & Saleem, 2020), focusing their attention on various aspects, such as understanding the creative process within an organization (Amabile, 1988, 1996, 2012; Amabile & Pratt,

2016), reviewing and comparing creative techniques (Haeser *et al*., 2015; Seclen-Luna & López-Valladares, 2020), determining how techniques are used in the generation of product concepts (Bourgeois-Bougrine *et al*., 2017; Silva *et al*., 2020), and problem definition in the creative process (Vizioli & Kaminski, 2017), among others.

According to Amabile (1996), Lubart (2007), and Sternberg (2010), creativity is a new and context-adaptable creation. Novelty can have different degrees from minimal deviations to something completely different, and adaptability refers to satisfying the difficulties of the situation, which gave rise to creation. There is no absolute norm that evaluates how creative a specific creation is. Thus, a more dynamic definition of creativity is a context-embedded phenomenon requiring potential, originality, and effectiveness (Corazza & Lubart, 2021); context-embedded indicates that resources, objectives, assessment criteria, and sociocultural implications of the creative process cannot be isolated from the context in which they occur (Amabile & Pratt, 2016).

Several authors have described the creative process by placing importance on different important aspects. A literature review of the work of some authors (Alencar, 2003; Amabile, 1996, 2012; Lubart, 2007; Sawyer, 2012; Sternberg, 2010) reveals different views and descriptions of the creative process. To summarize their contributions, figure 4 shows a comparison of the stages of the cited authors in chronological order.

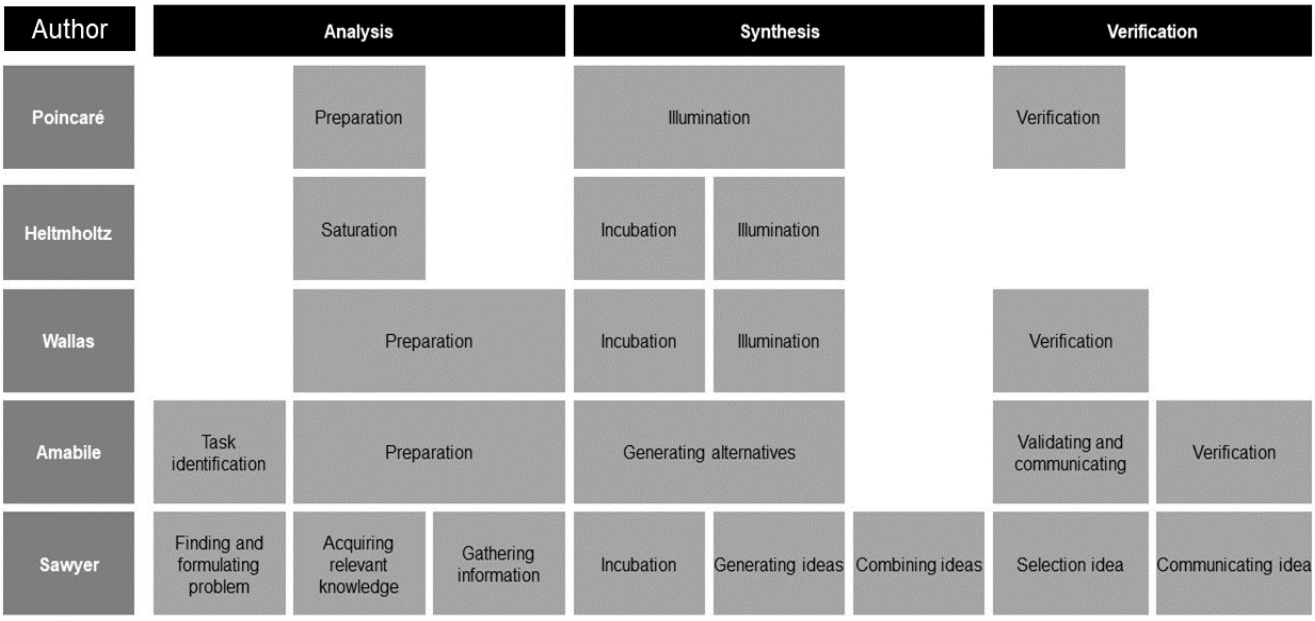

Figure 4. Creative process. **Source**: authors.

More contemporary authors present detailed descriptions about the creative process. However, as indicated in figure 4, it is possible to summarize the phases proposed by the different authors dealing with this subject in three stages: analysis, synthesis, and verification.

Analysis is a conscious phase in which the problem is defined and clarified, and the relevant information collected. In this phase, relevance of knowledge or baggage in the field of the problem is highlighted. Some authors propose that the synthesis phase has an unconscious part (incubation) where the mind makes multiple combinations of the problem elements using prior knowledge in order to generate solutions in an "unexpected" way. This phase also has a conscious part (illumination or generation of ideas) in which the most pertinent combinations are identified, thus assisting in addressing the problem, as indicated by Sawyer (2012). Finally, the Verification phase is where the most appropriate ideas are verified and selected, and then represented and communicated.

Other authors think of the creative process as a confluence of factors. Among them, Amabile (1996) relates determining factors to the proposed phases. There is no definitive theory that explains the creative process in detail, but from those in the know, it was possible to define a basic sequence and identify certain factors that influence such a process. Moreover, the creative process requires favorable conditions, with intrinsic motivation being a preponderant factor, along with the baggage of knowledge on the issue and the strategies for monitoring and evaluation (Alencar, 2003).

Sternberg (2010) defines structured problems, which have a defined path (algorithmic problems), and unstructured problems, which have no defined procedures for their solution nor a single solution. The solution of an unstructured problem implies divergent and convergent reflections, where information is associated and reorganized, and, in algorithmic problems, information and procedures are remembered and used directly. Thus, creativity is preponderant in solving unstructured problems (Lubart, 2007).

Analysis of FFE models

The theoretical background presented on FFE allowed a historical overview of this construct, the identification of how the key issues in FFE have evolved and also of the existing gaps in FFE. As indicated by various authors (Joachim & Spieth, 2020; Oliveira *et al.*, 2022; Park *et al.*, 2021), research on FFE has advanced but it is still not a consolidated topic in the literature. On the other hand, the theoretical referential on the degree of product innovation and its relationship with flexibility and iteration and the creative process, provide tools to analyze and understand the FFE from two dimensions: degree of innovation and time (project stage).

Figure 5, elaborated based on a content analysis of the authors indicated in table 2 and figure 1, is a mind map in which the main ideas around FFE are organized, placing incremental innovation in the lower part and DI in the upper section. As indicated, the companies present consolidated practices to carry out projects framed within incremental innovation, but they lack these practices in the context of DI (Salerno & Gomes, 2018).

Authors such as Canuto da Silva and Kaminski (2017), Khurana and Rosenthal (1998), Koen *et al*. (2001), Rozenfeld *et al*. (2006), and Uribe-Ocampo and Kaminski (2019b) propose in their PDP models a structuring to perform FFE in the incremental innovation context. Thus, the present analysis will focus more on DI, by seeking a relationship between the two contexts. As indicated, a gap in the FFE is to deepen the differences and similarities in incremental innovation and DI (Joachim & Spieth, 2020), or to reduce the tension between exploitation and exploration (Lavie *et al*., 2010; March, 1991).

As indicated by March (1991, p. 1), "Exploitation includes such things as refinement, choice, production, efficiency, selection, implementation, execution. Exploration includes things captured by terms such as search, variation, risk taking, experimentation, play, flexibility, discovery, innovation." These two sentences summarize the difference of FFE in both incremental and DI contexts. In sum, under incremental innovation, the ultimate goal of the process is efficiency in execution, while in the context of DI it is to explore and experiment in order to discover new possibilities.

The creative process is used as a lens to understand FFE. To depict this, figure 5 illustrates the early and late FFE with analysis, synthesis, and evaluation, which are consistent with the creative process. In this way, figure 5 allows graphically identifying the main elements that differentiate incremental innovation and DI contexts. This figure also presents a clear separation of early and late FFE in DI context. Early FFE at organizational level—problem finding—begins with an exploration of the environment, such as available technology and market conditions, to identify possibilities—idea genesis—and, finally, to structure them with the objectives of a firm. Then, an interface is executed in which the company prioritizes the ideas to be developed. Late FFE, project level—problem solution—, begins with an articulated idea and continues with a cycle of understanding, ideation of solution alternatives, and evaluation of alternatives. Both early and late FFE are independent and highly iterative cycles of analysis, synthesis, and verification, with their own objectives.

With FFE in the context of a DI, the problem to be solved is not algorithmic but rather an unstructured problem, or a non-decomposable problem, as defined by Frishammar *et al*. (2013), for which there are no clear solution pathways and whose sub-problems cannot be solved separately. Moreover, as the degree of innovation increases, this unstructured problem tends to become stronger, being creativity fundamental to proposing solutions.

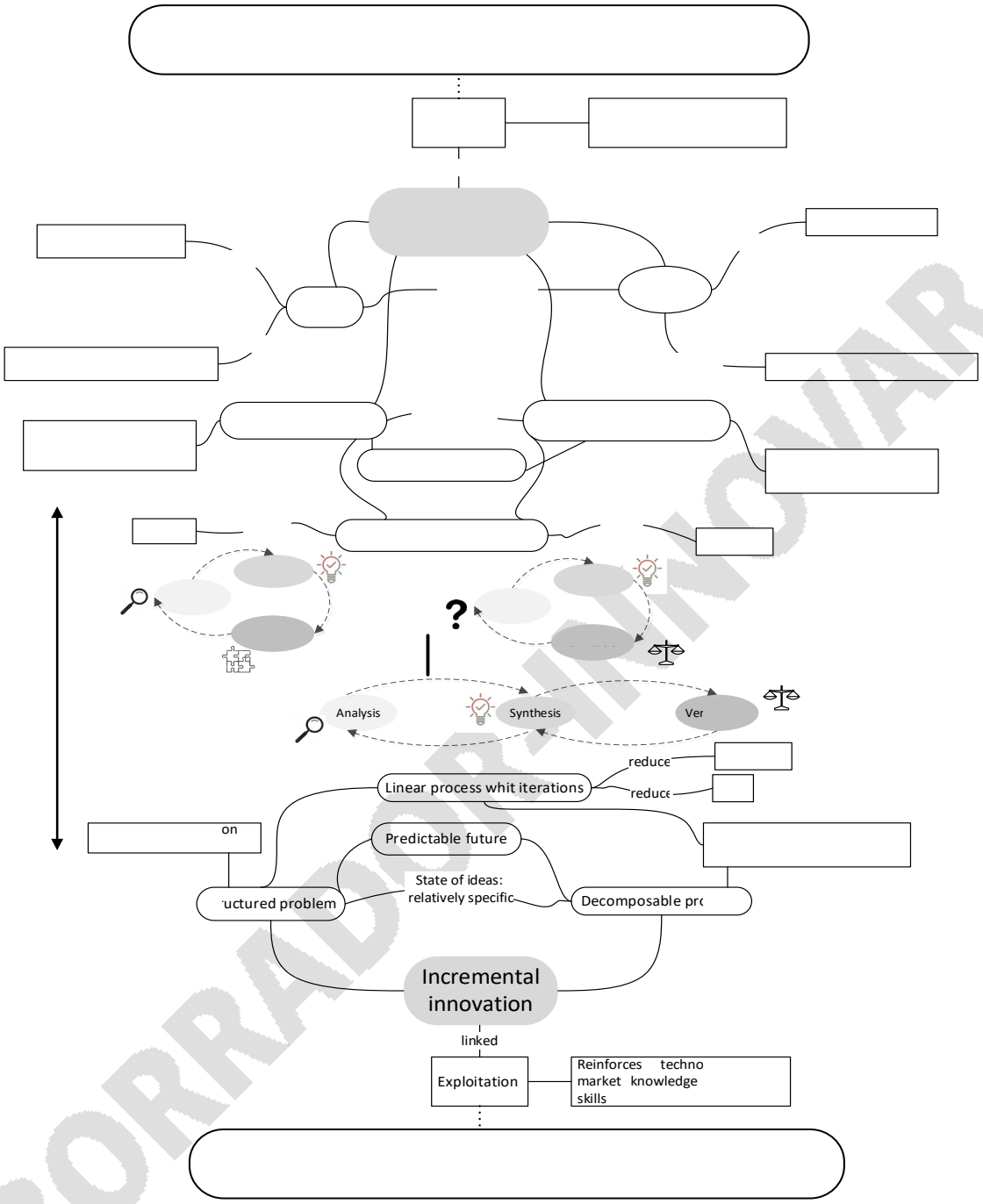

Figure 5. Mind map of the ffe process. **Source:** authors.

Based on the theoretical framework and the analysis of figure 5, an initial FFE model is proposed to clarify contexts of incremental innovation and DI, as shown in figure 6. In incremental innovation, as it was shown earlier, the literature presents proposals on how to perform the FFE. Thus, figure 6 depicts a PDP model that details the FFE process in this context (Uribe-Ocampo & Kaminski, 2019b). Consequently, a company in need

of systematizing the FFE in the context of incremental innovation could use the references indicated above or other existing proposals.

In a broad sense, the FFE in incremental innovation is divided into three phases: i) Strategic planning, which includes a definition of product development objectives—starting from the analysis of the market and technology—in order to define the product portfolio to be developed; ii) Project planning, referring to the implementation of macro project planning, definition of the product, project scope, and preparation of project planning; and iii) Feasibility study, comprising problem validation, solution, and verification. The main activities of Feasibility study are, validation of the existence of the market, identification of users' basic needs, gathering of pertinent information for PD, determination of the specifications and goals of the product, elaboration of concept proposals, economic and financial analysis, and evaluation of the possible actions to manage intellectual property.

By focusing on DI, figure 6 clarifies a separation between early—organization level—and late FFE—project level. Early FFE is organized into three phases that are performed iteratively: explore, determine, and structure. The *explore* phase involves an analysis of the environment in the external and internal domains to determine opportunities in the company's field of interest. The *determine* phase involves the initial ideation of possibilities for new products in the company's field of interest, and the *structure* phase links these possibilities to the company's strategy.

Various authors dealing with DI (Frishammar *et al*., 2016; Salerno & Gomes, 2018) highlight the complexity of structuring in this context, since the technologies used may be new and, hence, it is difficult to determine their potential. Similarly, it is not possible to determine the market acceptance of these technologies in the initial stages. Therefore, it is pertinent to add that in the context of a DI from the user/market driver, users may often lack clarity of their needs, or these may be more symbolic than functional, making it difficult to detect them and to articulate them with the company's objectives. As a result, early FFE offers possibilities for new products or as indicated in Figure 6—problem finding—, and this is identified at organizational level.

Authors dealing with DI or radical innovation from the organizational study, propose practices to help companies to systematize the early FFE (Bessant *et al*., 2014; Leifer *et al*., 2002; O'Connor & Rice, 2013; O'Connor *et al*., 2008; Salerno & Gomes, 2018). These practices aim to systematize DI at the organizational level prior to beginning the project, so that DI is not a matter of serendipity or carried out by a small group, generally, against the established rules of the company.

On the other hand, late FFE presents a project level since it is the beginning of a specific development. Late FFE, as indicated in figure 6, shows a structure with three iterative phases: understand, ideate, and evaluate. The *understand* phase involves an exploration of the problem based on the environment, user/market,

and technology. The problem is understood based on the idea of the new project to provide a clearer formulation of the problematic issue and the necessary information. The *ideate* phase involves the generation of ideas to solve the problem, which are debugged until new product concepts are conceived. Finally, the *evaluate* phase involves the assessment of initial ideas and concepts from user/market, technology, and business perspectives—economic, financial, strategic, and the management of intellectual property—to determine the best alternatives. Thus, late FFE provides new viable product concepts, as indicated in figure 6 (problem solving), that are identified at the product project level.

By contrasting figure 6 with the discussion on flexibility, iterations, and degree of innovation of the new product, in terms of the relationship among phases, as the degree of innovation increases, the interdependence relationship becomes stronger. In this sense, there is no information or approximation, which would allow an estimation of what is necessary to carry out the next phase. Thus, to complete one phase, progress has to be made in the subsequent phases. In this way, the process will be more iterative as the degree of innovation increases. For this reason, in the context of DI, both the early and late FFE phases are proposed with the concept of project spiral (explained pages above) as opposed to incremental innovation, where a sequential iterative process is proposed.

Grounded to the above, both early and late FFE phases can be interpreted as iterative cycles of analysis, synthesis, and evaluation, followed by an interphase at the end, in which strategic planning is conducted in early FFE and project planning in late FFE. It should be noted that early and late FFE are performed at different times, and usually by different teams. Early FFE is linked to the company's strategic plan, whose objective is to have many possibilities of products to develop, i.e., project ideas. On the other hand, late FFE is the beginning of the development of a specific idea, whose objective is to achieve viable solution concepts.

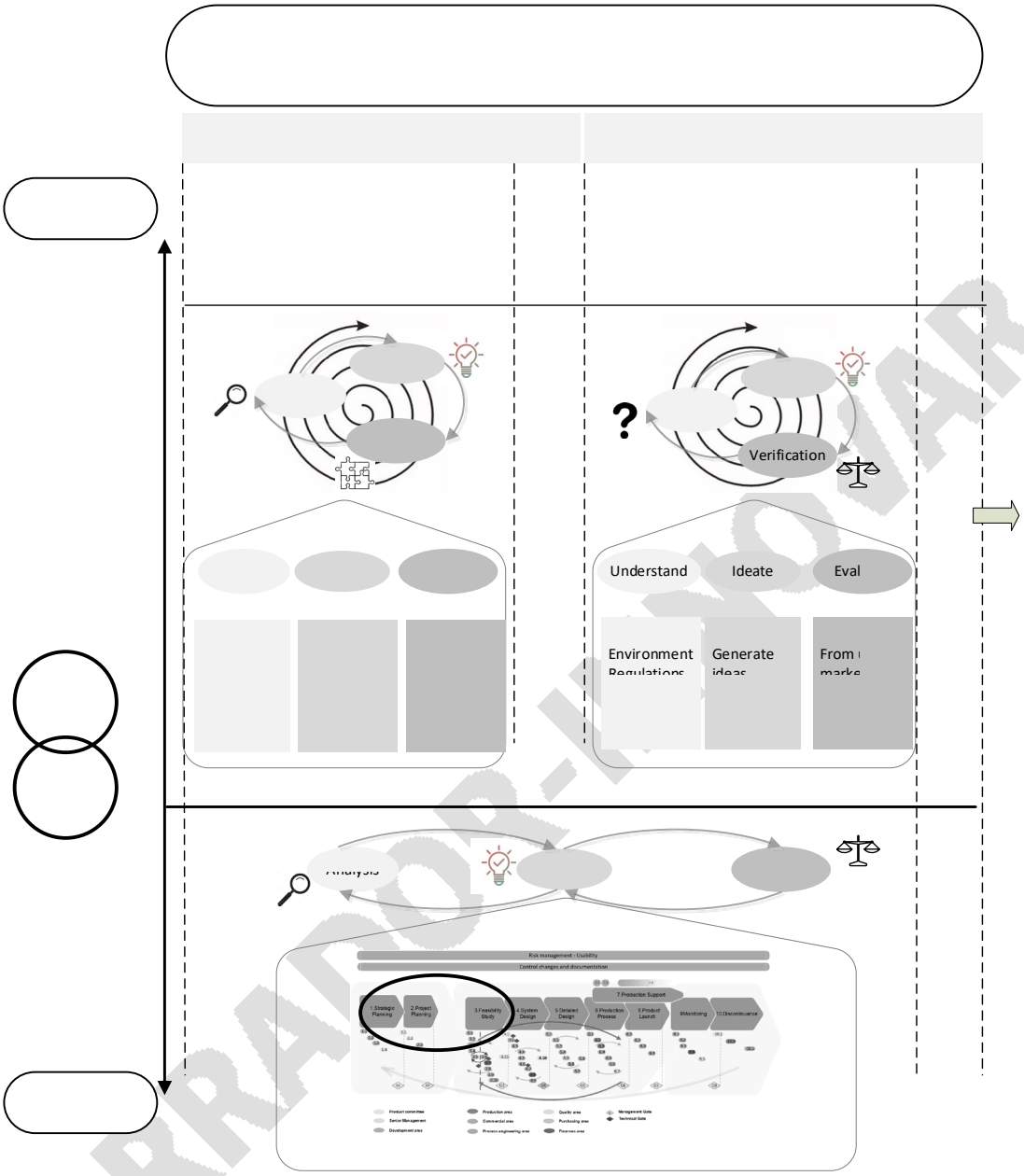

Figure 6. ffe model framework in incremental innovation and high degree of innovation. **Source**: authors.

Conclusions

The objective of this article was to propose an initial FFE model based on the degree of innovation of the new product to be developed, with the understanding that FFE constitutes the foundation of the future project and the opportunity to propose products with high aggregate value. The study of the different points of view of authors who deal with FFE, from its identification in academia in the last decades of the 20th century to proposals tracked to the second decade of the 21st century, summarized in figure 1 and table 2, as well as the understanding of the relationships of activities and their degree of independence and dependence, along with

the analysis of the creative process, made it possible to clarify the FFE construct in two dimensions: degree of innovation (i.e., incremental innovation versus DI) and the time dimension (project stage); in other words, early FFE versus late FFE, as shown in figure 6.

The model proposed in figure 6 is a first approach to FFE that synthesizes the differences in the incremental and DI contexts, explicitly, while highlighting elements such as the clear separation of early and late FFE and the interfaces where activities are performed, that is, organizational interface (project prioritization) and project interface (planning and resource allocation). This explicit clarification on incremental innovation versus DI and time—early FFE versus late FFE—is the main contribution of this article.

Considering that FFE is a construct that has evolved since its introduction, in the last decades of the 20th century, and that the available literature comes from diverse areas of knowledge, such as engineering, management, and design, which have different objectives and languages, there is some confusion about the meaning and scope of FFE and how to systematize the FFE process.

For companies that need to develop incremental and discontinuous products in a systematic way, figure 6 clarifies how to proceed in both cases. Regarding incremental innovation, some proposals consolidated in the literature were recommended and a general indication of how to proceed was presented. In the context of DI, a discussion of the late FFE process (project initiation) was carried out, and the main activities and their scope were indicated. In addition, the process based on project spiral was proposed and clarified, which is a relevant contribution due to the uncertainties inherent to DI. These elements constitute the foundation for understanding and systematizing the FFE in DI. This work also highlighted organizational culture, top management support, and external influence as elements that affect FFE performance.

Despite the insights provided in this paper, the proposed model does not examine details such as the task level nor indicates how these tasks should be performed, since the requirements of the segments in which companies operate present different needs. In this sense, future research proposals should implement the model in a specific sector, e.g., food industry or medical equipment firms, that need to move from incremental innovation to DI. Another possibility for future research is to insert methodologies into the model to support key activities, thus moving from indicating what needs to be done to describing how concrete actions can be deployed.

Disclosures

Authors declare no institutional or personal conflicts of interest.

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