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Exploratory and exploitative capability paths for innovation: A contingency framework for harnessing fuzziness in the front end

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A R T I C L E I N F O

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A B S T R A C T

Based on the results of a multiple case study of seven manufacturing firms, a contingency framework for harnessing fuzziness in the front end of innovation is proposed by delineating two discrete capability paths through which new product ideas are developed into corroborated product definitions. The study illustrates that ideas characterized by high levels of fuzziness benefit from following an exploratory path, where the creative potential of fuzziness is embraced by deploying problem-formulation and problem-solving capabilities. In contrast, ideas at low levels of fuzziness benefit from following an exploitative path, where fuzziness is tolerated by drawing upon idea-refinement and process-management capabilities. When the fuzziness level of the idea and the set of capabilities to develop the idea are poorly aligned, the idea-development process is either inefficient or runs the risk of stalling. These findings have theoretical and practical implications for the front end of innovation and new product idea development.

1. Introduction

Innovation is crucial for competitiveness and industrial renewal (Ridley, 2020). Yet the process of innovation is often ambiguous, uncertain, and unstructured (Rizova et al., 2018; Simms et al., 2021; Stevens, 2014). Nowhere is this more evident than in the front end of innovation (Florén and Frishammar, 2012). The front end begins with the conception of embryos of new product ideas and ends with the emergence of product definitions (Eling and Herstatt, 2017; Spieth and Joachim, 2017). The front end heavily influences subsequent phases of product development and determines overall product success and time to market (Markham, 2013). It is dynamic and interactive and, more importantly, requires multifaceted information processing (Akbar and Tzokas, 2013; de Brentani and Reid, 2012; Townsend et al., 2018). Thus, successfully navigating the path from new product ideas to corroborated product definitions is highly challenging for firms (Brunswicker and Chesbrough, 2018).

In this regard, firms with the appropriate front-end capabilities have an advantage (for an overview, see Florén et al., 2018). Capabilities are defined as "complex bundles of skills and accumulated knowledge, exercised through organizational processes that enable firms to coordinate activities and make use of their assets" (Day, 1994 p. 34). For example, front-end capabilities can relate to organizational processes to stimulate search, identification, alignment, legitimization, and selection of new ideas (Björk et al., 2010; Florén et al., 2018; Frishammar et al., 2011; Jissink et al., 2018). Thus, developing and deploying appropriate capabilities to tackle front-end information processing needs can lead to better front-end outcomes.

Multifaceted information-processing requirements are dominant in the front end because of various sources of fuzziness, which frequently hinder the emergence of corroborated product definitions (Florén and Frishammar, 2012; Stevens, 2014; Townsend et al., 2018). Prior studies mainly highlight three sources of fuzziness that front-end capabilities must address (Stevens, 2014): uncertainty (i.e., insufficient

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information), equivocality (i.e., multiple conflicting interpretations of information), and complexity (i.e., the number of situational elements/relationships to consider simultaneously; Zack, 2001; Stevens, 2014). Although previous research has established some best practices, it lacks sufficient details on the nature of the capabilities needed to manage such knowledge problems. These problems are the hallmark of front-end activities and arise from the interactions between numerous subcomponents, technologies, and systems (Nickerson and Zenger, 2004) or occur at the intersection between R&D, manufacturing, and marketing (Moenaert and Souder, 1990).

Recent studies have investigated sources of fuzziness and potential remedies (Chang et al., 2007; Frishammar et al., 2011; Reid et al., 2014; Stevens, 2014; Simms et al., 2021; Townsend et al., 2018). However, the literature still lacks an in-depth understanding of the role of specific organizational capabilities required to manage multiple sources of fuzziness and, more importantly, the way in which firms can apply different capabilities to respond to different levels of fuzziness (Chang et al., 2007). For example, capabilities for reaching consensus and addressing problems from multiple perspectives may be applicable to highly fuzzy development tasks, whereas simpler tasks may be a better fit for hierarchical governance processes (Nickerson and Zenger, 2004). There is limited knowledge on which front-end capabilities should be deployed under which circumstances (Hillson, 2002). Accordingly, there is still a critical gap in the research on capabilities in the front end of innovation.

Following the above discussion, the purpose of this study is to advance understanding of *how firms manage idea development at different levels of fuzziness by deploying appropriate capabilities.* In addressing our purpose, this article aims to shed light on how multiple sources of fuzziness interact and, ultimately, how front-end activities could be better organized to cope with numerous sources of fuzziness. To pursue this exploratory purpose, an inductive case study approach is used (Eisenhardt et al., 2016; Strauss and Corbin, 1998) involving seven manufacturing firms.

This study makes three contributions to the front-end literature. First, it contributes to the literature on sources of fuzziness (e.g., Frishammar et al., 2011; Simms et al., 2021; Stevens, 2014) *by suggesting a novel view of the interdependence and agglomeration of sources of fuzziness*. This enhances the discussion on *how* fuzziness manifests itself. So far, the prior literature has chiefly explored ways to manage a specific source of fuzziness (e.g., Schweitzer et al., 2016). Even though prior studies have highlighted that the development of new product ideas involves managing multiple fuzziness sources (Chang et al., 2007; Stevens, 2014), they fall short in discussing how the knowledge problems related to uncertainty, complexity, and equivocality interact and accumulate. This study contributes by suggesting that fuzziness cannot be fully understood by focusing solely on individual sources of fuzziness. Instead, the overall difficulty when searching for a solution must be considered at an aggregate level.

Second, this study provides new insights into *front-end capabilities and their appropriate deployment for ideas at different levels of fuzziness.* Although the literature describes various types of critical capability for front-end management (Björk et al., 2010; Börjesson and Elmquist, 2011; Gama et al., 2019; Thanasopon et al., 2016; Schweitzer et al., 2016), existing literature lacks insights into the front-end capabilities deployed to address different levels of fuzziness. The insights provided by this study indicate that certain capabilities, or sets of capabilities, work well together in certain situations. Therefore, our study extends prior research on front-end capabilities and provides a basis for a more integrated research agenda to understand capability combinations and complementarities in front-end projects.

Third, this paper presents a *contingency perspective on the front-end process*, linking agglomerated fuzziness levels to the use of appropriate capabilities. The framework adds to the front-end literature by responding to calls to better understand which conditions direct the use of different sets of practices or approaches for new product ideas (Jissink et al., 2018; Rizova et al., 2018). Such rich, complex explanations and reasoning have so far been lacking in the front-end literature (Eling and Herstatt, 2017). By proposing that ideas require a specific set of capabilities at each level of fuzziness, it is argued that not all product ideas can or should be treated in the same way.

2. Theoretical background and literature review

Two bodies of literature were used to explore how firms manage the development of ideas at different levels of fuzziness. First, the literature on sources of fuzziness provided insights into core definitions, the way in which different levels of fuzziness emerge, and actions to resolve, mitigate, or manage these different levels of fuzziness (Frishammar et al., 2011; Rizova et al., 2018; Stevens, 2014). Second, the literature that has discussed the use of front-end capabilities was reviewed (e.g., Björk et al., 2010; Girotra et al., 2010; Schweitzer et al., 2016; Thanasopon et al., 2016), with a focus on assessing which front-end capabilities could be deployed to deal with sources of fuzziness.

2.1. Levels and sources of fuzziness in the front end of innovation

This study considers three primary sources of fuzziness as described by Stevens (2014): uncertainty, equivocality, and complexity. This conceptual foundation is important because sources of fuzziness influence how firms select and deploy front-end capabilities (Frishammar et al., 2011; Stevens, 2014). Analogous concepts, such as ambiguity (Brun et al., 2009; Brun and Sætre, 2009; Stetler and Magnusson, 2015a, b) and variability (Chang et al., 2007) have been studied in the front-end literature. However, the approach of Stevens (2014) and Rizova et al. (2018) is followed in this research and, consequently, its scope is limited to three sources.

Uncertainty in the front end occurs "when not enough information is available, making identification of the problem and/or solution difficult" (Stevens, 2014, p. 433). High uncertainty may increase disagreements between project members concerning the expected profit, product design, and customer expectations (Christiansen and Gasparin, 2016) and may require systematic procedures to capture external inputs (Gama et al., 2019). In contrast, low uncertainty creates greater room for discussion and reflection in project planning (Hillson, 2002; Jissink et al., 2018). Uncertainty may be reduced by acquiring additional factual information (Zhang et al., 2019), implementing coordination models in virtual settings (Chamakiotis et al., 2020), and adopting flexible and faster front-end evaluation approaches (Dziallas, 2020). It may also be tolerated or sustained by using existing knowledge to infer values for missing data (Hillson, 2002; Zack, 2001).

Equivocality refers to situations where multiple, conflicting interpretations of the same data, facts, and information are made (Rizova et al., 2018). High equivocality levels frequently hinder the emergence of robust concepts and result in delays (Frishammar et al., 2011). Yet, equivocality may also have positive effects, such as triggering consensus formation and knowledge transfer, enhancing team creativity, preventing premature closures, and stimulating creative thinking among project members (Brun and Sætre, 2009; Eriksson et al., 2016; Stetler and Magnusson, 2015a,b; Zack 2001). Nevertheless, resolving equivocality is problematic because it involves, for example, establishing technical advice networks (Rizova et al., 2018), facilitating joint problem solving (Sjödin et al., 2016), organizing new communication flows between project members for perspective sharing (Zhang et al., 2019), and attaining internal cooperation and support to facilitate mutual understanding (Kim and Wilemon, 2002). Scholars disagree over whether the concept of equivocality includes ambiguity (Rizova et al., 2018) or whether ambiguity is a separate concept (Brun and Sætre., 2009; Brun et al., 2009; Chang et al., 2007). As both call for similar capability sets (see Rizova et al., 2018), we follow Daft and Lengel (1986) in using the two terms interchangeably.

Finally, complexity refers to the interaction of too many parts in a non-simple way (Chang et al., 2007). High complexity requires extensive testing to evaluate the interplay between components that create additional costs (Alam, 2006). Challenges involve project size (Kim and Wilemon, 2003), which is influenced by the number of technologies (Tatikonda and Rosenthal, 2000), possible components and their independence (Petre et al., 2006), and relations and functions designed for new markets (Chang et al., 2007).

Uncertainty and complexity may have more of an objective core (e.g., an objectively identifiable information deficit) (Frishammar et al., 2019). However, equivocality is more socially constructed; a situation that one actor sees as highly equivocal might be seen by another as simple and easily understood (Starbuck, 1976). Together, the previously cited studies provide valuable insights into sources of fuzziness during the front end of innovation. However, they have largely been restricted to individual or separate sources. In practice, sources of fuzziness rarely exist in isolation because they are interdependent and often occur in combination (for an overview, see Chang et al., 2007). Yet, despite these interactions, relatively little is known about aggregate levels of fuzziness and the sets of capabilities required to resolve these impediments. The reason for this lack of knowledge is that most research to date has exclusively focused on one-to-one methods and techniques (Alam, 2006; Koen et al., 2002; Rizova et al., 2018; Thanasopon et al., 2016). *Why* and *how* multiple sources of fuzziness influence the overall level of fuzziness have received much less attention, possibly because the answer may be beyond the scope of a simplistic cause–effect analysis.

2.2. Capabilities for managing fuzziness in the front end

The front-end literature mostly focuses on how levels of fuzziness arise individually. Recently, however, scholars have called for the examination of multiple sources of fuzziness (Stevens, 2014; Simms et al., 2021) and a better understanding of capabilities (Watson et al., 2017) based on a contingency perspective (Mellewigt et al., 2018). This study adopts such a perspective.

Table 1 summarizes the review of the management of sources of fuzziness. The front-end literature lacks detailed insights into how to deploy capabilities in situations or projects with varying levels of fuzziness. Moreover, the literature provides only cursory examples of activities rather than specific insights into the required capabilities. Organizational capabilities are frequently defined and operationalized as bundles of interrelated yet distinct routines and activities (e.g., Amit and Schoemaker, 1993; Felin et al., 2012;Henderson and Cockburn, 1994; Magistretti et al., 2021). Building on this view, this section presents a review of what has so far been published regarding capabilities for managing uncertainty, equivocality, and complexity.

First, the front-end capabilities that are important for dealing with sources of fuzziness are identified, with the focus placed largely on uncertainty reduction. Such capabilities include: ideation capabilities, which refer to a firm's ability to stimulate, identify, select, and implement new ideas (Björk et al., 2010); systematic idea generation capabilities, which refer to a firm's ability to capture, share, and recode new ideas systematically (Gama et al., 2019); openness capabilities, which refer to exploring, gathering, and assimilating operant resources based on inter-organizational partnerships (Thanasopon et al., 2016) and idea search strategies (O'Brien, 2020); customer-orientation capabilities, which refer to developing a responsive customer orientation (Schweitzer et al., 2016); and future-focus capabilities, which enable firms to act on forward-looking searches (Jissink et al., 2018). However, for many firms, such lists fall short in helping project members to develop ideas exposed to multiple sources of fuzziness. Indeed, it is unclear which capabilities are needed to manage not one but multiple sources of fuzziness.

Second, the literature describes capabilities that are organized sequentially and are devoted to radical and/or incremental innovations (Herstatt and Verworn, 2004). This reasoning is often structured successively through ideation capabilities (Björk et al., 2010) based on interorganizational collaboration, such as openness capabilities (Gama et al., 2019; Thanasopon et al., 2016), and oriented by either reduction or sustain modes (Brun et al., 2009). Ideation capabilities generally depend on market-oriented employees to develop an understanding of customers' needs through, for example, customer-orientation capabilities (Schweitzer et al., 2016) and are more effective in generating creative ideas by using business-to-business customer integration (Barrutia et al., 2019).

Third, new product ideas differ in quality (Girotra et al., 2010) and levels of fuzziness (Chang et al., 2007; Brun et al., 2009), yet the existing literature does not explain how these factors influence the capabilities that should be deployed. The implication is that, depending on the difficulty of developing new ideas, the resources required to create robust definitions will vary (Beretta et al., 2018; Koen et al., 2001). The circumstances that determine how front-end capabilities are best deployed have been largely overlooked. Studies have examined different settings, such as technical and market fuzziness in projects (Moenaert et al., 1995), use of sensitive idea management leadership for complex ideas (Boeddrich, 2004), the role of intuition and sensemaking in idea screening (Sukhov et al., 2021); fuzziness management in process firms (Kurkkio, 2011; Sjödin, 2019), stakeholder fuzziness (Zhang and Doll, 2001), and effective tools (Koen et al., 2001, 2002). However, studies have largely overlooked how levels of fuzziness affect the use of capabilities in managing idea development. For example, common management practices, such as stage-gate processes (Cooper, 2008) or interorganizational technology development (Gama et al., 2017), favor the adoption of standardized methods, techniques, and procedures to resolve sources of fuzziness, regardless of the nature of an idea. However, these one-size-fits-all approaches to innovation can hamper front-end efficiency.

Fourth, empirical studies have not explicitly investigated the effects of a mismatch between levels of fuzziness and front-end capabilities on front-end outcomes. Conceptual studies, however, warn that a mismatch can generate either an underload or an overload of internal resources, which influences a firm's overall performance (Zack, 2001). For example, investing significant resources in detailed information gathering, consensus formation meetings, and extensive prototype tests for ideas at low levels of fuzziness may cost more than the corresponding benefits (Frishammar et al., 2011; Samset and Volden, 2016). In contrast, underload occurs when firms fail to apply appropriate capabilities at higher levels of fuzziness. Overload reduces performance by overusing capabilities in dealing with simple tasks, whereas underload reduces performance by processing knowledge inefficiently (Zack, 2001; Sjödin et al., 2016).

In summary, prior studies offer valuable nuggets of knowledge on the sources of fuzziness and the necessary capabilities, thereby providing conceptual building blocks for this study. However, an in-depth understanding of how front-end capabilities work together and how to organize them to enable the management of different types of ideas is still lacking. The next section describes an inductive study designed to advance the current understanding of how firms manage the development of ideas at different levels of fuzziness by deploying the appropriate capabilities.

3. Methods

3.1. Research approach and case selection

To provide a deeper understanding of how firms deploy capabilities to manage idea development at different levels of fuzziness, a multiple case study approach was used for four reasons. First, this approach enabled the search for patterns in context-bounded phenomena (e.g., capabilities for idea development) by providing deeper insights into how and why firms deploy certain practices (Edmondson and McManus, 2007; Eisenhardt and Graebner, 2007). Second, research to understand aggregate levels of fuzziness is still at a nascent stage, so a case study

Table 1
Representative research on managing sources of fuzziness.

Author(s), year, and journal	Type of study and sample	Source of fuzziness	Insights into managing sources of fuzziness
Moenaert et al. (1995), IEEE Transactions on Engineering Management	Case study of 5 firms	Uncertainty	Efficient uncertainty reduction requires the creation of strong communication flows between departments through information systems that gather and structure information.
Koen et al. (2001), *Research-Technology Management*	Case study of 8 firms	Uncertainty	Proficient uncertainty reductions mainly focus on methods for opportunity identification including development of "what-if" scenarios, problem-solving methods, and adoption of less rigorous criteria to select potential new ideas.
Alam (2006), *Industrial Marketing Management*	Case study of 26 firms	Complexity	Fuzziness reduction largely relies on systemic involvement and interaction with customers, creation of proficiency on "idea hunting" in the firm, and establishment of project management methods.
Chang et al. (2007), *R&D Management*	Conceptual paper	Uncertainty, equivocality, complexity, and variability	To reduce multiple sources of fuzziness, the study suggests a decision-making method based on four activities. Sources of fuzziness include uncertainty, equivocality, complexity, and variability. Levels of fuzziness are described but not investigated.
Brun and Sætre (2009), *Creativity and Innovation Management*	Case study of 4 New Product Development projects	Equivocality (ambiguity)	Equivocality (ambiguity) can be either reduced or sustained. Reducing ambiguity includes testing hypotheses by interpretations and underlying assumptions and ensuring validity and reliability. Sustain ambiguity involves retaining flexibility, saving cost and time for ensuring a progression of the project. A certain amount of ambiguity is inevitable and even necessary to stimulate innovation.
Brun et al. (2009), *European Journal of Innovation Management*	Case study of 4 firms	Equivocality (ambiguity)	The study investigate how can equivocality (ambiguity) be classified and understood. The results indicate that equivocality (ambiguity) is classified by two four subjects and stem from three sources. Subjects include product, market, process and organizational resources ambiguity, whereas sources are originated from multiplicity and novelty of the subject and validity and reliability of information.
Zhang and Doll (2001), *European Journal of Innovation Management*	Conceptual paper	Uncertainty	Building upon uncertainty theory, the paper underscores the negative consequences of uncertainty for the project team's vision. It suggests that uncertainty reduces the team's sense of shared purpose and leads to unclear project targets.
Frishammar et al. (2011), *IEEE Transactions on Engineering Management*	Mixed-method approach in 4 firms	Uncertainty and equivocality	The study examines the dilemma between sequential and simultaneous management of sources of fuzziness. The results show that equivocality and uncertainty are reduced consecutively in successful projects and concurrently in unsuccessful projects.
Stevens (2014), *Technovation*	Case study of a firm	Uncertainty, equivocality, and complexity	The study establishes a cause-effect link between sources of fuzziness and organizational learning strategies. Insufficient information about how learning strategies interact to address multiple sources of fuzziness are provided.
Stetler and Magnusson (2015), *Creativity and Innovation Management*	Survey of 489 engineers and managers	Clarity and equivocality (ambiguity)	This study explored the influence of goal setting in different phases of innovation. Idea novelty increases under conditions of either high or low levels of goal clarity, whereas mid-range levels of goal clarity are related to fewer novel ideas.
Thanasopon et al. (2016), *Technovation*	Survey of 122 product developments	Uncertainty	The reduction of uncertainty includes the firm's ability to stimulate front-end project members to explore, gather, and assimilate operant resources from external sources through interorganizational partnerships and external search.
Schweitzer et al. (2016), *R&D Management*	Survey of 160 product developments	Uncertainty	To reduce uncertainties in the front end, firms are no longer encouraged to intensify R&D and market interaction but rather educate employees to take a proactive customer-orientation approach.
Spieth and Joachim (2017), *Technological Forecasting & Social Change*	Survey on 24 front-end experts	Uncertainty	Findings indicate that organizational capabilities and strategic orientation can reduce the uncertainty rate in the analysis of front-end activities.
Eliëns et al. (2018) *Journal of Product Innovation Management*	Survey on 184 New Product Development practitioners	Complexity and equivocality (ambiguity)	The front end contains high degree of complexity and equivocality (ambiguity). The results demonstrate that gatekeepers in the front end who think rationally are less likely to escalate their commitment that those who follow their intuition.
Gama et al. (2019) *Creativity and Innovation Management*	Survey of 146 manufacturing SMEs	Uncertainty	To reduce uncertainty, SMEs are encouraged to achieve high levels of systematic idea generation before collaborating with customers and suppliers.
Jissink et al. (2018), *Technovation*	Survey of 159 innovation projects	Uncertainty	The study highlights the importance of three principals to streamline forward-looking search and thereby reduce uncertainty in the front end of innovation.
Rizova et al. (2018), *Technovation*	Survey of 22 projects	Equivocality (ambiguity)	To resolve equivocality, project members are encouraged to use a high density of the technical-advice network.
Sjödin (2019) *International Entrepreneurship and Management Journal*	Case study of multiple ecosystem actors within process industries	Equivocality, Complexity, Uncertainty	Interdependence between fuzziness sources is illustrated. Joint knowledge-processing strategies (joint problem, solving, open communication and end-user involvement) help ecosystem partners address fuzziness
Zhang et al. (2019), *Journal of Business & Industrial Marketing*	Conceptual paper	Uncertainty and equivocality (ambiguity)	Equivocality rather than uncertainty is the dominant cause of front-end fuzziness. To reduce equivocality firms are encouraged to create rich channel to identify issues and share perspectives. Uncertainty reduction involves the addition of information on known issues.

Table 2
Description of studied cases.

Case	Manufacturing sector and size (no. of employees)	Example of ideas under development	Informant's titles
A	Telephone communications, 100.000 employees	5G solutions, cloud infrastructure, network automation	Research Manager, Senior Researcher, Innovation Manager, Strategic Product Manager, and Service and Business model Specialist
B	Medical equipment, 10.000 employees	Surgical and respiratory care products	Specialist Engineer, Quality Engineer, Mechanical Engineer, Manager Product Portfolio, Global Portfolio Manager, and Systems Engineer Manager
C	Packaging paper and plastic, 140 employees	Packing optimization including sacks and cartons	Laboratory Technician, Application Development Manager, Technical Service Director, and Application Development Director
D	Electronic equipment, 300 employees	Customized electronic development and production	Purchase Manager, Managing Director, R&D Manager, Component Preparation Specialist, and Project Manager
E	Construction and mining machinery, 40.000	Tools and industrial assembly solutions, power equipment and mobile construction	Global Project Manager, VP R&D, Manager R&D, VP Engineering Service, Director Global Strategy Project, VP Automation and Technology, Senior Project Manager
F	Vehicle systems, 85.000	Equipment for land and naval forces	Development Engineer, Technology Specialist, Director Business Development, Systems Analyst
G	Commercial vehicles, 50.000	Autonomous vehicles and renewable fuels solutions	Manager R&D, Director R&D, Manager Materials, Manager Electro Mobility

approach served the purpose of collecting rich and detailed data (Edmondson and McManus, 2007). Third, idea development in the front end of innovation is a complicated subject that involves complex information processing and tacit knowledge. Therefore, rich qualitative data were required to untangle the underlying constructs and contingencies between levels of fuzziness and front-end capabilities. Finally, a case study approach allowed in-depth discussion and theorizing on the evaluation and management of different types of project to develop new product ideas (e.g., Andriopoulos et al., 2018; Pauwels et al., 2016).

This multiple case study involved seven manufacturing firms. These firms were selected on the basis of three sampling criteria. First, all case firms had given high priority to improving their front-end processes in recent years. Second, all firms had appeared on lists of the most innovative firms nationally and, in some cases, globally. Furthermore, reviewing the websites and annual reports of the case firms revealed the extent of their innovation activities. For example, there was considerable evidence of new product launches in the last five years and innovative features included in new and existing product lineups. This evidence pointed to an enhanced likelihood of finding new product development projects with both high and low levels of fuzziness. Finally, all firms were part of a research project, which improved access to suitable respondents. The cases were selected from multiple manufacturing sectors (e.g., telephone and communication, construction and mining machinery, and vehicle systems).

3.2. Data collection

Data collection was conducted through interviews, workshops, and the collection of internal materials (e.g., workflow charts, PowerPoint presentations, and Excel spreadsheets). The respondents included engineers, mid-level managers, technical specialists, project managers, and senior executives, employed mainly in R&D and related functions. The respondents had 6–40 years of employment experience. This range of staff positions and experience added diversity to the sample and gave a more complete view of the capabilities for addressing sources of fuzziness inherent in front-end activities. Conducting interviews across several hierarchical levels ensured that the interviews represented firmwide perceptions, thereby mitigating potential position bias. In addition, interviewing both project participants and project external managers, who were not involved in the day-to-day work, added an external perspective on projects and their outcomes. Two initial workshops were conducted with 15 senior managers to explore challenges faced during the front end and, more importantly, to provide details and reasoning in relation to the characteristics of their procedures. The workshops lasted approximately 90 min each. To complement the exploratory insights, 36 interviews were conducted. The duration of the interviews ranged from 30 to 75 min. All conversations were recorded and transcribed; see Table 2 for case studies description.

During the interviews, open-ended questions relating to the overall purpose of the study were used. The existing literature provided the basis to develop the interview protocol. Specifically, questions were asked on a) issues and challenges experienced during front-end activities, b) routines and capabilities used to manage the front end, and c) overall reflections on outcomes and success criteria for the front end. Appendix A presents the interview protocol. During the interviews, the respondents were given substantial freedom to broaden the conversation. The discussion focused largely on the firm's internal aspects of idea development. The interview protocol was adapted and changed slightly throughout the data collection process so that emerging ideas and themes could be captured.

3.3. Data analysis

The data analysis followed the thematic analysis method described by Braun and Clarke (2006) and applied by Cacciotti et al. (2016) and Raja et al. (2018). The qualitative data analysis software MAXQDA (v. 12) was used to perform the analysis.

The first phase of the data analysis focused on in-depth analysis of the raw data (e.g., interview transcripts). The researchers familiarized themselves with the data by repeatedly reading the interview transcripts, recording initial ideas, and marking phrases and passages that were of interest. In the second phase, common and interesting words, expressions, phrases, and terms used by the respondents were coded. Thus, the data could be structured to generate initial codes and identify first-order categories. An example of a first-order category is mapping symptoms of problems to simplify interpretation. These codes express the voices and perspectives of the respondents largely in their own words. In parallel, comprehensive memos for each informant interview were created. The third phase was dedicated to searching for second-order concepts by collating several pertinent codes into more theoretically refined concepts. Examples of second-order concepts include problem-articulation and solution-search activities. In the fourth phase, the second-order concepts were revised and refined. Codes were excluded, added, or, in some cases, rearranged into different concepts. The purpose was to generate a thematic map providing an overview of the relevant quotations to facilitate reflections between the information collected from the respondents and secondary sources. A code matrix and a code-related browser supplied with the data analysis software were used to streamline the group discussion and make sense of the themes. In the fifth phase, all themes were revised and tied into the story of the analysis and the literature. Consequently, the analysis resulted in a thematic map consisting of several themes relating to how firms manage idea development for different levels and sources of fuzziness by deploying capabilities to develop corroborated product definitions.

4. Findings

The analysis identified two main cluster of themes (see Fig. 1): knowledge-processing requirements (fuzziness assessment) and front-end capabilities (problem-formulation capability, problem-solving capability, idea-refinement capability, and process-management capability). Before presenting these themes, it is important to note that all manufacturing firms described the ability to manage sources of fuzziness (uncertainty, equivocality, and complexity) as an aptitude that is fundamental to developing corroborated product definitions. On the issue of recognizing the sources of fuzziness, the respondents emphasized that those three sources of fuzziness were always present and often overlapped. This observation is consistent with the literature (Eling and Herstatt, 2017; Spieth and Joachim, 2017). However, dissimilar patterns emerged when the respondents presented their views on how manufacturing firms manage sources of fuzziness as they move from new product ideas to corroborated product definitions. The next section presents the findings, providing a separate section for each theme.

4.1. Evaluating knowledge-processing requirements through fuzziness assessment

The data analysis reveals that manufacturing firms increasingly conduct fuzziness assessment to evaluate different sources of fuzziness (uncertainty, equivocality, and complexity) in the product idea and its subcomponents (i.e., different technologies and pieces of knowledge) before formally beginning the front-end phase. Respondents pointed out that the assessment of fuzziness helps manufacturing firms efficiently navigate from new product ideas to corroborated product definitions. When the assessment of fuzziness is deficient, the risk of focusing on irrelevant matters or working negligently on important problems is greater. By analyzing the data, two magnitudes or ideal types of fuzziness emerged: *low levels of fuzziness* and *high levels of fuzziness*.

Low levels of fuzziness apply to situations where the solution for a new product idea is easily accessible, agreed on, or broken down into logical parts. According to many respondents, manufacturing firms frequently identify potentially valuable but unrefined product ideas that could be further developed. The following first-order concepts describe such situations: accessibility of sufficient information, easy to agree on idea contents, and the possibility of decomposing idea features or components.

For example, low levels of fuzziness is contingent on accessibility of sufficient information, such as when a product idea is characterized by insufficient but easily accessible technical, regulatory, and commercial information. This readily available information may relate to the clarification of product requirements and the evaluation of component availability for prototyping. This action can take the form of calls to customers to verify product designs, contacts with government agencies to comply with potential regulatory changes, or direct contact with suppliers to evaluate long-term component availability. For example, a development manager at C2 described a situation where easily accessible information was lacking:

> [information] can be a problem, but usually you solve it by more time, you can work with that bit and then you know what to ask for. It's easy to get hold of … So we learn, they should have that information to be able to act and to be able to proceed [with idea development] (Application Development Manager, C2)

Similarly, low levels of fuzziness can be characterized by easy to agree on idea contents i.e., situations where the divergent opinions that emerge during feasibility analysis and market-attractiveness assessment are fairly easy to handle. For example, the respondents acknowledged that for certain ideas ad-hoc consensus meetings were often sufficient to

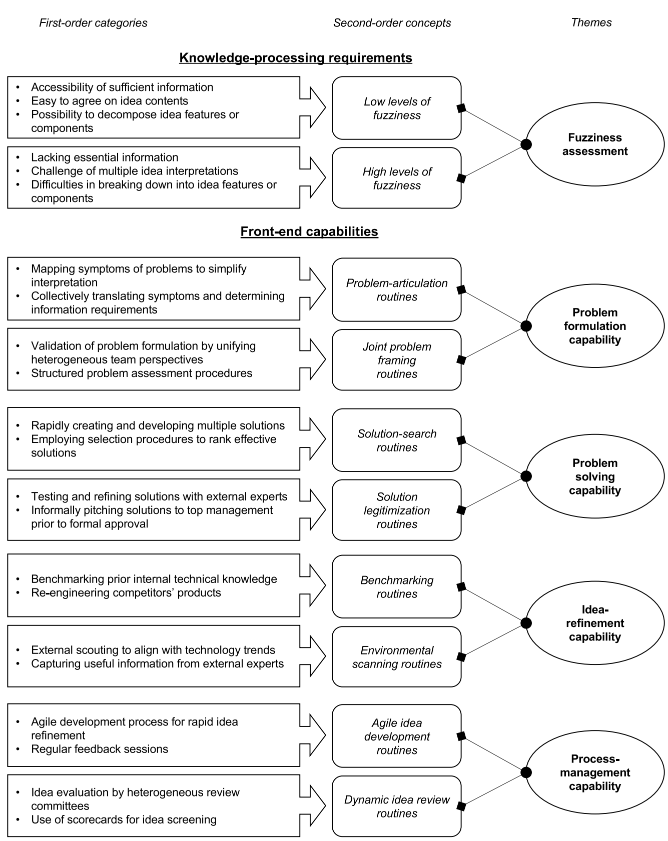

Fig. 1. Data Structure.

reach a common understanding and clarifying the next steps in. For example, a global portfolio manager at B4 mentioned that a mere acknowledgment of the possibility of diverging interpretations was helpful:

> We need to ask ourselves the question, where are we going? … It is too often that you do not raise the issue because you think, I think they know exactly and then it rolls on. I think it is very good that you sit down and manage these things through reconciliations (Global Portfolio Manager, B4)

A common description of low levels of fuzziness relates to the possibility of decomposing idea features or components, such as ideas that could easily be separated into smaller parts. According to the respondents, the deconstruction of a product idea into smaller parts facilitates the planning of experiments and allows fast and interactive modification of emerging product prototypes. For example, a director at firm E described how they address the development of multiple product components:

> The complexity is there all the time; we live with it. We have a good culture; we break it down into smaller parts and address it part by part. It will never be a problem for us. (Director of Global Strategic Products, E5)

High levels of fuzziness apply to situations where the solution for a new product idea is unlikely to be accessible, agreeable, or dividable. For example, respondents described situations of ill-defined or raw product ideas with insufficient information, conflicting subjective views, and too many situational elements to consider. In such cases, it is hard to understand the problems, symptoms, and potential solutions. Our respondents indicated that, if mismanaged, new product ideas with high levels of fuzziness can lead to inconsistent product definitions and time delays in creating robust solutions. The following characteristics describe such situations: lacking essential factual information, being challenged by multiple idea interpretations, and facing difficulties in breaking down product concepts into idea features or components.

A key challenge is lacking essential factual information, such as an absence of critical data to understand customer problems and symptoms and the related solutions. Such situations can lead to problematic consequences, such as difficulty in envisioning an adequate solution and in planning feasibility tests. However, respondents indicated that "less can be more," where having a lesser amount information can help decision makers during problem formulation. The respondents described this mindset as careful selection of a set of relevant facts and a broad overall perspective to identify and test alternative paths. For example, a systems analyst at F4 recalled:

> Well, it's become more important to work in an intelligent way with this uncertainty in the front end. Sometimes, we get confused when we have too much data to analyze for a prototype. We need to work wisely and only gather relevant information and ignoring details; otherwise, we get lost. (Systems Analyst, F4)

Another challenge relates to multiple idea interpretations, where contradictory views can exert a negative influence on product ideas. The general feeling was that the existence of contradictory standpoints within the development organization tends to escalate departmental conflicts and, therefore, delays product definition by weeks or months. The respondents indicated that open forums were a positive source of enrichment that could stimulate faster solution search. However, when mismanaged, they can also excessively prolong discussions, increase coordination costs, and even block important front-end decisions. For example, an R&D manager at G2 stressed the importance of managing the challenge of multiple idea interpretations:

> You think that it is obvious, and everyone does as they should. But they do not … They make their own interpretation, and then there will be conflicts in the future. (R&D Manager, G2)

Finally, difficulties in breaking down new product concepts into idea features or components relate to the challenge of understanding the interplay between numerous product functionalities. For example, customers may require too many functionalities that interact in a non-simple way. According to the respondents, non-simple interactions complicate planning, profitability estimates, and payback-period calculations, often resulting in longer development processes. For example, the following sentiment was expressed by a VP of engineering services at E4 and was echoed by several others:

> The simpler the problems you have, the simpler project members can create solutions. Sometimes, there are so many interactions among product features that it is extremely difficult to create a solution. (Vice President for Engineering Services, E4)

Although these poles – characterized by a *low level of fuzziness* and a *high level of fuzziness* – were referred to by many respondents, a senior researcher explained that ideas cannot always be easily classified on a binary scale. The respondent suggested that managers should be aware of the presence of a "gray zone." However, the binary rule of thumb was considered more applicable in practice than formally positioned situations spread across a spectrum.

4.2. Front-end capabilities

Front-end capabilities represent a set of practices, methods, and routines that enable manufacturing firms to take an initial idea and develop it into a corroborated product definition. The data analysis indicates that firms rely on a set of distinct routines, which are associated with four aggregate capabilities concerning the management of front-end innovation: problem-formulation, problem-solving, idea-refinement, and process-management capabilities.

4.2.1. Problem-formulation capability

The analysis identified problem-formulation capability as representing *a firm's ability to clarify and verify problems to create a unified problem formulation.* Problem formulation involves two key routines: *problem-articulation* and *joint problem framing.*

Problem-articulation routines are intended to verify missing information on symptoms and find unity in multiple interpretations of problems. Informants described the need to ensure a more comprehensive view of customer and end-user problems as a starting point for idea and solutions development. For example, the respondents highlighted the importance of implementing visual representation models to provide a holistic view of all problems and causes. Using representation models helps project members to map symptoms and illustrate possible underlying reasons, thus serving to simplify interpretations. Moreover, representation models display relationships between problems and consequences clearly and logically and facilitate a clear path to engage in further solution search. The importance of visual representations was highlighted by a manager at firm G:

> The first thing I'm thinking about is clarity to understand the target picture [visual representation model] and understand the situation and the task. (Manager R&D, G1)

Similarly, respondents underscored the need to collectively translate symptoms and sub-symptoms and to determine information requirements by using task forces to decode symptoms into problems. Indeed, customer needs or problems were often poorly understood, leading to misconceptions about the real problems that hindered the development of corroborated product definitions. The respondents also stated that, without decoding symptoms, firms might reject good ideas or promote bad ideas for political reasons. However, the respondents highlighted the importance of adopting cause-and-effect diagrams to maintain the focus of the project team on relevant problems and to ensure that no one wastes time chasing trivial or non-existent problems. This mindset was described by a director at firm G:

> We had a giant consulting firm that helped us build a map. So now we sit there with really complicated [problems] that we hardly understand. But we know what it means and where we are going. (Director of R&D, G3)

Joint problem framing routines refers to interactive cycles involving the interpretation of problems and symptoms, interactive discussions about solutions, and negotiations to converge on a definition of the solution to the problem. In reference to collectively framing a concept, the respondents underscored the benefit of maintaining the focus of project members on valuable problems and thereby improving the chances of finding feasible product definitions. For example, such efforts might involve validation of problem formulations by unifying heterogeneous team perspectives. This practice refers to deliberate efforts to reach a consensus so that the views of diverse groups do not result in divergent problem formulations. This practice is needed because teams often comprise individuals with heterogeneous knowledge, experience, information, interests, and cognitive structures, which may lead to divergent visions of the path forward. For example, a manager at manufacturing firm G stressed the importance of consensus in validating problems:

> We use diverse group formation to enhance the discussion and value of a solution. However, the challenge and maybe the main benefit is the consensus part because we have to exchange options and facts to convince others. (Manager, G4)

Informants also highlighted the need for separation and ranking of valuable solutions according to shared assumptions. For example, diverse procedures to frame problems such as failure mode and effects analysis (FMEA) can be applied. Such procedures help analyze the means or modes of each problem and study the consequences of proposed solutions. More specifically, an informant highlighted the benefit of undertaking such analysis in heterogeneous groups guided by documentation, which lists problems and opportunities, their consequences, and the estimated effort needed to solve them. A quality engineer at firm B explained the logic of this approach:

> We need to work out "do we have a concept here that we can continue working on?" Because problems can be so broad. (Quality Engineer, B2)

4.2.2. Problem-solving capability

The data analysis uncovered a collection of practices and routines that are conceptualized here as problem-solving capability. We define this as *a firm's ability to rapidly search, refine, and prioritize multiple solutions to create a unified product concept*. According to the respondents, problem-solving capability helps project members move from problem-formulation activities to corroborated product definitions. Problem-solving capability relies on two key routines: *solution-search* and *solution legitimization*.

Solution-search routines is a form of investigation whereby employees or teams cognitively and physically try to search for and solve problems quickly to move the product definition forward. These activities include rapidly creating and developing multiple solutions and then employing selection procedures to rank effective solutions.

Informants described rapidly creating and developing multiple solution prototypes to validate mental models and assess technical and commercial feasibility. They stressed the need to create multiple alternatives and varied solutions with lead customers using mock-ups addressing technical feasibility evaluation. The benefits of creating preliminary prototypes was mentioned by an innovation manager at firm A:

> A prototype … it is all about giving the manager an opportunity to look at and evaluate it, and then you decide on whether it is something to continue working on. (Innovation Manager, A3)

Another important routine is related to employing interactive selection procedures to rank effective solutions. These criteria are typically applied in idea review meetings, where the performance and effectiveness of different solutions are assessed. This typically includes hybrid assessment criteria (quantitative and qualitative) to select an appropriate solution at the preliminary stage. However, the respondents emphasized that selection procedures extend beyond technical aspects of the new solution to include business interest and commitment from organizational stakeholders. An innovation manager at firm An underscored this point:

> There is a selection procedure where we look at: Is there a technical challenge at this stage [remaining knowledge gaps]? And up until today we have said that if it is something that does not belong to our company research mainstream, we have to question: is there a champion that could be interested in running this from idea to final prototype? Is there an acceptance by management and is there an interest from a possible receiver internally, which would be the business department? (Innovation Manager, A3)

Solution legitimization routines refers to examination by external experts to identify criticisms and discussions with senior managers to legitimize solutions. In particular, respondents stressed that solution legitimization requires the testing of solutions using external experts as well as informal processes where solutions are privately pitched to top management prior to formal approval.

A key element concerns testing solutions with external experts to scrutinize a preliminary solution and pre-validate the product characteristics of a new concept. The general feeling was that this testing is important to mitigate potential deleterious effects of unacknowledged preconditions related to the product concept, thereby increasing the chances of developing a successful product definition. Indeed, respondents acknowledged that front-end activities do not occur in isolation. Despite extensive internal efforts to solve problems, firms often engage external partners to create robust solutions, which occasionally turns into formal alliances. For example, respondents indicated that receiving support from business consultants and technical evaluations by universities or research institutes is one of the most widely used practices to validate the effectiveness of product definitions. An R&D manager at firm G explained that they had a portfolio of partners to evaluate product concepts:

> We hold a portfolio of partners that we access for advice. You should have a framework and a process that enables you to keep a portfolio up to date all the time, (R&D Manager, G2)

A second component relates to informally pitching the solution to top management prior to formal approval. This refers to private meetings with directors to reach a consensus before a review meeting. These legitimization procedures were seen as a way of mitigating socio-political factors and pre-validating a list of future product definitions prior to board approval. For example, a systems analyst described how best to anchor product concepts with key stakeholders:

> Here, we can have a discussion [with the senior manager]. It is focused on the constructive: refining the solution before the formal decision. (Systems Analyst, F4)

4.2.3. Idea-refinement capability

Based on the analysis, we define an idea-refinement capability as *a firm's ability to use prior internal or external knowledge to validate an idea*. According to respondents, idea-refinement capability favors front-end outcomes by accelerating concept development using prior experiences. Idea-refinement capability is contingent on two key routines: *benchmarking* and *environmental scanning*.

Benchmarking routines refers to using existing knowledge to refine novel ideas (i.e., not re-inventing the wheel). Such practices positively influence the development of successful product definitions for simpler ideas. According to the respondents, manufacturing firms use best practices to increase the chances of ideas leading to effective outcomes.

Activities include benchmarking prior internal technical knowledge to scrutinize lessons learned from successful and failed development projects. The general perception of lessons learned is that storing and retrieving such knowledge represents a rich source of information, allowing project members to circumvent mistakes and expedite idea refinements. For example, an R&D manager at A4 described the benefits of reviewing prior project reports:

> You check very quickly, almost in the summary, what the project has done, what has been achieved as well as other lessons learned during the project that you should consider. (R&D Manager, A4)

Another way of doing this is re-engineering competitors' products by disassembling a product into its component parts to access potential complementarities. This activity is often performed by a dedicated group of R&D specialists to identify design improvements and cost-reduction opportunities with a view to stimulating discussions during the front end. As a systems engineering manager at firm B stated:

> We bought some of the competitors' products and tore them apart, and that was a part of "phase zero". It was an important input! From this observation, we improved the performance of our product. (Systems Engineering Manager, B6)

Environmental scanning routines refers to systematically scanning technology trends and evaluating competitors' products to detect opportunities and forestall threats. Our respondents indicated that external inputs were absorbed through external scouting practices to align with technology trends and capturing useful information from external experts.

As a first step, informants stressed the importance of performing structured search activities to identify emerging technology opportunities. For example, this practice can be performed by regular assessment of intellectual property (IP) that is publicly disclosed by direct and indirect competitors or scouting trade fairs. By monitoring IP developments, manufacturing firms can anticipate future technologies that might in some way influence the product definition. A mechanical engineer at firm B shared an experience with scouting:

> We do a scan to see what exists [internally] and what the competitors are doing and so on, but also to see different areas that are not linked to patient handling because, in some cases, we can see clearly that this thing used on a car can actually work on patient handling equipment. (Mechanical Engineer, B3)

There are also many benefits of systematic practices to obtain knowledge from external partners (e.g., suppliers and universities). The respondents stressed the importance of establishing good relationships with external experts to collect useful knowledge. For example, they indicated that suppliers have knowledge and expertise on the latest components and technologies available in the market, which enables project members to identify potential technical problems before a product definition is concluded. For example, as a development engineer at firm F affirmed:

> When you have a good relationship with a supplier, you quickly get to know if there is a problem [with the idea]. The supplier can come to you and say that they have a potential problem. (Development Engineer, F1)

4.2.4. Process-management capability

Process-management capability represents *a firm's ability to systematically coordinate and control front-end activities to effectively progress from new product ideas to corroborated product definitions*. For the respondents, coordination involves the alignment of joint activities among partners, whereas control entails the monitoring of preliminary achievements and results. Analysis of the respondents' statements reveals two key routines that underpin this capability: the *agile idea development* and *dynamic idea review*.

The ***agile idea development routines*** refer to the introduction of agile approaches to the management of front-end activities in pursuit of idea refinement. According to the respondents, manufacturing firms accelerate idea refinement using market validation practices by involving customers and other key actors. Such an interactive approach can be operationalized by employing agile development processes for rapid idea refinement using regular feedback sessions.

In particular, informants cited the benefits of agile development processes for rapid idea refinement through continuous engagement with partners. Such an approach is exhibited on various levels (strategic, tactical, etc.) of idea development. For example, many respondents mentioned that they had implemented agile principles (e.g., iterative cycles and feature-driven development) to help project members sharpen initial ideas in collaboration with external actors on the execution level but not on the strategic level. Such engagement allows manufacturing firms to constantly revisit the value proposition of the idea, the benefits sought, and the solution design based on reliable feedback. The use of agile principles for rapid idea refinement was viewed as an important tool to support the successful development of product definitions, as described below:

> We have an experimentation phase … that's when you start to build solutions … This is when we should use lean and agile ways to develop an idea. You should come up with a demo or something that you could show the customer before you move further into the prototyping. (Strategic Product Manager, A4)

A complementary practice was engaging in regular feedback sessions starting from the earliest activities in the front end. The respondents indicated that cross-functional review committees can act as critical sounding boards and provide timely feedback on the content and potential weaknesses of a new idea. In particular, the respondents reported that review committee members from diverse backgrounds, who have knowledge that the development team lacks, can strongly enhance initial ideas given the cross-fertilization of knowledge and expertise. For example, as a director at manufacturing firm C stated:

> The key is the mindset, openness, and some key people that have key competencies, but also this iterative approach, that you try and try again, quickly learning and feeding back new knowledge to the next test. That is something valuable. (Application Development Director, C4)

Dynamic idea review routines refer to structured activities aimed at addressing knowledge gaps in an accurate and timely manner during idea-refinement activities. According to the respondents, dynamic review practices allow for the active exchange of knowledge, which accelerates decision-making. For example, the respondents pointed out that, during the idea-refinement process, multifaceted ideas occasionally surface, which distract the teams in subsequent activities. Dynamic idea review practices are based on idea evaluation by heterogeneous review committees and are guided by scorecards for idea screening.

The logic of idea evaluation by heterogeneous review committees is to employ more structured idea review meetings that deploy people with a wide variety of experience. Using people from different functional and technological backgrounds was cited as an important way of addressing knowledge gaps and facilitating idea-refinement activities. The benefit of this practice was voiced by a manager at manufacturing firm C:

I think that the reason we have successful projects was that we have these cross-functional teams on the review committee. (Application Development Manager, C2)

Another helpful practice was the use of scorecards for idea screening where senior managers assessed all new product ideas against agreed criteria. This screening method typically used multiple factors such as strategic fit, competitive advantage, market attractiveness, technical feasibility, and financial rewards. Respondents argued that, although the screening method is useful for ranking ideas, the real value in the method is the behavioral aspect. Their argument is based on the likelihood that, when senior managers meet, discuss ideas and solutions, debate criteria, and make decisions, the chance of selecting viable ideas is increased. Moreover, the respondents stressed that scorecards encourage transparency and, consequently, leave less room for political decisions and "pet ideas."

We are guided by a checklist for selecting achievable solutions… So it's basically a checklist with a list of questions to [objectively] examine each solution. (Strategic Product Manager, A4).

4.3. A contingency framework for harnessing fuzziness in the front end

Based on the analysis, a process model is proposed, which outlines how firms can apply the identified sets of front-end capabilities to manage front-end ideas at different levels of fuzziness. The model is grounded in the themes and dimensions identified in the analysis. Whereas Fig. 1 reports the structure of the data, Fig. 2 depicts the relationships between the constructs to create a capability-based contingency framework for harnessing fuzziness in the front end.

As the proposed framework illustrates, the front-end process starts with a new product idea and ends with a corroborated product definition. The analysis shows that as the front-end process unfolds, daunting challenges arise in understanding the knowledge-processing requirements through fuzziness assessment and harnessing this fuzziness through deployment of appropriate capabilities. Informants from the cases studied viewed the overall examination of the level of fuzziness as a critical step in deciding on the knowledge-processing requirements and charting the path forward in idea development because doing so enables firms to select the appropriate development approach (i.e., which front-end capabilities to deploy). Thus, the results underline the importance of a contingency perspective in applying front-end capabilities for ideas at different levels of fuzziness. Specifically, ideas at high fuzziness levels benefit from following an *exploratory path*, where the creative potential of fuzziness is embraced through problem-formulation and problem-solving capabilities. By contrast, ideas at low fuzziness levels benefit from following an *exploitative path*, where fuzziness is tolerated/reduced and where idea-refinement and process-management capabilities are critical to drive efficiency. Thus, the proposed framework illustrates the need of firms to differentiate the management of initial innovation ideas contingent on the aggregate levels of uncertainty, equivocality, and complexity. It is also argued that firms must develop both sets of capabilities to harness the effects of varying levels of fuzziness during the front-end process. In addition, the sets of capabilities identified for exploratory or exploitative paths offer advantages when applied jointly rather than individually. Table 3 provides illustrative examples of the need for a contingency perspective to manage ideas at different levels of fuzziness by detailing the experience from projects (i.e., embedded unit of analysis) within the sample. The following sections describe these paths and the scenarios in which they should be applied.

4.3.1. Assessing the fuzziness level to understand knowledge-processing requirements

The first step in the framework involves conducting a *fuzziness assessment* prior to starting formal idea-development activities with the purpose of understanding the knowledge-processing requirements and thus selecting the appropriate set of capabilities to manage idea development. The goal is to identify the level of fuzziness of each new product idea and its underlying subcomponents (i.e., technologies or pieces of knowledge).

As a first step, assessment by the project team takes place through an individual evaluation of the level (low to high) of the sources of fuzziness (uncertainty, complexity, and equivocality) for each new product idea. Assessing fuzziness helps the team identify the extent of missing information and knowledge, the interdependence of idea-development tasks, and any substantial misunderstandings between project members. For example, for complexity, the nature of situational elements and relationships can vary from decomposable (i.e., easy to separate into different components and low interdependence with other functions; low level) to nearly non-decomposable (i.e., strong interdependence among components and actions; high level). Educating front-end participants on the characteristics of different sources of fuzziness is central to this assessment. Such an assessment can facilitate the deployment of dedicated activities by managers to manage or reduce fuzziness. Consequently, it is important to identify where the fuzziness originates (e.g., which sources).

However, the greatest benefits of fuzziness assessment are achieved when the evaluation goes beyond the analysis of individual levels of uncertainty, complexity, and equivocality to discern how they accumulate into overall perceived fuzziness. Naturally, this assessment is difficult because multiple factors must be considered simultaneously. Nevertheless, there seem to be some general guidelines that may support this evaluation on a scale of high to low. For example, respondents alluded to a simple rule of thumb for classifying the overall level of fuzziness based on the assumption that, if at least one of the sources of fuzziness is at a high level, the whole idea under development is categorized as having a high level of fuzziness. The reason for this classification is that a high level of fuzziness for any knowledge problem source would often spread, magnifying the challenges during early idea-development stages. Yet, although our data strongly signaled such interactions between fuzziness sources, we were not able to fully disentangle these interactions. Nevertheless, our discussions with front-end participants clearly exemplified the problems created by the agglomerative nature of sources of fuzziness. For example, informants mentioned that high complexity frequently led to misunderstandings and diverging interpretations (i.e., equivocality) during development activities. Similarly, high equivocality could hamper agreement on what information is needed to move forward, thereby stalling development progress and adding to uncertainty.

In addition, informants stated that having a standardized process for idea development was ill suited to dealing with high fuzziness regardless of the source, so a change in routines would be needed. Thus, when high fuzziness levels are detected for any source, these high levels should be taken seriously and should lead to a different development path. Thus, before commencing formal idea development, firms should assess both the level of overall fuzziness and its origins, and plan accordingly.

4.3.2. An exploratory path for developing ideas by embracing high levels of fuzziness

Ideas at high levels of fuzziness are not flawed per se. In fact, these ideas may offer the greatest potential for more radical innovation. However, highly fuzzy ideas require an alternative development approach capable of embracing the creative potential of fuzziness. The results suggest that the *exploratory path* is suitable for more novel or radical product ideas (or subcomponents) at high levels of fuzziness. For example, a case firm dealing with telecommunications equipment needed to develop a commercially successful product for a radically novel technology. The logical path in such situations is to decompose fuzziness into its subcomponents and engage in participative information processing and analysis to form a consensus. Indeed, highly fuzzy ideas may be challenging to work with because they tend to be vague, incomplete, and ambiguous, creating substantial challenges in how to

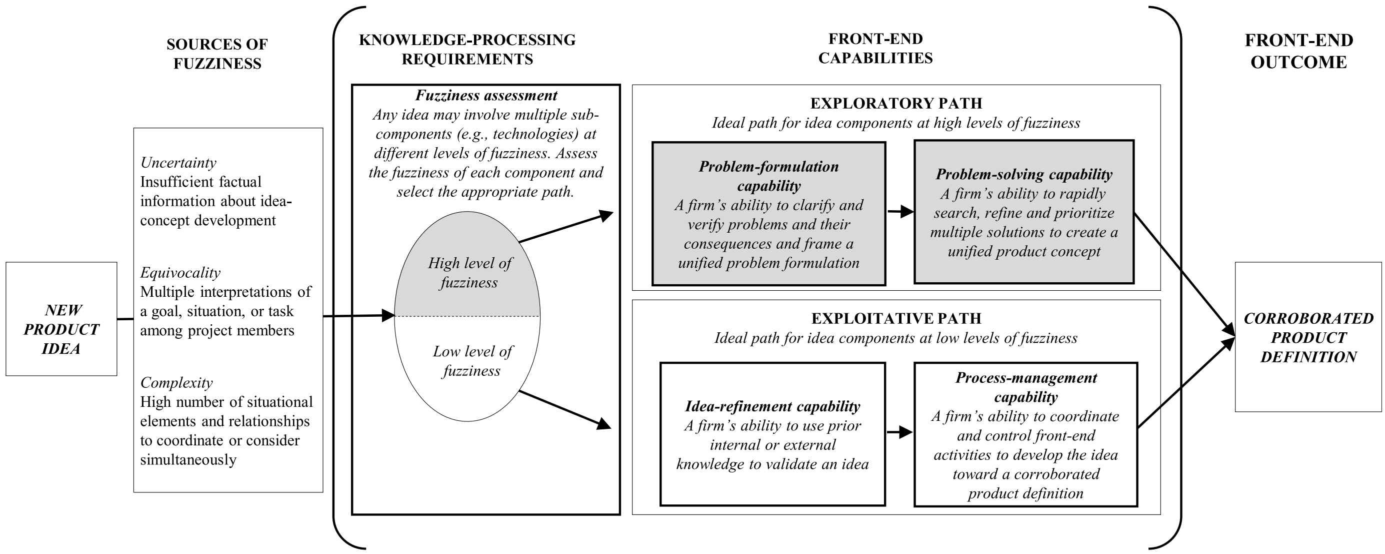

Fig. 2. A contingency perspective for managing new product ideas under different levels of fuzziness.

move forward. To address such challenges, the results support the joint application of two distinct capabilities: *problem formulation* and *problem solving.*

To initiate this path, problem-formulation capabilities should be applied first. Problem formulation is *a firm's ability to clarify and verify problems to create a unified problem formulation*. For example, challenges related to multiple interpretations of customer needs can be addressed through problem-articulation activities designed to translate symptoms (e.g., a customer wants a sturdier product design) into well-defined information requirements that open up different solution avenues (e.g., a customer needs greater availability of equipment) and underlying causes (e.g., availability is reduced by systematic overloading of machines). Thus, the systematic mapping of the underlying causes of problems provides an accurate foundation to solve these problems and create customer value.

Only after conceiving a clear frame for the underlying problems and causes can the firm apply *problem-solving capabilities*. Indeed, while it is tempting to jump directly to solution search, respondents pinpointed the deleterious issues associated with beginning with problem solving before accurate mapping and problem formulation had taken place. As stated previously, problem-solving capabilities refer to *a firm's ability to rapidly search, refine, and prioritize multiple solutions to create a unified product concept.* As explained in the analysis, this capability is particularly valuable for ideas with high levels of fuzziness because it allows firms to identify a number of potential solutions to problems and their causes and rapidly test and prioritize these solutions by involving key stakeholders internally and externally in joint problem solving. For example, a manufacturer of mining equipment described how the company had been testing multiple solutions for automated loading of rocks. To do so, it had involved expert end users from customers and partners in an agile way, which enabled it to quickly eliminate deficient solutions and progress to a more comprehensive product description.

Together, the set of problem-formulation and problem-solving capabilities enables firms to embrace high fuzziness levels by disentangling problems, clarifying information needs, and aligning multiple actors in the search for solutions. This process is achieved by a coordinated effort to understand the problem and involve key stakeholders in solving it. Indeed, respondents noted that an exploratory path entails a more comprehensive mapping of solution needs, more innovative solutions, and higher expected returns when generating a corroborated product definition. However, the contingency perspective is important because informants remarked that using an exploratory path is often time consuming and resource intensive (as illustrated by idea case 2 in Table 3) and should thus only be applied when needed (i.e., at high levels of fuzziness). For example, many respondents cautioned against applying these capabilities for just any new product idea. Specifically, applying the capabilities in the exploratory path to ideas at low levels of fuzziness was considered wasteful and counterproductive because it directed resources to clarifying product ideas that were already reasonably clear and because this misdirection may even cause over-engineering and failure.

4.3.3. An exploitative path to developing ideas at low levels of fuzziness

Ideas at lower levels of fuzziness may benefit from leveraging existing knowledge to speed up development by building on prior experience and market insights. The results suggest that the exploitative path is suitable for product ideas (or subcomponents) at low levels of fuzziness in order to encourage improvements and refinements of reasonably clear ideas. Examples include ideas for launching an upgraded version of an existing product or expanding the market through a product line extension. The logic of this path is to quickly develop new product concepts by building on internal and external knowledge and eliminating deficient ideas through monitoring internal strategies and market trends. Following an exploitative path involves applying *idea-refinement* and *process-management capabilities*.

As a first step, firms should apply *idea-refinement capabilities*, which refer to *a firm's ability to use prior internal and external knowledge to validate an idea.* It allows firms to rapidly validate ideas based on experiences from prior trials and analyses by experts. For example, firms can quickly assess external trends and threats by applying external scouting or contacting external experts to validate an emerging concept. Relying on the prior experience of internal employees can also be valuable in reducing time to market. Respondents expressed the view that more incremental product ideas can be quickly developed by recombining existing technologies and features while ensuring their validity through external scouting and environmental analysis.

After refining a new product idea, formal idea development can start, where *process-management capability* is helpful in moving forward. Process-management capability refers to *a firm's ability to coordinate and control front-end activities to develop the idea into a corroborated product definition.* Respondents stressed that starting the formal idea-development process is often unfruitful if the idea is not sufficiently validated and refined. However, when the idea has been refined sufficiently, process-management capability complements idea-refinement capability. It does so by helping project members to efficiently reach a consensus and to proficiently manage internal development practices by

Table 3

Illustrative embedded case examples of the need for a capability-based contingency perspective.

Illustrative case	Level of fuzziness	Applied front end capabilities	Front end outcomes
Idea case 1: Commercial vehicle: *Idea for creating an innovative coating technology for corrosive components in truck undercarriage*	*High fuzziness:* High need to align the idea to internal production capabilities in different plants (H. Com), lacking understanding of important parameters related to weather abrasions (M. Unc). Low agreement on the value of applying the Technology (H. Equ)	*Explorative:* Extensive work in involving cross-functional actors toward defining coating needs by assessing installed base maintenance data and future production capabilities (PFC). Iterative processes for searching for right properties and seeking support from key actors (PSC).	*Success:* Strong agreement on product definition and a go ahead to launch a formal development project.
Idea case 2: Medical equipment: *Idea to create smart hospital bed incorporating, sensors, connectivity and analytics*	*Low fuzziness:* Good understanding of digital features that support doctors, nurse and patients' needs as these had been mapped in prior projects (L. Unc). Easy integration of established digital sensors (L. Com). Digitalization widely regarded as key to competitiveness and project member were aligned (L. Equ.)	*Explorative:* Development team closely involved the software team and tried to sketch the concept jointly to address end-user needs (PFS). Multiple rounds of discussion and potential customer interactions, provides lot of insights to create a comprehensive solution addressing all identified customer needs (PSC).	*Failure:* Team spent 12 months preparing the concept ended up with an overengineered and over budgeted concept. Competitors had already launched a simpler smart bed solution. Concept was deemed to costly and not aligned with modest customer needs for simple digital features.
Idea case 3: Commercial vehicle: *Idea for expanding service business towards larger fleet customer segment by incorporating connectivity device for sharing use data from vehicle operating system*	*Low fuzziness:* Idea followed recommendations for features uncovered in strategy analysis towards expanding existing services portfolio (L. Unc). Project team and market facing service unit shared a common view of requirements (L.Equ). Easy integration of standardized components available on the market with only limited need for customization (L. Com)	*Exploitative:* Leveraging prior internal reports combined with insights from other industries lead to idea refinement (IRC). Iterative development cycles fast-tracked research progress coordination by streamlined process routines (PMC).	*Success:* Service concept with developed within the allocation budget and before deadline enabling rapid continuation of formal development. Key stakeholders also found the concept to be well aligned with already in place service innovation strategy and pushed market commercialization.
Idea case 4: Telcom communications: *Idea for developing 5G connectivity system for new market industrial application*	*High fuzziness:* Need to redesign the entire product line with new technology and limited information about the potential business cases. Limited information about the regulatory requirements (H.Unc). Need for designing system capable of supported many different use cases created complex system architecture (H.Com). Development team initially had a clear joint view of the objectives but disagreement arose as complex competing requirements surfaced (L.Equ - > H. Equ)	*Exploitative:* R&D team engaged extensively in trend analysis, discussion with new potential customer segments and build the idea through internal knowledge databank related to previous version (i.e. 4G) of technological development (IRC). Development process prioritized speed and coordinated involvement of multi-unit team members that generated lot of innovative ideas (PMC).	*Failure:* Product concept was inferior and lacked business case. Many decisions about technical features were taken without sufficient customer segment understanding.

Legend: H = High, L = Low, Unc = Uncertainty, Com = Complexity, Equ = Equivocality, PFC = Problem formulation capability, PSC = Problem solving capability, IRC = Idea refinement capability, PMC = Process management capability.

working toward established performance indicators in an iterative fashion. For example, respondents stressed the importance of applying an agile development process and holding regular feedback sessions with customers and key internal actors when refining ideas to validate the effectiveness of a solution.

Together, the two capabilities corresponding to the exploitative path help firms follow a fast-tracked, efficient approach to developing new product ideas. This path is suitable for ideas that have low levels of fuzziness where established knowledge can be leveraged and key internal and external actors can be involved in the validation process. Indeed, respondents noted that an exploitative path entails greater focus on shorter turnaround times, more structured project planning, and appropriate resource commitments to generate a corroborated product definition. However, the contingency perspective illustrates that firms should not attempt to apply them to more challenging/highly fuzzy ideas because this approach may lead to unsuccessful and uncorroborated product definitions. For example, respondents argued that tackling a highly fuzzy idea with the approach of reusing existing knowledge frequently led to frustration and misunderstanding of the underlying problems (as illustrated by idea case 4 in Table 3). In fact, several respondents cautioned against this one-size-fits-all approach, which is often prescribed by process-focused managers seeking to impose structure in the front end.

5. Discussion

This study contributes to the front-end literature by examining how firms (and projects within firms) manage the development of ideas at different levels of fuzziness by deploying the appropriate sets of capabilities to develop corroborated product definitions. Based on a multiple case study of seven manufacturing firms, a capability-based contingency framework is proposed for harnessing fuzziness in the front end. The results illustrate the importance of assessing fuzziness levels at the initial stage and following specific exploratory and exploitative capability paths, depending on the nature of the idea and concept under development. As more and more firms invest in innovation, these findings are important, particularly in idea and concept development where sustaining a competitive advantage is the ultimate goal (Ridley, 2020).

5.1. Theoretical implications

The findings contribute to emerging discussions on the examination of multiple sources of fuzziness (Chang et al., 2007; Stevens, 2014), the need to better understand sets of capabilities for innovative ventures (Watson et al., 2017), and the contingency perspective on firms' actions in the front end (Mellewigt et al., 2018).

First, this study *contributes by suggesting a novel view of the interdependence and agglomeration of sources of fuzziness*. Notably, the study builds on prior literature (e.g., Stevens, 2014; Frishammar et al., 2011) that highlights the importance of mapping a critical set of sources of fuzziness (uncertainty, equivocality, and complexity) that front-end teams are likely to face in idea development and, consequently, must deal with. The analysis extends the literature by proposing a theoretical framework that not only addresses the sources of fuzziness one by one but also illustrates their interactions and how, through a process of accumulation, they affect front-end activities at different levels. For example, highly complex ideas are non-decomposable (Nickerson and Zenger, 2004). Consequently, such ideas make information gathering and sensemaking challenging, which can give rise to further uncertainty and equivocality (Sjödin, 2019). Such a perspective enhances the discussion on what drives fuzziness and how the sources of fuzziness interact and accumulate. In particular, we argue that fuzziness cannot be fully conceptualized by focusing on individual sources only. The aggregate must also be considered. This conceptualization extends the existing literature on individual sources of fuzziness and the specific learning strategies applied to manage them (Stevens, 2014; Frishammar et al., 2011; Zhang et al., 2019), and it provides a novel avenue for further in-depth research.

Second, the study contributes to the capability perspective by *identifying two distinct sets of capabilities, namely exploitative and exploratory front-end capabilities*. The front-end literature is rich in detailing key activities (Jissink et al., 2018), processes (Gama et al., 2019), and foundational factors (Florén et al., 2018). However, studies of front-end capabilities are scarce. A capability perspective may therefore provide a more comprehensive understanding of the complex bundles of skills, knowledge, and organizational processes that enable firms to coordinate activities and make use of their assets to drive idea and concept development in the front end (Watson et al., 2017). In particular, the novelty of a front-end capability perspective arises from the combination and sequencing of capabilities, routines, and activities into discrete capability sets. Indeed, some front-end studies have identified individual capabilities that are relevant in the early stages of innovation but provide limited insights into how to deploy these capabilities together to address different sources of fuzziness (Björk et al., 2010; Thanasopon et al., 2016; Schweitzer et al., 2016).

It is argued that acknowledging the use of different types of capability in the front end of the innovation process is important. As the findings illustrate, certain capabilities seem to work well together, when matched with appropriate levels of fuzziness. For example, problem formulation and problem solving provide an exploratory capability set that is well suited to enhancing the formulation and iterative solving of complex, ambiguous, and poorly structured problems. In contrast, idea refinement and process-management provide an exploitative-capability set following a somewhat simpler approach to innovation by leveraging existing sources of knowledge and recombining them to create rapid and refined product concepts. These findings extend prior research on front-end capabilities (Björk et al., 2010; Thanasopon et al., 2016; Gama et al., 2019; O'Brien, 2020). They provide the basis for a more integrated research agenda to understand capability combinations and complementarities in front-end projects. Indeed, our findings resonate with the resource-based view of innovative enterprises (i.e., Randhawa et al., 2018; Watson et al., 2017).

Third, and perhaps most importantly, the study contributes by *suggesting a contingency perspective to harness fuzziness in the front end*. Central to this contribution is the proposition of cause–effect links between levels of fuzziness, application of organizational capabilities, and successful outcomes. The structured contingency framework delineates two paths depending on the fuzziness level. While it is acknowledged that the front-end literature illustrates the differences between incremental and radical innovation (de Brentani and Reid, 2012; Florén and Frishammar, 2012; Markham, 2013), a contingency perspective on idea and concept development analogous to the viewpoint presented in this study is still lacking in the front-end literature (Florén et al., 2018). The idea that capabilities are not efficient in themselves but are useful in the way they are chosen according to the nature of the problem encountered during development (i.e., fuzziness levels) contribute to an understanding of the efficiency of front-end processes and capabilities. The proposed framework therefore enables a more finely grained analysis of the appropriate paths for harnessing fuzziness in idea development and points to the need for ambidexterity in front-end capabilities. Here, the suggestion is that companies must be skilled in both approaches because they may need to conduct different project types at the same time. Therefore, the framework responds to calls to provide a better understanding of the conditions that shape the use of different sets of practices for or approaches to new ideas (Jissink et al., 2018; Rizova et al., 2018).

An important additional insight advanced by the contingency framework is that high fuzziness levels are not unsound in themselves. Rather, they require a particular type of management (Brun and Sætre, 2009; Chang et al., 2007; Frishammar et al., 2011) to harness their potential benefits. Firms that can embrace high fuzziness levels through the exploratory capability path can in fact reap substantial benefits by creating corroborated product definitions for more radical innovation ideas.

5.2. Managerial implications

This study carries implications for R&D and innovation managers and engineers who are responsible for or work within the framework of idea-development processes in manufacturing firms. First, project members and managers are encouraged to invest time and resources in the assessment of the fuzziness level of innovative ideas. A practical rule of thumb is that, if at least one of the sources of fuzziness is at a high level, the whole idea is categorized as having a high level of fuzziness. The reason for this classification is that a high level of fuzziness is likely to spread from the interaction that occurs among the sources of fuzziness and further accumulate to create higher fuzziness levels. Thus, the interactive nature of the sources of fuzziness can intensify knowledge problems for front-end managers if not addressed in the initial phase. Based on this classification, managers should then select and deploy appropriate actions.

Second, this research provides recommendations on the required capabilities required to harness fuzziness in idea development in the front end. Innovation managers are encouraged to prioritize investment in capability development and, more importantly, the development of diverse sets of capabilities for idea development. Ideas with high levels of fuzziness benefit from following an exploratory path, where fuzziness is embraced through problem-formulation and problem-solving capabilities. In contrast, ideas with low levels of fuzziness benefit from an exploitative path, where fuzziness is tolerated through idea-refinement and process-management capabilities. Capability development is costly, time consuming, and path dependent. One suggestion for making capability development more efficient is to develop two discrete, dedicated project teams that are trained and used exclusively for each path. This approach would facilitate quicker formalization of routines and more efficient use of resources.

Third, managers are recommended to consider a more structured contingency approach for managing idea development at different levels of fuzziness. For low levels of fuzziness, managers are encouraged to adopt a fast-track exploitative path, which relies on idea-refinement capability and process-management capability to ensure speed and efficiency. In contrast, more challenging ideas should follow the exploratory path to embrace the creative potential of ideas with high levels of fuzziness. In such cases, following the exploitative capability path would not be feasible and would impede development. In other words, when the level of fuzziness of the idea and the set of capabilities deployed to develop an idea are poorly aligned, the idea-development process is either inefficient or runs the risk of stalling. Whereas correct selection helps firms improve efficiency in terms of resource use, inappropriate selection can lead to overload or underload of internal resources, which reduces efficiency in terms of cost, time, and quality of idea development.

Consequently, competitive advantage can be gained by early adopters of any technique designed to systematically and reliably overcome biases in front-end activities. The theoretical framework outlined in this manuscript and operationalized as a structured process constitutes just such a technique. As a result, it may offer firms a way to achieve competitive advantage for some time to come.

5.3. Limitations and outlook

Although the results of this study are based on numerous interviews at seven firms, the empirical data were gathered solely from manufacturing firms. While a focused sampling technique reduces contextual variations and helps deliver robust findings, project managers operating outside the manufacturing industry should consider industry-specific variations as they interpret the findings. Furthermore, although all case firms were globally active, the primary data collection centered on R&D units in Sweden. Cultural differences (e.g., power distance and tolerance of ambiguity) and varying contexts may influence the appropriate management of front-end activities. Bearing these limitations in mind, we propose several avenues for further research.

First, we recommend further research on aggregate levels of fuzziness. While our study clearly indicated interactions and agglomerations among fuzziness sources, we were not able to fully disentangle these dynamics given our dataset and research design. Accordingly, we call on future research to further address these questions. Specifically, future research could shed light on how different fuzziness sources interact and accumulate in day-to-day project work and how they are best dealt with. For example, our research indicates that highly complex ideas often lead to equivocality (e.g., misunderstandings) and uncertainty (e.g., challenges in obtaining appropriate information) as idea development progresses. Studying how such problems unfold would be a very relevant pursuit for further inquiry. Thus, scholars are encouraged to perform real-time project-level studies following each idea over the course of its development to fully capture the dynamics and interdependencies of harnessing fuzziness in the front end. In doing so, there is potential for researchers to assess overall fuzziness not only in terms of aggregate levels (high/low) but also by considering: which subcomponents are contributing, how they interact and evolve over time, and which areas are affected. Such studies should seek to extend our research to provide a comprehensive examination of how different sources of fuzziness interact to provide a more nuanced contingency framework.

Second, there are significant opportunities in further studying the appropriate front-end capabilities and paths in different situations. For example, we recommend further research into ideas or subcomponents of ideas that are not easily classified as having low or high fuzziness. There may also be ideas exhibiting moderate fuzziness that require a hybrid development path. For example, additional capabilities and practices related to agility (Kohtamäki et al., 2020), or co-creation (Marcos-Cuevas et al., 2016) may warrant examination.

Third, future research should empirically examine the potential consequences of a mismatch between ideas at different levels of fuzziness and applied front-end capabilities. Although the results suggest that such a misalignment might create either underload or overload of internal resources and thereby hamper a firm's performance, there is scope for further detailing of the underlying mechanisms and effects of such a mismatch in the front end.

Fourth, we acknowledge that this research has focused mainly on firms' internal processes for developing ideas. However, front-end activities do not occur in insolation in today's era of open innovation, ecosystems, and digitalization. Accordingly, future studies should investigate how different collaborative settings (i.e., alliances, partnerships, ecosystems, and artificial intelligence techniques) influence the front-end assessment and appropriate capability deployment. Or they may wish to investigate how particular digital technologies, such as artificial intelligence (Sjödin et al., 2021), influence front-end capabilities. For instance, ideas developed in a collaborative setting may require absorptive capacity and collaborative competency to stimulate idea development between organizations. Thus, expanding the proposed framework by adding more externally focused front-end capabilities and routines would be a worthwhile undertaking. In addition, investigating front-end capabilities in the earliest stage of ecosystem formation, which is undoubtedly challenged by considerable uncertainty, complexity, and equivocality, could be of interest in seeking to understand how firms manage the alignment of diverse ecosystem actors around a focal value proposition idea.

Finally, the limited level of resources available in the front end makes individual actions and interactions important because they provide informal access to resources and expertise to navigate the fuzzy-idea landscape. Further research on the role of individuals in the front end (e.g., Sjödin et al., 2019) and how they work to identify required competencies, stimulate solution search, and use personal networks throughout the organization to harness fuzziness would further enrich understanding of this phenomenon.

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Appendix A. Supplementary data

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