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A Design Management Model for Product Development in SMEs: The Integrated Design Management (IDM) model

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Abstract

SMEs significantly impact the economy of any country, but due to their size, they often face human and financial resource constraints. Additionally, the multidisciplinary nature of innovation makes it challenging for them to gather all the resources and skills needed for effective design project development. Considering these constraints, it is imperative that the innovation and the design process must be managed efficiently and in a structured way to achieve the defined objectives. However, the current tools analyze design management, classify good practices, examine their degree of integration, and map their benefits, but fall short of outlining how SMEs can implement design management. This article presents the Integrated Design Management (IDM) model, designed to help SMEs with little or no previous design experience to systematically implement design management for the new product development process. The model's validation through feedback from participants knowledgeable in design management reinforces its reliability and applicability, enabling SMEs to navigate design complexities.

Keywords: design management, model, design strategies, SMEs, product development.

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1 Introduction

Design as a qualified resource for innovation and its added value for New Product Development (NPD) has been increasingly recognized. Its effective use can positively contribute to the organization's performance (Ahmed et al., 2024; Berends et al., 2011; Bruce et al., 1999; Chiva & Alegre, 2007, 2009a). Nevertheless, good design does not simply happen by accident; instead, it arises from a well-managed process (Bruce & Bessant, 2002). The literature classifies the practices inherent to this design process management as design management (Chiva & Alegre, 2007, 2009a). The Design Management Institute [DMI] (2022) defines design management-related activities as "the ongoing processes, business decisions, and strategies that enable innovation and create effectively-designed products, services, communications, environments, and brands that enhance our quality of life and provide organizational success." Within the scope of design management, the context of SMEs is particularly challenging and important (according to the European Commission (2003) recommendation 2003/361/EC, an SME is a firm that meets the following conditions: (i) number of employees ≥10 and < 250 and (ii) annual turnover above 2 million euros and under 50 million euros, or (iii) annual total assets above 2 million euros and under 43 million euros). Although SMEs often face human and financial resource constraints and, in some cases, lack of design experience (Bruce et al., 1999; Fernández-Mesa et al., 2013; Lewis & Brown, 1999; Oakley, 1982), they contribute to a large share of the economic activity in European Union countries (Audretsch et al., 2009; Dabić et al., 2023). Therefore, considering the strategic value that design represents for business performance and competitiveness (Alarcon et al., 2015; Berends et al., 2011; Bruce et al., 1999; Chiva & Alegre, 2009a; Parkman, 2023), improving the product development process and the respective management of the process is imperative. Currently, there is a growing demand for tools for developing and applying design management structures in companies (Gancho, 2023; Wolff et al., 2016). However, a predominant focus in the design management literature has been outlining definitions, goals, and objectives. At the same time, there has been little emphasis on how companies with little or no prior design experience can implement design management. To attend to this need, this article presents the Integrated Design Management (IDM) model, a new structured model for SMEs with little or no previous design experience to systematically implement, manage, and control the NPD process within the scope of operational design management. This new model is based on the research results of Carneiro et al. (2021) concerning the parameters and criteria for design management during SMEs' new product development process.

This article is structured as follows. First, the theoretical background on design management, the role of SMEs, the design management models, and the theoretical bases that underlie the model are presented, followed by a review of the existing design management tools (models, audits, and checklists). Next, the development of the IDM model is presented, outlining the systematic process of creating a framework tailored to the unique challenges faced by SMEs. Following this, the model's validation is discussed, incorporating insights from industry experts to evaluate its effectiveness. Finally, this research addresses the theoretical and managerial contributions of the IDM model, outlines research limitations, suggests avenues for future research, and summarizes the key conclusions.

2 Theoretical Background

2.1 Design Management and Product Development Process in SMEs

In the context of SMEs, design management in the product development process is an emerging topic (Ahmed et al., 2024; R. Cooper & Press, 1995; Gancho, 2023; Manzakoğlu & Er, 2018; Parkman, 2023; Zapata-Roldan & Sheikh, 2022). Since the 1960s, design management has been employed as a strategic resource to enhance project efficiency (Acklin, 2013; de Mozota, 2003) and is recognized as a key factor in firm performance (Hertenstein et al., 2005). This is particularly relevant for SMEs, as they can drive innovation and change (Acklin, 2010). It is recognized that SMEs significantly contribute to any country's economic performance (Ford & Terris, 2017), with their capability to develop new products and innovate being an essential source of economic growth (Bruque & Mayano, 2007). Companies that manage design effectively and efficiently often outperform their competitors. According to the DMI Design Value Index (Westcott et al., 2014), design-led companies have consistently maintained a substantial stock market advantage over the last ten years, outperforming the S&P 500[1] by 228%. Therefore, a good design results from a properly managed process (Bruce & Bessant, 2002). This is true for large companies, particularly SMEs, who often face human and financial resources constraints (Bruce et al., 1999; Fernández-Mesa et al., 2013; Lewis & Brown, 1999; Oakley, 1982). SMEs may struggle to invest in design or design management skills (Ford & Terris, 2018; Lee, 2020), and simply engaging in design-related activities does not guarantee the desired goals (Dabić et al., 2023; Topaloğlu & Er, 2017b).

In this sense, there is a demand for tools (models, audits, and checklists) for applying design management in companies (Wolff et al., 2016). The broad range of the available design management tools suggests a variable scope for the subject. Tools and other scoreboards that emerged became means that stimulated the development of indicators that allow measuring design in organizations (Pinheiro & Franqueira, 2020). The evaluation of design through detailed models of its processes and maturity, supported by studies on the design absorption capacity (Acklin, 2013; Braga, 2017; Wolff et al., 2016) and design management maturity models (Best et al., 2010; Danish Design Centre, 2003; Kootstra, 2009), enables an understanding of the impact of design on organizations. They implicitly address organizational learning and propose ascending maturity levels in design management. Audit models/tools (Moultrie et al., 2006b, 2006a; Topaloğlu & Er, 2017b) seek to identify and incorporate new responsibilities and capabilities needed to support the change and expansion of the design context and roles. All these tools aim to explain better design management, categorize practices, evaluate the degree of their integration, and map their benefits (Lewis et al., 2009). Although these tools allow better comprehension and understanding of the complexity of design management in companies, they fall short of outlining exactly how SMEs, with little or no previous design experience, can implement and apply design management.

To address this gap and establish the foundations for a new model to support the application of design management in SMEs, Carneiro et al. (2021) conducted a systematic literature review on design management in the product development process in the context of SMEs. They identified five main topics that address the main activities and concepts involved in the design management process associated with product development and innovation: Design Management Integration; Design Function Organization; Design Management Capabilities; Tools and Methods; and Managing Design Projects. These topics and their respective subtopics were extensively described, analyzed, and discussed, revealing a complex set of parameters and dependencies to be carefully considered, as illustrated in the diagram in Figure 1.

It can be observed that each group of topics extracted from the literature contains a set of relevant subtopics, all interconnected either directly or indirectly. However, the complexity increases as interconnections between subtopics from different groups form a complex and intricate web of connections. SMEs face this complexity when implementing innovation projects, making a systemic and global approach challenging and can lead to neglecting the analysis of some of these crucial topics. Structuring this intricate network of connections, interconnections, and parameters to formulate a systematic methodological approach is essential for an SME. This allowed for a deep and comprehensive analysis of the challenges, difficulties, impacts, and risks in implementing an innovation project while ensuring adequate process management to achieve the intended results.

1. The Standard and Poor's 500, or S&P 500, is a stock market index that monitors the stock performance of 500 major companies listed on United States of America stock exchanges. It is widely recognized and stands as one of the most frequently tracked equity indices.

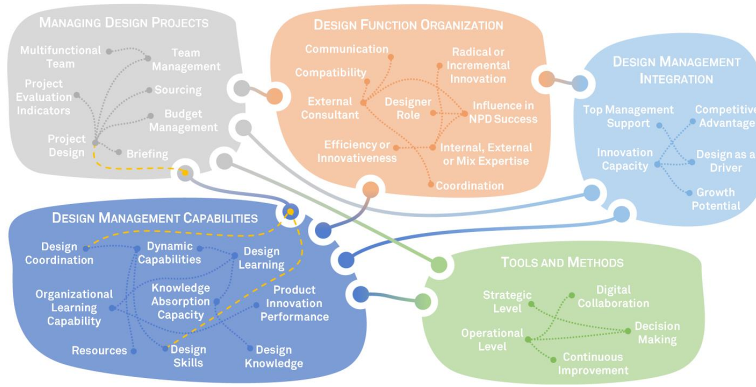

Figure 1. Visual representation detailing the primary topics and parameters for design management during SMEs' new product development process.
Source: Carneiro et al. (2021, p. 213, Figure 8), licensed under CC BY-NC-ND 4.0.

2.2 An Overview of Current Design Management Tools: Models, Audits, and Checklists

Assessing the design process and design management capabilities remains a relevant topic for academic research (R. Cooper & Press, 1995) and business practice (Inns, 2002). Such assessments allow companies to analyze how they handle design activities and decisions (Topaloğlu & Er, 2017a), evaluate the performance of the project(s) and track its progress over time (Project Management Institute, 2017), and reflect on the effectiveness of their design process and results (Best, 2006; R. Cooper & Press, 1995; Topaloğlu & Er, 2017a). This enables companies to become aware of design routines, recognize existing shortcomings, identify opportunities, and implement actions for improvement and change (Topaloğlu & Er, 2017a). Within the scope of academic research, the assessment and exploration of existing organizational capabilities allow for understanding associated problems and identifying the conditions that facilitate design and design management good practices (Best et al., 2010; Dickson et al., 1995; Heskett & Liu, 2012; Moultrie et al., 2006a; Storvang et al., 2014). In the words of Inns (2002), "some form of assessment or audit is needed to ascertain current levels of capability before opportunities for further improvement can be identified" (p. 240). In the academic literature, design and design management assessment tools are designated under the terms of "audit," "checklist", and "model" (R. Cooper & Press, 1995; Manzakoğlu & Er, 2018; Topaloğlu & Er, 2017a). R. Cooper & Press (1995) state that an audit is "a research activity, involving asking questions, searching for answers and testing the reliability of those answers to gain new knowledge and move forward" (p. 212). In turn, checklists, according to Downey & Banerjee (2010), "are a mechanism for reminding and/or prompting attention to issues or topics. A checklist can be general (e.g., outlining the steps in a process so steps are not missed) or specific (listing detailed items to be addressed)" (p. 27). Nilsen (2015) explains that models:

> "can be described as theories with a more narrowly defined scope of explanation; a model is descriptive, whereas a theory is explanatory as well as descriptive. [...] A model typically involves a deliberate simplification of a phenomenon or a specific aspect of a phenomenon." (p. 2)

According to the different types of assessments that design management tools perform, they can be classified based on their primary focus, such as:

- **Design Maturity Assessment**: These tools assess the maturity level of an organization's design capabilities or design management practices. They typically provide a framework or set of criteria for evaluating an organization's design maturity level and categorize organizations into different levels based on their performance.
- **Design Capability Assessment**: These tools evaluate an organization's design capabilities or competencies. They assess the skills, knowledge, and experience of individuals or teams involved in the design process and the design-related resources, infrastructure, and systems.
- **Design Process Assessment**: These tools evaluate both the efficiency and effectiveness of an organization's design process. They examine the design process from various perspectives, such as the quality of design outputs, the process efficiency, the stakeholder level of involvement, and the level of innovation.
- **Design Value Assessment**: These tools assess the value created by an organization's design activities. They evaluate design's economic, social, environmental, and cultural impacts and may provide a framework for measuring the return on investment in design.

This classification scheme helps categorize the tools based on their primary focus, providing a framework for selecting the most appropriate tool for a specific situation or need. Table 1 summarizes the most relevant audits, checklists, and models to assess design management in organizations. This compilation is based on reviewing various articles exploring these tools and their applications. Each entry in the table includes an indication of the main focus of the respective tool, highlighting its intended purpose and relevance in the field of design management.

Tools employing maturity grids enable measuring an organization's design integration level across key aspects, such as design strategy, culture, process, and results. In 2009, Kootstra (2009) introduced the "Design Management Staircase" audit/model to assess the impact and significance of design management within SMEs. It provides a clear framework for classifying design management capability into four maturity levels (no design management; design management as project, design management as a function, and design management as culture) according to five factors (process; expertise; resources; planning; and awareness) and the steps needed to climb the ladder towards more advanced design management practices.

In the literature, some significant tools exist in the context of design capability. In 2003, the Danish Design Centre (2003) developed the "Danish Design Ladder," a four-step model for assessing design capabilities and performance in the Danish context. However, despite being a helpful tool for organizations to assess their design practices, a fundamental limitation is that it does not provide a clear framework to progress through the different design stages. In 2012, Heskett & Liu (2012) developed "A Model for Developing Design Capacity" to evaluate design management practices in Chinese companies. Unlike the static structure of the "Danish Design Ladder," this model provides a dynamic framework and a mechanism to track changes and transitions between different levels within the company. Based on Heskett & Liu's spider web model, a Danish initiative by Storvang et al. (2014) introduced the "Design Capacity Framework." This framework covers various design aspects, such as design awareness, design processes, innovation drivers, user involvement, and design capabilities, and it goes beyond earlier models like the "Design Management Staircase" and the "Danish Design Ladder," by emphasizing the significance of user involvement in the design process and the company's innovation drivers.

Table 1. Design Management Assessment Tools: Audits, Checklists, and Models.

Name	Author(s)	Structure	Focus	Areas of Coverage
Design Management Staircase	Kootstra (2009)	Audit/Model	Design Maturity Assessment	Model/audit to classify a company's design management capability into four steps (Design Management as Culture; Design Management as Function; Design Management as Project; and No Design Management) according to five factors (process; experience; resources; planning; and awareness).
Design Sensitivity and Design Management Effectiveness Audit	Kotler & Rath (1984)	Audit	Design Capability Assessment	Audit from the marketing perspective is composed of a "Design Sensitivity Audit" (that will point out the impact and significance that design plays in the company's marketing decision-making process) and a "Design Management Effectiveness Audit" (that ranks how well management uses design).
Self-Assessment of Design Management Skills	Dickson et al. (1995)	Audit	Design Capability Assessment	Self-evaluation tool for assessing design management skills across five distinct groups: Innovation Skills; Organizational Change; Involving Others; Specialized Skills; and Basic Skills.
Design Audit Tool for SMEs	Moultrie et al. (2007)	Audit	Design Capability Assessment	Audit tool for design-related activities and their result in NPD processes of SMEs.
Design Management Audit Tool	Topaloğlu & Er (2017a)	Audit	Design Capability Assessment	Audit composed of nine dimensions (Strategy; Investment; Planning; Design Processes; Design Organization; Research for Design; Training and Development for Design; Design Integration; and Culture and Climate for Design) aimed at identifying and accommodating emerging capabilities and responsibilities essential to support the changing and broadening context and functions of design.
Danish Design Ladder	Danish Design Centre (2003)	Model	Design Capability Assessment	Four-step model (Design as Strategy; Design as Process; Design as Form-Giving, and Non-Design) to evaluate and rate a company's design use.
A Model for Developing Design Capacity	Heskett & Liu (2012)	Model	Design Capability Assessment	Model to evaluate the design management practice in Chinese enterprises grounded on six criteria: Company Size; Design Awareness; Design as a Competitiveness Factor; Design Process; Internal Design; and Design Work Assigned To.

Name	Author(s)	Structure	Focus	Areas of Coverage
Design Management Absorption Capacity	Acklin (2013)	Model	Design Capability Assessment	Model to measure and evaluate the design knowledge absorption process by SMEs with little or no previous design experience.
Design Capacity Model	Storvang et al. (2014)	Model	Design Capability Assessment	Model to evaluate the design management capacity of the Danish companies based on five criteria: Innovation; Design Capabilities; Design Awareness; Processes; and Users.
Double-Loop Design Management Model	Wolff et al. (2016)	Model	Design Capability Assessment	Model to assess how designers and companies, focusing on SMEs, absorb and incorporate new design methods as they progress in learning and refining their procedures.
The Design Innovation Spectrum	Na et al. (2017)	Model	Design Capability Assessment	Model to assess the design influences on innovation and help prioritize the areas for enhancement to elevate manufacturing companies' innovativeness level.
Design Management Capability Framework in Global Value Chains	Manzakoğlu & Er (2018)	Model	Design Capability Assessment	A model that links design management and the global value chains literature to help develop more effective policies regarding the strategic use of design.
ISO 9001	International Organization for Standardization [ISO] (2015)	Checklist	Design Process Assessment	Checklist for internal/external audit of the quality of the product/service development process.
A Model to Evaluate the NPD Process in SMEs	Hernandez et al. (2014)	Model	Design Process Assessment	Model for diagnosing and evaluating the NPD process in manufacturing SMEs.
Corporate Design Audits Checklist	Topalian (1984)	Checklist	Design Process Assessment	Checklist to conduct corporate design audits.
The Value Chain Model	de Mozota (1998)	Model	Design Value Assessment	Model for design management excellence composed of three levels: Operational, Functional, and Anticipative Design.
Balanced Score Card Tool	de Mozota (2006)	Model	Design Value Assessment	Model to assess the impact of the design value on a company in four perspectives: Customer Value; Performance Value; Learning Perspective; and Financial Value.
The DMI Design Value Scorecard	Westcott et al. (2014)	Model	Design Value Assessment	Model to assess the value of an organization's design activities across three functional areas: Tactical, Organizational, and Strategic.

Focused on the capabilities of individuals rather than the capabilities of organizations, Dickson et al. (1995) developed the "Self-Assessment of Design Management Skills" tool, which aids individuals assessing their design management skills and identifying areas for improvement. The tool consists of questions about design management skills, strategy, organization, and implementation. With a more marketing-focused perspective, one of the first and most influential design assessment tools is the "Design Sensitivity and Design Management Effectiveness Audit," developed by Kotler & Rath (1984) to assess the role of design in the organization's marketing decision-making process. This tool comprises two main components: the design sensitivity audit and the design management effectiveness audit. The design sensitivity audit assesses how design is integrated into an organization's marketing strategy, by measuring the level of design expertise within the organization, the extent to which design is used to differentiate the company's products from those of competitors, and the extent to which design is used to create a unique corporate image. On the other hand, the design management effectiveness audit assesses how well the organization manages the design process, considering the role of design in the decision-making process, the level of resources allocated to design, and the degree to which design is integrated into the overall strategy. Despite its structured approach to assessing the role of design in organizations' marketing decision-making process, some researchers have criticized the model for its narrow focus on marketing and for overlooking other design aspects, such as aesthetics and user experience (R. Cooper & Press, 1995).

Specifically considering the SMEs, Moultrie et al. (2007) developed the "Design Audit Tool for SMEs" to assess the design capabilities and process and identify areas for improvement of manufacturing SMEs in the UK. The audit tool covers five areas of design capability (design strategy, design processes, design organization, design skills and resources, and design performance). It also includes various aspects of design processes, such as the organization's approach to concept generation, prototyping, testing, and implementation. However, it may have limitations for certain types of SMEs (e.g., service-based or creative industries) and may require additional support and guidance to be implemented effectively (Moultrie et al., 2007). Focused on the design process, Hernandez et al. (2014) propose "A Model to Evaluate the NPD Process in SMEs." The model is based on a set of criteria identified through a comprehensive literature review and expert opinion and covers various aspects of the NPD process, including strategy, market analysis, product design, development, testing, launch, and post-launch evaluation. The model consists of three main stages: (1) pre-evaluation, where the SME assesses its readiness and identifies key stakeholders involved in the NPD process; (2) evaluation, where the SME evaluates the NPD process based on identified criteria; and (3) post-evaluation, where the SME develops an action plan to improve its NPD process based on the evaluation results. However, the model assumes that the SME has a basic understanding of the NPD process and the relevant concepts and tools, which may not always be accurate. Additionally, it does not provide guidance on how to implement the action plan or monitor the progress of the NPD process improvement. Topalian's (1984) "Corporate Design Audits Checklist" is a framework for evaluating the design effectiveness of a company. The extensive checklist, covering fourteen categories, "should provide a sensible guide to an organization's involvement with and attitude towards design, as well as its approach to managing design" (Topalian, 1984, p. 60). While it provides a range of topics to be audited, it does not offer specific guidance on measuring and testing these activities or establish the criteria for their evaluation.

2.2.1 Design Management Tools Limitations, Research Gaps, and Opportunities

Having reviewed the most relevant design management tools in the context of design capabilities and process, the limitations, research gaps, and opportunities are now highlighted. It can be seen that, despite a considerable amount of design management tools, there is a lack of tools specifically designed for SMEs. This has been the focal point of theoretical debates in the academic literature (Chiva & Alegre, 2005; R. Cooper et al., 2009; de Mozota, 2003; Ravasi & Stigliani, 2011), highlighting the need to balance universal design management principles with SMEs' specific needs and constraints (R. Cooper et al., 2009). Some researchers argue that traditional design management models are unsuitable for SMEs due to their resource limitations, structure, and culture, suggesting a more flexible approach (Chiva & Alegre, 2005; Ravasi & Stigliani, 2011). SMEs face unique challenges, such as limited resources, a flat organizational structure, and a focus on innovation and agility (Bruce et al., 1999; Chiva & Alegre, 2009a; Deakins & Freel, 1998; Lindman et al., 2008; Ravasi & Stigliani, 2011). As such, design management models that work well for larger organizations may not be suitable for SMEs. Others argue that design management principles are universal and that SMEs can benefit from applying these principles (R. Cooper et al., 2009; de Mozota, 2003). However, the models should be tailored to SMEs' needs and constraints. The debate also concerns the formality and complexity of the design management models, with some advocating a simple and informal approach for SMEs (Liedtka & Ogilvie, 2011), while others suggest a more formal and structured approach is needed to ensure consistency and effectiveness (Chiva & Alegre, 2005; Ravasi & Stigliani, 2011). Overall, the debate centers on balancing design management principles with SMEs' specific needs and characteristics to develop effective design management models that can support their growth and success (Deakins & Freel, 1998; Liedtka & Ogilvie, 2011).

It is also possible to observe a considerable number of tools to assess the design capabilities in organizations, contrasting with the much-reduced number of tools in the design process. Design process tools are used to evaluate the efficiency and effectiveness of the design processes within an organization, helping companies identify improvement areas and optimize their design processes to achieve better outcomes. This holds particular relevance within SMEs, where the criticism often revolves around their ad hoc, unstructured, and unplanned approaches to product development and innovation processes, lacking the adoption of systematic procedures (Acklin, 2013; Berends et al., 2011; Hoffman et al., 1998; March-Chordà et al., 2002; Scozzi et al., 2005). The development and use of these tools are relevant mechanisms to help implement and systematically apply design management in the NPD process.

Despite of the benefits of tools aimed at the design process, some limitations were identified in existing tools. For example, the "Design Audit Tool for SMEs" (Moultrie et al., 2007) is criticized for focusing more on design capability than the design process and may require additional support and guidance to be implemented effectively. This can represent a stress factor, considering that SMEs encounter serious constraints: lack of internal expertise, tight timeframes, modest budgets, and restricted resources (Acklin, 2013; Berends et al., 2011; Bruce et al., 1999; Lewis & Brown, 1999; Oakley, 1982). The "Model to Evaluate the NPD Process in SMEs" (Hernandez et al., 2014) assumes that SMEs have a basic comprehension of the NPD process and the relevant concepts and tools, which is not always the case (Acklin, 2013; Berends et al., 2011; Gorb & Dumas, 1987; Hoffman et al., 1998; March-Chordà et al., 2002; Scozzi et al., 2005). For example, criticisms have been directed at its product development and innovation methods, often characterized as ad hoc, lacking in planning and structure, thus failing to embrace systematic procedures (Acklin, 2013; Berends et al., 2011; Hoffman et al., 1998; March-Chordà et al., 2002; Scozzi et al., 2005). Or else, they might engage in what is known as "silent design" decisions: instances where

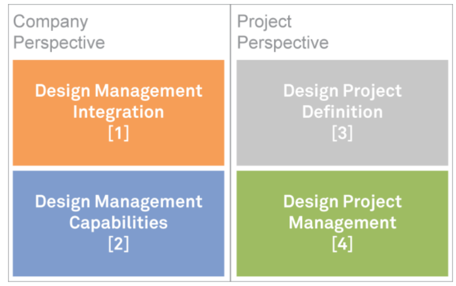

Figure 2. The four main areas of action of the Integrated Design Management (IDM) model.

non-designers or individuals who do not perceive themselves as designers unknowingly participate in design activities without recognizing their involvement in the process (Gorb & Dumas, 1987). The "Corporate Design Audits Checklist" (Topalian, 1984) lacks specific guidance on measuring and testing the design process or the criteria against which to evaluate it, so it is of no practical relevance. Considering all this, continuous research and development in design process tools is a critical factor in SMEs' business success and a relevant design management topic.

3 The Integrated Design Management (IDM) Model

Having as a theoretical basis the research of Carneiro et al. (2021), the proposed model comprises four main areas of activity: Design Management Integration [1], Design Management Capabilities [2], Design Project Definition [3], and Design Project Management [4] (Figure 2). The first two areas are on a more strategic level as they focus on the company's perspective, while the other two work on a more operational level, as they are directly related to the project perspective. Design management from the company's perspective is associated with the incorporation process into the organizational environment so that design becomes a real objective in the organization's vision and strategy. This integration implies the existence or creation of organizational factors for an adequate Design Management Integration [1], which directly contributes to the success of the NPD. Besides, it also involves the Design Management Capabilities [2], that is, routines, behaviors, processes, and organizational practices.

Design management from a project perspective is related to the development of a specific project or group of projects, that is, to the activities that take place during the process of converting an idea into a product, from its creation to its launch and market introduction (Best et al., 2010; Casas & Merino, 2011; Centro Português de Design, 1997; de Mozota, 2003; Straioto & Figueiredo, 2015). Therefore, it assumes responsibility for implementing new ideas and gathering information by integrating different areas and creating a good network of external collaborations for the Design Project Definition [3]. Furthermore, it encompasses the planning, organization, control, personnel, financing, materials, and time to achieve a project's objectives, that is, Design Project Management [4].

Design Management Integration [1] and Design Management Capabilities [2] correspond respectively to the diagram topic in Figure 1 with the same name. Design Project Definition [3] is a precursor to Design Project Management [4] by defining the project's scope. Design Project Management [4] encompasses all elements related to project management. Therefore, this area includes the remaining three topics on the diagram: Managing Design Projects, Design Function

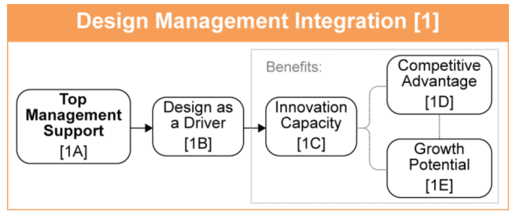

Figure 3. The Integrated Design Management (IDM) model: Design Management Integration [1].

Organization, and Tools and Methods. Merging these three topics into a single area of analysis, Design Project Management [4], is justified by the fact that these three topics are inseparable from each other in project management and must be considered simultaneously. Decisions in any of them have effects on the other(s).

3.1 Design Management Integration [1]

Merely being open to exploring design and design management within SMEs does not ensure the success of NPD or the effectiveness of investments made in design and innovation (Braga, 2017). So, why are some companies more successful in product development and innovation than others?

There are pre-conditions/organizational factors widely studied in the literature that allow an adequate integration of design management in the company and increase the success of a new product. The key factors that favor innovation include establishing a suitable organizational structure, cultivating an innovative environment, demonstrating the capability and readiness to take risks, and, in particular, and quite decisively, the top management's continued support [1A] (Figure 3), or in the specific case of SMEs the owner/founder (R. G. Cooper, 1999; Lindman et al., 2008; Zapata-Roldan & Sheikh, 2022). The established literature on design management and NPD management acknowledges top management involvement and support as key success factor (Felekoglu & Moultrie, 2014), which has the most significant impact on the time and cost of NPD and can create long-term sustainable solutions (R. Cooper et al., 2011).

> "In most small businesses, design consultants interact with marketing managers or engineers, who will eventually need the support of more senior managers or the small business owners themselves to make decisions. The inability to successfully champion the project with the top seemed to prove fatal for many projects" (R. Cooper et al., 2011, p. 237).

Top management is committed to long-term product innovation efforts (Gerlitz, 2016). The company, driven by design [1B], can generate and exploit the capacity for innovation [1C] to develop products within the organization (Gerlitz & Prause, 2017) and to gain a competitive advantage [1D] over the competition, both of which are essential for the company's growth [1E] (Figure 3). It is a trident of benefits that enhance each other in a constant loop.

The main function of the top management is to prepare the stage for the introduction of innovation and positively influence the development of new products, and to be a facilitator acting behind the scenes and less of an actor on the stage (R. G. Cooper, 2011, 2019). The top management develops the vision, defines the objectives, and outlines the product innovation strategy. It provides the required resources for product development, ensuring these remain dedicated to the project, even in times of scarcity. It is fully committed to product development by consistently reviewing projects and making prompt Go/No-Go decisions at different stages of the projects (R. G. Cooper, 2019; Felekoglu & Moultrie, 2014). Not less important, it creates an

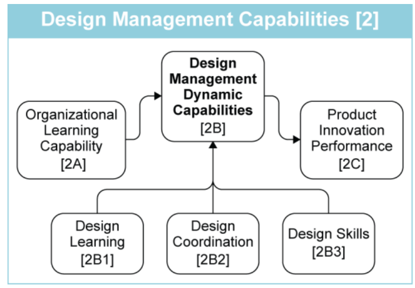

Figure 4. The Integrated Design Management (IDM) model: Design Management Capabilities [2].

enthusiastic environment and supports the committed champion – "an individual who commits themselves to the design activity. The best champion is the chief executive officer, but another person may act in that role too" (Gorb & Dumas, 1987, p. 37) – operating as mentors, facilitators, or "godfathers" of project team leaders (R. G. Cooper, 2019; Felekoglu & Moultrie, 2014).

The absence of support from the top management is a real obstacle to implementing an effective product innovation process and an integration of design management capable of allowing the exploration of design as a driver of innovation in the company (Acklin, 2013; Ahmed et al., 2024; Braga, 2017). Top management support is the fundamental foundation and the first step towards a real and effective integration of design management in the company.

3.2 Design Management Capabilities [2]

Innovation involves generating ideas and their transformation and implementation, translated into new products and processes. Organizational learning capabilities [2A] encompass the processes of acquirement, assimilation, dissemination, exploration, and use of knowledge. These capabilities are closely linked to product innovation performance [2C] (Acklin, 2013; Fernández-Mesa et al., 2013; Lemon & Sahota, 2004). Organizational learning capabilities are the ability to learn and are widely recognized as a critical indicator of an organization's effectiveness and potential to grow and innovate (Fernández-Mesa et al., 2013; Jerez-Gómez et al., 2005). Despite the organizational learning capability being positively correlated with product innovation (Damanpour, 1991; Fernández-Mesa et al., 2013; Koc & Ceylan, 2007), it might not be sufficient to attain high levels of product innovation performance. Therefore, other organizational capabilities, such as design management capabilities [2B], are deemed necessary (Fernández-Mesa et al., 2013) (Figure 4).

Design management capabilities act as a crucial mediator between product innovation performance and organizational learning capability (Ceptureanu et al., 2016; Fernández-Mesa et al., 2013). The literature classifies design management capabilities as dynamic capabilities (Acklin, 2013; Dickson et al., 1995; Fernández-Mesa et al., 2013; Manzakoğlu & Er, 2018). Dynamic capability is the organization's capability to effectively integrate and reconfigure its internal and external resources to address challenges or adversities. These capabilities encompass organizational routines, behaviors, processes, and practices that incorporate and reorganize resources.

This leads to the question: what are dynamic design management capabilities? Design management as a dynamic capability is based on three pillars: design learning [2B1], design coordination [2B2], and design skills [2B3] (Santos et al., 2018). Design learning [2B1] arises from learning and acquiring knowledge (Fernández-Mesa et al., 2013) and is considered the main method to achieve strategic innovation (Santos et al., 2018). In organizations, design processes and activities involve internalizing routines (work, research, selection, evaluation, monitoring, etc.), practices (procedural, methodological, communication, etc.) (Meirelles & Camargo, 2014), and experiences that lead to better results. In this sense, design learning corresponds to the ability to acquire and absorb knowledge and practices and disseminate them throughout the organization (Santos et al., 2018).

As for design coordination [2B2], Chiva & Alegre (2009a) and Santos et al. (2018) show that design management is a management of skills and practices that allows the organization to attain good design. Therefore, properly coordinating process-related processes and design activities enables the company to reach better outcomes (Chiva & Alegre, 2009a; Ravasi & Stigliani, 2012; Santos et al., 2018). In the engineering design context, coordination involves "the effective utilization of resources in order to carry out tasks for the right reasons, at the right time, to meet the right requirements and give the right results" (Duffy et al., 1993, p. 260). Coates et al. (2004) identify the main elements of the nature of the operational coordination of projects as follows:

- **Coherence:** harmonious integration of resources and tasks to prevent chaos;
- **Communication:** an interaction that encompasses the exchange of information, data, and knowledge;
- **Task management:** organizing and managing tasks along their corresponding dependencies to facilitate their successful completion;
- **Schedule management:** planning management, assigning tasks to resources, executing the schedule throughout the design process;
- **Resource management:** organizing and managing resources in an optimized and continuous way throughout the design process;
- **Real-time support:** managing and adapting to a dynamic design development process.

Thus, design coordination is the ability to manage the activities, routines, and practices required for the design process (Santos et al., 2018).

Lastly, design skills [2B3] encompass a range of knowledge and techniques that produce creativity and innovation. Literature supports that design competencies, when managed effectively, positively affect the performance of SMEs (Bruce et al., 1999). Dickson et al. (1995) propose five design management skills, which today remain a reference for several studies in the design management field (Chiva & Alegre, 2007, 2009a; Fernández-Mesa et al., 2012; Fernández-Mesa et al., 2013; Kootstra, 2009; Santos et al., 2018): basic skills, specialized skills, involving others, organizational change, and innovation skills.

- **Basic Skills**: the most basic skills to manage the design process and to develop high-quality and cost-effective products rapidly launched in the market, or as Perks et al. (2005) classify, the traditional design skills, which encompasses aesthetics, visualization, and technical skills;
- **Specialized Skills**: the ability to manage specialized tasks and activities essential in the design process, including new product estimation costs, using computer-aided design (CAD) tools, proficiency to assess manufacturability, and finding skilled design professionals (Chiva & Alegre, 2009a, 2009b; Perks et al., 2005);
- **Involving Others**: the ability to involve others, such as suppliers, users, etc., in the design process. Gorb & Dumas (1987) highlight the relevance of the active involvement of several actors in the product design process;

- **Organizational Change**: the ability to manage the changes that naturally occur in a dynamic design development process, but also more systematic changes, such as changing conventional ways of doing things in the company, like fostering collaboration among various departments/functions to engage in an integrated design process instead of a sequential one;
- **Innovation Skills**: the ability to manage innovation, become aware of competitors' innovations and imitations, and look for new ideas to be one step ahead of the competition. Perks et al. (2005) state that design is a substantial catalyst for innovation, proposing new markets and segments. The capabilities include observation, research, and business analysis.

3.3 Design Project Definition [3]

For a product development project to begin, a Design Project Definition [3] is mandatory, with the definition of specifications, requirements, and project objectives so that later the development team knows its mission. This project definition occurs by elaborating a written briefing [3A] (Figure 5). "The design brief is an early definition of the design problem and the possible descriptions of the strategy to solve it" (Read & Bohemia, 2012, p. 1587). The elaboration of the briefing is an essential step for the execution of a project because it will determine the steps to be followed toward the success of the internal initiative or the objective desired by the customer. As such, there is no justification for avoiding this document (Centro Português de Design, 1997). It is a basic instrument in the relationship with the project team and fulfills several missions:

- Informs the project team of what is intended;
- Serves as an element of evaluation for the options taken;
- Keeps project focus across different disciplines and departments.

The briefing must be written comprehensively and clearly and is a fundamental prerequisite for any design project and a key factor for successful design management (Roy & Potter, 1990). Roy & Potter (1990) found that an inadequate briefing was notably correlated with project failure (19% incidence), while Ravasi & Stigliani (2011) state that an ambiguous briefing was one of the main factors for project failure in SMEs, with an incidence just above 60%. The responsibility of preparing the briefing lies with the company, as highlighted by Gašović & Salai (2012). This document serves as a reference for the project team. Successful companies often have the briefing prepared by a group of individuals representing crucial areas (design, marketing, production, etc.) within the organization, and not by a single individual so that in addition to including information on performance requirements and product costs, it also provides information such as target market and user details, competition, production restrictions/limitations, etc. Another crucial aspect is the significance of a briefing being discussed, analyzed, and agreed upon with the project team (Roy & Potter, 1990). The briefing is seen as evolutionary until the team mutually agrees upon a product specification (Bruce & Morris, 1994). There is no specific method or set of rules for preparing and composing a briefing or standardized guidelines governing the briefing's content.

Analyzing the state of the art in the formulation of a briefing (Blyth & Worthington, 2010; Centro Português de Design, 1997; R. Cooper & Press, 1995; Gašović & Salai, 2012; Ulrich & Eppinger, 2012) is concluded that the elaboration of a briefing should focus on five fundamental pillars:

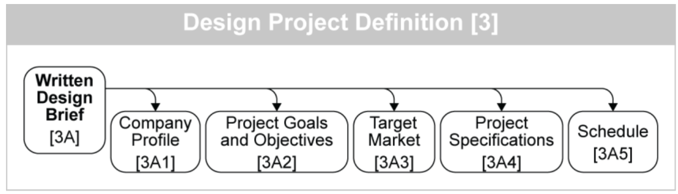

Figure 5. The Integrated Design Management (IDM) model: Design Project Definition [3].

- **Company Profile [3A1]**: includes information on history, size, business strategy, competitive positioning, global configuration of products and services, competition, etc. On the other hand, it should include information about the company's production process, existing technologies, subcontracting possibilities, production constraints, etc.;
- **Project Goals and Objectives [3A2]**: The required performances are specified, for example, improving reputation, reducing costs, or increasing sales. It all comes down to the project´s role and represents the impact it will have on the company's business;
- **Target Market [3A3]**: refers to information about the target audience, the market size, and the segment to which the product is addressed. Information on competitive benefits should also be included, and the product's production cost and target price should be identified;
- **Project Specifications [3A4]**: refers to all product design requirements and the technical constraints of the product, namely technical requirements, product architecture, and production process (required technologies and technical skills; production constraints, materials, etc.). The necessary resources (human and non-human) must be identified;
- **Schedule [3A5]**: defines the project's duration and the estimated completion time for each stage of the design process.

3.4 Design Project Management [4]

The first decisions about a design project are associated with the design activities, which require effective methods of sourcing, evaluation, etc. (Bruce et al., 1999; Bruce & Morris, 1994; Gašović & Salai, 2012). This is because design errors often occur in this initial process (Kess et al., 2009; Roy & Potter, 1990). The initial design phase of an NPD project should, therefore, evaluate and analyze three different aspects of the process: Project Implementation [4A], Team Management [4B], and Tools [4C] (Figure 6).

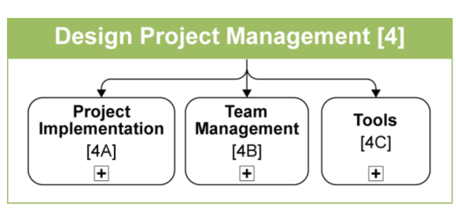

Figure 6. The Integrated Design Management (IDM) model: Design Project Management [4].

3.4.1 Project Implementation [4A]

Project Implementation [4A] is an important step for a successful project. The initial phase of a project is where the resources, characteristics, success criteria, and main deliverables are analyzed and planned. The deeper and more detailed this phase, the lower the chances of project failure. This phase is defined into four main stages: design expertise sourcing [4AA], project budget [4AB], NPD risk analysis [4AC], and project evaluation indicators [4AD] (Figure 7).

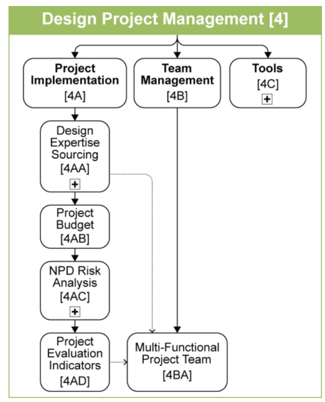

Figure 7. The Integrated Design Management (IDM) model: Project Implementation [4A] in the Design Project Management [4].

3.4.1.1 Design Expertise Sourcing [4AA]

The group of professionals who together develop a product constitutes the project team. There are no projects without project teams (Ulrich & Eppinger, 2012). In this sense, it is necessary to examine the human resources needed to set up a multifunctional project team [4BA]. This involves competencies from design, engineering, finance, marketing, and other areas. The company must be aware of the challenges that this can bring, analyzing if it has these resources internally or whether it has to subcontract them (Figure 8).

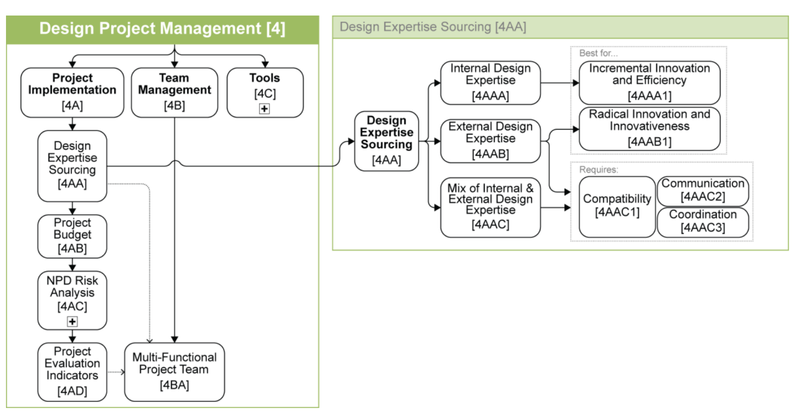

Figure 8. The Integrated Design Management (IDM) model: Design Expertise Sourcing [4AA] in the Project Implementation [4A].

Adopting the taxonomy of Bruce & Morris (1994), the design function is classified as either solely internal design expertise [4AAA], exclusively external design expertise [4AAB], or a blend of both [4AAC]. By internal design expertise [4AAA], it is understood that design competencies are within the company (Bruce & Morris, 1994). Familiarity with the production process, easy coordination, and accessibility of the project team provides a more efficient design process [4AAA1]. Internal design is perceived as more advantageous than external design, notably in industries where incremental innovation [4AAA1] is a priority (Perks et al., 2005). External design expertise [4AAB] refers to design competencies external to the company, where design professionals are specifically chosen and hired to execute the necessary design activities and tasks for the company (Bruce & Morris, 1994). Yao & Guo (2009) classify cooperation with external design expertise into five categories: cooperation with design companies, consultants, or agencies; cooperation with freelance designers; cooperation with universities and research institutes; cooperation with the competition; and cooperation with upstream and downstream companies in the supply chain. The relative benefits of external design are mainly mentioned for bringing new ideas, high levels of creativity, and innovation [4AAB1]. This is especially pertinent for radical product innovations (new to the market) [4AAB1], where meaningful design is a key differentiating factor requiring high creativity and imagination (Abecassis-Moedas & Benghozi, 2012; Czarnitzki & Thorwarth, 2012). In a combination of internal and external design expertise [4AAC], the external design professional is hired to supplement the internal design team's resources, ensuring timely project completion and offering fresh ideas or specialized expertise (Bruce & Morris, 1994).

When considering an approach that involves external design expertise, it is necessary to consider that the crucial aspect of the relationship between design buyer-supplier is the compatibility [4AAC1] between the two parties. There are three dimensions of compatibility. They concern the "characteristics of the individuals from the client and design companies involved in the relationship; the type of expertise required and offered by the client and design professional; and their respective approaches to working together" (Bruce & Morris, 1994, p. 596) (Figure 9).

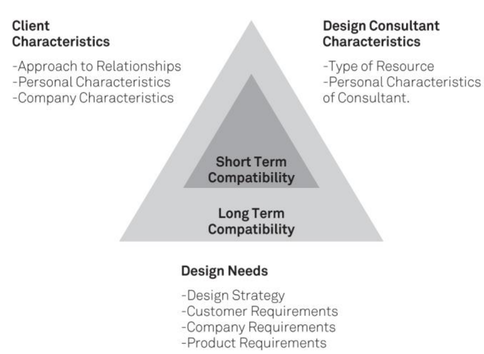

Figure 9. Compatibility model depicting the client-designer relationship. Adapted from Bruce & Morris (1994, p. 596, Figure 2).

Despite significant changes in design management over the past few decades, the fundamental concepts outlined in the Bruce & Morris (1994) taxonomy remain relevant today (Meng & Guo, 2024). Recent studies underscore the importance of aligning design capabilities with organizational strategy. For instance, Dabić et al. (2023) and Zapata-Roldan & Sheikh (2022) highlight that utilizing internal versus external design expertise substantially influences design quality and innovation. Lee (2020) extends this literature by exploring effective management of external design (design outsourcing). Furthermore, Liedtka (2018) emphasizes how design thinking fosters collaboration across disciplines, enabling organizations to harness insights from both internal and external resources. In conclusion, Bruce & Morris's taxonomy remains vital for navigating contemporary design challenges.

3.4.1.2 Project Budget [4AB]

A new product foresees an investment, and before making any profit, it is necessary to evaluate the available resources and find a way to obtain financing (Centro Português de Design, 1997). "Most people without experience in product development are astounded by how much time and money are required to develop a new product" (Ulrich & Eppinger, 2012, p. 5). In addition to the direct expenses on the development effort (costs with specific project facilities, if applicable, human resources, external services, costs of the prototype(s), investment in the product launch and promotion), often the company also needs to invest in tools and equipment necessary for production. This cost is usually as significant as the remaining product development budget (Centro Português de Design, 1997; Ulrich & Eppinger, 2012).

Investments in a product development project are usually underestimated, which leads to the premature end of many projects, even in more advanced stages (Centro Português de Design, 1997). According to Ulrich & Eppinger (2012), the uncertainty of costs and time is high at the beginning of the project, and the forecasts can only have an accuracy between 30 and 50%. In the following project phases, uncertainty diminishes to approximately 10%. Therefore, the budget must consider a contingency margin.

Additionally, it is essential to establish mechanisms for controlling and managing the budget and general control rules. A simple cost control process is shown in Figure 10. According to Centro Português de Design (1997) if the project management is well executed, the first prototype occurs at a midpoint of the time and costs of the project. Until the definition of the prototype, that is, the elaboration of all the documentation and plans for its execution, it should consume about 1/3 of the time and approximately 25% of the project's cost.

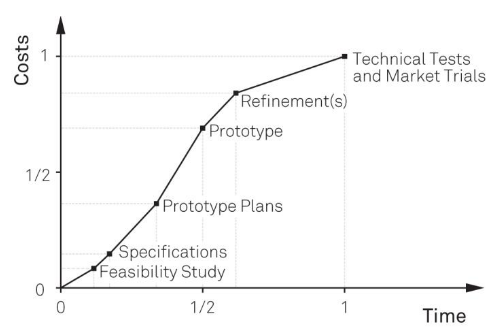

Figure 10. Project cost control. Adapted from Centro Português de Design (1997, p. 79, Figure 18).

3.4.1.3 NPD Risk Analysis [4AC]

Although the NPD risk analysis was not mentioned in the research of Carneiro et al. (2021) and as such, does not appear in the author's diagram, the truth is that the capability to identify and handle risks is progressively acknowledged as crucial in innovation (Keizer et al., 2002) and an important tool aiding SMEs in mitigating risks that may prevent their success in NPD (Kim & Vonortas, 2014; Mansor et al., 2016). For these reasons, risk analysis is included in the new proposed model.

Risk analysis and management consist of identifying possible uncertainties and trying to control them, thus reducing the impact and probability of adverse events on the project (Park, 2010; Vencato, 2014). Results of the research by Moenaert et al. (1995) conclude that as uncertainty decreases throughout the new product innovation process, the greater the possibility of success in its commercialization. Risk represents something that may or may not occur during any project phase. However, it will impact costs, deadlines, quality, or user satisfaction if it occurs (Park, 2010; Vencato, 2014). The true essence of project risk is defined not just by its probability and consequences but also by the company's capability to influence and control risk factors. Therefore, according to Keizer et al. (2002), a project activity is classified as "risky" if:

- The probability of an unfavorable/bad outcome is high;
- The capability to influence it within the project's resources and timeframe is limited;
- Its potential repercussions are significant.

Based on the investigations by Keizer et al. (2002), Ahn et al. (2010), Park (2010), Vencato (2014), and Mansor et al. (2016), the risks identified in the performance of NPD were compiled and compared in Table 2. As can be seen, there is a slight variation in the classification of risks identified by the different authors, the main difference often being their designation. For example, in the case of Keizer et al. (2002, p. 214), the authors classify project team, internal organization, co-development with external parties, and supply and distribution as operational risks. However, these risks align with the risks the other authors classified as organizational risks.

In summary, the risks associated with NPD can be classified into six categories: technology risks [4AC1], market risks [4AC2], financial risks [4AC3], organizational risks [4AC4] (includes risks associated with internal organization, human resources, project, and suppliers), operational risks [4AC5] and external risks [4AC6] (Figure 11).

Technological risks reveal an organization's (in)capability to understand or predict aspects of the technological environment, such as the level of internal technology (both at the product and production process level), skills to deal with technology, and learning capabilities of project team members, but also the external technological environment, such as technological paradigm shifts (Mansor et al., 2016; Park, 2010). The market introduces risks to the project due to a lack of knowledge about competition and competing products, user needs and expectations, and changes in economic and social conditions (Park, 2010). Regarding financial risks, access to capital is constantly one of the significant challenges SMEs faces. In the literature, they are seen as highly dependent on external financing. In the case of bank loans, these involve the risk of fluctuating interest rates. Additionally, another concern in this area is the risk of the project going over budget (Mansor et al., 2016).

Table 2. Comparison of risks that affect the NPD performance according to different authors.

	Keizer et al. (2002)	Ahn et al. (2010)	Park (2010)	Vencato (2014)	Mansor et al. (2016)
1	Technology Risk	Technology	Technology Risk	Technology Risks	Technology Risk
2	Market Risk		Market Risk		Market Risk
3	Financial Risk	Budget		Management Risks	Financial Risk
4	Operations Risk	Organizational Impacts; Human Resources; Vendor	Organizational Risk; Supplier Risks	Organizational Risks; Management Risks	Organizational Risk
5	Schedule	Operational Risk	Execution Risks; Management Risks		
6				External Risks	

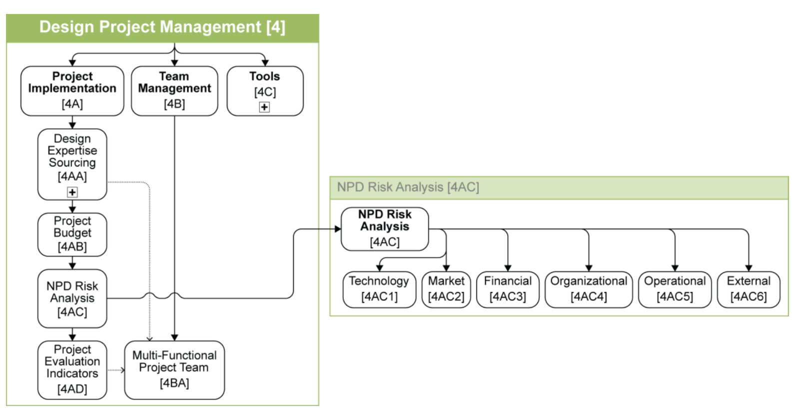

Figure 11. The Integrated Design Management (IDM) model: NPD Risks [4AC] in the Project Implementation [4A].

In turn, organizational risks are related to the organization's structure, management, and strategy. According to the literature, these can be divided into subcategories: internal organization, human resources, project, and suppliers. Internal organization includes risks such as organizational (in)stability at various hierarchical levels, problems with the organization's internal processes and procedures, conflict with the company executing the project (outsourcing the design project), and difficulty in protecting information. The availability of human resources, collaboration with external parties, the rotation of project team members, and team demotivation are risks associated with the organization's human resources. Project risks involve changing project requirements, inadequate communication between those involved in the process, and inadequate documentation control. Supplier risk management involves changes in the supply and distribution chain, changes in supplier relationships, and raw material shortages.

The other two remaining risk categories are operational risks and external risks. Operational risks contrast with other risks as they involve established processes rather than handling unforeseen circumstances. They are associated with losses resulting from non-conformities or inefficiencies in an organization's operational process related to cost, quality, labor, equipment, schedule, and production (Park, 2010). Finally, external risks are outside the organization's domain and include political, regulatory, and climate risks (Table 3).

3.4.1.4 Project Evaluation Indicators [4AD]

A process for defining appropriate indicators and evaluation criteria must be established in a product development project. This allows, on the one hand, the investment results to be analyzed and scrutinized. On the other hand, to draw conclusions about the process, namely, what went less well, the mistakes made, and what could be improved. In this way, the project evaluation should emphasize project management and the project result (Centro Português de Design, 1997). Communicating the evaluation process and criteria to the entire project team is considered a good practice [4BA] (R. Cooper & Press, 1995; Gašović & Salai, 2012).

Table 3. Risk categories and risk types in NPD.

1. Technological Risks	1.1. Not fully understanding or anticipating changes in available technology; 1.2. Organizational capabilities to apply the technology (both at the product and production level); 1.3. Lack of technical skills and learning capabilities for the use of technology; 1.4. Physical resources available for the use of technology; 1.5. Limits of technology in terms of performance; 1.6. Uncertainty regarding the requirements; 1.7. Intellectual property; 1.8. The user lacks a comprehensive understanding of the technology integrated into the new product or service;
2. Market Risks	2.1. Knowledge of competitors and competing products; 2.2. User needs and expectations for the product; 2.3. Market size and growth; 2.4. Change of economic and social conditions;
3. Financial Risks	3.1. Financial (in)stability of the company; 3.2. Access to capitals; 3.3. Commercial viability of the project; 3.4. Project exceeds the stipulated budget; 3.5. Currency fluctuations (exchange rates, interest rates);
4. Organizational Risks	*Internal Organization* 4.1. Organizational (in)stability; 4.2. Governance issues related to corporate policies; 4.3. Problems with internal processes/procedures; 4.4. Problems related to the company executing the project (outsourcing the design project); 4.5. Difficulty in protecting information; *Human Resources* 4.6. Human resources availability; 4.7. Collaboration with external parties; 4.8. Project team members change/rotation; 4.9. Team demotivation; *Project* 4.10. Change of project requirements; 4.11. Inadequate control of the project´s documentation; 4.12. Inadequate communication between those involved; *Suppliers* 4.13. Changes in the supply and distribution chain; 4.14. Changes in supplier relationships; 4.15. Shortage of suppliers and raw materials;
5. Operational Risks	5.1. Quality variation; 5.2. Production cost variation; 5.3. Variation of the component production time; 5.4. Productivity variation; 5.5. Defect(s) in the execution of the work(s); 5.6. Unavailability to use equipment(s); 5.7. Inability of those involved to perform the work(s); 5.8. Lack of quality of the equipment(s);
6. External Risks	6.1. Governmental acts that interfere with the execution of the project; 6.2. Law changes (legal/regulatory); 6.3. Occurrence of natural disasters;

The process of controlling and evaluating a design project is a demanding activity (Gašović & Salai, 2012) because it can occur at several levels within companies: strategic level, tactical level (intermediate), and operational level (R. Cooper & Press, 1995).

At the strategic level, for example, through achieving targets or comparing design performance against design strategy (Bruce et al., 1999; R. Cooper & Press, 1995). Once project objectives and goals have been established in the briefing process, top management can use these goals to define criteria for evaluating project outcomes. These criteria can be financial, technical, and operational. Still, they can also be design attributes, such as improved innovation, higher product quality and production process, improved packaging, storage and distribution, etc. (R. Cooper & Press, 1995). At the tactical level, assessing the design project(s) return on investment. For this, it is important to establish the evaluation criteria because the short-term return might not be financial; it could be associated with, for example, the successful entry into a new market (R. Cooper & Press, 1995). Another crucial evaluation is to assess the entire design process and verify that the established objectives have been achieved in both the process and the product. The product is evaluated internally but can also rely on external inputs, such as user input. The design process is internally evaluated but can also use external contributions, such as suppliers, the external project team (if applicable), etc. (R. Cooper & Press, 1995).

At the operational level, the evaluation becomes more detailed, for example, such as assessing the concept concerning the briefing (the extent to which the product attributes align with the desired attributes outlined in the briefing), evaluation of the use in the market, evaluation of the design effectiveness (once the product is on the market user feedback is valuable), etc. (Bruce et al., 1999; R. Cooper & Press, 1995).

3.4.2 Team Management [4B]

Successful product development is never done by just one individual and even less by a group of individuals from the same area of expertise (e.g., engineering or industrial design). It is a multidisciplinary activity, as it requires contributions from different areas of knowledge and involves various departments/functions of a company (engineering, design, marketing and sales, production, purchasing, quality, finance, etc.) (Ulrich & Eppinger, 2012). Lockwood (2010) has demonstrated that companies that have established a cross-functional team approach [4BA] in product development are more successful. However, it is not enough to create a multidisciplinary team. It is necessary to have a good and effective project team management so that the intended results are achieved (Best, 2018). The study by Scott-Young & Samson (2008) shows that astute project team management is related to a project's success in terms of efficiency and effectiveness.

Team management involves monitoring the performance of team members, offering feedback, resolving issues, and handling changes to enhance project performance and carry out required activities. This process is carried out throughout the project (Project Management Institute, 2017; Soni, 2020). It requires different management and leadership skills to encourage teamwork and create high-performance teams, such as conflict management, communication, decision-making, emotional intelligence, influence, negotiation, and leadership (Project Management Institute, 2017). The most common problems in team management are fear of conflict, lack of trust, lack of commitment, avoidance of responsibility, and inattention to results (Lencioni, 2002).

3.4.3 Tools [4C]

Successful innovation management also relies on effectively utilizing tools, techniques, and methods (R. G. Cooper & Kleinschmidt, 1987; de Waal & Knott, 2018, 2019). It can improve

NPD performance by refining both the product and the efficiency of the development process itself (Maylor, 2001). Several empirical investigations support that using appropriate techniques and tools can help companies perform better in developing and launching new products (R. G. Cooper & Edgett, 2008; de Waal & Knott, 2018; Maylor, 2001; Nijssen & Lieshout, 1995; Yeh et al., 2010). However, using more tools does not necessarily mean better NPD performance. In certain circumstances, adopting tools and practices might hinder NPD performance in SMEs due to occasional evidence of adverse effects of tool adoption observed in larger companies (Ahmad et al., 2013; Meyer & Utterback, 1995; Olson et al., 1995). de Waal & Knott (2018) show that there is no scientific support that employing a greater number of tools is related to better NPD performance in small companies. This is justified by small companies' limited capacity or resources to assimilate and utilize a larger set of tools without adversely impacting other NPD tasks (de Waal & Knott, 2012). For the model, the definition of de Waal & Knott (2010) about NPD tools was adopted, such as "any structured aids, managerial or technical in nature, used for structuring or influencing the management and effective execution of the NPD process and associated activities" (p. 255), which includes methods and techniques.

There is a large variety of tools to support the NPD process. Using a four-stage NPD process framework (1.Concept Generation; 2.Concept Development & Validation; 3.Product Development & Testing; 4.Commercialization & Review), de Waal & Knott (2019) assembled a compilation of 76 tools mentioned in the literature representing 12 perspectives (1.Engineering & Design; 2.Market & Market Research; 3.General Management; 4.Manufacturing; 5.Risk Management; 6.Product Strategy; 7.Project Finance; 8.Creativity and Problem-Solving; 9.Information Management; 10.Team Support; 11.Learning & Review; 12.Decision Support) (Figure 12), covering a wide range of domains within the realm of innovation activities, both at a strategic level (decision-making support, product strategy, general management) and operational/process level, as can be seen in Table 4.

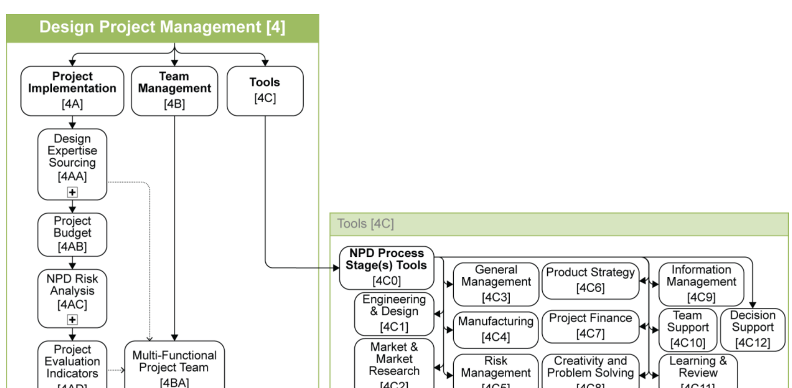

Figure 12. The Integrated Design Management (IDM) model: Tools [4C] in the Design Project Management [4].

Table 4. Tools for NPD. Adapted from de Waal & Knott (2019, p. 22, Table 1).

		NPD Process Stage						NPD Process Stage			
Tools	P	1	2	3	4	Tools	P	1	2	3	4
Design for Six Sigma				x		Porters Five Forces			x		
Design for X (DfX)				x		PESTE Analysis	P6		x		
Gamma Prototype					x	Portfolio Analysis			x		
Value Analysis/Value Engineering				x		Scenario Planning			x		
Quality Function Deployment	P1			x		Intellectual Property Protection			x	x	x
Design of Experiments				x		Competitor Analysis		x			
Computer Aided Engineering				x		Financial Analysis	P7		x		
Rapid Prototyping			x			Cashflow Forecast			x		
Beta Prototype				x		Sales Forecast			x		
Collaborative Product Development		x	x	x	x	Synectics		x			
Alpha Prototype			x			TRIZ	P8	x			
Computer-Aided Design			x	x		Delphi Method		x			
Design Mock-up			x			Morphological Analysis			x		
Diffusion Models		x	x			Roadmapping		x			
Discrete Choice			x			Product Life Cycle		x			
Conjoint Analysis			x			Focus Group		x	x		
Ethnography			x			Brainstorming		x	x		
Lead User	P2		x	x		Configuration Management System				x	x
Voice-of-the-Customer		x	x	x	x	Engineering Document Management System	P9			x	x
Beta-testing				x		Project Intranet				x	x
Limited Roll-out (Test Marketing)				x	x	Knowledge Management		x	x	x	x
In-market Testing					x	Change Control System				x	x
Needs Analysis		x	x			Tele/Video-conferencing	P10	x	x		
Concept Testing		x				Teambuilding			x		
Total Quality Management	P3				x	Cross-functional Teams			x	x	

	NPD Process Stage						NPD Process Stage				
Tools	P	1	2	3	4	Tools	P	1	2	3	4
Concept Statement		x				Workflow	P10			x	x
Feasibility Study	P3		x			Design Review Meetings			x	x	x
Business Case			x			Malcolm Baldrige Awards Framework				x	x
Marketing Plan					x	Expert Systems	P11	x			
Project Management				x	x	Post-Launch Review					x
Computer Integrated Manufacturing	P4				x	Post-Project Review					x
Statistical Process Control					x	Benchmarking		x	x		
Computer Aided Manufacturing					x	Customer Satisfaction Tracking					x
Process Flow Diagram					x	Real Options Theory			x		
Fault Tree Analysis		x				Selection Criteria & Screening	P12	x	x	x	
Market/Computer Prediction Models	P5		x			Decision Screens			x		
Risk Assessment Matrix			x			Stage-gates		x	x	x	x
Failure Mode Effects Analysis				x		Checklists			x	x	

3.5 IDM Model Overall View

Once each of the four main areas of the IDM model activity has been analyzed in detail, this can be seen more broadly to understand how these areas relate to each other (Figure 13) since they do not "work" separately.

Design Management Integration [1], in the figure of Top Management Support [1A], has an important and influential role in the remaining three areas. On the one hand, the continued support of the administration or the owner/founder and their commitment to design enhance and leverage the Design Management Capabilities [2] because SMEs are strongly controlled by the owner/founder (Acklin, 2013; Fueglistaller, 2004; Mintzberg, 1979), who is often involved in strategic and operational plans. Therefore, they often act as "gatekeepers," deciding design knowledge's usefulness (Cohen & Levinthal, 1990), directly influencing the capability to obtain, absorb, transform, and exploit new knowledge. On the other hand, it also plays a leading role in Design Project Definition [3] and Design Project Management [4], which can take different forms. Support can be provided by top management influence, for example, by defining the company's innovation strategy and choosing some structural solutions over others, committing resources to the cross-functional project team, and getting involved in the development process through project reviews and promptly making decisive Go/No-Go decisions, among others.

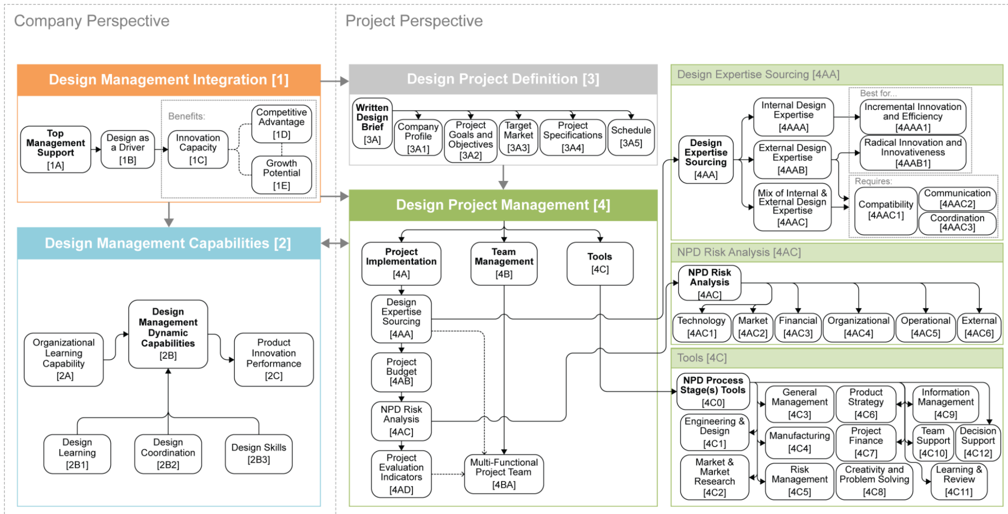

Figure 13. The Integrated Design Management (IDM) model overview.

Design Management Capabilities [2] and Design Project Management [4] are intrinsically linked and mutually influenced. The ability to acquire, assimilate, transform, and explore knowledge in design learning [2B1], design coordination [2B2], and design skills [2B3] allows leveraging the Design Project Management [4] process, making it more efficient, systematized and agile. On the other hand, the continued and reiterated practice of Design Project Management [4] allows to understand the process itself, draw lessons from what went less well, the mistakes made, understand what can be improved, and, consequently, seek and implement appropriate solutions to improve the design process, in a continuous search for an increasingly methodical and less fallible process.

Last but not least, the Design Project Definition [3], in the figure of the Design Brief [3A], is a precursor of the Design Project Management [4] because it is in this area that the design problem is defined and the possible strategies determined. As such, it assumes a leading and decisive role, first in defining the project and, later, in developing and managing the design process.

4 The Integrated Design Management (IDM) model Evaluation and Validation

This section presents the evaluation process for examining the IDM model's technical judgment. An exploratory phase serves as an opportunity to improve and refine the model, and this culminates in the validation phase, where the final artifact is evaluated. One crucial aspect of the validation phase is engaging with end users to assess the ability and usability of the model. Their feedback is crucial for determining the model's effectiveness for future use (Bilgin et al., 2014; Bullinger, 2008).

4.1 Methodological Procedures

For the IDM model evaluation and validation process, the following methodological procedures were adopted:

- **Participants**: Eleven participants were carefully selected due to their familiarity with design management and the product development process, both in academic and business contexts (Table 5). In the sessions, which lasted 1.5 hours, the participants were familiarized with the IDM model and the evaluation procedures. Participants' responses were collected during the session to avoid bias associated with elapsed time. The questionnaire used to collect participants' responses is provided in Appendix B. The final sample of eleven evaluations provided the results analyzed according to the Attribute Agreement Method.

- **Evaluation Criteria**: For Hevner et al. (2004), evaluating a designed artifact requires establishing relevant metrics and collecting and analyzing suitable data. The main purpose of the evaluation is to determine the research progress and assess the functionality of the artifact works (Bilgin et al., 2014; March & Smith, 1995). The selection and quantity of criteria for evaluating a model depend on the subject of the designed artifact. Some studies have employed four, five, or nine criteria to evaluate their work (Hevner et al., 2004; Holsapple & Joshi, 2002; March & Smith, 1995; Montoya-Weiss & O'Driscoll, 2000). The criteria were carefully selected based on their ability and representativeness to evaluate whether the designed model fulfilled its intended purpose. Then, the selected criteria were the following: Completeness, Comprehensiveness, Utility, Consistency, and Understandability.
- **Data Analysis**: The participant's responses were analyzed using the Attribute Agreement Method, a quantitative approach that has been used in recent investigations (Barradas et al., 2016; Pereira et al., 2020) to evaluate models and ontologies in the field of innovation. In this method, the participant's responses, based on a five-point Likert scale, are converted to a binary scale (Table 6). The results comprise the average sum of the evaluations of all eleven participants for each of the five criteria (see Equation (1)).

$$\text{Approval} = \frac{100}{n}\sum_{i=1}^{n} x_i \tag{1}$$

In Equation (1), n corresponds to the number of effective validations and x_i to the assigned classification. The IDM model evaluation follows the same rule applied in other studies (Barradas et al., 2016; Pereira et al., 2020), and if the approval is ≥ 70, the model is considered validated.

Table 5. Participant profile.

P	Gender	Expertise	Position
1	F	Biomedical Engineer	R&D Manager
2	M	Laboratory Equipment	Chief Enterprise Officer (CEO)
3	M	Metallurgical Engineer/Industrial Designer	Chief Enterprise Officer (CEO)
4	M	Recreational Craft Development and Production	Chief Operating Officer (COO)
5	M	Mechanical Engineer	Technical Product Director
6	M	Operations Management	Assistant Professor
7	M	Mechanical Engineer	Product and Systems Development Director
8	M	Mechanical Engineer	Chief Enterprise Officer (CEO)
9	F	Materials Engineer	Project Manager
10	M	Mechanical Engineer	Product Design Engineer
11	M	Product Designer	Project Coordinator

Table 6. Evaluation coding.

Likert Scale	Binary Scale
1. Strongly Disagree	
2. Disagree	
3. Neither Agree Nor Disagree	0
4. Agree	
2. Strongly Agree	1

4.2 Results

The results of the IDM model evaluation are presented in Table 7. The top-performing criteria were Comprehensiveness, Utility, and Understandability, achieving a 100% approval score. Completeness scored 81.82%, while Consistency reached 90.91%. Overall, the model gathered consistent validation across all five criteria, achieving an approval rate of 94.55%. These results indicate a successful evaluation and approval of the IDM model.

Table 7. IDM Model Attribute Agreement Analysis.

Criteria	Participants											Score
	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	P11	
Completeness	1	1	1	1	1	1	1	1	0	0	1	81,82%
Comprehensiveness	1	1	1	1	1	1	1	1	1	1	1	100,00%
Utility	1	1	1	1	1	1	1	1	1	1	1	100,00%
Consistency	1	0	1	1	1	1	1	1	1	1	1	90,91%
Understandability	1	1	1	1	1	1	1	1	1	1	1	100,00%
									IDM Model Overall Evaluation			94,55%

Figure 14 illustrates the histogram of the scores, providing a visual representation of the data. On the x-axis lies the Likert scale, while the y-axis displays the count of participant scores allocated to each evaluation criterion. This illustration highlights the high level of approval across the evaluated criteria. Notably, only one negative evaluation appears for the Completeness criteria, marked by a "Disagree" response. Additionally, "Neither Agree Nor Disagree" occurrences are minimal, totaling just two instances across all five criteria. This neutral stance from participants might be due to difficulties comprehending the IDM model's concept representation, unfamiliarity with certain concepts, or a lack of opinion on the topic. Overall, the IDM model comprehensively illustrates the concepts, influences, and relationships in the NPD process within the scope of operational design management.

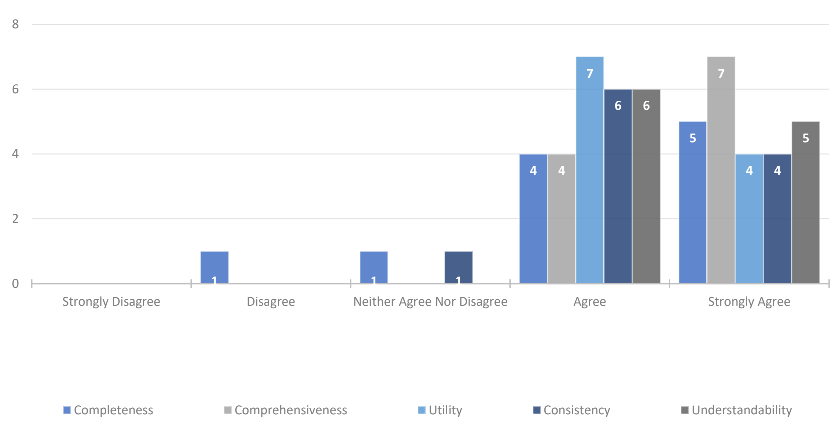

Figure 14. Histogram of IDM model evaluation results.

5 Discussion

The IDM model presents a comprehensive framework that integrates various aspects of design management, addressing the unique challenges faced by SMEs with little or no previous design experience. This investigation's multifaceted theoretical contributions shed light on the complexities and interrelations inherent in the design management process.

5.1 Theoretical Contributions

One of this article's primary contributions is developing a comprehensive framework that encapsulates the key parameters and activities associated with design management in SMEs. By synthesizing existing literature and empirical findings, the IDM model provides a structured approach that clarifies the often-nebulous nature of design management. This enhances the understanding of how various elements interact within the design management process.

Moreover, the model emphasizes the interconnectedness of the design management process, reflecting the dynamics within organizations. As organizations evolve, the interplay among different departments and functions significantly influences design outcomes. This perspective aligns with Gancho's (2023) assertion that effective integration of design and management practices is crucial for improving organizational performance, further validating the IDM model's relevance and applicability in real-world contexts.

Another significant contribution is the emphasis on the continuous and iterative nature of design management as articulated in the IDM model. This perspective challenges traditional views that often treat design as a linear process. Instead, the model positions design management as a dynamic and evolving practice that requires constant adaptation and responsiveness to changing market conditions and technological advancements. As noted by Dabić (2023), the adoption of digital design practices is vital for SMEs seeking to enhance their competitiveness, reinforcing the IDM model's emphasis on continuous adaptation and responsiveness. This theoretical stance aligns with recent design management literature shifts that advocate for agility and adaptability in practice, particularly in the context of rapid digital transformation.

The validation phase of the IDM model, which involved gathering feedback from experienced participants familiar with design management, reinforces the model's reliability and applicability. The high approval rates across criteria such as Comprehensiveness, Utility, and Understandability indicate that the model is not only theoretically but also practically relevant. This validation establishes a strong foundation for the IDM model, confirming its potential as a guiding tool for SMEs navigating design management challenges. It suggests that theoretical models can bridge the gap between academia and practice, providing tangible benefits for organizations aiming to enhance their design capabilities.

5.2 Managerial Contributions

From a managerial perspective, the IDM model provides several actionable insights for SMEs. It serves as a practical guide that enables managers and decision-makers to navigate the complexities of design processes systematically, fostering a more structured and informed decision-making approach. By understanding the interrelated components of the design management process, organizations can better identify and prioritize the key activities and practices necessary for successful design management.

However, implementing the IDM model also poses potential challenges for SMEs. One challenge may arise from the model's complexity, which could overwhelm organizations unfamiliar with structured frameworks. Additionally, the adoption of the model may require cultural shifts within organizations. Meng & Guo (2024) highlight the importance of embedding design within an organization's culture, which further supports the IDM model's view that cultural alignment is crucial for successful design management. SMEs may face resistance to change from employees accustomed to traditional practices, making the transition to an integrated design management approach difficult. Overcoming this resistance will require effective change management strategies, including clear communication about the benefits of the new model and involving staff in the implementation process.

Furthermore, SMEs may encounter resource constraints that hinder the effective implementation of design management practices as outlined in the IDM model. It is crucial for managers to assess their operational capacities and align the model's practices with their available resources, ensuring that the application of design management is feasible and sustainable.

In summary, the IDM model contributes to the theoretical landscape of design management, offering a structured framework that enhances the understanding and application of design management practices in SMEs. By integrating theoretical insights with practical applications and validating its effectiveness through participant feedback the model offers a comprehensive, interconnected, and iterative framework that aligns with contemporary management theories and practices, while acknowledging the potential challenges they may face in its implementation.

6 Research Limitations and Future Research

This article aims to present a new model to help SMEs with little or no experience in design implement and apply design management in a structured way. In the realm of design management, pinpointing specific aspects that either influence or are influenced by it can be challenging. Therefore, it might be worthwhile to explore alternative approaches to include in the proposed model to capture the various interactions and influences involved comprehensively. Additionally, models are representations of reality and can be conceived in different ways, carrying out all the restrictions and limitations associated with a representation.

One of the strengths of this new model lies in its comprehensive nature, encompassing a broad spectrum of parameters and topics relevant to the design management process. It is not the purpose of this model to cover these parameters individually but as a whole. It is our understanding that design management is a continuous, uninterrupted process where the different aspects are intimately interconnected and cannot be considered separately. Like in a company, where the various departments are interconnected and when something changes, everyone is affected, the same happens with design management. Gancho (2023) noted that effective integration of design and management practices is essential for enhancing overall organizational performance. This article proposes the IDM model as a useful and easy-to-apply model, where a set of choices were made regarding the inclusion and exclusion of activities to ensure a balanced analysis without compromising depth. Although it is possible to criticize the model for the deliberate omission of some parameters, the model's depth and content align closely with the research objectives: to capture the good practices and activities inherent to the application of design management in SMEs.

The model's applicability can be further strengthened by incorporating recent insights from design management research. For instance, Dabić (2023) highlights how digital transformation impacts SMEs, urging the adoption of agile design management practices to remain competitive in a rapidly changing market. Meng & Guo (2024) emphasize the critical role of technological tools in facilitating the implementation of design management frameworks, suggesting that SMEs must adopt technologies aligned with their operational capacities to scale effectively. By leveraging such technologies, SMEs can efficiently manage design processes without requiring extensive internal design teams, which is particularly important for their long-term growth and adaptability.

Constructing a tool, empirically supported by this model, for use in an industrial context is an important work to be carried out soon. Therefore, the tool should include this model and combine categories, concepts, general architecture, and relationships between elements when appropriate (Blessing & Chakrabarti, 2009; Platts, 1993). It should integrate design management into the company in a structured way, aligning with contemporary digital and technological trends. The delivery of the tool should be part of a structured process that includes a sequence of events and supplementary materials if required (Platts, 1993). The practical application involves an intricate relationship between the model, the tool, and its delivery process. Any change or adjustment in one aspect may potentially influence the others. Platts (1993) suggests this co-development approach, acknowledging that applying the tool could lead to refinements in the model.

In this sense, developing an initial prototype of the tool and its industrial application can provide important feedback on the process and the underlying theoretical concepts. Future research can explore the model's scalability across different industries, including integrating new technologies and digital solutions (Dabić et al., 2023), as well as adapting of frameworks that better align with SME operational capacities (Meng & Guo, 2024). The authors aim to continue with the research in this domain, particularly with translating the model into a tool and its application in a case study in an industrial context in the nautical area.

7 Conclusions

Given the growing importance of design management in academic research and business practice, this article presents the Integrated Design Management (IDM) model, tailored for applying design management in SMEs with little or no previous experience in designing and developing new products. The findings highlight the model's potential as a structured framework for navigating the complexities of design management. From a theoretical point of view, this article provides several contributions.

To begin with, the IDM model synthesizes a comprehensive set of activities, parameters, processes, and best practices inherent in the application of design management for SMEs, grounded in a systematic review of the literature and empirical research. By clarifying the often-ambiguous elements of design management, the model enhances practitioners' understanding, enabling better decision-making and more effective design processes. Moreover, the IDM model bridges theoretical insights with practical applications, providing a clear roadmap for SMEs to integrate design into their business strategies. Furthermore, the model was validated through empirical feedback from experienced participants, confirming its practical relevance and reliability. High approval ratings across key evaluation criteria – such as Comprehensiveness, Utility, and Understandability – underscore its effectiveness as a guiding tool for SMEs. This validation strengthens the model's credibility, reinforcing its role as an actionable framework that aligns with the needs and capacities of SMEs.

The IDM model also contributes to the ongoing debate within the design management community, encouraging further discussion among scholars and practitioners about the critical activities and processes necessary for effective design management in SMEs. Based on a comprehensive literature review and empirical findings, its development provides a solid foundation for potential adaptations and expansions across various industries. Finally, the IDM model serves as a solid and structured basis for developing a practical and useful tool, particularly suited for industrial contexts, to guide and facilitate the application of design management in SMEs within the context of NPD.

In conclusion, the IDM model contributes to theoretical debate in design management while providing practical insights for SMEs aiming to enhance their design capabilities. Although the model presents significant opportunities for improving design management practices, it is essential to acknowledge potential challenges in implementation, such as resource constraints and shifts in organizational culture. By proactively addressing these challenges, SMEs can leverage the IDM model to foster innovation, enhance competitiveness, and contribute to sustainable growth in their respective markets.

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Declaration of Interests

There are no conflicts of interest involved in this article.

8 References

Abecassis-Moedas, C., & Benghozi, P.-J. (2012). Efficiency and Innovativeness as Determinants of Design Architecture Choices. *Journal of Product Innovation Management*, *29*(3), 405–418. https://doi.org/10.1111/j.1540-5885.2012.00914.x

Acklin, C. (2010). Design-Driven Innovation Process Model. *Design Management Journal*, *5*(1), 50–60. https://doi.org/10.1111/j.1948-7177.2010.00013.x

Acklin, C. (2013). Design Management Absorption Model: A Framework to Describe and Measure the Absorption Process of Design Knowledge by SMEs with Little or no Prior Design Experience. *Creativity and Innovation Management*, *22*(2), 147–160. https://doi.org/10.1111/caim.12022

Ahmad, S., Mallick, D. N., & Schroeder, R. G. (2013). New Product Development: Impact of Project Characteristics and Development Practices on Performance. *Journal of Product Innovation Management*, *30*(2), 331–348. https://doi.org/10.1111/j.1540-5885.2012.01002.x

Ahmed, A., Ayentimi, D. T., & Sandow, J. N. (2024). Organisational creativity on product innovation performance of SMEs: exploring mechanisms and boundary conditions. *Innovation*, 1–21. https://doi.org/10.1080/14479338.2024.2389898

Ahn, J. O., Jeung, H. S., Kim, J. S., & Choi, H. G. (2010). A framework for managing risks on concurrent engineering basis. *International Journal of Management Science and Engineering Management*, *5*(1), 44–52. https://doi.org/10.1080/17509653.2010.10671090

Alarcon, J., Lecuona, M., & Ormeno, G. (2015). Design Management to Increase Small and Medium Multisector Enterprises (SMEs) Competitiveness: Interdisciplinarity Experience with Public Funding. In L. G. Chova, A. L. Martínez, & I. C. Torres (Eds.), *International Conference on Education and New Learning Technologies (Edulearn)* (pp. 3067–3075). IATED Academy. https://library.iated.org/view/ALARCON2015DES

Audretsch, D., van der Horst, R., Kwaak, T., & Thurik, R. (2009). *First Section of the Annual Report on EU Small and Medium-sized Enterprises*. http://ec.europa.eu/enterprise/policies/sme/files/craft/sme_perf_review/doc_08/spr08_annual_reporten.pdf

Barradas, L. C., Rodrigues, E. M., & Ferreira, J. J. P. (2016). Deriving an ontology for knowledge management in collaborative innovation networks. *International Journal of Innovation and Learning*, *19*(3), 335–357. https://doi.org/10.1504/IJIL.2016.075658

Berends, H., Reymen, I., Stultiëns, R. G. L., & Peutz, M. (2011). External designers in product design processes of small manufacturing firms. *Design Studies*, *32*(1), 86–108. https://doi.org/10.1016/j.destud.2010.06.001

Best, K. (2006). *Design Management: Managing Design Strategy, Process and Implementation* (1st ed.). Ava Book.

Best, K. (2018). *The Fundamentals of Design Management* (1st ed.). Ava Book.

Best, K., Kootstra, G., & Murphy, D. (2010). Design Management and Business in Europe: A Closer Look. *Design Management Review*, *21*(2), 26–35. https://doi.org/10.1111/j.1948-7169.2010.00062.x

Bilgin, G., Dikmen, I., & Birgonul, M. T. (2014). Ontology Evaluation: An Example of Delay Analysis. *Procedia Engineering*, *85*, 61–68. https://doi.org/10.1016/j.proeng.2014.10.529

Blessing, L. T. M., & Chakrabarti, A. (2009). *DRM, a Design Research Methodology* (1st ed.). Springer London. https://doi.org/10.1007/978-1-84882-587-1

Blyth, A., & Worthington, J. (2010). *Managing the Brief for Better Design*. Routledge. https://doi.org/10.4324/9780203857373

Braga, M. F. (2017). The choice of design. From businesses' conditions to businesses' attitudes. *The Design Journal*, *20*(sup1), S635–S646. https://doi.org/10.1080/14606925.2017.1353011

Bruce, M., & Bessant, J. (2002). *Design in Business: Strategic Innovation Through Design* (1st ed.). Pearson Education Limited.

Bruce, M., Cooper, R., & Vazquez, D. (1999). Effective design management for small businesses. *Design Studies*, *20*(3), 297–315. https://doi.org/10.1016/S0142-694X(98)00022-2

Bruce, M., & Morris, B. (1994). Managing external design professionals in the product development process. *Technovation*, *14*(9), 585–599. https://doi.org/10.1016/0166-4972(94)90041-8

Bruque, S., & Mayano, J. (2007). Organisational determinants of information technology adoption and implementation in SMEs : The case of family and cooperative firms. *Technovation*, *27*(1), 241–253. https://doi.org/10.1016/j.technovation.2006.12.003

Bullinger, A. C. (2008). *Innovation and Ontologies - Structuring the Early Stages of Innovation Management* (1st ed.). Gabler Verlag. https://doi.org/10.1007/978-3-8349-9920-7

Carneiro, V., Barata da Rocha, A., Rangel, B., & Alves, J. L. (2021). Design Management and the SME Product Development Process: A Bibliometric Analysis and Review. *She Ji: The Journal of Design, Economics, and Innovation*, *7*(2), 197–222. https://doi.org/10.1016/j.sheji.2021.03.001

Casas, D. D., & Merino, E. A. D. (2011). Gestão de Design & Design Thinking: Uma Relação Possível. *E-Revista LOGO*, *2*(1), 1–7. https://doi.org/10.26771/e-revista.LOGO

Centro Português de Design. (1997). *Manual de gestão de design* (1st ed.). Porto Editora.

Ceptureanu, S. I., Melinte, C. S., Ceptureanu, E. G., & Borisov, D. (2016). Capabilities of SMEs in Romanian clothing industry. *Industria Textila*, *67*(4), 265–269.

Chiva, R., & Alegre, J. (2005). Organizational Learning and Organizational Knowledge: Towards the Integration of Two Approaches. *Management Learning*, *36*(1), 49–68. https://doi.org/10.1177/1350507605049906

Chiva, R., & Alegre, J. (2007). Linking design management skills and design function organization: An empirical study of Spanish and Italian ceramic tile producers. *Technovation*, *27*(10), 616–627. https://doi.org/10.1016/j.technovation.2007.05.015

Chiva, R., & Alegre, J. (2009a). Investment in Design and Firm Performance: The Mediating Role of Design Management. *Journal of Product Innovation Management*, *26*(4), 424–440. https://doi.org/10.1111/j.1540-5885.2009.00669.x

Chiva, R., & Alegre, J. (2009b). Organizational Learning Capability and Job Satisfaction: an Empirical Assessment in the Ceramic Tile Industry. *British Journal of Management*, *20*(3), 323–340. https://doi.org/10.1111/j.1467-8551.2008.00586.x

Coates, G., Duffy, A. H. B., Whitfield, I., & Hills, W. (2004). Engineering management: operational design coordination. *Journal of Engineering Design*, *15*(5), 433–446. https://doi.org/10.1080/09544820410001697145

Cohen, W. M., & Levinthal, D. A. (1990). Absorptive Capacity: A New Perspective on Learning and Innovation. *Administrative Science Quarterly*, *35*(1), 128. https://doi.org/10.2307/2393553

Cooper, R. G. (1999). The Invisible Success Factors in Product Innovation. *Journal of Product Innovation Management*, *16*(2), 115–133. https://doi.org/10.1111/1540-5885.1620115

Cooper, R. G. (2011). Perspective: The Innovation Dilemma: How to Innovate When the Market Is Mature. *Journal of Product Innovation Management*, *28*(s1), 2–27. https://doi.org/10.1111/j.1540-5885.2011.00858.x

Cooper, R. G. (2019). The drivers of success in new-product development. *Industrial Marketing Management*, *76*(July 2018), 36–47. https://doi.org/10.1016/j.indmarman.2018.07.005

Cooper, R. G., & Edgett, S. J. (2008). Maximizing Productivity in Product Innovation. *Research-Technology Management*, *51*(2), 47–58. https://doi.org/10.1080/08956308.2008.11657495

Cooper, R. G., & Kleinschmidt, E. J. (1987). New Products: What Separates Winners from Losers? *Journal of Product Innovation Management*, *4*(3), 169–184. https://doi.org/10.1111/1540-5885.430169

Cooper, R., Junginger, S., & Lockwood, T. (2009). Design Thinking and Design Management: A Research and Practice Perspective. *Design Management Review*, *20*(2), 46–55. https://doi.org/10.1111/j.1948-7169.2009.00007.x

Cooper, R., Junginger, S., & Lockwood, T. (Eds.). (2011). *The Handbook of Design Management* (2nd ed.). Bloomsbury.

Cooper, R., & Press, M. (1995). *The Design Agenda: A Guide to Successful Design Management* (1st ed.). John Wiley & Sons Inc.

Czarnitzki, D., & Thorwarth, S. (2012). The Contribution of In-house and External Design Activities to Product Market Performance. *Journal of Product Innovation Management*, *29*(5), 878–895. https://doi.org/10.1111/j.1540-5885.2012.00935.x

Dabić, M., Stojčić, N., Afawubo, K., Chouki, M., & Huck, N. (2023). Market orientation, restructuring and collaboration: The impact of digital design on organizational competitiveness. *Creativity and Innovation Management*, *32*(3), 425–441. https://doi.org/10.1111/caim.12567

Damanpour, F. (1991). Organizational Innovation: A Meta-Analysis of Effects Determinants and Moderators. *Academy of Management Journal*, *34*(3), 555–590. https://doi.org/10.2307/256406

Danish Design Centre. (2003). *The Economic Effects of Design*.

de Mozota, B. B. (1998). Structuring Strategic Design Management: Michael Porter's Value Chain. *Design Management Journal (Former Series)*, *9*(2), 26–31. https://doi.org/10.1111/j.1948-7169.1998.tb00201.x

de Mozota, B. B. (2003). *Design Management: Using Design to Build Brand Value and Corporate Innovation* (1st ed.). Allworth Press.

de Mozota, B. B. (2006). The Four Powers of Design: A Value Model in Design Management. *Design Management Review*, *17*(2), 44–53. https://doi.org/10.1111/j.1948-7169.2006.tb00038.x

de Waal, G. A., & Knott, P. (2010). Product development: An integrative tool and activity research framework. *Human Systems Management*, *29*(4), 253–264. https://doi.org/10.3233/HSM-2010-0732

de Waal, G. A., & Knott, P. (2012). Product Innovation Tool Adoption Behaviour in Technology-Based New Ventures. *International Journal of Innovation Management*, *16*(03), 1240001. https://doi.org/10.1142/S1363919612400014

de Waal, G. A., & Knott, P. (2018). NPD Tools, Thoroughness and Performance in Small Firms. *International Journal of Innovation Management*, *23*(06), 1950050. https://doi.org/10.1142/S1363919619500506

de Waal, G. A., & Knott, P. (2019). Drivers of thoroughness of NPD tool use in small high-tech firms. *Journal of Engineering and Technology Management*, *53*(May), 19–32. https://doi.org/10.1016/j.jengtecman.2019.05.002

Deakins, D., & Freel, M. (1998). Entrepreneurial Learning and the Growth Process in SMEs. *The Learning Organization*, *5*(3), 144–155. https://doi.org/10.1108/09696479810223428

Design Management Institute [DMI]. (2022). *What is Design Management?* https://www.dmi.org/page/What_is_Design_Manag

Dickson, P., Schneier, W., Lawrence, P., & Hytry, R. (1995). Managing design in small high-growth companies. *Journal of Product Innovation Management*, *12*(5), 406–414. https://doi.org/10.1016/0737-6782(95)00056-9

Downey, L., & Banerjee, S. (2010). Building an Information Architecture Checklist. *Journal of Information Architecture*, *2*(2), 25–42.

Duffy, A. H. B., Andreasen, M. M., Maccallum, K. J., & Reijers, L. N. (1993). Design Coordination for Concurrent Engineering. *Journal of Engineering Design*, *4*(4), 251–265. https://doi.org/10.1080/09544829308914785

European Commission. (2003). European Commission Recommendation 2003/361/EC of 6 May 2003 concerning the definition of micro, small and medium-sized enterprises (Text with EEA relevance) (notified under document number C(2003) 1422). *Official Journal of the European Union*, 36–41. http://data.europa.eu/eli/reco/2003/361/oj

Felekoglu, B., & Moultrie, J. (2014). Top Management Involvement in New Product Development: A Review and Synthesis. *Journal of Product Innovation Management*, *31*(1), 159–175. https://doi.org/10.1111/jpim.12086

Fernández-Mesa, A., Alegre-Vidal, J., Chiva-Gómez, R., & Gutiérrez-Gracia, A. (2012). Design Management in SMEs: Extending the Bundle of Dynamic Capabilities. *International Conference on Organizational Learning Knowledge and Capabilities (OLKC)*, 1–17.

Fernández-Mesa, A., Alegre-Vidal, J., Chiva-Gómez, R., & Gutiérrez-Gracia, A. (2013). Design management capability and product innovation in SMEs. *Management Decision*, *51*(3), 547–565. https://doi.org/10.1108/00251741311309652

Ford, P., & Terris, D. (2017). NPD, Design and Management for SMEs. In E. Bohemia, C. de Bont, & L. S. Holm (Eds.), *Conference proceedings of the Design Management Academy* (pp. 325–341).

Ford, P., & Terris, D. (2018). An Intimate Approach to the Management and Integration of Design Knowledge for Small Firms. *Design Management Journal*, 58–70. https://doi.org/10.1111/dmj.12036

Fueglistaller, U. (2004). *Charakteristik und Entwicklung von Klein- und Mittelunternehmen (KMU)*. KMU Verlag HSG.

Gancho, S. (2023). The Existing Gap Between Design Management and Management - Contributions on How to Bridge It Successfully. In N. Martins & D. Raposo (Eds.), *Communication Design and Branding: A Multidisciplinary Approach. Springer Series in Design and Innovation , vol 32.* (pp. 305–316). Springer Nature Switzerland. https://doi.org/10.1007/978-3-031-35385-7_18

Gašović, M., & Salai, S. (2012). Managing initial design projects. In S. Kuzmanović (Ed.), *International Symposium on Machine and Industrial Design in Mechanical Engineering (KOD)* (pp. 85–90). University of Novi Sad.

Gerlitz, L. (2016). Integrating design management concept in entrepreneurial practices: evidence from the cross-border project. *International Scientific Conference Business and Management*, 1–10. https://doi.org/10.3846/bm.2016.07

Gerlitz, L., & Prause, G. (2017). Design Management as a Driver for Innovation in SMEs. *Kindai Management Review*, *5*, 41–59. https://www.kindai.ac.jp/rd/research-center/management-innovation/download-data/Kindai_Management_Review5.pdf

Gorb, P., & Dumas, A. (1987). Silent design. *Design Studies*, *8*(3), 150–156. https://doi.org/10.1016/0142-694X(87)90037-8

Hernandez, M. C., Montoya, M. V., & Martínez, J. F. (2014). Development of a Model for Evaluating the NPD Process in SMEs: A Latin American Experience. *Procedia CIRP*, *21*, 449–454. https://doi.org/10.1016/j.procir.2014.03.123

Hertenstein, J. H., Platt, M. B., & Veryzer, R. W. (2005). The Impact of Industrial Design Effectiveness on Corporate Financial Performance. *The Journal of Product Innovation Management*, *22*(1), 3–21. https://doi.org/10.1111/j.0737-6782.2005.00100.x

Heskett, J., & Liu, X. (2012). Models of developing design capacity: Perspective from China. In E. Bohemia, J. Rieple, & A. Liedtka (Eds.), *Proceedings of the DMI 2012 International Research Conference* (pp. 225–238). Design Management Institute.

Hevner, A. R., March, S. T., Park, J., & Ram, S. (2004). Design Science in Information Systems Research. *MIS Quarterly*, *28*(1). https://doi.org/10.2307/25148625

Hoffman, K., Parejo, M., Bessant, J., & Perren, L. (1998). Small firms, R&D, technology and innovation in the UK: a literature review. *Technovation*, *18*(1), 39–55. https://doi.org/10.1016/S0166-4972(97)00102-8

Holsapple, C. W., & Joshi, K. D. (2002). A Collaborative Approach to Ontology Design. *Communications of the ACM*, *45*(2), 42–47. https://doi.org/10.1145/503124.503147

Inns, T. (2002). Design Tools. In M. Bruce & J. Bessant (Eds.), *Design in Business: Strategic Innovation through Design* (pp. 237–251). Pearson Education Limited. https://www.amazon.co.uk/Design-Business-Strategic-Innovation-2002-01-10/dp/B01FGLRLHW?asin=0273643746&revisionId=&format=4&depth=1

International Organization for Standardization [ISO]. (2015). *ISO 9001:2015 Quality Management Systems - Requirements* (ISO 9001:2015). https://www.iso.org/obp/ui/#iso:std:iso:9001:ed-5:v1:en

Jerez-Gómez, P., Céspedes-Lorente, J., & Valle-Cabrera, R. (2005). Organizational learning and compensation strategies: Evidence from the Spanish chemical industry. *Human Resource Management*, *44*(3), 279–299. https://doi.org/10.1002/hrm.20071

Keizer, J. A., Halman, J. I. M., & Song, M. (2002). From experience: applying the risk diagnosing methodology. *Journal of Product Innovation Management*, *19*(3), 213–232. https://doi.org/10.1111/1540-5885.1930213

Kess, P., Belt, P., Harkonen, J., Anussornnitisarn, P., & Phusavat, K. (2009). Learning about design and development: the roles of industrial design and concurrent engineering. *International Journal of Innovation and Learning*, *6*(6), 659. https://doi.org/10.1504/IJIL.2009.026650

Kim, Y., & Vonortas, N. S. (2014). Managing risk in the formative years: Evidence from young enterprises in Europe. *Technovation*, *34*(8), 454–465. https://doi.org/10.1016/j.technovation.2014.05.004

Koc, T., & Ceylan, C. (2007). Factors impacting the innovative capacity in large-scale companies. *Technovation*, *27*(3), 105–114. https://doi.org/10.1016/j.technovation.2005.10.002

Kootstra, G. L. (2009). *The incorporation of design management in today's business practices. An analysis of design management practices in Europe*. https://www.bcd.es/site/unitFiles/2585/DME_Survey09-darreraversió.pdf

Kotler, P., & Rath, G. A. (1984). Design: A Powerful But Neglected Strategic Tool. *Journal of Business Strategy*, *5*(2), 16–21. https://doi.org/10.1108/eb039054

Lee, S. H. (2020). Design outsourcing management: Mitigating risks and achieving objectives. *Creativity and Innovation Management*, *29*(4), 719–731. https://doi.org/10.1111/caim.12411

Lemon, M., & Sahota, P. S. (2004). Organizational culture as a knowledge repository for increased innovative capacity. *Technovation*, *24*(6), 483–498. https://doi.org/10.1016/S0166-4972(02)00102-5

Lencioni, P. M. (2002). *The Five Dysfunctions of a Team*. John Wiley & Sons Inc.

Lewis, A., & Brown, R. (1999). Key issues in managing the product development process in very small manufacturing companies. *PICMET '99: Portland International Conference on Management of Engineering and Technology. Proceedings Vol-1: Book of Summaries (IEEE Cat. No.99CH36310)*, 261–265. https://doi.org/10.1109/PICMET.1999.808092

Lewis, A., Murphy, D., & Mougenot, C. (2009). *Overview of design management methodologies*.

Liedtka, J. (2018). Why Design Thinking Works. *Harvard Business Review*, *96*(5), 72–79.

Liedtka, J., & Ogilvie, T. (2011). *Designing for Growth: A Design Thinking Tool Kit for Managers*. Columbia Business School Publishing.

Lindman, M., Scozzi, B., & Otero-Neira, C. (2008). Low-tech, small- and medium-sized enterprises and the practice of new product development. *European Business Review*, *20*(1), 51–72. https://doi.org/10.1108/09555340810843690

Lockwood, T. (2010). Integrating design into organizational culture. *Design Management Review*, *15*(2), 32–39. https://doi.org/10.1111/j.1948-7169.2004.tb00159.x

Mansor, N., Yahaya, S. N., & Okazaki, K. (2016). Risk Factors Affecting New Product Development (NPD) Performance in Small Medium Enterprises (SMEs). *International Journal of Recent Research and Applied Studies*, *27*(1), 18–25. www.arpapress.com/Volumes/Vol27Issue1/IJRRAS_27_1_03.pdf

Manzakoğlu, B. T., & Er, Ö. (2018). Design Management Capability Framework in Global Value Chains: Integrating the Functional Upgrading Theory from OEM to ODM and OBM. *The Design Journal*, *21*(1), 139–161. https://doi.org/10.1080/14606925.2018.1395577

March-Chordà, I., Gunasekaran, A., & Lloria-Aramburo, B. (2002). Product development process in Spanish SMEs: an empirical research. *Technovation*, *22*(5), 301–312. https://doi.org/10.1016/S0166-4972(01)00021-9

March, S. T., & Smith, G. F. (1995). Design and Natural Science Research on Information Technology. *Decision Support Systems*, *15*(4), 251–266. https://doi.org/10.1016/0167-9236(94)00041-2

Maylor, H. (2001). Assessing the relationship between practice changes and process improvement in new product development. *Omega*, *29*(1), 85–96. https://doi.org/10.1016/S0305-0483(00)00025-6

Meirelles, D. S. e, & Camargo, Á. A. B. (2014). Capacidades Dinâmicas: O Que São e Como Identificá-las? *Revista de Administração Contemporânea*, *18*(spe), 41–64. https://doi.org/10.1590/1982-7849rac20141289

Meng, Y., & Guo, S. (2024). Design Embedded in SME's Organizational Culture Model. In C. Stephanidis, M. Antona, S. Ntoa, & G. Salvendy (Eds.), *HCI International 2024 Posters. Communications in Computer and Information Science, vol 2118* (pp. 61–68). Springer Nature Switzerland. https://doi.org/10.1007/978-3-031-61963-2_7

Meyer, M. H., & Utterback, J. M. (1995). Product development cycle time and commercial success. *IEEE Transactions on Engineering Management*, *42*(4), 297–304. https://doi.org/10.1109/17.482080

Mintzberg, H. (1979). The Structuring of Organisations. In *The Structuring of Organizations*. Prentice-Hall.

Moenaert, R. K., De Meyer, A., Souder, W. E., & Deschoolmeester, D. (1995). R&D/Marketing Communication During the Fuzzy Front-End. *IEEE Transactions on Engineering Management*, *42*(3), 243–258.

Montoya-Weiss, M. M., & O'Driscoll, T. M. (2000). From Experience: Applying Performance Support Technology in the Fuzzy Front End. *Journal of Product Innovation Management*, *17*(2), 143–161. https://doi.org/10.1016/S0737-6782(99)00032-6

Moultrie, J., Clarkson, P. J., & Probert, D. (2006a). A tool to evaluate design performance in SMEs. *International Journal of Productivity and Performance Management*, *55*(3–4), 184–216. https://doi.org/10.1108/17410400610653192

Moultrie, J., Clarkson, P. J., & Probert, D. (2006b). Development of a product audit tool. *Proceedings of the Institution of Mechanical Engineers, Part B: Journal of Engineering Manufacture*, *220*(7), 1157–1174. https://doi.org/10.1243/09544054JEM452

Moultrie, J., Clarkson, P. J., & Probert, D. (2007). Development of a Design Audit Tool for SMEs. *Journal of Product Innovation Management*, *24*(4), 335–368. https://doi.org/10.1111/j.1540-5885.2007.00255.x

Na, J. H., Choi, Y., & Harrison, D. (2017). The Design Innovation Spectrum: An Overview of Design Influences on Innovation for Manufacturing Companies. *International Journal of Design*, *11*(2), 13–24. http://www.ijdesign.org/index.php/IJDesign/article/view/2637/776

Nijssen, E. J., & Lieshout, K. F. M. (1995). Awareness, use and effectiveness of models and methods for new product development. *European Journal of Marketing*, *29*(10), 27–44. https://doi.org/10.1108/03090569510098483

Nilsen, P. (2015). Making Sense of Implementation Theories, Models and Frameworks. *Implementation Science*, *10*(53), 1–13. https://doi.org/10.1186/s13012-015-0242-0

Oakley, M. (1982). Product design and development in small firms. *Design Studies*, *3*(1), 5–10. https://doi.org/10.1016/0142-694X(82)90073-4

Olson, E. M., Walker, O. C., & Ruekert, R. W. (1995). Organizing for Effective New Product Development: The Moderating Role of Product Innovativeness. *Journal of Marketing*, *59*(1), 48. https://doi.org/10.2307/1252014

Park, Y. H. (2010). A study of risk management and performance measures on new product development. *Asian Journal on Quality*, *11*(1), 39–48. https://doi.org/10.1108/15982681011051813

Parkman, I. D. (2023). How Do We Get Paid for This? The Relationship Between Strategic Design Management and Pricing Power. *Cubic Journal*, *6*(6), 34–43. https://doi.org/10.31182/cubic.2023.6.59

Pereira, A. R., Ferreira, J. J. P., & Lopes, A. (2020). A Knowledge Representation of the Beginning of the Innovation Process: The Front End of Innovation Integrative Ontology (FEI2O). *Data & Knowledge Engineering*, *125*, 20. https://doi.org/10.1016/j.datak.2019.101760

Perks, H., Cooper, R., & Jones, C. (2005). Characterizing the role of design in new product development: An empirically derived taxonomy. *Journal of Product Innovation Management*, *22*(2), 111–127. https://doi.org/10.1111/j.0737-6782.2005.00109.x

Pinheiro, G., & Franqueira, T. (2020). Da gestão do design ao Chief Design Officer - para uma narrativa histórica dos anos 50 até à atualidade. *International Conference on Innovation and Entrepreneurship in Marketing and Consumer Behaviour*, 184–196.

Platts, K. W. (1993). A Process Approach to Researching Manufacturing Strategy. *International Journal of Operations & Production Management*, *13*(8), 4–17. https://doi.org/10.1108/01443579310039533

Project Management Institute. (2017). *A Guide To The Project Management Body of Knowledge (PMBOK® Guide)* (6th ed.). Project Management Institute, Inc.

Ravasi, D., & Stigliani, I. (2011). Successful Design Management in Small and Medium-Sized Businesses. In R. Cooper, S. Junginger, & T. Lockwood (Eds.), *The Handbook of Design Management* (2nd ed., pp. 231–243). Bloomsbury.

Ravasi, D., & Stigliani, I. (2012). Product Design: a Review and Research Agenda for Management Studies. *International Journal of Management Reviews*, *14*(4), 464–488. https://doi.org/10.1111/j.1468-2370.2012.00330.x

Read, D., & Bohemia, E. (2012). The functions of the design brief. *Proceedings of International Design Conference - DESIGN 2012*, *DS 70*, 1587–1596.

Roy, R., & Potter, S. (1990). Managing design projects in small and medium-sized firms. *Technology Analysis & Strategic Management*, *2*(3), 321–336. https://doi.org/10.1080/09537329008524018

Santos, R. dos, Bueno, E. V., Kato, H. T., & Corrêa, R. O. (2018). Design management as dynamic capabilities: a historiographical analysis. *European Business Review*, *30*(6), 707–719. https://doi.org/10.1108/EBR-11-2016-0147

Scott-Young, C., & Samson, D. (2008). Project success and project team management: Evidence from capital projects in the process industries. *Journal of Operations Management*, *26*(6), 749–766. https://doi.org/10.1016/j.jom.2007.10.006

Scozzi, B., Garavelli, C., & Crowston, K. (2005). Methods for modeling and supporting innovation processes in SMEs. *European Journal of Innovation Management*, *8*(1), 120–137. https://doi.org/10.1108/14601060510578619

Soni, V. D. (2020). Importance and Strategic Planning of Team Management. *International Journal of Innovative Research in Technology*, *7*(2), 47–50. https://www.researchgate.net/publication/342571600

Storvang, P., Jensen, S., & Christensen, P. R. (2014). Innovation through Design : A Framework for Design Capacity in a Danish Context. *Design Management Journal*, *9*(1), 9–22. https://doi.org/10.1111/dmj.12006

Straioto, R. G. T., & Figueiredo, L. F. G. (2015). A Co-Criação Sob a Ótica Da Gestão De Design: Uma Introdução Aos Níveis Estratégico, Tático E Operacional Do Co-Design. *Proceedings of the 4th International Conference on Integration of Design, Engineering & Management for Innovation (IDEMI)*, 1–12. https://www.semanticscholar.org/paper/A-CO-CRIAÇ~AO-SOB-A-ÓTICA-DA-GEST~AO-DE-DESIGN-%3A-UMA-Straioto/688f777cfca96abc48f868f929fc3386aa735fa1

Topalian, A. (1984). Corporate Identity : Beyond the Visual Overstatements. *International Journal of Advertising*, *3*(1), 55–62. https://doi.org/10.1080/02650487.1984.11105000

Topaloğlu, F., & Er, Ö. (2017a). Discussing a New Direction for Design Management through a New Design Management Audit Framework. *The Design Journal*, *20*(sup1), S502–S521. https://doi.org/10.1080/14606925.2017.1353000

Topaloğlu, F., & Er, Ö. (2017b). From Design Management to Strategic Design Management: Triggers, Enablers and Challenges in Building Strategic Design Management Capabilities. In E. Bohemia, C. de Bont, & L. S. Holm (Eds.), *Conference Proceedings of the Design Management Academy* (Issue 3, pp. 1019–1041). https://doi.org/10.21606/dma.2017.102

Ulrich, K. T., & Eppinger, S. D. (2012). *Product Design and Development* (5th ed.). McGraw-Hill Irwin.

Vencato, M. F. (2014). Ferramenta para Análise e Avaliação de Riscos no Planejamento de Projetos de Pesquisa e Desenvolvimento. *Revista de Gestão e Projetos*, *5*(2), 102–111. https://doi.org/10.5585/gep.v5i2.253

Westcott, M., Sato, S., Mrazek, D., Wallace, R., Vanka, S., Bilson, C., & Hardin, D. (2014). The DMI Design Value Scorecard: A New Design Measurement and Management Model. *Design Management Review*, *24*(4), 10–16. https://doi.org/doi.org/10.1111/drev.10257

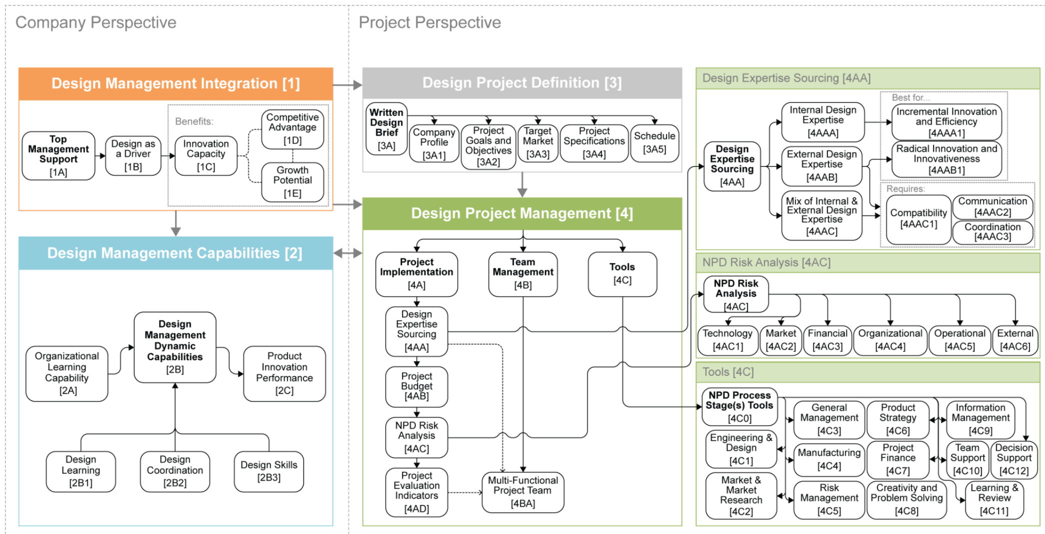
Wolff, F., Capra, A., Dutra, F., & de Mozota, B. B. (2016). Double-Loop Design Management Model. In E. Bova (Ed.), *The 20th dmi: Academic Design Management Conference Proceedings* (pp. 1–11). Design Management Institute. https://doi.org/10.13140/RG.2.2.11798.96320

Yao, S., & Guo, Q. (2009). Study on the enterprise design management of external cooperation. *International Symposium on Computational Intelligence and Design (ISCID)*, *2*, 207–209. https://doi.org/10.1109/ISCID.2009.199

Yeh, T.-M., Pai, F.-Y., & Yang, C.-C. (2010). Performance improvement in new product development with effective tools and techniques adoption for high-tech industries. *Quality & Quantity*, *44*(1), 131–152. https://doi.org/10.1007/s11135-008-9186-7

Zapata-Roldan, F., & Sheikh, N. J. (2022). A Design Management Agent-Based Model for New Product Development. *IEEE Transactions on Engineering Management*, *69*(5), 2026–2038. https://doi.org/10.1109/TEM.2020.2995141

9 Appendix A: The Integrated Design Management Model (IDM)



10 Appendix B: Questionnaire used in Validation Phase

Thank you for considering taking part of this research. I kindly ask you to please answer the following questions. Your analysis will be of significant help for evaluating the Integrated Design Management (IDM) Model.

Name: ______________________________ **Gender**: ( ) Male ( ) Female

Area of Expertise / Position: ______________________________

Concerning the DMIM, please mark how strongly you agree or disagree with each of these criteria.

	Strongly Disagree	Disagree	Neither Agree Nor Disagree	Agree	Strongly Agree
Completeness	( )	( )	( )	( )	( )
Comprehensiveness	( )	( )	( )	( )	( )
Utility	( )	( )	( )	( )	( )
Consistency	( )	( )	( )	( )	( )
Understandability	( )	( )	( )	( )	( )

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