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Title: Exploring the Interplay of Sensemaking, Market Agility, and Information Technology Alignment in Business Model Innovation

Year: 2025

Version: Accepted manuscript

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Please cite the original version:

Awan, U., Golgeci, I., & Mention, A.-L. (2025). Exploring the Interplay of Sensemaking, Market Agility, and Information Technology Alignment in Business Model Innovation. *IEEE Transactions on Engineering Management* 72, 3937-3951.
<https://doi.org/10.1109/TEM.2025.3609246>

Exploring the Interplay of Sensemaking, Market Agility, and Information

Technology Alignment in Business Model Innovation

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Abstract—Manufacturing firms are facing the complex challenge of deploying information technology (IT) alignment and establishing market agility to drive business model innovation (BMI). While existing literature has established a link between organizational sensemaking and BMI, the interaction between market agility and organizational sensemaking for BMI remains unexamined. Drawing from a knowledge base view, this study addresses this research gap by examining the moderating effect of IT alignment on the mediating role of market agility in the relationship between sensemaking capability and BMI. Our data, collected from 232 engineering manufacturers, along with the application of PLS-SEM to test the conceptual model, reveal that the effect of organizational sensemaking capability on BMI through market agility depends on IT alignment. These findings enhance our understanding of IT alignment's role in a firm's development of BMI via market agility, providing valuable implications for managerial practices by underscoring the importance of IT alignment for BMI. By grasping this interaction, managers can unlock the potential for more effective and innovative business models, fostering enhanced competitiveness and sustained growth.

Index Terms—Business model innovation; Information technology alignment; Market agility; Sensemaking capability

MANAGERIAL RELEVANCE STATEMENT—This study is extremely important for managers in the manufacturing sector who are striving to drive BMI. It clarifies the vital interplay between sensemaking, market agility, and IT alignment and provides actionable insights for enhancing organizational responsiveness and competitiveness. By recognizing that sensemaking and IT alignment are essential components, managers can effectively integrate them to promote market agility and drive successful BMI. The findings highlight that organizational sensemaking capability significantly impacts BMI through market agility, but this relationship depends on IT alignment. A high level of IT alignment can enable firms to quickly reconfigure systems and

processes in response to market changes. However, if not managed properly, it may also limit agility by enforcing overly structured decision-making processes. Consequently, managers must find a balance between maintaining structured IT systems and allowing flexibility for sensemaking and agile responses to market dynamics. These insights emphasize the necessity for managers to align IT strategies with business objectives while ensuring that sensemaking processes remain unimpeded. By doing so, firms can better capture and interpret environmental signals, leading to more effective and innovative business models. In summary, this research presents a strategic framework for leveraging IT and sensemaking capabilities to optimize BMI, thus ensuring a sustained competitive advantage in a dynamic business environment.

I. INTRODUCTION

Business model innovation has shifted from its historical emphasis on broad-scale novel variations focused on value creation and delivery within existing business practices [1, 2] to customizing firms' product offerings to improve competitiveness [3]. Recent research highlights that the complexities and challenges associated with business model innovation (BMI) are inherently tied to a firm's ability to develop and utilize sensemaking capability [4]. This capability allows managers to interpret and formulate strategies for navigating complex and uncertain situations [5]. The ability to perceive external inputs is essential for initiating the BMI process [1]. Moreover, the existing literature lacks clarity on how managers influence the connection between shared understanding and knowledge among business actors regarding the vision and plan [2], both of which are crucial for reconfiguring activities within current business models [3].

In recent years, many firms have embraced managerial sensemaking to reduce the tension associated with gaining a competitive advantage and responding to external changes and unexpected market conditions [4]. Consequently, researchers have become increasingly interested in how information technology alignment and business plans facilitate the identification of environmental threats and opportunities [5]. According to Tallon et al. [5], strategic information technology (IT) alignment is defined as "the extent of fit between information technology and business strategy" (p. 464). IT alignment plays a crucial role in research examining the relationship among agility, competitive advantage, and firm performance [6]. However, much of the BMI literature has focused on "prerequisites," "process," and "effects" [3], rather than on understanding

how to extract cues from internal and external environments and attribute meaning to actions [7]. The literature, however, offers limited insight into "how internal alignment develops through cognitive processing" [8] (p. 1880). Although the importance of integrating business and IT strategy has been acknowledged in the literature on sensemaking [7], [9], there is little clarity about how various organizational capabilities, processes, and outcomes of sensemaking influence firms' existing business models [3], [10], revealing contradictory results regarding agility and BMI.

BMI has long been recognized as a structured process for modifying and enhancing how a firm generates and delivers value to its customers [11]. Moreover, Clauss et al. [12] assert that the choice of system functions, requirements, and strategic configurations influences the value creation process. In contrast, a low level of reconfiguration resources limits firms' ability to transform their internal capabilities into value creation and delivery [3], [10]. So far, little attention has been given to how business IT alignment connects to a firm's capability to quickly reconfigure its systems [11], [12]. Thus, it remains unclear whether a high level of IT reconfiguration aids in creating value when a firm adapts to changing market conditions [11], [12]. Although previous research has detailed the benefits of IT alignment across various domains within the information science literature [7], [9], there is little empirical evidence addressing the impact of sensemaking and BMI. Firms may face challenges when they focus on reconfiguration as they seek to gain diverse perspectives by drawing insights from their networks to clarify uncertainties. Bellisario et al. [8] highlighted the importance of the sensemaking perspective as a relevant approach to "explore internal alignment from the cognitive perspective to explain the influence" (p.1880).

As firms become increasingly adapted to their external environment, existing research indicates that a high level of sensemaking (which includes perceiving, interpreting, and constructing meaning) can enhance market agility [13]. The firm's ability to effectively and efficiently capitalize on market changes involves redeploying resources to improve products or services rapidly and create business value [14]. Recently, literature has emphasized that sensemaking is critical for

adapting to a highly competitive external environment [15]. Yet, it remains unclear whether market agility depends on sensemaking [16]. The literature has yet to address how managers make sense of and “respond speedily to opportunities for innovation in the current digital age” [17] (p. 141). BMI strongly emphasizes transforming resources to create new value propositions. While BM design requires rapid reconfiguration to effectively respond to external changes [18], [19], research has explored the boundary conditions of various managerial and agility factors in BMI [15]. The existing literature on business models has examined the organizational characteristics that may hinder or facilitate the BMI process. However, to date, the literature lacks a systematic analysis of how IT alignment is employed in sensemaking and its impact on BMI as a process [3].

Against this backdrop, we respond to the calls [20] to clarify whether sensemaking capability hinders or fosters BMI, and we unpack the nexus of relationships connecting sensemaking capability to BMI in the engineering manufacturing industry. Additionally, this study examines whether IT alignment interacts with sensemaking capability to develop BMI through market agility. This leads to our research question: *In what ways does IT alignment shape the relationship between market agility and BMI, and how does this interaction affect the mediating role of market agility?* The context of the research is within the engineering and manufacturing sector, examined from an operations management perspective. This research study differs from previous research in several ways and contributes to the engineering management literature. First, this study expands the concept of sensemaking capability for BMI by exploring market agility, developing a conceptual model that has not been previously studied. Second, it extends and contributes to prior research findings [21], which suggest that sensemaking can lead to a competitive advantage if employees are “better able to comprehend environmental turbulence and frame it for the future” (p. 29). It expands the theoretical foundation of sensemaking capability by incorporating the knowledge-based view (KBV) while focusing on social and relational knowledge resources, which are essential elements of sensemaking that enable a firm’s ability to seize

opportunities and maintain a competitive advantage. Third, research has yet to investigate how IT alignment may regulate the relationship between sensemaking capability and market agility. The literature presents mixed findings on “whether, in fact, alignment helps or hurts agility” [5] (p. 464). Previous research has acknowledged sensemaking for internal alignment, but "consistency in the understanding and interpretation of strategic objectives has remained somewhat neglected" [8] (p. 1881). Our study examines this unexplored area by investigating how IT alignment (high-level vs. low-level) interacts with sensemaking capability to influence market agility. We advance the literature on sensemaking capability by identifying the positive effects of sensemaking capability at a low level of IT alignment that can enhance market agility.

This paper is organized to thoroughly explore sensemaking and BMI. In Section II, we first provide an overview of BMI, outlining its significance and various forms. Next, we examine KBV and sensemaking capability, emphasizing their roles in promoting innovation. This section concludes by analyzing how sensemaking capability directly impacts BMI. Following this, Section III outlines the data collection methods used in our study. Section IV presents and interprets the findings. Finally, we conclude with a discussion of these findings.

II. BACKGROUND AND HYPOTHESIS DEVELOPMENT

A. Overview of Business Model Innovation

BMI, a dynamic and transformative process, stands at the forefront of organizational strategy, driving firms to reimagine how they create, deliver, and capture value [22]. Rooted in the broader landscape of innovation theory [3]. BMI transcends product or service-centric approaches, focusing on the holistic redesign of a firm’s core architecture. Extant research on BMI concentrates on four domains of understanding BMI [9]. The first domain focuses on defining and conceptualizing BMI, often providing classificatory schemes. The second domain examines BMI as a dynamic process and explores capabilities, leadership, and learning mechanisms as antecedents of successful BMI. The third domain examines the outcomes of BMI, including new and innovative business models,

often contextualized within specific industries or types of innovation. Finally, the fourth domain explores the performance implications of BMI, examining the link between the BMI process and its outcomes, as well as the effects of different types of business models on firm performance.

BMI often starts with a reassessment and refinement of the value proposition — the unique value that a firm offers to its customers [19], [23]. That said, BMI is also expected to bring value to the firm through a revenue model [24], which involves changes to how a firm makes money. It can include the introduction of new revenue streams, modifications to pricing structures, or the adoption of alternative product development strategies. Furthermore, it can include changes in distribution channels, partnerships, or the integration of digital platforms. Likewise, BMI can also involve optimizing costs and operational efficiency. This may include adopting new technologies, process improvements, or outsourcing strategies. Accordingly, BMI involves changes to the core activities and processes that drive a firm's operations.

Clauss et al. [15] have identified multiple facets of BMI, including value proposition, value creation, and value capture, as discrete yet interrelated elements. While this multi-dimensional approach to BMI provides valuable granularity, we opted to conceptualize BMI as a unified construct in this study to better align with our research focus and context. The primary reason for our choice is the study's emphasis on understanding BMI at an organizational level, where value proposition, value creation, and value capture are often interdependent and collectively pursued as part of the firm's overarching strategic adaptation. For firms operating in dynamic and competitive markets, BMI initiatives are typically integrated efforts, with each facet reinforcing the others to achieve coherent and rapid responses to market demands. Additionally, conceptualizing BMI as a single construct allows us to capture the overall strategic shift represented by BMI.

By treating BMI as a cohesive construct, we can better reflect the fluid and iterative nature of business model changes in our empirical context, where firms frequently do not view BMI as discrete alterations to value proposition, value creation, and value capture but instead as an

integrated process. This perspective aligns with recent research that supports a holistic view of BMI, particularly in dynamic environments where the boundaries between components are less distinct and more closely interwoven as firms respond to complex external pressures.

BMI is a critical element for many businesses in the modern world. Markets are subject to constant changes, driven by technological advancements, shifts in consumer behavior, regulatory changes, and economic fluctuations [22]. BMI allows firms to adapt swiftly to these changes, ensuring they remain relevant and can capitalize on emerging opportunities while mitigating risks. A unique and well-crafted business model sets a firm apart from competitors by offering distinct value propositions, revenue models, or operational efficiencies. BMI provides a sustainable competitive advantage, making it challenging for rivals to replicate or compete effectively [12]. Similarly, BMI focuses on creating and delivering superior value to customers, meeting their evolving needs and preferences. In turn, enhanced value creation increases customer satisfaction, loyalty, and positive brand perception, contributing to long-term success. Table A in the supplementary file, presents the prior research on sensemaking and BMI, highlighting its focus, findings, and contributions to the literature.

B. Knowledge-Based View and Sensemaking Capability

KBV asserts that knowledge, both tacit (experiential and often unspoken insights held by individuals within the organization) and explicit (formalized and codified information), is a core strategic resource that can grant firms a sustainable competitive advantage [25]. Previous studies have demonstrated that knowledge resources and capabilities are essential for effectively deploying and utilizing IT within an organization [26], [27]. According to KBV, organizations can develop their unique assets by efficiently collecting, integrating, and applying both tacit knowledge, which is rooted in individuals' expertise, and explicit knowledge, which is formalized in organizational structures and processes [28], [29]. The KBV, derived from organizational social and relational knowledge, serves as a foundation for managers to interpret and share knowledge informally,

enabling them to navigate uncertainty, make strategic decisions, and drive organizational success [30]. Following Pisano [31], KBV is described as a combination of how managers utilize and process knowledge to construct meaning and make sense of an uncertain environment, thus supporting managerial decision-making. Furthermore, Paiola and Gebauer [4] emphasized that external market insights regarding industry trends and competitors empower managers to improve their ability to adapt and respond effectively to anticipated challenges and opportunities. As firms continue to struggle to generate and deliver value through new and innovative product design technologies, relying solely on current practices is insufficient [32]. Continuously updating knowledge and integrating it into operations are crucial for developing capabilities [32]. Some researchers have indicated that the knowledge-creating and sharing aspects of quickly responding to market shifts enable firms to detect emerging challenges related to customer preferences and adjust external processes to create innovative solutions [33].

KBV is a theoretical perspective that highlights the role of knowledge as a vital organizational resource for achieving a competitive advantage [34]. KBV arose as a response to the limitations of the traditional resource-based view and emphasizes the significance of intangible and often tacit knowledge as a source of competitive advantage [34]. Firms need not only to possess knowledge but also to continuously apply new knowledge in upgrading the process [25]. Thus, firms adopting the KBV are encouraged to develop knowledge-based capabilities like sensemaking capability [5]. Applying KBV can offer valuable insights into how firms can leverage and manage knowledge to enhance their marketing strategies and competitiveness [34]. Firms accumulate knowledge about their products, customers, and markets. Tacit knowledge, often possessed by employees, can be crucial in understanding customer needs and preferences [34]. The literature highlights that managers rely on past experience and perform their tasks with conflicting and incomplete information. Thus, cognitive and social processes may shape managers' interpretation of knowledge and their response to changing market conditions [35].

Fan et al. [36] theorize and empirically validate information processing theory into its perspective to integrate the different supply chain stages to identify risk management. Beyond this, other scholars confirm that to process the increasing amount of information effectively in an uncertain environment [37], [38], managers must devote more effort to enhancing their abilities in sharing, disseminating, and utilizing information during task execution [39].

Sensemaking capability revolves around the assumption that individuals engage in a cognitive process to interpret and anticipate a firm's potential outcomes [40]. While sensemaking may seem broad, in this study, it is specifically defined as an organizational capability that encompasses cognitive framing, the interpretation of environmental cues, and the integration of distributed knowledge across teams. Drawing on the KBV, we assert that sensemaking capability represents a critical intangible knowledge resource, enabling firms to absorb, interpret, and respond to market signals in a volatile business environment. Sensemaking is not an abstract cognitive exercise; rather, in a manufacturing context, it refers to the distributed yet converging interpretation of external signals, which is essential for reconfiguring internal routines toward innovation [41].

Sensemaking capability, market agility, and IT alignment represent different but complementary dimensions of organizational responsiveness. While sensemaking pertains to cognitive processing, market agility relates to behavioral responses, and IT alignment reflects the technological enablement of those responses. Together, they form a triadic structure of sensing, enabling, and executing innovation.

Gupta et al. [39] noted that strategic information exchange facilitates a timely and accurate flow of information among individuals, teams, and departments. As the literature highlights, information exchange is likely to lead to systematic sharing, dissemination, and utilization of critical information to improve decision-making. Whereas sensemaking is the collective process by which individuals and firms interpret and make sense of ambiguous, tacit, and complex situations through the interaction of individuals within an organization [5]. Sensemaking is an ongoing meaning

development involving collecting information, framing it, and creating a coherent understanding of an otherwise complex and ambiguous situation. Capabilities highlighted by KBV [34, 27] are essential for sensemaking in dynamic and uncertain environments. The ability to adapt knowledge, learn from experiences, and update mental models aligns with the core premises of KBV vis-à-vis sensemaking capability. As such, sensemaking is one of the major underlying capabilities of KBV as it enables firms to interpret changes in their environment [38]. Following the KBV, we argue that by leveraging social and relational knowledge, managers can make sense of, interpret, and respond to emerging market conditions, which fosters adaptability and responsiveness in a fast-changing environment. Thus, a clear distinction exists between information exchange capability and sensemaking, as sensemaking is the ability to understand, create new meaning, and anticipate future scenarios; see, for example [36], [41].

C. Sensemaking Capability and Business Model Innovation

Drawing on the background provided above, we develop our hypotheses that examine the connections among sensemaking capability, market agility, IT alignment, and BMI. Manager sensemaking capability refers to a firm's ability to make sense of the current situation and interpret cues to explore alternative courses of action [42]. Knowledge is crucial for envisioning and predicting customer value and reconfiguring resources to create value [43]. The process of reconfiguring resources to create value represents BMI [44]. BMI involves the ability to introduce innovative variations into an existing business model [45]. BMI enables firms to increase revenue and return on investment [46]. KBV has been utilized to illustrate that a firm's ability to integrate a diverse range of perspectives and modify existing processes will likely generate more value for its customers [47], [48]. The knowledge resources and capabilities require intricate interactions among individuals and other actors within the network to gather information, interpret meanings, and capture insights over time [38], [41]. Information exchange promotes the development of the cognitive processes necessary for understanding and interpreting information. Moreover, effective

information exchange allows firms to share insights, navigate complex situations, and adapt their strategies in response to emerging trends or disruptions [4], [23].

When management fails to understand the significance of knowledge complexity [13], [49], they are unlikely to choose suitable resources for refining, implementing, and transforming BMI. [44], [50]. Knowledge resources seek to enhance both individual and collective learning, promoting the generation of new knowledge [51]. Recently, Chen et al. [52] have emphasized that sensemaking capability is crucial for enhancing strategic responses to understand changes and foster strategic innovation. Following this perspective, we anticipate that a firm's ability to efficiently process and integrate information is key to recognizing opportunities for creating value and delivering products in the markets. Therefore, we hypothesize:

H1: *Sensemaking capability is positively associated with business model innovation.*

D. Sensemaking Capability and Market Agility

Sensemaking is a cognitive process that reduces uncertainty through two stages: first, an initial context that motivates deliberate action, and second, an introspective context that helps managers evaluate the significance of newly acquired information in the context of existing opportunities [41], [53]. Sensemaking allows firms to navigate market uncertainties and prepares them to respond and adjust quickly in a rapidly changing business environment [54]. It enables firms to address customer needs and make sense of the market and reconfiguration process across departments thoughtfully and purposefully [16], [55]. The firm can emerge when sensemaking is enacted and proactively seeks to establish an understanding of the external environment [56]. Sensemaking can positively impact the firm's ability to speed up information processing to make and carry out flexible and rapid decisions in market conditions [57]. This means that construction and interpreting changes in the environment may explain and describe the firm's ability to introduce novel ideas and understand customer needs to respond swiftly and effectively to changes in the market environment [58], which brings forth the concept of market agility.

Market agility refers to a firm's ability to respond to changes quickly and effectively in the market environment [16]. The core pillars and building blocks of market agility are speed, iteration, decision-making, and sensemaking[16]. It strategically manages the influence of technology-related information to create meanings for future organizational development [59]. It signifies a firm's reaction to an unexpected or ambiguous situation that includes observing and categorizing the development while striving to interpret the information [60]. Adapting to and navigating the uncertain environment while seizing opportunities for market growth requires market agility [61], [62]. As managers continually strive to identify new information for adapting and creating new knowledge [63], it requires understanding and interpreting actions to make quick and decisive decisions that influence the market's level [55]. This indicates that a firm needs a sensemaking capability to incorporate various learning perspectives, allowing it to adapt and respond quickly to environmental changes while enhancing market agility [64], [65]. In line with this, a firm's ability to process and interpret complex information may enable it to quickly adjust its product and service strategies to address the changing needs of customers [66]. Thus, we hypothesize:

H2: *Sensemaking capability is positively associated with market agility.*

E. Mediating Hypothesis

Current research indicates that sensemaking may help firms rapidly capture and analyze information to comprehend the evolving nature of market trends [54], [67]. Sensemaking capability enhances understanding by accelerating information processing and utilizing critical information for long-term competitive edge [42]. Firms with strong sensemaking capabilities are better equipped to understand market dynamics, customer needs, and competitive forces. This enhanced understanding, stemming from sensemaking, provides a foundation for more agile responses.

Extant research [12] has found that gathering insights into customer needs and proactively identifying market conditions enable BMI. According to Sheng [21], "*knowledge resource built on organizational sensemaking to exploratory and exploitative product innovation*" (P.65).

Sensemaking embedded in knowledge and learning resources by creating meaning from diverse information [16] are critical to building to meet evolving market demands and seize new opportunities [56] [63]. Firms with strong sensemaking capabilities are likelier to identify novel ideas and opportunities for BMI [12]. Thus, KBV offers a valuable lens for understanding how firms employ sensemaking capabilities that focus on internal processes to make timely decisions to address market change effectively [23].

Firms existing knowledge resources and externally built resources through information exchange may increase their ability to rapidly sense [68] and respond to changes in the external business environment [23]. Exchanging information helps identify new product development opportunities and fosters an innovative culture, establishing the foundation for market agility in implementing and testing new business ideas models [59], [66]. According to research, information exchange significantly impacts learning and knowledge development, facilitating a shared understanding of how to adapt to market changes [63], [68]. The exchange of information is also viewed as creating a new meaning (interpretation) for something that has already occurred during the organizing process but has never been recognized as a separate autonomous process [42]. While other studies suggest that information exchange supports and enhances sensemaking activities [69]. Previous research has focused on determining what external information exchange triggers internal research and development to meet new customer needs [59], [70]. Studies on information exchange suggest that achieving alignment between market agility and sensemaking requires coordinating internal resources [8], [39]. Firms with high market agility can quickly adapt to changes in customer behavior, technological advancements, or competitive actions [6]. Additionally, the integration and interpretation of knowledge are central to understanding existing market conditions. The KBV emphasizes internal factors that enhance knowledge generation and utilization productivity [71]. Research indicates that the generation and integration of knowledge are closely linked with a robust sensemaking capability, which is likely to promote BMI through market agility [54], [72].

Moreover, BMI often involves experimenting with new approaches, products, or services [6]. Agile firms can experiment more easily [19], quickly testing and refining new business models. Sensemaking enables firms to learn from market feedback and make informed decisions. The insights gained from sensemaking guide the iterative process of experimenting with various business models. As a mediator, market agility facilitates the execution of these experiments. Akgün et al. [73] explored the mediating effect of process effectiveness between team sensemaking and new product success. Firms that rely on their employees as key resources, rather than physical assets, are more likely to sense changes in the market and successfully adapt to the development of BMI [20], [74]. For instance, [75] examined organizational agility as a mediator between open innovation and BMI. Even if individuals struggle to establish a solid shared understanding of market developments and implement decisions for reconfiguring internal processes [19], firms may still fail to drive production and process innovation [76] [77] [78]. According to KBV [79], a firm that recognizes the utmost value of its knowledge for generating new ideas—rather than physical assets or standard procedures—can gain a clear perspective in refining and developing BMI. This discussion leads us to infer that firms capable of making sense of the market and responding promptly are more likely to innovate their business models. Thus, we hypothesize:

H3: *Market agility mediates the relationship between sensemaking capability and BMI.*

F. Moderated-Mediation Role of Information Technology Alignment

IT alignment is a dynamic process that enhances the effectiveness and efficiency of business planning and performance [27]. It is defined as “the extent of fit between information technology and business strategy” [5]. This process involves harmonizing IT strategies and activities with a firm’s overall business strategy and objectives. Additionally, it ensures that IT initiatives, systems, and processes are closely integrated and supportive of the broader goals and functions of the business. Successful IT alignment is crucial for firms to leverage technology effectively [29]. Therefore, it is often a strategic imperative for firms seeking to maximize value from their

technology investments by ensuring that technology supports business objectives and improves responsiveness to market changes. Against this backdrop, we posit that IT alignment acts as a boundary condition that determines whether cognitive insights (sensemaking) are transformed into market-oriented reconfiguration (market agility). Even with superior cognitive processes, misalignment between IT and business can hinder responsiveness and delay execution. IT alignment can improve information flow, decision speed, and cross-functional integration, the exact mechanisms through which sensemaking transforms into market agility. Therefore, as articulated below, IT alignment is likely to strengthen the pathway between sensing and acting.

Sensemaking has been linked to cognitive theory, resource dependency, and the dynamic capabilities view [56] [57]. Additionally, the resource-based view (RBV) and KBV have also been applied in sensemaking studies [23] [58] [74]. Some scholars further indicate that KBV helps explain a firm's ability to learn and share ideas in changing environments [56] [57] [59]. Therefore, KBV facilitates addressing rapidly changing market conditions by integrating and building on existing knowledge to create new ways to respond to market demands [68]. Other studies have emphasized the importance of integrating technology resources to ensure that the deployment of systems effectively supports the firm's business goals. However, Neill et al. [63] noted that a lack of information exchange between departments and business units may lead to misaligned strategies, thereby reducing the firm's ability to make effective decisions on creating value [56]. This underscores the significance of IT alignment to mitigate risks associated with misaligned initiatives and maximize synergies across organizational units, enhancing the firm's adaptive capacity.

IT alignment focuses on ensuring that IT objectives and initiatives are directly aligned with the firm's strategic goals and priorities [80]. It guarantees that technology investments contribute to the firm's overall success and that IT resources are allocated to initiatives that deliver the most significant value in achieving these strategic objectives. Moreover, research indicates that IT alignment can serve as a crucial boundary condition for achieving agility and BMI [15], as it

enhances sensemaking and decision-making for several reasons. IT alignment can significantly influence market agility and BMI. Specifically, it fosters rapid decision-making, resource reconfiguration, and cross-functional communication, all of which are essential for translating insights gained from sensemaking into effective BMI. Without IT alignment, these efforts may be impeded or misaligned with the organization's objectives, thus limiting the impact of market agility on BMI. Therefore, IT alignment serves as a vital and effective moderator, likely strengthening the connection between sensemaking capability and BMI through market agility.

IT alignment evolves through observing information by interacting at multiple levels and interpreting it, developing connections between pieces of information, and integrating diverse perspectives to anticipate a firm's future [6], [27], [81]. IT alignment serves as an organizational resource that enhances information levels and diverse perspectives for making informed decisions and swiftly adapting to changing market dynamics [9], [27], highlighting its potential role in boosting the influence of market agility. It enables a firm to effectively integrate and respond to market insights by facilitating data flow, optimizing resource utilization, and ensuring that agile market responses are both timely and aligned with strategic goals. When IT systems and processes align with business objectives, they can improve the flexibility and speed with which market insights (from sensemaking) are transformed into BMI.

Furthermore, IT alignment can ensure that information flows smoothly across the firm, aiding in processing market data and sensemaking activities [82]. Therefore, firms with high IT alignment can integrate technology smoothly into their processes [29]. Market agility is contingent on the firm's ability to adapt its operations swiftly. Aligned IT systems enable the deployment of new technologies [80], adjustments to existing processes, and the rapid implementation of BMI [3]. Conversely, low IT alignment may create silos, reduce adaptability, and result in resource misallocation, thus diluting the effects of market agility on BMI. Additionally, as the quality of sensemaking pertains to the resource scope and plan for the IT implementations [6], high IT

alignment plans can negatively impact the firm's ability to understand, interpret, and give meaning to information in accommodating evolving environmental uncertainties [27], [83]. Liang et al. [6] suggest that, more significantly, the IT alignment may reduce the ability to interpret the information exchange and anticipate the changes as it leaves less room for initiation and cognitive sensemaking. Supporting these findings, [38], [41] argued that in conditions of high technology alignment, there is a greater need for organizations to promote information exchange among managers. Chen et al. [45] found that information exchange facilitates the exploration of new ideas, leading to better decision-making in the value-creation process.

Conversely, lower IT alignment may present opportunities to avoid excessive reliance on automated systems, thereby increasing the importance of sensemaking and market agility [70], [73], [81]. IT alignment might create a perception that managers concentrate more on the quantitative aspects of information using available data [9], potentially neglecting the value of human interaction for interpreting and anticipating market developments [6], [26]. For instance, a manager's effectiveness in perceiving, interpreting, and analyzing information relies on the leveraging and application of information technologies [27]. Thus, with enhanced market agility [17], the firm can allocate resources to generate greater value for its customers [20]. Considering the ever-growing unpredictability of today's business environments [74], leveraging market agility improves the firm's capacity to create value for customers by adapting internal processes [14].

On balance, we posit that the strength of the mediating role of market agility is contingent on the level of IT alignment within the firm. Thus, we hypothesize:

H4: *IT alignment moderates the mediating effect of market agility between sensemaking capability and BMI such that the mediating role of market agility is stronger (weaker) under high (low) levels of IT alignment.*

The hypothesized relationships are shown in Figure 1.

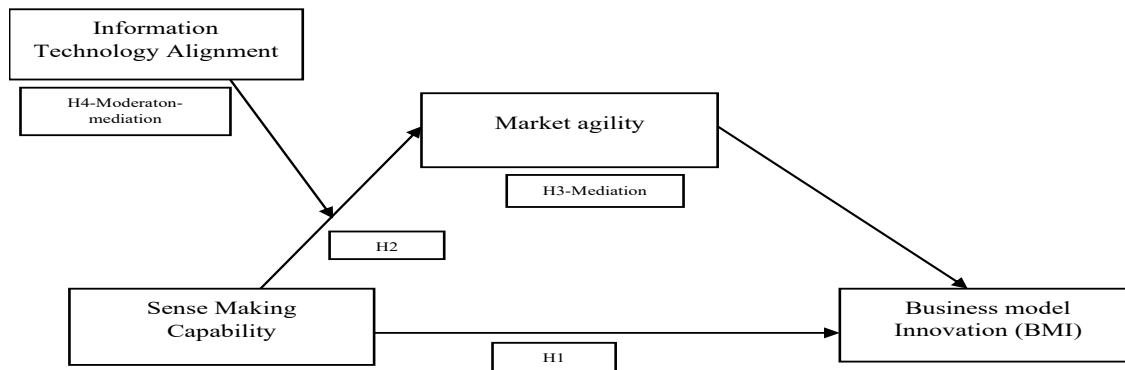


Figure 1 Hypothesized moderated-mediation model

3. METHODOLOGY

To test our conceptual model, we collected data from managers and senior executives in Pakistan over five months, from December 2022 to April 2023. The sampling frame included 1,354 domestic industrial manufacturers listed with the Securities and Exchange Commission of Pakistan (SECP)¹. We randomly distributed 569 questionnaires via email, resulting in 232 usable responses and a 40% response rate. Participants were assured of the security and anonymity of their information, used only for research. A pre-test evaluated face validity through consultations with six industry professionals and three academic experts, who provided insights to align the survey with our framework. Their feedback improved question clarity and relevance. Figure 2 shows the research design process flow.

The demographic representation in Table 1 shows that most respondents come from firms that have been in business for over 20 years. Regarding firm age, the majority fall into the 21–30 years category, accounting for 32.8% (76 firms), while firms aged 31 years and older represent 31.9% (74 firms). When assessing firm size by employee count, our data reveals that the largest segment, comprising 49.1% (114 firms), includes firms with more than 251 employees, indicating that our sample contains larger organizations. Firms with 51–250 employees make up 33.6% (78 firms), while smaller firms with fewer than 50 employees account for 17.2% (40 firms). Our study included respondents from various manufacturing sectors. The largest group of respondents came from the

¹ (<https://www.secp.gov.pk/list-of-registered-companies/>)

manufacture of food products (62 respondents, 26.7%), followed by the manufacture of footwear (39 respondents, 16.8%) and the production of products made from wood, straw, and plaiting materials (31 respondents, 13.4%). This shows that most data are derived from well-established firms operating for decades.

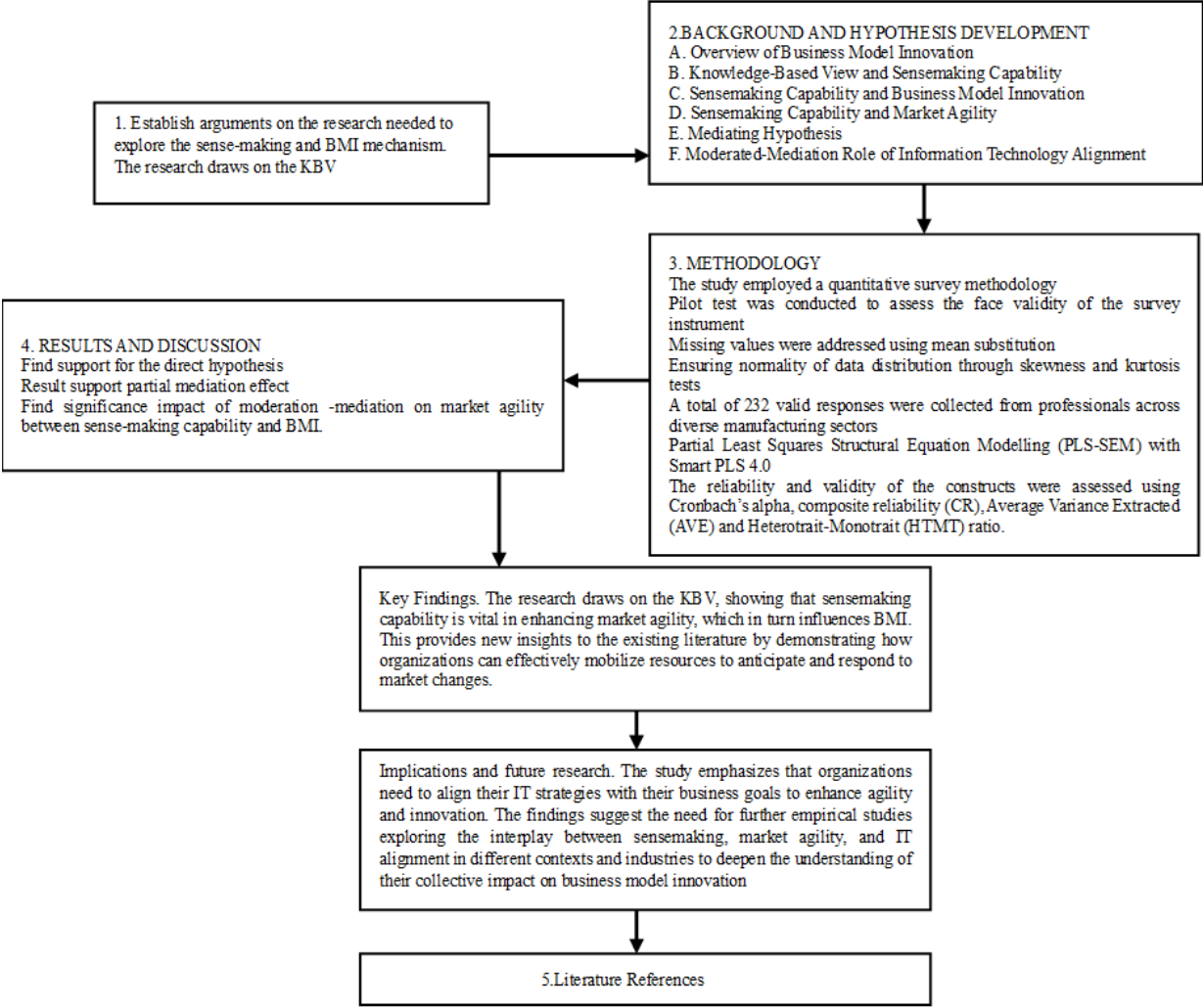


Figure 2: Quantitative research design

According to Bakker and Josefy [85], a broad industrial sample enhances external validity and improves the generalizability of research findings by including firms from various sectors such as manufacturing, services, and technology, which captures a comprehensive view of the business landscape. Furthermore, Leicht-Deobald et al [86] pointed out that established firms have greater access to resources and are better equipped to successfully integrate and implement new processes.

Following Leicht-Deobald et al. [86], since our data includes firms of varying ages and sizes, we controlled for firm age in our analysis. Table 1 provides a demographic profile of the respondents.

Table 1. The demographic profile of the respondents

	Managerial position	Number (%)	Industry category	Number (%)
1	Manager corporate development	43(18.5%)	Manufacture of food products	62 (26.7%)
2	Planning and Development Manager	76(32.8%)	Manufacture of footwear	39 (16.8%)
3	Manager digital business operations	60(25.9%)	Manufacture of products of wood, straw, and plaiting materials	31 (13.4%)
4	Market intelligence and implementations	40(17.2%)	Manufacture of paper and paper products	22 (9.5%)
5	Others	13(5.6%)	Manufacture of chemical products	10 (4.3%)
Firm age (Number of years in the business)			Manufacture of basic pharmaceutical products	13 (5.6%)
1	≤ 10	39(16.8%)	Manufacture of glass products	13 (5.6%)
2	11–20	43(18.5%)	Manufacture of iron and steel	7 (3.0%)
3	21–30	76(32.8%)	Manufacture of structural metal products	18(7.8%)
4	≥ 31	74(31.9%)	Manufacture of electronic components and other equipment	8 (3.4%)
Firm size (Number of employees)			Manufacture of sports goods	9(3.9%)
	less than 50	40(17.2%)	Experience	
	Between 51 and 250	78(33.6%)	Less than 5	21(9.1%)
	More than 251	114(49.1%)	Between 6 and 10	75(32.3%)
			11 and 15	88(37.9%)
			More than 16	48(20.7%)

Examining Table 2 reveals mean values for ITA (5.24), SMC (4.74), MCA (5.30), and BMI (5.26), with corresponding standard deviations of 1.123, 1.27, 1.16, and 0.93. Since all mean values fall between 4.7 and 5.3, the mean and standard deviation values indicate that the data distribution aligns with the assumption of normality [79]. Additionally, we examined the correlation values, and our analysis shows that no correlations exceed 0.90, indicating the reliability of our data.

A. Measurement

1) Sensemaking Capability: In line with the previously published research, we used a measure of sensemaking capability using a seven-point Likert scale ranging from 1 (strongly disagree) to 7 (strongly agree). Sensemaking capability measure has been used previously across various research disciplines [21], [87]. We adapted sensemaking measures from Weick [64], particularly focusing on the strategic information exchange dimension of sensemaking capability, and used 5 items to measure the construct, which has been measured and validated by Neil et al. [72]. In prior research domains, scientists have regarded sensemaking as facilitated by the cognitive frameworks that

influence individual knowledge [21]. For example, some researchers considered sensemaking as bounded to prior experience and beliefs revise their existing knowledge frames [13, 38, 42]. These studies have provided unique yet complementary contributions to the process of sensemaking through the knowledge and information perspectives. Following, Weick [41], as individual “requisite knowledge to sense variations in the technological environment” (p.312). Accordingly, in this study, we adopt the KBV rather than focusing solely on information processing, highlighting how knowledge structures underpin and guide sensemaking.

The measure includes: (1) “Major changes in our industry and important developments outside our industry are communicated across departments in the organizations”. (2) “Research and development personnel in our business spend time discussing customers’ future needs with other functional departments”. (3) “In making strategic decisions, managers in our organization have formal information links established between all parties involved in decisions”. (4) “In making strategic decisions, managers in our organization take the necessary time to train employees in new tasks relating to such decisions properly”. (5) “Data on customer satisfaction are disseminated at all levels of the organization regularly”. We did not include Sensemaking items (1) and (3) in the final data analysis after receiving expert feedback.

2) *Market Agility (MCA)*: We adopted three items from Lu [17] to measure market agility. We asked respondents to assess “to what extent do you agree with the following statements concerning the organization change due to the market agility on a 1 to 7 scale (1 = not at all true; 7 = very true). The items included: (1) “We are quick to make and implement appropriate decisions in the face of market/customer changes”. (3) “We treat market-related changes and cost efficiency.” Similarly, market agility item (2) “We constantly look for ways to reinvent/re-engineer our organization to serve our marketplace better”. was removed because it overlapped with BMI item (7) “Focus is on making major changes in the combination of costs incurred when operating the firm”.

3) *Information Technology Alignment*: The IT alignment scale was developed by Tallon and Pinsonneault [80] and has been found to have good validity and reliability when used in developing countries. The items included in the survey are: (1) “The IS strategy is congruent with the corporate business strategy in our organization”. (2) “Decisions in IS planning are tightly linked to the organization’s strategic plan”. (3) “Our business strategy and IS strategy are closely aligned”. (4) “Overall, the IS in our organization meets the needs of the business strategy”. We used a seven-point Likert scale of 1: not implemented to 7: fully implemented “to assess the extent to which these activities implemented within their firm”.

Table 2. Mean, standard deviation, and correlational analysis

	TID	ED	DS	WS	FS	FA	ITA	SMC	MCA	BMI	CIM
TID	1										
ED	.083	1									
DS	-.015	-.145*	1								
WS	-.061	-.172*	.129	1							
FS	-.085	-.020	.261**	.225**	1						
FA	.013	-.079	.105	.086	.113	1					
ITA	.019	.086	-.027	-.143	.037	-.090	1				
SMC	.051	.068	.060	.228**	.032	-.104	.415**	1			
MCA	.041	.006	-.008	-.090	.077	-.085	.525**	.494**	1		
BMI	-.022	-.069	-.015	-.075	.042	-.070	.413**	.358**	.565**	1	
CIM	-.002	-.071	.099	.015	.065	-.059	.093	-.011	.042	.122	1
Mean	4.04	2.41	2.59	2.70	2.32	2.80	5.24	4.74	5.30	5.26	5.50
SD	3.09	1.15	1.40	0.89	0.75	1.06	1.123	1.27	1.16	0.93	0.861

TID: Type of industry; ED: Education; DS: Managers designations; WS: Work experience; FS: Firm size (number of employees); FA: Firm Age (number of years in business); ITA: Information technology alignment; SMC: Sensemaking capability; MCA: Market agility; BMI: Business model innovation; CIM: Competitive intensity in new market SD: Standard deviation.

* Correlation is significant at the 0.05 level.

** Correlation is significant at the 0.01 level.

4) *Business Model Innovation*: For the scale of BMI, we assessed BMI using 7 items adopted from Zott and Amit [88]. BMI refers to the firm’s ability to create and deliver value by making continuous configurations and reconfigurations in firm value propositions to meet the current and future customers’ needs. On a scale from 1 (strongly disagree) to 7 (strongly agree), the respondents were asked to rate whether they believe the firm has gotten the most out of exploiting existing competencies and innovative processes over the past three years. BMI items included in the survey are: (1) “Focus is on developing radically new products and/or services”. (2) “Focus is on

developing and/or acquiring new resources and competencies” (3) “Focus is on developing new core processes and activities”. (4) “Focus is on establishing relationships with strategic business partners”. (5) “Focus is on developing tools for building customer relationships”. (6) Focus is on selling products and/or services through new channels”. We chose several demographic and contextual items (experience, individual education, firm size, and firm age) as individual-level and firm-level control variables. The firm’s size and age can be estimated by its natural logarithms of employees and years in business.

B. Reliability and Validity

We followed commonly recommended procedures to assess the construct validity of measurement items. The values of Cronbach’s alpha (CA) and composite reliability (CR) varied from 0.85 to 0.89 and exceeded the recommended threshold value of 0.70 [90]. The AVE of all latent variables exceeds 0.5, justifying the convergent validity of the construct. The square root of average variance extraction (AVE) exceeds the respective sum of the square of correlations of all the items [91], with a significant standardized factor loading of all items (factor loading >0.50) [92]. Although PLS-SEM is robust to minor deviations from normality, we ensured the normality of our data, with values falling within the acceptable ranges of -2 to +2 for skewness and -7 to +7 for kurtosis [92]. As can be seen in Table 3, all the constructs have a Cronbach alpha and CR well above the indicated levels. We conducted an ANOVA (Analysis of Variance) test to examine whether significant differences existed in the data collected from respondents across various geographical regions. This analysis aimed to determine whether respondents' geographical location influenced their perspectives, particularly regarding BMI. The ANOVA results indicate that there are no statistically significant differences among respondents from different geographical areas concerning their impact on BMI ($p > 0.05$) [92].

Table 3. Scale and items factors and reliability and validity

Variable	Items	Factor loadings	Cronbach’s α	CR	AVE	Collinearity statistics (VIF)
Market			0.772	0.821	0.817	

Agility (MCA)	MCA1	0.912				1.671
	MCA3	0.896				1.671
Information Technology Alignment (ITA)			0.889	0.893	0.750	
	ITA1	0.895				2.730
	ITA2	0.864				2.318
	ITA3	0.865				2.453
	ITA4	0.838				2.052
Sensemaking Capability (SMC)			0.782	0.821	0.695	
	SMC2	0.912				1.882
	SMC4	0.896				1.816
	SMC5	0.737				1.422
Business Model Innovation (BMI)			0.842	0.867	0.552	
	BMI1	0.754				1.874
	BMI2	0.706				1.878
	BMI3	0.660				1.562
	BMI4	0.816				2.512
	BMI5	0.810				2.417
	BMI6	0.698				1.288

C. Common Method Bias

According to the suggestions of Hair et al. [92], we conducted Harman's single-factor test to assess the potential for common method bias (CMB). All items from the constructs included in the study underwent an exploratory factor analysis (EFA) without rotation. The results indicated that a single factor accounted for 35.4% of the total variance, which is below the cutoff value. This suggests that common method bias is not a significant concern in our study, as no single factor dominated the variance in the data. Following Henderson and Venkatraman [81], the survey questionnaire was initially reviewed by the researchers and designed to minimize item ambiguity and enhance readability. Second, we obtained informed consent from the respondents to participate in the survey. Third, respondents were assured that participation was voluntary and that their anonymity would not be disclosed to any third party. CMB refers to variance that can influence results due to common assessment differences in the observed and expected relationships between items [82] [83]. CMB can pose a significant threat to construct validity and obscure the results, as noted in early study recommendations [84] and recent developments in the literature [85]. We took several measures to minimize the CMB. First, we mixed the order of the construct in crafting our questionnaire so that

a respondent could respond correctly. Second, following the pervasive norm of previous studies, we assess all the variables on “mono methods” [86]. The monomethod approach involves assessing all the constructs on one scale using Likert scale questions [86]. Lastly, during our data collection we also introduced marker variable in the questionnaires to assess the common method bias. For details, refer to the supplementary file A, section 2.

D. Addressing Endogeneity Threat

Endogeneity poses a potential threat to the validity of empirical findings in research, especially when there is a risk that the independent variable correlates with the error term [93], [94]. In the context of our paper, endogeneity could occur if unobserved variables simultaneously influence both independent and dependent variables. Thus, following [95], we examined the normality of the data and employed the “Gaussian copula” approach to identify and correct endogeneity biases in regression models and address the potential threat of endogeneity. We utilized the Gaussian copula approach using the maximum likelihood function in PLS-SEM. This method simplifies addressing endogeneity biases in regression models to achieve the desired results [96]. The outcome of the Gaussian copula test provides evidence of insignificant differences between the independent and dependent variables [95]. Our results support the notion that the independent variable in our model does not account for the error terms of the dependent variable [97].

4. RESULTS AND DISCUSSION

We used SPSS version 24 and PLS-SEM (v4.035) for data cleaning, operationalization, and model estimation. We tested the structural model after confirming the constructs’ reliability and validity. The coefficient of determination (R^2) measures the model's explanatory power and indicates the variance explained by market agility and BMI through sensemaking capability, which are 0.393 and 0.383, respectively. According to Chin et al. [98], R^2 values of 0.67 indicate “substantial,” 0.33 indicate “moderate,” and 0.19 indicate “weak.” The results demonstrate that the model is free from multicollinearity issues, with all VIF values below 4 [89]. To better assess the model's predictive accuracy, we applied the blindfolding procedure, as [89] suggests that Q^2 values greater than zero

reflect the model's predictive accuracy. Generally, Q^2 values greater than 0, 0.25, and 0.50 indicate that the PLS-path model has small, medium, or large predictive relevance, respectively. The results for H1 reveal that the path coefficient between sensemaking and BMI is significant and positive ($\beta = .45, p < 0.05$), supporting our hypothesis. H2 posits that sensemaking capability significantly enhances market agility ($\beta = .512, p < 0.05$), providing evidence in favor of H2. Our findings indicate that manufacturing firms with strong sensemaking capabilities are more adept at implementing BMI, underscoring the importance of sensemaking capability in this process.

A. Mediation and Moderated-Mediation Analysis

Our mediation analysis for testing H3 is based on the suggestion by MacKinnon et al. [93], using the process and the Hayes macro process with PLS-SEM. [99] describes the conditions necessary for causal inference in mediation analysis. Second, when testing the effect of the mediation variable, we followed existing guidelines [89]. Some studies provide detailed conceptualizations and recommendations for interpreting mediation output. For instance, Zhao et al. [100] offer valuable insights for assessing whether the mediation is partial or full. According to Hayes and Preacher [101] and Preacher et al. [102], it is not enough to show that the effect of X on Y decreases in size when M is included in the model. Researchers should consider the indirect effect of a x b using a bootstrap test. By applying Hayes and Preacher's [101] process model 4 (bootstrap analysis with a 95% confidence interval), we find that the indirect effect is positive and significant through the mediator MCA ($b=.249, SE=.0048, CI (.166, .357)$), and the CI does not include zero. The direct effect of sensemaking capability on BMI is also significant ($b=.209, SE=.081, CI (0.050, 0.366)$), which supports the full mediation effect of market agility. This indicates that the result supports full mediation, thereby validating the mediation hypothesis (H3). The findings demonstrate that sensemaking capability is a crucial factor for both market agility and BMI. Our results illustrate that sensemaking capability serves a dual role in driving both market agility and BMI. We suggest that

manufacturing firms prioritizing sensemaking can better interpret and act on information swiftly, which may allow them to adapt to market changes and innovate their business models.

Furthermore, as proposed in H4, IT alignment positively moderates the mediation influence of market agility on the link between sensemaking and BMI. Following the moderated-mediation analysis guidelines [101], the interaction effect of sensemaking capability and IT alignment on market agility was statistically significant ($b = -.096$, $SE = .047$, $CI (-.188, -.0005)$). IT alignment exerts a positive effect on MCA ($b = 0.33$, $CI: 0.215, 0.467$). Our results confirm that the direct effect of sensemaking capability on BMI is significant ($b = 0.209$, $CI (.051, .366)$).

To further test the moderated-mediation effect, we used Process macro model 7 with 10000 bootstrap samples. We employed PROCESS Model 7 to examine the moderated mediation relationship of IT alignment (ITA) on the mediation effect of market agility between sensemaking capability and BMI. Model 7 in the PROCESS macro enables us to explore how the indirect effect of the independent variable (sensemaking capability) on the dependent variable (BMI), through the mediator (market agility), is influenced by the moderator (IT alignment). The model fit statistics of $R^2 (0.3271)$ and $F(2, 229) = 55.65$, $p < 0.001$ indicate that the model is significant. The index of moderated-mediation is $-.047$, $SE: 0.023$, and $CI (-.095, -.002)$. Since the confidence interval (CI) does not include zero, this indicates that IT alignment significantly but negatively moderates the mediation effect of market agility between sensemaking capability and BMI. Our findings suggest that IT alignment negatively moderates the mediation effect of market agility between sensemaking capability and BMI. As manufacturing firms increase IT alignment, the mediating role of market agility in linking sensemaking capability to BMI becomes weaker. The results of the indirect effect of sensemaking on BMI through market agility at different levels of IT alignment ($M \pm 1 SD$) are shown in Figure 3. Previous literature has examined the moderating impact of IT spending on the relationship between IT capability and market agility [14], as well as the role of agility as a mediator between IT alignment and firm performance [5]. In this regard, our research addresses a gap in the

literature by examining how IT alignment shapes the mediating effect of market agility between sensemaking capability and BMI. However, when IT alignment is high, firms rely less on market agility to drive BMI. Conversely, when IT alignment is low, firms increase their reliance on market agility to drive BMI. These findings suggest that market agility plays a crucial mediating role in connecting sensemaking capability to BMI.

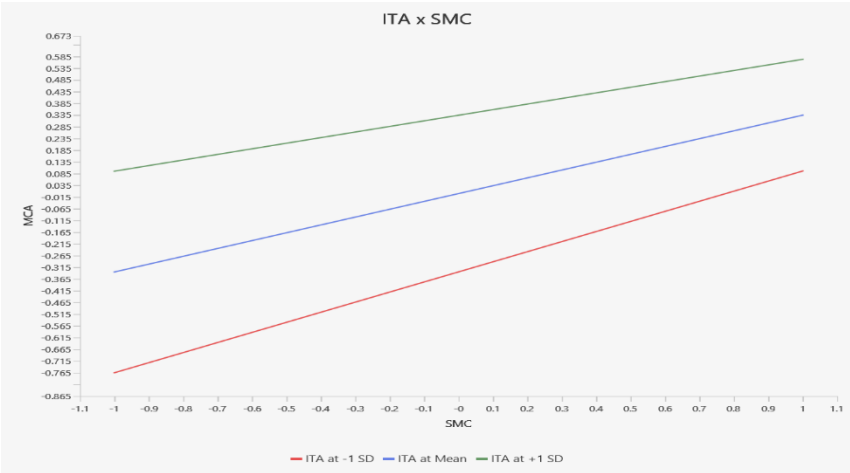


Figure 3 Relationship between sensemaking and BMI moderated by IT alignment.

B. Conclusions and Theoretical Contributions

This study aimed to investigate the moderating role of strategic IT alignment in the relationship between sensemaking capability and BMI, with a particular emphasis on the mediating effect of market agility. Furthermore, this research sought to determine whether the strength of market agility as mediation varies depending on the level of IT alignment. Our results highlight that a low level of strategic IT alignment is critical in determining how sensemaking capability affects firms’ BMI. Our findings emphasize the significance of sensemaking and market agility, which are essential for accelerating BMI. The results of our study make a significant contribution to the engineering management literature. First, from a literature perspective, there is limited understanding of when and how firms successfully translate or hinder market agility to structure and leverage resources to trigger BMI. Our study empirically validates the importance of market agility for engineering manufacturing firms in developing and implementing BMI. Research in this area has confirmed that sensemaking is crucial for BMI [103]. However, the mechanism of sensemaking capability on

BMI has not been explored concisely [13], [103]. Consistent with Möller [47] and Möller et al. [104], we demonstrate that sensemaking capabilities create conditions that support BMI, mediated by market agility. We provide evidence that sensemaking capabilities are not only useful for BMI, but also that the development and implementation of BMI are influenced by market agility. Our study contributes to KBV by showing that sensemaking capabilities, as a vital organizational knowledge asset, can enhance BMI through market agility.

The second contribution from a theoretical perspective involves exploring the role of sensemaking capability in shaping market agility, drawing on the KBV. Our study advances theoretical understanding of sensemaking capability by demonstrating how social and relational knowledge resources enhance managers' abilities to make sense of, interpret, and respond to emerging market conditions. Managers do not operate in isolation; instead, they rely on interpersonal networks, shared experiences, and collaborative knowledge exchange to interpret complex situations and make informed decisions. This highlights that leveraging the KBV through social and relational knowledge is a fundamental aspect of managerial sensemaking. From the KBV of sensemaking capability, we propose that it underpins quick adaptation and aids in reorganizing firm resources to address new market challenges.

Third, the novelty of our research lies in examining the moderating impact of IT alignment on the mediation of market agility between sensemaking and BMI. Our research extends the current understanding of the conditions under which IT alignment helps or hinders agility [5]. Building on Chesbrough et al. [105] and Sjödin et al. [106], we enhance the literature on BMI by identifying the critical role of IT alignment in the process through which market agility mediates the relationship between sensemaking capability and BMI. Our findings suggest that at low levels of IT alignment, the mediating effect of market agility on the connection between sensemaking and BMI is pronounced. Conversely, when IT alignment is high, it weakens the mediating effect of market

agility in converting sensemaking into BMI. As IT alignment increases, the positive influence of market agility in transforming sensemaking into BMI diminishes.

C. Managerial Implications

The results of this study present several important managerial implications and policy insights. First, our findings support the view that market agility mediates the relationship between sensemaking capability and BMI. Additionally, they indicate that a sense-based perspective can simplify situations by exploring alternative tacit responses in challenging circumstances [40]. Our findings may help firms discern when and to what extent they should prioritize developing market agility. We advise research and development managers that if sensemaking capability development is pursued, BMI can still be enhanced by bolstering market agility. Therefore, we suggest that sensemaking capability is crucial for formulating strategies to respond to complex and uncertain situations, as well as for the advancement of BMI.

Second, our results indicate that a firm is likely to create pathways for developing BMI through market agility. In this regard, top management should enable managers to utilize their skills and abilities to adapt to and navigate uncertain market conditions. Accordingly, our findings underscore the significance of market agility. Thus, managers should focus on establishing conditions that enhance market agility. This may involve adopting agile methodologies, promoting cross-functional collaboration, and ensuring that decision-making processes are streamlined and responsive to market changes.

Third, our findings suggest that a significant interaction effect exists between IT and sensemaking on market agility. This evidence supports the idea that low IT alignment and sensemaking capability are closely linked to the development of market agility. Following expert advice [40], our findings reveal that aligning IT strategies with sensemaking can help firms swiftly adapt to rapid market changes [11], [48]. Our results imply that a low level of IT alignment and sensemaking capability might be beneficial for responding quickly to fast-paced market changes.

Hence, managers in the engineering department focused on developing sensemaking capability need to understand how IT alignment may balance risks and benefits for enhancing market agility. Consistent with Barr [107], we recommend that managers in engineering management effectively interpret the external environment by integrating information from various sources and recognizing the needs of each area when addressing changes in the external landscape.

D. Limitations and Future Research Directions

Our study is not without certain limitations that open avenues for future research. First, our research is cross-sectional, and the sample for data analysis was collected from a developing country. Although our sample is sufficiently large, we collected data specifically from engineering manufacturers. Future research could consider longitudinal studies to observe the evolution of BMIs over time in firms with varying degrees of sensemaking capability, market agility, and IT alignment by gathering data from digital platform firms. This approach can provide insights into the sustainability of BMIs and how firms adapt their sensemaking processes and IT strategies in response to changing market dynamics.

Second, while data from a developing country support the study's ideas, future research could explore other contexts to delve deeper into the phenomenon. Another limitation of our data collection methodology lies in the geographical and economic context of the study. Since we gathered data exclusively from managers and senior executives in Pakistan, a developing country, the findings may be more applicable to economies with similar characteristics, such as those experiencing rapid technological change and industrial growth. The specific challenges and opportunities faced by firms in Pakistan, particularly regarding IT alignment, may not fully reflect those in more developed economies, where infrastructure, market conditions, and regulatory environments differ significantly. Our findings may offer fresh insights for other developing countries, especially where rapid IT adoption and alignment are critical for BMI. However, they may not be directly generalizable to developed economies with more stable IT infrastructure and

advanced technological ecosystems. In this light, we suggest that future research could explore cross-country comparisons by conducting studies in other developing or emerging markets to better understand how contextual factors shape the relationship between IT alignment, sensemaking, market agility, and BMI. We believe that a comparative study with developed economies could further illuminate any variations in how IT alignment moderates the relationship between sensemaking capability and BMI across different economic environments.

Third, in this study, we controlled for the effect of respondents' work experience, as our correlation analysis indicates that respondents' experience positively and significantly correlates with sensemaking capability. For this reason, we have included respondent experience as a control variable. Future research should consider the moderating impact of specific control variables, such as firm age and employee experience, to examine the interplay between sensemaking and BMI while considering organizational-level capabilities as potential moderators.

Fourth, strategic information exchange dimension used in this study to measure sensemaking capability may not neatly fit as a general measure for sensemaking capability in other contexts. As literature on sensemaking has been reviewed from different theoretical perspectives [108, 109], the sensemaking capability can enrich empirical studies of information processing theory to technological change. Thus, one potential future research is to conduct of quantitative analysis of the impact of strategic information processing on capability reconfiguration through sensemaking capability, see for example [110].

Additionally, scholars can complement this quantitative research with in-depth qualitative investigations, including interviews and case studies, to capture the nuances and contextual factors influencing the proposed relationships. Qualitative research can provide a richer understanding of the organizational processes involved in sensemaking, market agility, IT alignment, and BMI, offering a more in-depth and contextualized view of these phenomena.

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Supplementary file Section 1

Table A Prior research on Sensemaking and Business model innovation

Ref.	Method	Sensemaking	Findings about sensemaking and agility
[1]	Empirical analysis	Sensemaking	This study found a positive effect of strategic foresight on sensemaking but no direct relationship between sensemaking and BMI.
[2]	Empirical analysis	Customer demandingness and international market agility	This highlights the role of business model adaptation in an international challenge during crises through local market exposure and conditions (sensing mechanisms).
[3]	Qualitative study	Strategic sensemaking	Authors identified (understanding complex social issues) and sense-giving (communicating their vision to others) as important for transformational value creation.
[4]	Conceptual	Sense-based perspective	As organizations engage in continuous activities, collective sensemaking processes will repeatedly lead to changes in resourcefulness and resource linkages.
[5]	Qualitative study	Sensing and seizing	Research is needed to explore how sensemaking capabilities help firms detect environmental and organizational changes impacting their business models.
[6]	Qualitative	Organizational sensemaking	By examining organizational sensemaking in the context of ERP implementation, it identifies potential drivers of ERP implementation.
[7]	Qualitative	Managerial sensemaking	This study proposes that managerial sensemaking has implications for bringing changes in the business environment.
[8]	Literature review	Organizational response and IT capabilities	Information technology capabilities enhance a firm's processes for knowledge search and enable firms to sense and respond to changing external conditions. This study also highlights that IT capabilities lead to improved performance.
[9]	Empirical analysis	Organization sense-making	This study establishes a link between organizational sensemaking and exploratory and exploitative product innovation. Sensemaking can impact product innovation.
[10]	Conceptual	Role of sensemaking processes in decision-making and change	This study emphasizes the importance of sensemaking in contemporary organizations, especially in dealing with complexity during turbulent times. Findings show that the presence of sensemaking has significant macro-level consequences within organizations.
[11]	Conceptual	Sensemaking and adaptive processes	This study proposes that the sensemaking framework is related to discovering diverse resources that can foster the development of new, valuable relationships and help identify and recognize areas needing adjustment.
[12]	Qualitative	Exploration of sensemaking	Individuals identifying novel information can facilitate better exploratory sensemaking for radical ideas.
[13]	Empirical analysis	Organizational sensemaking	Organizations that have sensemaking capability can control cost and customer performance. Difficulties in interpreting market signals can hinder a team's ability to respond effectively, potentially leading to missed opportunities or delayed responses.
[14]	Empirical analysis	Sensemaking capability	Sensemaking capability has a significant positive effect on new product development. Further, the relationship between sensemaking capability and new product success is mediated by information implementation and speed-to-market.
[15]	Empirical analysis	A sensemaking perspective	The study proposes that perceptions of IT impact at the process level (the locus of noticing) are positively related to perceptions of IT impacts at the firm level (the locus of sensemaking). A more locus of information technology is positively related to sensemaking.

Section 2, Application of marker variable

The use of marker variable approach to test or correct the CMV in survey-based research is commonly applied [16]. Lindell and Whitney [17] proposed the marker variable approach to detect the CMV. We assessed the variable to be included in the study should meet the following criteria: (1) the variable must meet the reliability criteria, (2) the variable must be measured with multiple items, and (3) it must be unrelated to at least one of the other theoretically related predictors in the study [17]. In the survey research, we introduce a marker variable that was theoretically unrelated to the other study variables. Following [18]. We adopted the competitive intensity of a new market as the extent to which strategic pressure and rivalry affect a firm in its market during the new product introduction stages. We adapted measures from Kim et al. [18] measures with 7-point likert scale, (1) “Competition in this product market is cutthroat”, (2) “there are many promotion wars in this product market”, (3) “one hears of a new competitive move almost every day” and (4) “price competition is a hallmark of this product market”. The factor loadings of competitive intensity of new market are, 0.815, 0.807, 0.643, and 0.846

To assess the potential impact of common method bias (CMB), the marker variable technique was employed within the PLS-SEM framework using SmartPLS software. The results indicate that the inclusion of the marker variable did not significantly alter the structural relationships among the main constructs. The paths ITA → MCA (0.334* vs. 0.332**), MCA → BMI (0.485 vs. 0.476), and SMC → BMI (0.209 vs. 0.215) remained statistically significant and consistent in magnitude, both before and after accounting for the marker variable. The * sign indicates the absence of a marker variable, and ** represents the path coefficients with a marker variable. When a marker variable, competitive intensity in new markets, was included in the model to test for CMB, we observed some slight changes in the path coefficients. However, the overall relationships remained largely unaffected. The key structural path coefficients (ITA → MCA, MCA → BMI, SMC → BMI, SMC → MCA) show very minimal change when the marker variable (CIN) is introduced. Further, the marker variable itself did not demonstrate significant effects on any of the model constructs (CIN → BMI, $p = 0.108$; CIN → ITA, $p = 0.226$), indicating that the method bias is likely negligible in this study. The results indicate that the inclusion of the marker variable did not significantly alter the structural relationships among the main constructs. For details, see Table 1A for the summary of the path coefficients with and without marker variables.

Path	Without Marker Variable	With Marker Variable
ITA → MCA	0.334 ($p = 0.000$)	0.332 ($p = 0.000$)
ITA × SMC → MCA	-0.096 ($p = 0.040$)	-0.096 ($p = 0.039$)
MCA → BMI	0.485 ($p = 0.000$)	0.476 ($p = 0.000$)
SMC → BMI	0.209 ($p = 0.009$)	0.215 ($p = 0.007$)
SMC → MCA	0.335 ($p = 0.000$)	0.336 ($p = 0.000$)

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