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Original Article

An AHP Approach to Assess New Product Development Process Framework: An Exploratory Study

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Abstract *- An effective New Product Development (NPD) process framework, coupled with robust communication, data management, and knowledge handling, stands as a basis for success in NPD projects. Within the dynamic landscape of India's manufacturing industry, particularly in the automobile sector, managing NPD poses a significant challenge. Previous studies have proposed diverse NPD process frameworks to facilitate successful product development and highlighted the necessity of market success. This paper presents the five most used NPD frameworks and evaluates the most effective framework using the Analytical Hierarchy Process (AHP) approach. The exploratory study demonstrates how decision criteria can be prioritized and scoring guidelines established to assess the NPD Process Framework. The results of this research will provide a practical pathway for Indian manufacturing industries to incorporate new strategies and actions to realign strategies and actions.*

Keywords - *Analytical Hierarchy Process (AHP), New Product Development (NPD), New Product Development process framework, Product Lifecycle Management (PLM).*

1. Introduction

New Product Development (NPD) is the process of transforming identified market opportunities into a viable and profitable product, generally involving a structured series of steps that businesses undertake to achieve their commercialization objectives [51]. New product development gives organizations an excellent chance to maximize profits and enhance efficiency [30]. Strong global competition, fueled by swift technological advancements and constantly evolving consumer preferences, underscores the importance of businesses creating innovative and competitive new products to achieve success. A company's ability to survive and thrive in today's fast-changing market largely depends on developing innovative and improved products [85]. In today's dynamic business landscape, where customer preferences evolve quickly, businesses must remain flexible and responsive to these changes [7]. For organizations to achieve success, they need to enhance their product development skills and design products that align with changing consumer preferences. Technological progress reshapes the market landscape each year, leading to shifting customer needs and greater market adaptability, ultimately adding complexity to managing New Product Development (NPD). The reality is that out of every seven new product ideas, roughly four proceed to development, about one and a half make it to market, and only one turns out to be successful [1]. No company wants to create faulty products or cancel a launch due to defects. Canceling projects during the Product Development (PD) phase harms the industry, as it results in the waste of valuable resources, creates a competitive edge for others by preventing the introduction of new or enhanced products, and causes overall financial setbacks [57]. In order to satisfy the growing demand for high-quality products that cater to changing customer needs, organizations must swiftly deliver exceptional products, ensuring the New Product Development process is flawless [30]. A research study showed that the success of new products depends on an effective NPD process that includes customer focus, cross-functional collaboration, support from top management, the presence of a project champion, solid planning and execution with an experienced project manager, and a clear process with formal metrics [83].

The NPD process is vital, particularly for companies operating in markets where product changes occur quickly [58]. A clearly defined development process is valuable for various reasons, including ensuring quality, improving coordination, and supporting planning and management [5]. The NPD process involves a series of activities across integrated development stages: product planning, concept development, manufacturing, production, sales, and distribution, during which a product is created to meet customer demand and requirements. The NPD process differs from one company to another, and no one-size-fits-all approach is suitable for every situation and industry. The choice of processes is typically determined by the structure a company adopts to handle uncertainties and risks [29]. Traditional product development methods tend to be slow and inefficient, with many companies taking 3 to 4 years to launch a product. Although formal NPD processes have become common in most companies and no longer offer a competitive advantage (only 6% report not having such processes), organizations are increasingly turning to flexible, customized approaches suited to the complexity and scale of each project [2]. In today's organizations, NPD carries significant risks, but successful companies credit their achievements to robust, efficient processes that prioritize quality and effectiveness. The New Product Development (NPD) process framework outlines the sequential stages of product design and development using flowcharts [88]. NPD frameworks translate theoretical concepts into practical applications through systematic methods, reflecting the leadership goals of the organization [84].

Leading companies continuously refine and utilize effective NPD frameworks to sustain their competitive advantage. Adopting these frameworks improves planning, decision-making, technology use, milestone evaluation, cost efficiency, creativity, market penetration, revenue, and quality. Research shows that numerous frameworks have been developed, highlighting different aspects of the NPD process. Over 600 frameworks are documented in academic literature, employing various models and methods [18], and the number continues to grow with the expansion of NPD research. All these frameworks aim to establish formal and appropriate procedures, focusing on technical and managerial aspects, adopted designs, development processes, and fostering innovation. These frameworks can be either sequential or concurrent. To succeed in a competitive market and reduce the risk of failure, companies must consistently improve the performance of their product development frameworks, focusing on three key factors: time, cost, and quality. Rapid, cost-effective, and low-risk product launches are vital to meet demand.

Companies are increasingly moving away from traditional product development models, adopting more modern approaches that offer greater agility, flexibility, and better alignment with their organizational structures and operations [55]. In the Indian manufacturing sector, many companies, particularly small and medium-sized ones, lack a standardized terminology for new product development. Each company creates its own unique framework for developing new products, which often lacks structure despite having some similarities. This inconsistent approach to the NPD process leads to inefficiency, misdirected efforts, increased need for clarification meetings, inaccurate resource and schedule forecasts, greater task interdependence, and reactive problem-solving. Selecting and effectively using the right NPD process framework enhances an organization's planning and decision-making, technology adoption, evaluation at key milestones, labor and overhead costs, product and service quality, creativity and innovation, need for engineering and design changes, market entry capabilities, revenue and profit margins, and inventory costs [14]. To address these challenges and improve efficiency, it is crucial to emphasize systematic screening, monitoring, and progression frameworks [59]. It is now clear that proper selection and management of the NPD process framework has become essential for companies to remain competitive in the market. Some excel in this area, while others struggle due to a lack of understanding of how to effectively develop and implement an optimal NPD framework. The NPD process framework must be flexible and responsive to shifting market and customer demands. Therefore, having an efficient, streamlined, and adaptable NPD process framework is vital for ensuring a company's long-term sustainability and determining the success or failure of product outcomes [78]. The commercial success rate of New Product Development (NPD) projects in many firms remains low, with only about one out of four projects achieving success.

This is largely due to immature NPD process frameworks, which are plagued by significant flaws such as omission errors, poor execution, questionable project selection, and the use of inappropriate NPD process frameworks. A study by Anand and Kodali (2008) revealed that nearly 50% of product development costs are wasted during the NPD process. Additionally, Rajeshwari (2017) found that fewer than 15% of generated ideas succeed in the market. While leading companies achieve an 82.2% success rate, others only manage 52.9%. These inefficiencies result in substantial costs, wasted effort, and energy due to high failure rates. Despite the potential benefits of an effective NPD framework, considerable room remains for improvement. Analysis of various NPD frameworks and the programs within them has highlighted weaknesses that raise concerns, and in some cases, these flaws have negatively impacted organizational success.

Approximately 24% of companies implementing an NPD framework report worse time-to-market performance, and 63% of executives are either somewhat or very dissatisfied with their firm's new product efforts. Moreover, 46% of resources invested in new product programs are wasted on technical and commercial failures. This disappointing success rate has led to numerous studies focusing on the problems and inefficiencies associated with the NPD process framework. Research indicates that new product success rates have not improved in the past 30 years. Challenges with implementing NPD process frameworks arise because product development is not yet fully recognized, managed, or taught as a process, making it difficult to design efficient process interfaces. The necessary concepts and techniques have only been recently developed, emphasizing the need for improved process interfaces and more effective service identification and delivery. In today's highly competitive business environment, organizations face significant pressure to deliver exceptional customer value and surpass customer expectations. As a result, many companies have recognized the critical need for rapid and efficient new product development.

This has made the product development process framework a focal point of attention and concern [27]. While the literature highlights numerous frameworks, this paper examines prominent and widely referenced models such as BAH, Stage-Gate, Lean Startup, IDEO, and Ex-PD. Each framework presents distinct advantages and limitations, requiring careful consideration for effective implementation [17]. Stage-Gate and BAH offer structured methodologies that are ideal for stable industries and traditional settings. In contrast, Lean Startup, IDEO's Design Thinking, and ExPD emphasize flexibility and adaptability, making them particularly effective in dynamic and innovation-driven sectors.

For organizations aiming to excel in competitive markets, adopting the most effective New Product Development (NPD) process framework is essential. A robust framework ensures that NPD activities prioritize three critical dimensions: time, cost, and quality. Implementing the right framework enhances planning and decision-making, maximizes technology utilization, enables milestone evaluations, improves cost efficiency, fosters creativity, strengthens market penetration, drives revenue growth, and enhances product quality. NPD frameworks are diverse and tailored to meet the specific needs of various organizations, industries, and products. The selection of an appropriate framework depends on factors such as product characteristics, market dynamics, organizational culture, and desired innovation levels. To increase the success rate of NPD initiatives, managers must adopt comprehensive process frameworks that align with their corporate strategy and focus on the firm's strategic priorities.

These frameworks span multiple stages, from idea generation to ensuring product functionality, and require meticulous planning, design, development, deployment, evaluation, and control throughout the process [56]. Functional teams are often deployed to streamline the complex tasks involved in NPD, from design to launch [21]. However, the complexity of NPD frameworks remains a significant challenge [15]. Factors contributing to this complexity include simultaneous engineering, concurrent activities, the demand for "first-time-right" products, profitability requirements, and the risks associated with managing multiple projects simultaneously [44]. Product development operates within an open system influenced by both internal and external forces, necessitating adaptability. The most fundamental challenge in NPD is uncertainty, which brings risks and potential losses. Given the substantial investment of time, financial resources, and human capital in NPD, selecting the optimal process framework becomes increasingly critical. Thus, the success rate of New Product Development (NPD) projects remains low due to improper selection of NPD process frameworks. Despite the potential benefits of effective frameworks, issues such as inefficient time-to-market performance, unsatisfactory NPD efforts, and high failure rates persist. Rapid and efficient NPD is crucial in the highly competitive market, rapid and efficient NPD is crucial, leading organizations to adopt frameworks like Stage-Gate, BAH, Lean Startup, IDEO, and Ex-PD. Structured frameworks like Stage-Gate and BAH work well for stable industries, while flexible approaches like Lean Startup and IDEO are more suitable for dynamic, innovation-driven sectors.

The selection of the right framework is required for effective management of time, cost, and quality, driving revenue growth and improving product quality. However, selecting the best framework remains complex due to factors like organizational culture, product characteristics, and market dynamics. Companies must adopt frameworks that align with their strategy to improve NPD success rates, fostering creativity and innovation while managing uncertainty and risks. To address the challenges in New Product Development (NPD), this study proposes evaluating and ranking NPD frameworks using a standardized self-assessment model based on the Analytical Hierarchy Process (AHP) method, as outlined by Klaus D. Goepel in 2013.

AHP, a technique within Multi-Criteria Decision-Making (MCDM), is widely used across various fields such as industry, government, and pharmacology to assess and prioritize conflicting criteria. AHP, a specific MCDM technique, generates options to identify the best decision, making it particularly useful for selecting the most suitable NPD framework. This paper begins by reviewing five widely cited NPD frameworks, comparing them based on key aspects such as applicability, implementation, decision-making processes, goals, management, and costs. These comparisons inform the identification of framework characteristics across seven dimensions: strategy, research, commercialization, process, project climate, company culture, and performance metrics. These dimensions are then prioritized using the AHP model to delineate success factors for NPD. This model offers industries a self-assessment tool to manage their NPD processes and improve performance. The paper concludes with key insights and recommendations for future research directions.

2. Overview of Selected NPD Frameworks

The previous researcher emphasized that most NPD frameworks are managerial in nature, with nearly all of them adhering to the generic new product development phases outlined by Ulrich and Eppinger (2016). This study considers the most commonly cited NPD frameworks.

- BAH framework
- Stage-Gate framework
- Lean start-up framework
- IDEO Framework
- Ex-PD framework

2.1. BAH Framework

Over the years, numerous comprehensive NPD process models have been developed, with one of the most renowned being the seven-step product development process framework by Booz, Allen, and Hamilton (BAH). This framework includes the stages of NPD strategy, idea generation, screening, business analysis, development, testing, and commercialization, which are now regarded as more iterative in nature [53]. In their research and publications, Booz concluded that the probability of failure decreases when using the BAH framework, as it provides a consistent and holistic approach by emphasizing strategy from the outset and integrating external networks and environmental factors. In 1982, Booz et al. updated the framework to incorporate concept development and testing stages, reflecting changes in the market and emphasizing factors such as new discoveries, emerging technologies, varying levels of innovation, and industry-specific characteristics.

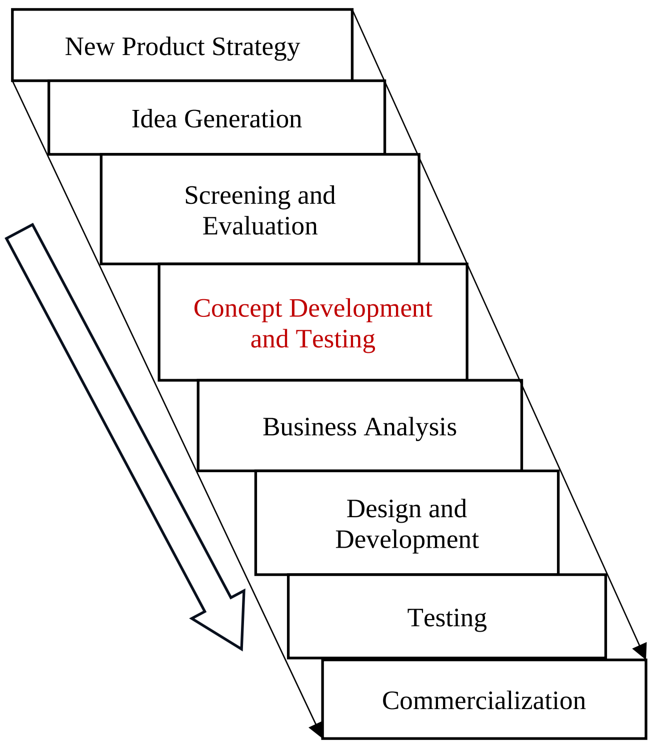

Fig. 1 The revised Booz, Allen and Hamilton NPD model

2.2. Stage-Gate Framework

The first generation of New Product Development (NPD) process frameworks was introduced by NASA in the 1960s. NASA's approach was heavily engineering-focused, concentrating on technical development activities while overlooking marketing aspects. To address this limitation in NASA's Phase Model, the second-generation Stage-Gate system was developed by Cooper [87]. In 1985, Cooper introduced the New Prod process, which comprised seven stages to guide a product from idea generation (stage I) to product launch (stage VII). This process sought to improve effectiveness, efficiency, and commercial success while reducing development timelines. The New Prod process served as the foundation for the later Stage-Gate model, allowing the process to be halted at the end of any stage. 1990 Cooper introduced the Stage-Gate NPD framework, as depicted in Figure 2, featuring five stages and gates.

This framework has since become a cornerstone for modern NPD processes used across various industries [78]. Cooper developed the Stage-Gate framework after conducting extensive research on successful companies proficient in transitioning products from ideation to market and on firms that experienced failures in NPD [67]. Table 1 summarizes the activities and actions undertaken at each stage and gate of the original Stage-Gate process, as Cooper (1990) described.

Table 1. Stage and gate wise activity and actions

Stage /Gate Name	Activity	Actions
Start	Discovery	Market survey and idea generation
Gate1	Idea Screen	Selection and prioritisation of ideas
Stage1	Scoping	Market and technology analysis
Gate 2	2nd Screen	Decision on project progress
Stage 2	Build business case	Business case preparation includes a launch plan
Gate3	Go to development	Financial and technical feasibility analysis (Project go ahead)
Stage 3	Development	Preliminary design
Gate 4	Go to testing	Proto build and testing
Stage 4	Testing and validation	Detailed design, tooled-up parts build and testing
Gate 5	Go to launch	Approval for Market launch
Stage 5	Launch	Market launch and product commercialization
Post-launch review	Monitoring	Project evaluation

Cooper's groundbreaking work 1995, illustrated in figure 3, represented a major evolution of the Stage-Gate Model, shifting from isolated departmental approaches to strong cross-functional collaboration. Expanding on the earlier Stage-Gate Model developed with Kleinschmidt in 1994, Cooper introduced four essential "Fs": flexibility, fluidity, focus, and fuzzy gates designed to streamline and accelerate the overall process [26]. Although these enhancements improved the efficiency of the process, they also introduced additional complexity, impacting its feasibility.

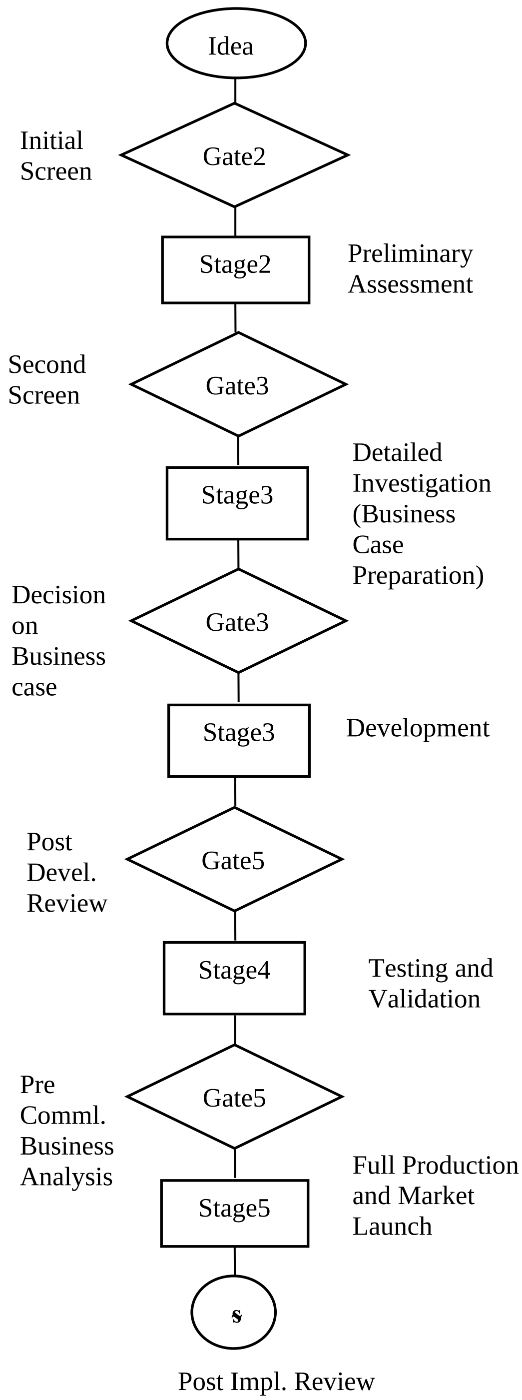

Fig. 2 Stage gate NPD process model

To address these challenges, Cooper developed variations that incorporated the "Fs." One such adaptation is the Stage-Gate Lite model, designed for moderate-risk projects such as line extensions or significant modifications. This version emphasizes flexible requirements, allowing stages to overlap before advancing to gate evaluations. Another variation is the Stage-Gate Xpress model, created specifically for projects involving minor changes or limited business impact.

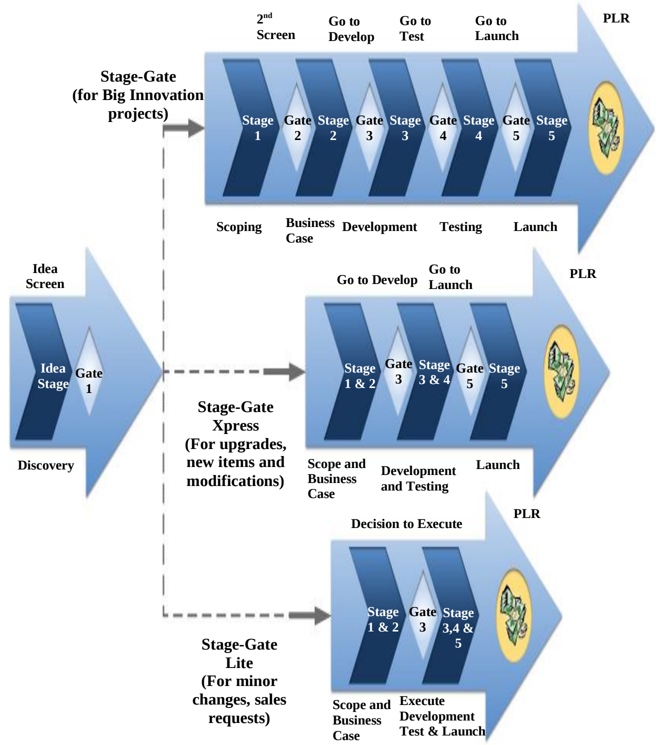

Fig. 3 Stage-Gate NPD process model for major, moderate and minor projects [61]

This streamlined approach is well-suited for marketing campaigns or addressing requests from the salesforce. In 2008, Cooper introduced the most basic form of the Stage-Gate process, as depicted in Figure 4. This simplified concept involves a sequence of stages for collecting new product development information, integrating data, and conducting investigations, followed by gates that serve as decision points. At each gate, resource allocation decisions are made to either continue or terminate the project. Based on Corning's strategy, the risk-oriented contingency framework for Stage-Gate procedures was first introduced by Kirk in 2013 and illustrated in Figure 5 [67].

This approach aims to reduce uncertainties and enhance risk management by gathering comprehensive data and information. Integrating a business model canvas approach into the Stage-Gate process creates a hybrid system that enables a tailored and adaptable process [42]. Cooper emphasizes that future generations of Stage-Gate processes must be more agile, flexible, dynamic, and accelerated while being leaner, faster, more adaptive, and focused on risk management. However, concerns about excessive bureaucracy and lengthy development timelines were recognized and addressed in the next generation of Stage-Gate systems. Although the basic structure of stages and gates remains the same, implementing these processes has evolved significantly from Cooper's original model. Figure 6 illustrates the spiral development stages as an innovative feature in the next generation Stage-Gate processes.

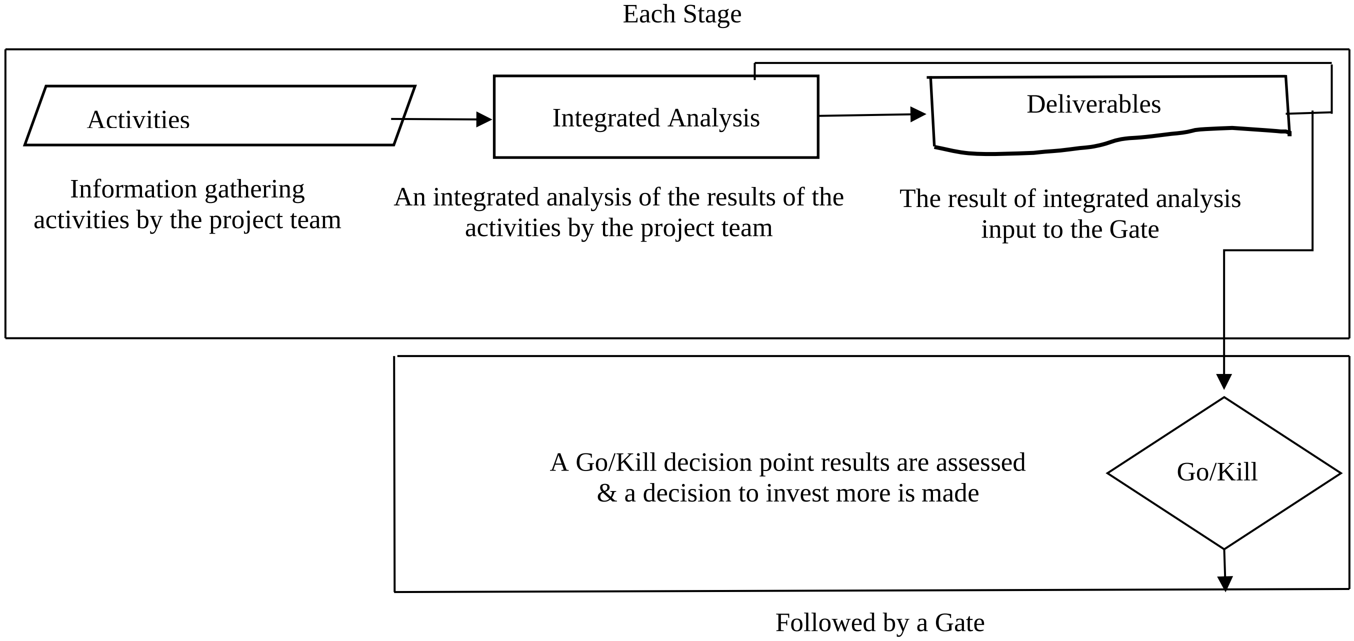

Fig. 4 The most fundamental form of a stage-gate process

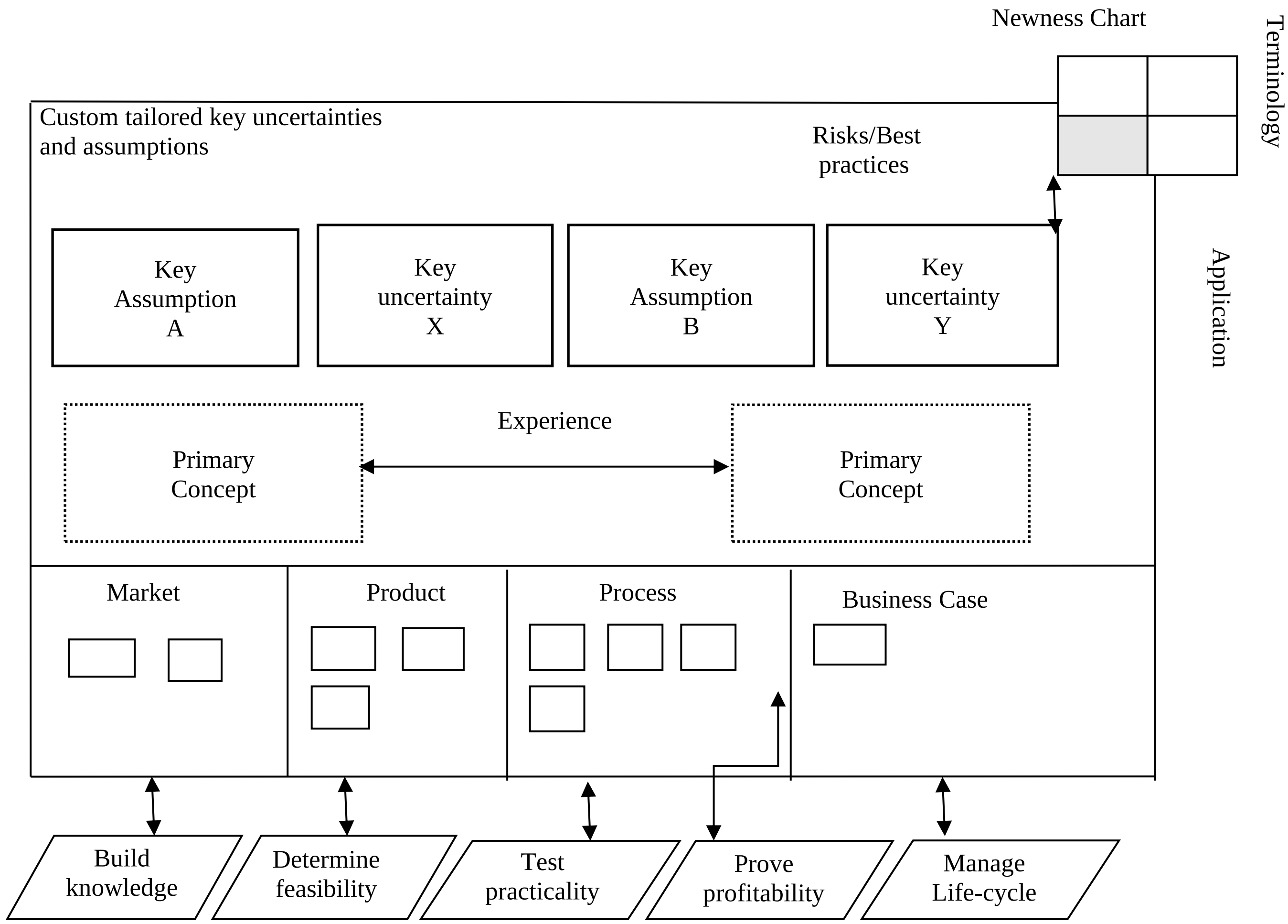

Fig. 5 Corning's risk-based contingency model

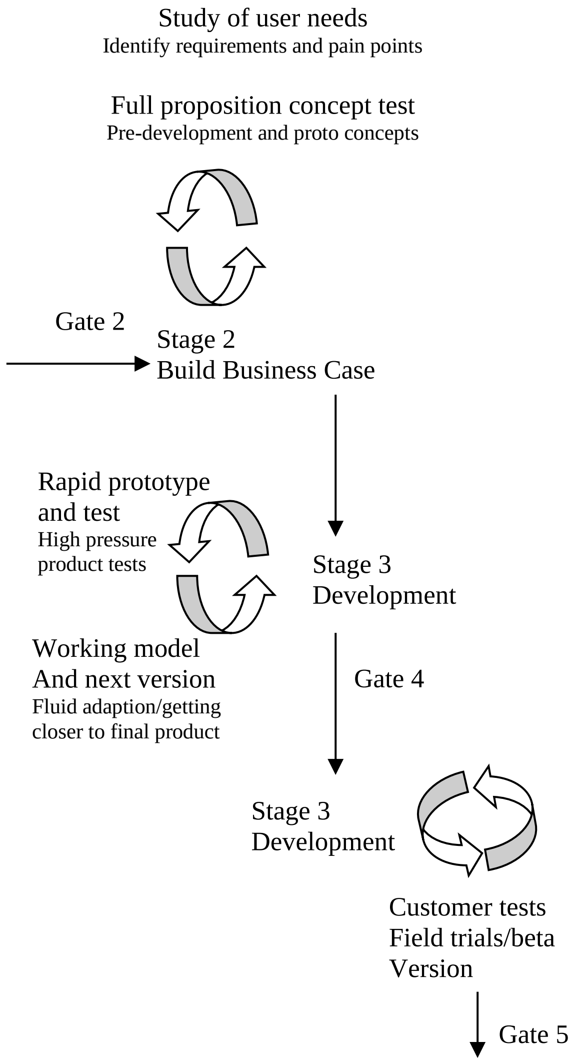

Fig. 6 Integration of spiral development phases in the Stage-Gate process

The spiral approach does not alter stages 1 and 5, which remain unchanged from the original model, and therefore, they are excluded from Figure 6 [78]. In 2014, Cooper integrated the previously developed methods into the Triple-A system, marking a significant advancement in idea-to-launch processes. The Triple-A system focuses on three key objectives: adaptivity (flexibility), agility, and acceleration, aiming to enhance the traditional Stage-Gate process. While the framework for managing NPD projects has remained consistent over time, variations in process specifics and goals have emerged. The Triple-A system is intended to serve as the foundational concept for future iterations of Stage-Gating systems. Originally designed for software development, agile methodologies have more recently been incorporated into traditional Stage-Gating approaches. This integration led to the creation of an Agile-Stage-Gate hybrid process in 2016 by Cooper and Sommer, as shown in Figure 7. After initial testing and adoption of hybrid processes in the manufacturing industry, several studies have highlighted positive outcomes.

These include improved focus and prioritization, increased team confidence, better alignment between procedures and systems, enhanced production, improved communication and management, and faster adaptation to changes [78]. The I2P3 process, developed by Evonik Creavis GmbH, was specifically tailored for the chemical industry. It includes a thorough evaluation of the entire industrial landscape. Additionally, the I2P3 process takes into account the three pillars of the triple bottom line: People (social factors), Planet (environmental factors), and Profit (economic factors). The complete I2P3 process, depicted in Figure 8, follows six stages similar to Cooper's original Stage-Gate process. It involves making well-informed decisions using a comprehensive set of categories and criteria that address all three dimensions of the triple bottom line, with a strong focus on sustainability. Gate decisions require a detailed evaluation and assessment of these dimensions [6].

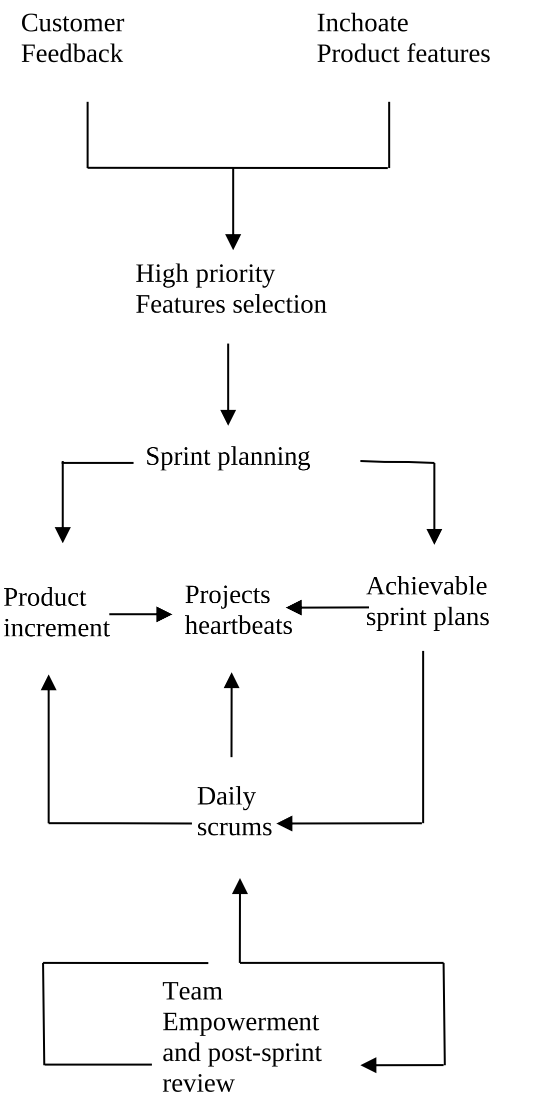

Fig. 7 Process and framework of agile–stage-gate hybrid processes

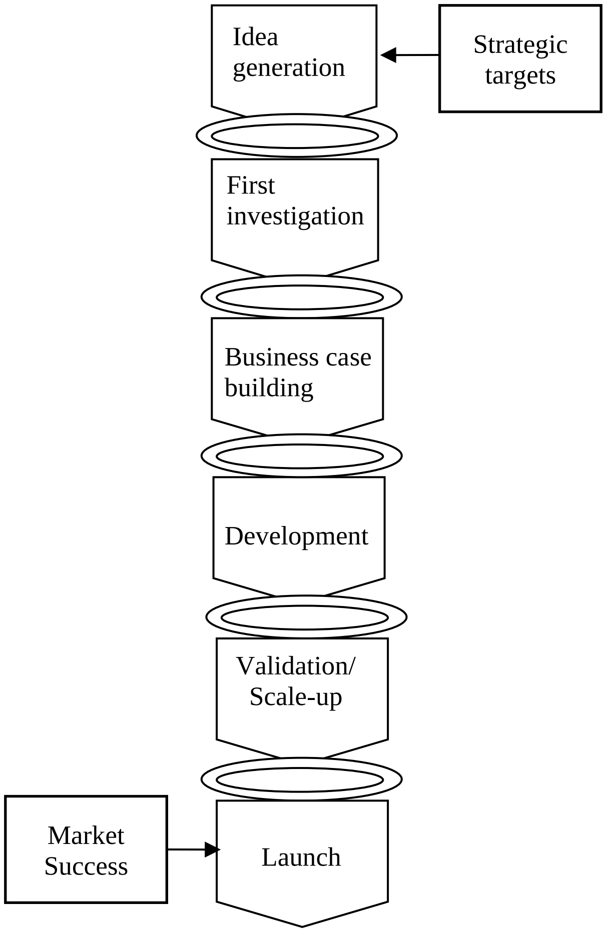

Fig. 8 Structure of the I2P3 process

2.3. Lean Startup Framework

Ries (2011) popularized the Lean Startup methodology, which encourages entrepreneurs to experiment with their target customers by creating a minimum viable product (MVP) to gather feedback. This approach allows entrepreneurs to make strategic adjustments based on the results of these tests, providing the flexibility to change direction if they find their current strategy is ineffective. The Stage-Gate system and Lean Startup share several similarities: both view entrepreneurship as a structured process, include conceptual product development, and, in the case of the NexGen Stage-Gate system, incorporate a procedure similar to the Build-Measure-Learn cycle.

Spiral development, an enhancement to the Stage-Gate process, mirrors the feedback loop of Build-Measure-Learn in Lean Startup. However, there are key differences between the two. The Lean Startup follows a continuous process, whereas Stage-Gate treats product launch as the final step. Lean Startup promotes multiple iterations, while the traditional Stage-Gate model offers only 'go' or 'kill' decisions. Incorporating spiral development in the NexGen system reflects the growing recognition of the cost-effectiveness of experimenting with digital technologies.

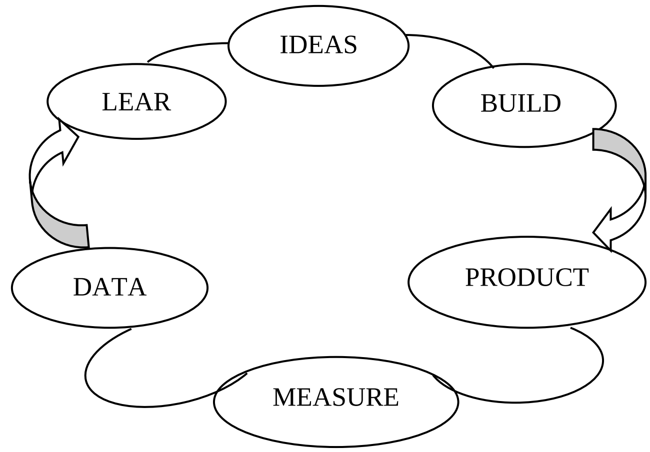

Fig. 9 Lean Startup NPD process framework

2.4. IDEO Framework

IDEO, a renowned design and innovation consultancy Kelley (1991), utilizes a human-centered design approach to develop new products. Although IDEO's framework does not follow a rigid structure, it generally includes key stages such as understanding and observing, visualizing and realizing, evaluating and refining, conducting detailed engineering, and maintaining collaboration with manufacturing during implementation. IDEO's approach emphasizes the value of iterative processes, continuous feedback, and collaboration among diverse teams throughout the design phase. This flexible framework encourages creativity, a focus on users, and rapid iterations, fostering innovation in new product development [86].

2.5. Ex-PD Framework

Drotar and Morrissey (2015) introduced the Exploratory Product Development (Ex-PD) strategy to revolutionize the product creation process. Ex-PD offers organizations a flexible and adaptable approach that moves away from the rigid phases of the phase-gate process, allowing them to better navigate the uncertainties in a constantly evolving market. The strength of Ex-PD lies in its ability to handle unbalanced and volatile markets, where uncertainty and risk are prevalent during product development. Ex-PD is grounded in the idea that unknown or not fully understood elements contribute to these uncertainties and risks. Its primary goal is to reduce these uncertainties by improving the understanding of what is unknown. Companies that can swiftly adapt to changes in the market, technological advancements, regulatory shifts, or the effects of globalization can minimize uncertainties and risks, ultimately leading to successful product outcomes. Ex-PD is recognized as a comprehensive and holistic methodology that considers the complex nature of product development. It highlights the importance of managing the process as an integrated system, incorporating key elements such as strategy, portfolio management, organizational structure, team dynamics, culture, performance metrics, market knowledge, customer insights, and process management.

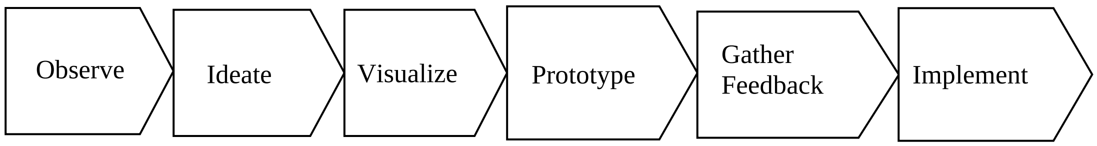

Fig. 10 IDEO NPD process framework

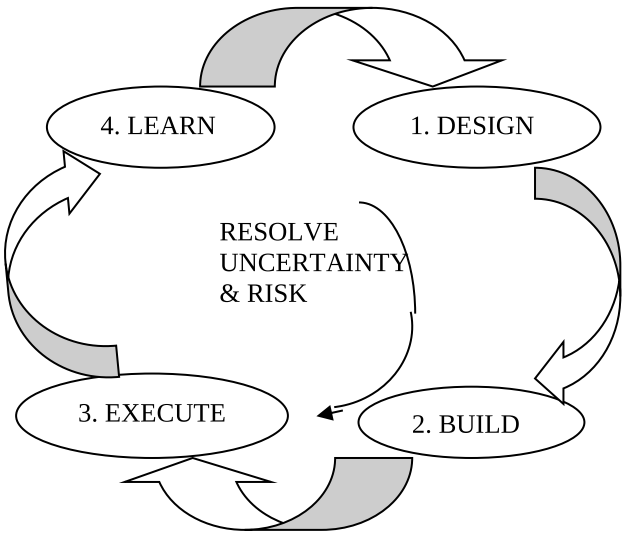

Fig 11. Ex-PD NPD process framework

To further support this strategy, Drotar and Morrissey developed the Product Risk Framework, a software tool that helps product development teams identify and effectively address the most significant uncertainties and risks throughout the development process.

3. Comparison of Selected NPD Process Frameworks

These five NPD process frameworks are compared across various aspects, including applicability, implementation process, decision-making, objectives, management, and costs, all critical for successfully executing new product development. These factors vary depending on the industry, company, product type, and market conditions. The information discussed about each of the five frameworks serves as the basis for comparing them against each of these aspects. The comparison reveals that these five NPD process frameworks are well-suited for new product development in Indian industries. The shared features of these frameworks that contribute to their suitability include:

- Involvement of additional stakeholders, such as clients, vendors, and subcontractors
- Facilitation of the simultaneous execution of tasks
- Focus on designers, engineers, and manufacturers
- Utilization of concurrent engineering tools and techniques

The comparison of these five NPD frameworks is shown in Table 2. The Stage-Gate framework serves as an organizational tool for product development, enabling the measurement and management of efforts to facilitate informed decision-making while mitigating financial risks and missed opportunities [87]. This process is structured into sequential stages with specific activities, deliverables, and decision points designed to manage risk and ensure progress. By emphasizing thorough upfront planning, the model establishes clear objectives, scope, budgets, and timelines. A survey by Griffin (1997) revealed that 60% of U.S. companies employ a structured, cross-functional Stage-Gate methodology for New Product Development (NPD), while 38.5% lack any formal NPD process [74]. Further independent studies by innovation consulting firms have concluded that 70-85% of leading U.S. organizations utilize the Stage-Gate model to manage the process from ideation to product or service launch [9]. Major corporations like Procter & Gamble, Emerson Electric, ITT, 3M, Tata Motors, Ford and M&M have implemented and benefited significantly from this approach [82]. The Stage-Gate model offers a systematic approach to transforming ideas into market-ready products, acting as a "blueprint for managing the new product development process to enhance efficiency and effectiveness" [64]. A distinctive feature of this model is its integration of customer feedback at nearly every stage. While widely regarded as valid, the Stage-Gate model has undergone scrutiny in product development literature over two decades [10].

Since its introduction 40 years ago, leading firms have refined the model, incorporating techniques like Value Stream Mapping to eliminate bureaucracy and adopting concurrent and parallel processes [65]. Despite its strengths, the model has limitations. Buggie (2002) contends that the model is unsuitable for new product development and should only serve as a milestone control tool. The gates' emphasis on identifying flaws may discourage radical innovation. Furthermore, the model's linearity and lack of rapid feedback mechanisms pose challenges, especially in fast-moving market environments. Thomke (2003) highlights the necessity of rapid feedback, while Kline and Rosenberg (1986) stress the importance of iterative feedback throughout the innovation process. Cooper has acknowledged these critiques and suggested optimizations to address these issues [63]. Becker (2006) notes that a narrow model interpretation leads to suboptimal outcomes. Gates are intended to ensure sound business decisions and prevent flawed products from reaching the market. It focuses primarily on internal organizational factors and follows a linear process from exploration to commercialization [49]. Critics like Munoli (2017) argue that the model prioritizes managerial and business needs at the expense of technical experimentation, innovation, and creative problem-solving. Drotar and Morrissey (2015) identified six significant drawbacks of the Stage-Gate approach:

- The process may encourage superficial completion of documentation without meaningful reflection.
- Standardization overlooks the unique characteristics and risks of individual projects.
- Managing multiple process paths for different project types (e.g., new products, revisions, or experimental technologies) is complex.
- The extensive activities and documentation can create a false sense of security.
- The rigid structure hinders adaptability to market or technological changes.
- The phased structure introduces delays due to batching in activities and gate reviews.
- This structured approach is better suited to companies operating in stable environments requiring clear guidance and organization [47]. Many critiques arise from improper implementation rather than the model itself, emphasizing the importance of correct application for success [87].

Over the years, numerous detailed models for New Product Development (NPD) have been introduced, with the Booz, Allen, and Hamilton (BAH) model, published in 1982, being one of the most notable. This model, often considered the foundation for subsequent NPD systems, encompasses the fundamental stages commonly referenced in the literature [53]. As one of the earliest NPD models, the BAH framework continues to be utilized by companies today. Its significance lies in its role as the basis for later models, which can often be directly traced back to it. The BAH model provides a structured and balanced approach, making it applicable to various traditional industries. However, as an older framework, it lacks the detailed stage definitions and checkpoints found in more contemporary models. Additionally, it emphasises less formal decision-making points and continuous cross-functional collaboration, reflecting its linear nature. While systematic, the BAH framework does not deliver the same level of rigor in documentation and compliance compared to newer methodologies. The Lean Startup methodology, popularized by Ries (2011), emphasizes experimentation to help entrepreneurs identify their customer base. A key aspect of this approach involves creating a Minimum Viable Product (MVP) to gather customer feedback. Unlike traditional models, Lean Startup follows an open-ended process and encourages iterative development. Similarly, the Stage-Gate system shares the objective of efficiently bringing new products to market. Inspired by practices from the software industry, particularly Agile Development, Lean Startup promotes an iterative and incremental approach to product creation [33]. This method aims to minimize wasted effort and time throughout the development process [73]. Lean Startup emphasizes rapid experimentation, which can accelerate development but may not be ideal for all companies, particularly those with a lower tolerance for risk.IDEO, a prominent product development company, was founded in 1991 by merging three companies: David Kelley Design, ID Two, and Matrix Product Design. Recognized as one of the world’s leading design firms, IDEO has received more awards than most other firms in the industry.

Table 2. Comparison of five macro-categories NPD frameworks

Aspects	Stage-Gate System Cooper (1990)	Lean Start-Up Ries (2011)	IDEO David Kelley (1991)	BAH Booz, Allen &Hamilton (1982)	Ex-PD Mary Drotar and Kathy Morrissey (2015)
Applicability	Well-funded, established companies with diverse product lines thrive in stable market conditions.	Entrepreneurs, intrapreneurs, governmental bodies, and emerging businesses	IDEO offers design services to clients across diverse sectors, spanning medical, computer, retail, food, and automotive industries in both public and private domains.	The luxury industry, in particular, merits distinctive attention and focus.	Ex-PD is better suited for product development in volatile and unpredictable markets.
Process	Divided into typically five stages- 1. Initial inquiry, 2. Thorough examination, 3. Development,	It begins with the entrepreneur's vision, taking a leap of faith. The Build-Measure-Learn approach is embraced to test	IDEO structured the product development process into five key steps: 1.Understanding/ Observing,	The BAH model unfolds in seven steps: 1. New product strategy, 2. Idea generation, 3. Screening, 4. Business	The Ex-PD approach comprises three interconnected segments within its process: strategy, Idea generation and selection, and Explore

	4. Testing and Validation, 5. Production and Launch of the product undergo progressive development and refinement at each step.	fundamental assumptions or hypotheses. The product undergoes continual modifications based on frequent and early customer feedback.	2.Visualizing/ Realizing, 3.Evaluating/ Refining, 4. Implementing/ Detailed Engineering, and 5.Implementing/ Manufacturing Liaison.	analysis, 5. Development, 6. Testing, and 7. Commercialization.	and Create.
Decisions	Following each stage, senior managers make a pivotal decision to either proceed or halt the project (Go/Kill).	Choose to persist or pivot. Should the hypotheses prove incorrect, iterate on the project and test refined hypotheses. If rejected, alter the strategy—this shift is referred to as pivoting.	Prototyping and brainstorming stand as crucial approaches in the product development process. Brainstorming sessions assist the project team in generating and finalizing solutions.	The feedback obtained from testing offers nonprofit executives an additional chance to prepare their products for market entry.	Ex-PD assumes that the product team lacks sufficient knowledge or awareness of the factors contributing to uncertainty and risk.
Goal	Efficiently and effectively launch a polished final product.	Launch a product to validate your assumptions, refine it using feedback, and minimize the wastage of both time and capital resources.	IDEO encourages designers and engineers to rapidly produce prototypes, focusing on various small project sections.	Reducing risk can lead to assured long-term growth and eventual profitability through new product introductions.	Ex-PD's main objective is to diminish uncertainty and risk by minimizing the unknown factors.
Management	A gatekeeper, someone with a vested interest in the product but not directly managing it, determines each gate.	Owners usually double as project managers, with no specifically assigned gatekeepers. Decisions hinge on customer responses to the Minimum Viable Product (MVP).	The IDEO project team regularly convenes client meetings to gather and incorporate their feedback.	A consistent framework that centers on a comprehensive 360° vision, particularly led by an initial stage dedicated to strategy, allows the process to engage with external networks and the environment.	Ex-PD is characterized as a dual-focused, integrated systems approach that requires holistic management, integrating vital elements: strategy, portfolio management, organization/teams/ culture, metrics, market/customer understanding, and process.
Expense	Costs rise with each subsequent gate; generally, the product doesn't generate revenue during its development phase.	As the product scales up, expenses grow, but there's a simultaneous revenue generation during the process.	Costs escalate with rapid prototyping. Generally, the product doesn't yield revenue during its development phase.	Costs rise at each stage. Generally, the product doesn't produce revenue during its development.	Costs escalate with each stage. Generally, revenue isn't generated during the product's development phase.

The company has grown rapidly over the past several years, employing over 660 professionals from various disciplines. IDEO collaborates with organizations across both public and private sectors, helping them adopt innovative design approaches to drive growth. Its notable clients include Apple Inc., AT&T, Coca-Cola, Microsoft, Steelcase, PNC Financial Services, and Palm. The company's success is largely attributed to its use of design thinking, a consumer-centric approach focused on understanding and fulfilling user needs. By prioritizing the consumer, IDEO has become a leader in innovation. However, its flat organizational structure has introduced challenges, such as placing significant responsibilities on project leaders and making it difficult to manage team members effectively. This is particularly challenging because team members often come from diverse disciplines and disband after project completion [86].

IDEO's design thinking methodology is especially well-suited for creative industries centered on user experience and iterative design. It offers flexibility and adaptability but may lack the same emphasis on formal evaluations, documentation, and traceability. While IDEO's process fosters creativity through interdisciplinary collaboration, it does not provide the same level of structured progression as some other methodologies. Similarly, while frameworks like Lean Startup, IDEO's design thinking, and Ex-PD prioritize adaptability, they may require additional efforts to align with regulatory requirements. Ex-PD is a dynamic approach designed to minimize the risk of product failure by identifying and addressing key risks early and throughout the development process.

By prioritizing activities that target the most critical risks and eliminating unnecessary tasks and documentation, Ex-PD accelerates product development. This approach adapts to the unique needs of each project as it evolves, offering both speed and efficiency. Ex-PD employs a two-fold strategy to enhance product development. First, it views the process as an integrated system with interconnected elements. Second, it fundamentally redesigns the development process to reduce uncertainties and risks while leveraging new information. By identifying and addressing risks at the outset and continuously throughout the project, Ex-PD minimizes uncertainty and uncovers unique, project-specific challenges. Key benefits of Ex-PD include [47]:

- Increased speed
- Flexibility and adaptability
- Alignment with strategic goals
- Effective risk mitigation
- Customer-focused product development
- Real-time prioritization and resource optimization
- Rapid learning from uncertainties and early termination of unviable projects
- Reduced bureaucracy and paperwork
- Enhanced decision-making through empowered teams.

However, while Ex-PD mitigates risks through adaptive strategies, the absence of formal gate reviews can result in less structured risk management. The flexible nature of Ex-PD may also lead to less detailed documentation, posing challenges for regulatory compliance. Although its adaptability and agility are significant strengths, Ex-PD might struggle with predictable timelines and outcomes, complicating resource planning and project management.

Moreover, the simultaneous exploration of multiple paths can spread resources thin, potentially diluting focus and effort, particularly in environments with limited resources. Various NPD frameworks explained above offer distinct advantages and limitations, making them suited to different organizational needs and industries. The choice of framework depends on the industry, company size, project complexity, and the need for innovation or control. Effective application of these models can significantly improve NPD outcomes, but their successful implementation requires careful alignment with organizational needs and project goals.

4. Dimensions of New Product Development

The success of New Product Development (NPD) using process frameworks involves multiple interconnected dimensions, including strategy, research, commercialization, processes, project climate, company culture, and metrics with performance measurement. Best practice studies often highlight the practices of high-performing companies, as observed by researchers. Extensive research has been conducted on NPD practices and dimensions. Loch (2000) examined NPD practices across dimensions such as customer focus, demand-driven innovation, cross-functional collaboration, top management support, the presence of a champion, and the effective execution of a defined process with formal measurement. Cormican and O'Sullivan (2004) emphasized dimensions like strategy and leadership, culture and climate, planning and selection, structure and performance, and communication and collaboration.

Similarly, Dooley et al. (2002) categorized NPD into four dimensions: strategic implementation (covering project selection, goals, product strategy, and customer involvement), process control (encompassing metrics, documentation, and execution control), enhancing human resources, and improving the early stages of NPD. Cooper and Kleinschmidt (1995) outlined nine best practice dimensions, including NPD process, strategy, resource allocation, senior management commitment, strategic alignment, team composition, and organizational structure.

More recently, Kahn et al. (2006) proposed six areas for best practices: strategy, portfolio management, process, market research, people, and performance evaluation. This framework was further refined using a Delphi methodology with 20 NPD experts, resulting in seven key dimensions: strategy, process, research, project climate, company culture, commercialization, and metrics and performance measurement [37]. The Kahn and Barczak (2007) framework was selected for this research due to its comprehensiveness and validation through the Delphi method. The framework's inclusivity has been supported by benchmarking studies, such as the Product Development Management Association (PDMA) Comparative Performance Assessment Study by Adams Bigelow (2004) and the American Productivity Quality Center's NPD best practices research by Cooper et al. (2002, 2004).

As a result, it is regarded as a relevant and current framework within the evolving field of NPD. Nicholas and Ledwith (2011) examined NPD best practices from a practitioner's viewpoint, finding that strategy is considered the most critical aspect of NPD success regardless of company size, while metrics and performance evaluation are seen as the least important.

This contrasts with previous findings highlighting excellence in the NPD process as the primary driver of success. The seven dimensions critical to NPD success, shaped by benchmarking studies, aim to guide companies in adopting and sustaining effective NPD frameworks [25, 46, 63, 68, 69,70].

These dimensions include:

- Strategy: Establishing vision and direction for R&D, technology management, product lines, and projects while prioritizing, selecting, and allocating resources.
- Research: Leveraging methods like focus groups, surveys, and ethnographic studies to understand customers, competitors, and market trends, driving innovation.
- Commercialization: Activities focused on marketing, product launches, and post-launch monitoring to ensure customer adoption and market growth.
- NPD Process: Implementing structured stages, gates, and knowledge management systems to guide product development.
- Project Climate: Fostering team integration and collaboration through effective leadership, motivation, and human resource practices.
- Company Culture: Emphasizing management values that support NPD strategies and collaboration with external stakeholders, such as customers and suppliers.
- Metrics and Performance Measurement: Tracking and assessing the progress of NPD projects and the overall effectiveness of programs.

Given the significance of the New Product Development (NPD) process, it is essential to define the dimensions precisely, considering its unique activities and developmental phases. For each dimension delineating new product development success, the characteristics are identified as shown in Table 3. To evaluate the New Product Development (NPD) process framework and its key dimensions, two criteria matrices were created to form the basis for the NPD audit. The first matrix consisted of five selected NPD process frameworks, while the second matrix outlined seven dimensions crucial for NPD success. NPD company experts evaluated each matrix and assigned perceived scores using the scale matrix provided in Table 4. The feedback from the respondents was then used as input for the Analytic Hierarchy Process (AHP), which was executed using MS Excel 2013.

The Excel workbook used for the AHP process includes 20 input worksheets for conducting pair-wise comparisons. It also contains a sheet to consolidate all judgments, a summary sheet to present the final results, and additional sheets with reference materials, such as the random index, Geometric Consistency Index (GCI) limits, and judgment scales. Lastly, a dedicated sheet for solving the eigenvalue problem using the Eigenvector Method (EVM). Further details about the AHP process and how the AHP template is applied are provided in the following sections.

5. An Analytic Hierarchy Process for NPD Process Framework Assessment

This section uses the Analytical Hierarchy Process (AHP) methodology to assess the most effective NPD process framework. Through an exploratory study, it illustrates how decision criteria can be ranked and scoring guidelines developed to evaluate the NPD process framework.

5.1. AHP Approach and NPD Study

The use of Multiple Criteria Decision Analysis (MCDA) methods, such as the Analytic Hierarchy Process (AHP), has proven valuable in addressing real-world decision-making challenges in business and management. Applying a Multi-Criteria Decision-Making (MCDM) approach typically involves three key steps: (1) identifying criteria and alternatives, (2) assigning weights to the criteria and prioritizing alternatives, and (3) synthesizing the results.

Developed by Thomas L. Saaty, AHP is a mathematical method designed to handle complex decision problems involving multiple criteria, and it is widely recognized across various domains [4, 79, 80]. Several studies have applied the AHP method in New Product Development (NPD).

For instance 2010, Pun et al. used AHP to evaluate NPD performance, while Klos (2015) applied AHP in ERP-based decision support systems for NPD. In their model, AHP was used to assess new products and select the best option using ERP/PLM data. Calantone et al. (1999) highlighted AHP as a highly effective theoretical approach for screening new products. Additionally, Salgadoa et al. (2012) successfully utilized AHP to prioritize NPD activities in electronics manufacturing.

Table. 3 Characteristics of NPD dimensions

Dimensions	Characteristics
Strategy	A process is created to facilitate portfolio management.
	NPD goals that are clearly outlined and visible across the company.
	The company perceives NPD as a long-term strategy.
	The mission and strategic plan support defining strategic arenas for new opportunities.
	The goals of New Product Development (NPD) are evidently in sync with the company's mission and strategic blueprint.
	Projects within a portfolio that adhere to the New Product Development (NPD)strategy.
	Regular assessments are conducted for NPD projects and programs.
	Continuous opportunity identification allows for real-time adjustments to the strategic plan, responding promptly to market forces and emerging technologies.
	Projects are systematically ranked or prioritized based on certain criteria.
	Careful consideration is given to balancing the quantity of projects with the available resources at hand.
Research	Consistent execution of concept, product, and market testing is a standard expectation for all NPD projects.
	The emphasis on research is substantial whenever market research is conducted.
	The involvement of customers/users is fundamental to the New Product Development (NPD) process.
	Examinations of customers and users centre on both present and future needs and challenges they encounter.
Commercialization	Decisions regarding the marketing budget remain unchanged until the point of launch.
	The launch team comprises members from various functions or departments, fostering a cross-functional setup.
	Decisions spanning manufacturing, logistics, marketing, and sales are made by cross-functional teams.
	A post-launch project review meeting occurs following the introduction of the new product.
	Commercialization is an integral formal component within the NPD (New Product Development) process.
NPD Process	Distinct and predetermined criteria for Go/No-Go decisions are established for every review gate.
	The NPD process is designed to be flexible and adjustable, tailored to accommodate each specific project's requirements, scale, and risk profile.
	The NPD process is transparent and thoroughly documented.
	All NPD personnel can access suitable hardware, software, and technical support within the IT infrastructure.
	An established and transparent NPD process is in place.
	Reviews of projects occur upon completion.
Project Climate	Each project is backed by a central cross-functional team that stays committed to the project from start to finish.
	Each project designates a project leader for each stage, who can be easily identified.
	Formal and informal communication channels coordinate NPD activities across functional areas.
	NPD personnel are involved in only one project at a time
Company Culture	The NPD process is endorsed by senior management.
	The company collaborates closely with clients to create innovative solutions.
	NPD's Innovation ideas originate from internal and external sources within the organization.
	Management's main focus is not on operational efficiency and cost reduction.
Metrics & Performance Measurement	Established measures are in place to assess NPD projects uniformly.
	Consistent criteria are available to evaluate the entire NPD effort uniformly.
	The evaluation of all NPD projects is conducted stage by stage by the Cross-Functional Team (CFT).

Steinberg and Wall (2013) applied AHP to help prioritize features difficult to quantify in product development. Schiraldi et al. (2013) used AHP to examine customer preferences for prioritizing product needs in NPD projects. The literature strongly suggests that AHP is a preferred method for capturing expert judgment in ranking NPD frameworks and dimensions. Due to its flexibility and ease of use, AHP can be effectively implemented in NPD studies using spreadsheet programs such as MS Excel [28]. The AHP model's mathematical formulation is carried out using a matrix. The pairwise comparisons of these elements will create a comparison matrix. Pairwise comparisons are performed for all criteria, starting from the top level of the hierarchy. These criteria form the foundation for conducting the pairwise comparisons. Following these guidelines, an AHP framework was established to support the study [52]. Despite its popularity, AHP has several limitations and potential biases, particularly concerning assigning weights to different criteria. AHP relies on pairwise comparisons, and this comparison is inherently subjective. It can vary based on the decision-maker's perspective, leading to inconsistencies in the final weight assignments, which can affect the accuracy of the derived weights. Non-monotonic behaviour related to the rank reversal phenomenon can undermine the stability and reliability of the decision-making process. AHP also involves various biases, such as equalizing, anchoring, overconfidence, and cognitive bias. To mitigate these limitations and biases, it is essential to involve multiple stakeholders in the decision-making process, provide training to enhance judgment accuracy and employ sensitivity analysis to assess the robustness of the results. The process involved the following steps:

- Define the objective or goal.
- Identify the criteria relevant to selecting an NPD process framework.
- Determine the alternatives.
- Develop a hierarchical structure for analysis.
- Gather empirical data and information.
- Conduct pairwise comparisons for each level of criteria.
- Perform a consistency check.
- Compute the global weights for each criterion.
- Integrate the results.
- Conduct sensitivity analysis.
- Finalize the ranking of the proposed alternatives.

5.2. Methodology

The criteria matrix for evaluating the five selected NPD frameworks and seven dimensions can be framed as a Multi-Criteria Decision-Making (MCDM) problem. To implement the AHP approach, a flexible AHP spreadsheet template developed by Goepel (2013) using MS Excel is utilized.

The following steps outline how to operate the AHP Excel template and interpret the results:

1. Open the Excel file titled "AHPcalc version dd.mm.yy.xls."
2. Navigate to the "Summary" worksheet.
3. Input values in the green fields as follows:
   - "n=" for the number of criteria (2-10)
   - "Scale" (default value: 1)
   - "N=" for the number of responders (1-20)
   - Alpha (α) threshold for accepting inconsistency (recommended value: 0.1)
   - "p" for the selected participant (default is "1")
   - Consensus (default is "100%")
   - Objective (text field for project/category description)
   - Author (optional, text field)
   - Date (optional, date format)
4. In the table, input the criteria names and any related comments for each criterion.
5. Go to the "In1" worksheet:
   - Enter the name of the decision maker/respondent.
   - Assign a weight for evaluation and include the date.
   - The scale assigned by all responders will be entered into the corresponding input worksheets, such as "In1," "In2," "In3," and so on.
   - The priorities derived from the pairwise comparisons will be displayed on each input sheet using the Row Geometric Mean Method (RGMM).
   - The integrated decision matrix, combining all contributors, is calculated by determining the weighted geometric average of each participant’s contributions.
   - The final computation using the Eigenvector Method (EVM) will be displayed only in the summary sheet.

For the pairwise comparisons, the scale matrix is established as outlined in Table 4, where the criteria are evaluated using a five-point scale: 1 for Equal Importance, 3 for Moderate Importance, 5 for Strong Importance, 7 for Very Strong Importance, and 9 for Extreme Importance.

Table. 4 Scale matrix for defining pairwise comparisons

Scale	Definition	Explanation
1	Equal importance	The objective is equally influenced by two elements
3	Moderate Importance	One element is slightly favoured over another based-on experience and judgment.
5	Strong Importance	One element is greatly preferred over another based-on experience and judgment.
7	Very Strong Importance	One element exhibits a significantly higher preference than another, as evidenced by its clear dominance in practical applications.
9	Extreme Importance	The proof supporting one element over another is of the utmost confirmation level.

Table. 5 First Criteria matrix for assessing NPD process Framework

Criteria A	Criteria B
(1) Stage Gate	(1.1) BAH (1.2) Lean Startup (1.3) IDEO (1.4) Expd
(2) BAH	(2.1) Lean Startup (2.2) IDEO (2.3) Expd
(3) Lean Startup	(3.1) IDEO (3.2) Expd
(4) Lean Startup	(4.1) Expd

Two criteria matrix tables are defined and used to collect empirical data. The first criteria matrix included selected five NPD process frameworks shown in Table 5, and the second criteria matrix includes seven dimensions delineating new product development success shown in Table 6. The criteria matrix for defining pairwise comparisons is shown in Table 7. For example, the respondent has to provide the importance between the criteria and the scale of importance. The initial evaluation involves comparing criterion 1 with criterion 2. Within the penultimate column, the participant must choose between A (indicating that criterion 1 is more significant than 2) or B (indicating that criterion 2 is more significant than 1). In the final column of the chart, the participant indicates the degree of importance - the extent to which criterion 1 surpasses criterion 2 or vice versa. Valid inputs are integers from 1 to 9, as defined in the scale matrix. The process is repeated for all pairwise criteria comparisons. The structured form was developed to seek the inputs form the NPD experts for pairwise comparison. The initial section gathers fundamental background details regarding the industry and participants, while the subsequent section gathers feedback from the participants based on the scale matrix, which includes important measures of NPD process frameworks and NPD dimensions.

Table. 6 Second criteria matrix for assessing the best NPD dimension

Criteria A	Criteria B
(1) Strategy	(1.1) Research (1.2) Commercialization (1.3) NPD Process (1.4) Project Climate (1.5) Company Culture (1.6) Metrics and performance measurement
(2) Research	(2.1) Commercialization (2.2) NPD Process (2.3) Project Climate (2.4) Company Culture (2.5) Metrics and performance measurement
(3) Commercialization	(3.1) NPD Process (3.2) Project Climate (3.3) Company Culture (3.4) Metrics and performance measurement
(4) NPD Process	(4.1) Project Climate (4.2) Company Culture (4.3) Metrics and performance measurement
(5) Project Climate	(5.1) Company Culture (5.2) Metrics and performance measurement
(6) Company Culture	(6.1) Metrics and performance measurement

Table. 7 Criteria matrix for defining pairwise comparisons

Sr No	A	B	A OR B (More Importance?)	Scale (1-9) (Comparison over A VS B)
1	Criteria 1	Criteria 2		
		Criteria 3		
		Criteria 4		

Table 8. Profile of respondents

Sr. No	Position	Type of Industry	Sector of company	Product Type
1	Retired Manager	Multi National	Automobile/Ancillaries	Highly standardized
2	VP	Domestic Private	Electrical & Electronics	Standard with custom options
3	Manager	Domestic Private	Automobile/Ancillaries	Highly standardized
4	Manager	Domestic Private	Automobile/Ancillaries	Standard with custom options
5	CEO	Domestic Private	Others	Highly customized
6	GM Plant Head	Domestic Private	Automobile/Ancillaries	Highly standardized
7	Plant Head	Domestic Private	Automobile/Ancillaries	Highly standardized
8	Director	Multi National	Others	Standard with custom options
9	Manager	Multi National	Automobile/Ancillaries	Highly standardized
10	Manager	Domestic Private	Automobile/Ancillaries	Standard with custom options

5.3. Sensitivity Analysis in AHP

The outcome of the AHP method is represented as criteria weights that align with the decision-makers interests and the consistency of the provided comparisons. The determination of the weight for each interest must be logically justifiable. Given the variety of interests, the criteria weights for each decision maker may differ based on their specific conditions.

Sensitivity analysis in AHP is a technique used to evaluate how variations in the input data, such as criteria weights, pairwise comparisons, or decision-maker preferences, impact the final ranking or prioritization of alternatives. This analysis helps decision-makers assess the robustness of their choices and the influence of uncertainties in their judgments [45]. In this paper, the objectives of sensitivity analysis in AHP are:

- Robustness Check: Ensures that small changes in input weights do not significantly alter the final decision.
- Understanding Impact: Identifies which criteria or inputs most influence the outcome.
- Decision Confidence: Increases confidence in the selected alternative by confirming its stability under varying conditions.
- Exploration of Scenarios: Simulates different scenarios by modifying criteria weights or alternatives to reflect changes in circumstances.

Types of sensitivity analysis in AHP include Weight Sensitivity, Pairwise Comparison Sensitivity, Criteria Addition/Removal Sensitivity, and Alternative Sensitivity, each evaluating how weight changes, comparisons, criteria, or alternatives affect decision rankings. Methods for performing sensitivity analysis in AHP include Graphical Sensitivity Analysis for visualizing the effects of weight changes, Scenario Analysis for simulating "what-if" scenarios, Automatic Weight Adjustment using computational tools, and Threshold Analysis to identify critical weight thresholds that influence rankings.

The steps involved in conducting sensitivity analysis in AHP are defining the decision model, calculating initial priorities, performing baseline ranking, systematically varying parameters, observing changes in rankings, and interpreting the results to assess decision robustness. Sensitivity analysis is a crucial element of the AHP process, as it improves decision-making by providing insights into result stability and highlighting the impact of key criteria or judgments. By utilizing sensitivity analysis, decision-makers can ensure more reliable, informed, and robust outcomes. Generally, the steps in this method are as follows [31].

- Prepare the decision matrix
- Determine the criteria weight
- Normalizing the value of the criterion for the alternative
- Determine the alternative rank

$$V_i = \sum_{j=1}^{n} W_j R_{ij}$$

Where: Vi = rank for each alternative, Wj = weight value of each criterion, Rij = normalized performance rating value. A larger Vi value indicates that alternative Ai is preferred.

6. Result and Discussion

The selected responders (Table 8) went through the defined criteria matrix (Table 7), where criteria are selected NPD process frameworks and seven dimensions of NPD (Tables 5 and 6). They provided the importance between criteria and the scale of importance referring to Table 4. The scale assigned by all ten responders is then used as input for the AHP template worksheet, where each input sheet shows the resulting priorities separately for each criterion of NPD process frameworks and NPD dimensions. The final calculation using the Eigen Vector Method (EVM) is shown in the summary sheet separately for the NPD process framework and NPD dimensions, as shown in Tables 9 and 10.

Table 9. Summary sheet for NPD frameworks

AHP Analytic Hierarchy Process (EVM multiple inputs)			
n=	5	n=Number of Criterion N=Number of Participants	
N=	10		
P=	0		
Scale=	1		
α=	0.1		
Objective	Calculate Weight with Pairwise Comparisons		
Author	BGS		
Table			
Sr No	Criterion	Weight	+/-
1	Stage Gate	60.5%	14.7%
2	BAH	10.3%	1.4%
3	Lean Startup	15.9%	2.8%
4	IDEO	4.6%	1.6%
5	Ex-PD	8.8%	0.7%
Result			
Lambda=	5.093	Eigenvalue (Lambda) Psi= Ordinal Inconsistency MRE=Mean Relative Error CR= Consistency Ratio GCI=Geometric Consistency Index	
Psi=	0.00%		
MRE=	21.90%		
GCI=	0.08		
CR=	2.10%		

For consistency check of the model as per the summary sheet shown in Tables 9 and 10, consistency and safety indices such as Consistency Ratio (CR), Geometric Consistency Index (GCI), Eigenvalue (Lambda), Ordinal inconsistency (Psi) and Mean Relative error (MRE) are calculated. Saaty (1994) proposed the thresholds 5% for n = 3, 8% for n = 4 and 10% for n > 4 and Aguaron and Moreno-Jimenez (2002) proposed GCI = 0.31 for n = 3, GCI = 0.35 for n = 4 and GCI = 0.37 for n >4. According to Saaty, the acceptable degree of inconsistency is if CR is smaller or equal to threshold 0.10.

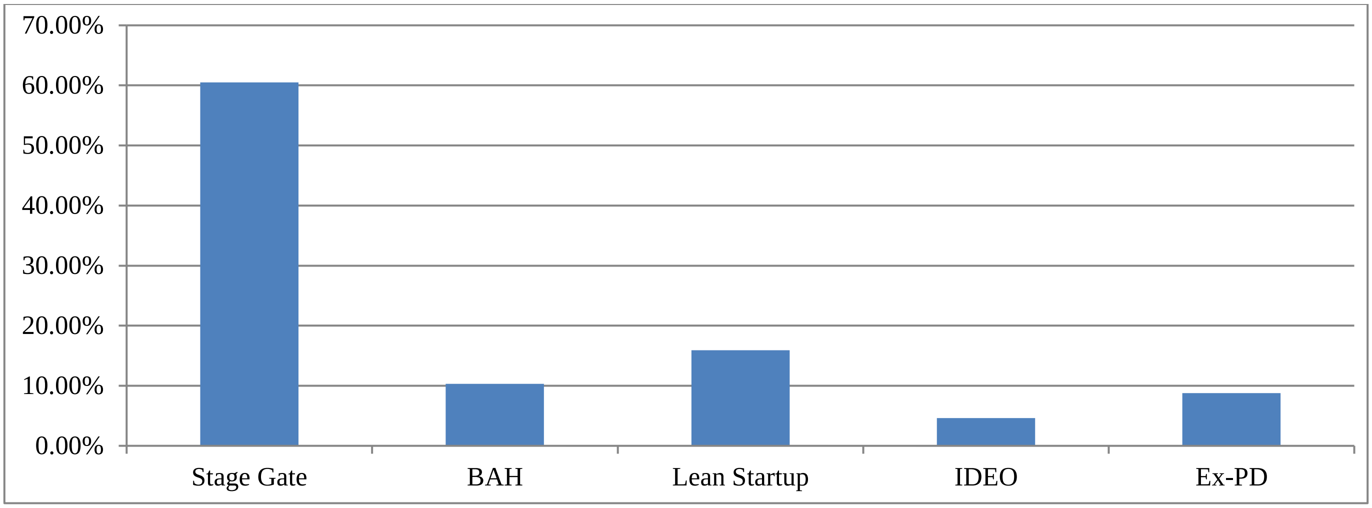

Fig. 12 Pairwise comparisons for NPD Frameworks

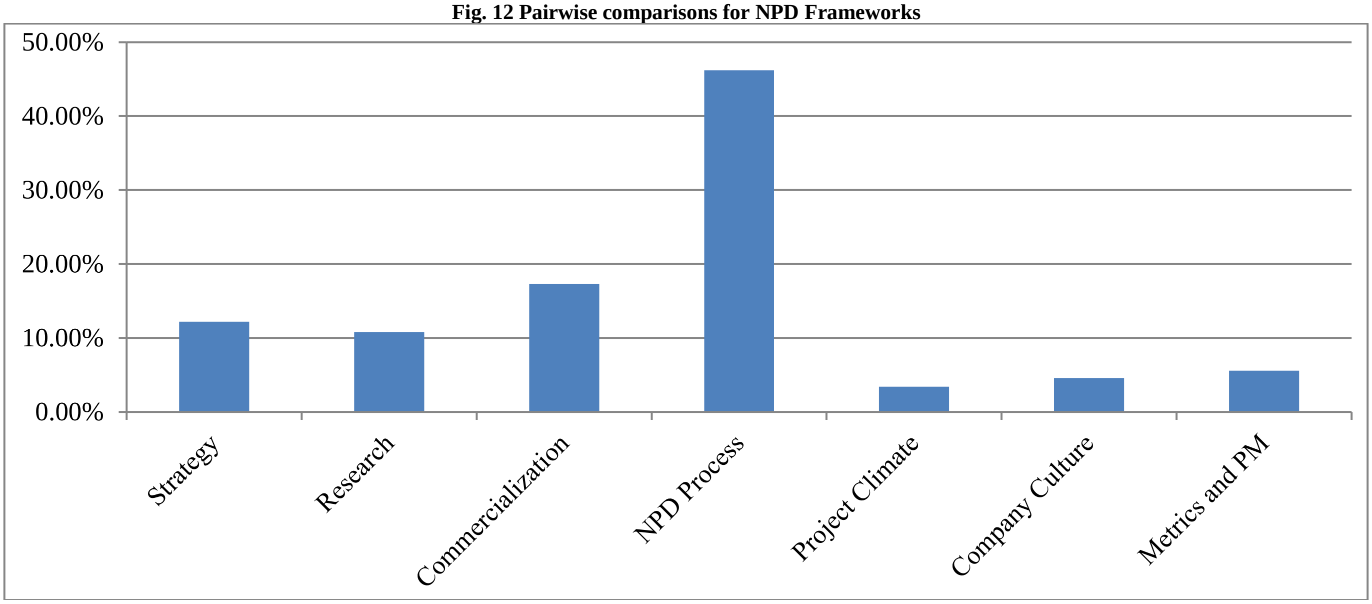

Fig. 13 Pairwise comparisons for NPD dimensions

Table. 10 Summary sheet for NPD dimensions

AHP Analytic Hierarchy Process (EVM multiple inputs)			
n=	7	n=Number of Criterion N=Number of Participants	
N=	10		
P=	0		
Scale=	1		
α=	0.1		
Objective	Calculate Weight with Pairwise Comparisons		
Author	BGS		
Table			
Sr No	Criterion	Weight	+/-
1	Strategy	12.2%	2.8%
2	Research	10.8%	2.6%
3	Commercialization	17.3%	2.8%
4	NPD Process	46.2%	18.4%
5	Project Climate	3.4%	1.5%
6	Company Culture	4.6%	1.4%

7	Metrics and PM	5.6%	1.3%
Result			
Lambda=	7.269	Eigenvalue (Lambda) Psi= Ordinal Inconsistency MRE=Mean Relative Error GCI=Geometric Consistency Index CR= Consistency Ratio	
Psi=	0.00%		
MRE=	30.20%		
GCI=	0.12		
CR=	3.3%		

Table. 11 Summary sheet of sensitivity analysis using SAW for NPD model

NPD Conceptual Model	Stage Gate System	Lean Start-Up	IDEO	BAH	Ex-PD
Original Weights-AHP model	0.609	0.159	0.044	0.104	0.084
Performance Score of an alternative	1	0.17	0.25	0.1	0.14
All criteria have the same weight	0.2	0.2	0.2	0.2	0.2
Performance Score of an alternative	1	0.2	0.29	0.08	0.15
Stage-Gate weight leading to equal preferences of the alternatives	0.5	0.125	0.125	0.125	0.125
Performance Score of an alternative	1	0.18	0.26	0.1	0.14
Rank	1	3	2	5	4

Table 9 assessed the Stage-Gate NPD process framework with calculated highest weight of 60.5%, BAH 10.3%, Lean startup 15.9%, IDEO 4.6% and Ex-PD 8.8% with CR 2.1%, GCI 0.08, Psi 0%, and Eigenvalue 5.093 Similarly, table 10 shows the assessment for NPD dimension wherein NPD process with the highest weight of 46.2% followed by Strategy 12.2%, Research 10.8%, Commercialization 17.3%, Project climate 3.4%, Company culture 4.6% and Metrics and PM 5.6% with CR 3.3%, Psi 0%, Eigenvalue 7 and GCI 0.12. The resulting weightage comparison of each selected NPD process framework and NPD dimension is shown in Figures 11 and 12. As per the result shown in Tables 9 and 10, the consistency ratio is less than the threshold value, and the geometric consistency index in both cases is within the limit as the consistency indicators are within the acceptable limits, so both the AHP models can be accepted. Sensitivity analysis allows us to understand how robust our original decision is and what the drivers are (i.e., which criteria influenced the original results.

From the sensitivity analysis result table as shown in Table 11, selecting the criteria weights in three different ways, i.e. firstly using the same weights generated in the AHP NPD framework model, secondly keeping all criteria weights the same and thirdly by keeping Stage-Gate weights leading to equal preferences of the alternatives we can express our final recommendation as follows: In all three cases there is no change in the ranking sequence and critical performance measure sequence. In all three cases of change in the criteria weights using the SAW method sensitivity analysis, it was found that Stage-Gate is the most critical criterion and the most critical performance measure. Similarly, sensitivity analysis using the SAW method shows that the NPD process is also the most critical criterion and most critical performance measure in line with Stage-Gate. Shepherd and Ahmed (2000) state that a robust New Product Development (NPD) framework is crucial for maintaining a competitive edge. A strong NPD framework not only enhances the success of new products but also bolsters overall company health, serving as a key competitive advantage. The authors highlighted three primary benefits of effectively implementing an NPD framework: reduced costs in product development, accelerated time to market providing "first-mover" advantages, and significant new product advantages. The AHP clearly indicates that the stage-gate NPD framework outweighs the remaining four frameworks. The results are consistent with the literature, as many researchers highlighted the importance of the Stage-Gate NPD process framework compared to other frameworks. 60% of all investigated NPD functions implemented some form of the Stage-Gate process to enhance product innovation [3, 41, 46]. The implementation of Stage-Gate frameworks provides a top-level overview to facilitate decision-making at key review points, dividing the overall process into more manageable stages to direct information-generating tasks [60]. The Stage-Gate process is characterized by low risk, immediate rewards, and a focus on incremental projects [16].

According to Harmancioglu et al. (2007), the level of competition in the industry is directly correlated with the implementation of formal stage gate processes, and Hamidizadeh et al. (2018) highlighted that the Stage-Gate model is the most famous model of new product development. Considering the performance and operations in NPD, the Stage-Gate NPD process framework proves to be more potent than other models. Though other frameworks are effective and useful under certain conditions, the Stage-Gate process offers several advantages. The Stage-Gate process is highly structured, with clear checkpoints (gates) between stages that ensure projects are evaluated systematically. This enables teams to make informed go/kill decisions, prioritize resources effectively, and reduce the risk of pursuing non-viable projects, enhancing predictability and control over the NPD process. By dividing the project into distinct stages with reviews at each gate, the Stage-Gate process helps identify and address risks early.

This staged approach reduces the likelihood of costly failures by ensuring only the most promising projects progress. The Stage-Gate process can systematically reduce uncertainties by assessing risks at each gate, helping companies make informed decisions before proceeding to the next stage. Lean Startup framework emphasizes flexibility and iterative development, which can sometimes lead to a less predictable path. Lean Startup often involves taking risks through rapid experimentation, which can be advantageous for speed but may not suit all companies, especially those with higher risk aversion. As one of the older models, BAH may lack the same level of granularity in stage definitions and checkpoints and may not emphasize the same level of formal decision-making checkpoints. IDEO's approach is more flexible and iterative, focusing on design thinking and innovation, sometimes leading to less formalized evaluations.

Stage-Gate provides thorough documentation and traceability of decisions and progress, which can be crucial for regulatory compliance and internal audits. On the other hand, IDEO’s process, while innovative, might not emphasize documentation and traceability to the same extent. Although Ex-PD explores multiple paths to mitigate risk, lacking formal gate reviews can lead to less structured risk management. The flexible approach of Ex-PD may result in less rigorous documentation, potentially complicating compliance with stringent regulatory requirements. Cross-functional collaboration in the Stage-Gate process is highly structured, ensuring thorough and consistent integration of diverse perspectives at each stage and gate. This leads to well-rounded decision-making and resource optimization. While other frameworks like Lean Startup and Ex-PD offer greater flexibility and agility, they may lack the same formalized, structured cross-functional collaboration level. IDEO’s design thinking excels in fostering creativity through interdisciplinary teams but may not offer the same level of structured progression.

The BAH framework, being more linear, may not emphasize continuous cross-functional integration as robustly as the Stage-Gate process. The Stage-Gate process ensures thorough documentation and regulatory compliance through its structured stages and formal gate reviews. This makes it particularly advantageous in regulated industries where comprehensive documentation and adherence to standards are critical. While Lean Startup, IDEO’s design thinking, and Ex-PD offer flexibility and adaptability, they may require additional efforts to meet regulatory requirements. The BAH framework, while systematic, does not provide the same level of rigour in documentation and compliance as the Stage-Gate process. The applicability of NPD processes depends on the specific needs and characteristics of the industry. The Stage-Gate process excels in highly regulated and resource-intensive industries where structure, compliance, and risk management are critical. Lean Startup and Ex-PD frameworks are best suited for fast-paced, innovative industries that require flexibility and quick iterations. IDEO’s design thinking is ideal for creative industries focused on user experience and iterative design. The BAH framework offers a balanced, systematic approach that can fit a wide range of traditional industries. Understanding the unique demands of each industry is essential for selecting the most appropriate NPD process. The literature suggests that the Stage-Gate framework is more suitable for pharmaceuticals, medical devices, aerospace, automotive, consumer goods, and any industry with stringent regulatory requirements. The results of this research, intended for the Indian automotive sector, align with the findings of the literature. Stage-Gate provides a clear, linear progression through well-defined stages, each with specific deliverables and criteria for advancement. This predictability is beneficial for planning, scheduling, and managing resources.

Resources are allocated more efficiently and controlled by committing resources stage-by-stage, ensuring resource progression as projects meet predetermined criteria. Lean Startup's iterative approach might lead to resource challenges if initial experiments fail to provide clear directions. Though Ex-PD is adaptable, its flexible nature can lead to less predictability in timelines and outcomes, which might complicate resource planning and project management. Also, simultaneous exploration of multiple paths in Ex-PD can lead to resource spread, which might dilute efforts and focus, especially in resource-constrained environments. The AHP analysis (Table 10) shows that the ‘NPD process’ emerges as one of the important dimensions followed by commercialization, strategy and research. The NPD process is an important NPD dimension considering the success of newly developed products. The quality of new product development is strongly depending on the quality of the NPD process [11]. Effectively, all the important decisions are made and efficiently made available for each decision within the process itself [81].

The NPD process plays a crucial role in the business success of organizations, especially for those competing in markets prone to swift product changes [58]. The NPD processes necessitate the involvement of key functional departments within the organization, including strategic planning, marketing, product design and development, manufacturing, maintenance, quality, sales, and financial planning [40]. Performance and operations in NPD, considering quality, cost, and delivery time, are more important in the NPD process. Commercialization, strategy and research dimensions are also key contributors. Each of these dimensions plays a crucial role in ensuring the success of a new product in the market. The NPD process and the dimensions of commercialization, strategy, and research are critical to the successful development and launch of new products. Each dimension plays a distinct yet interrelated role in ensuring that new products are well-conceived, strategically aligned, thoroughly researched, and successfully brought to market. By integrating these dimensions effectively, companies can enhance their NPD efforts, leading to innovative products that meet market needs and drive business growth.

7. Conclusion

The research aimed to evaluate the most suitable NPD process framework and critical NPD dimensions in the Indian automobile manufacturing industry using the Analytical Hierarchy Process (AHP) approach. The Stage-Gate process offers several advantages over other NPD frameworks, making it particularly suitable for industries that require rigorous structure, regulatory compliance, and systematic risk management. In contrast, other frameworks like Lean Startup, BAH, IDEO, and Ex-PD have their merits under specific conditions, and the Stage-Gate process excels in providing a clear, linear progression with well-defined stages and formal decision checkpoints as required in the automobile sector. It excels in ensuring structure, compliance, risk management, and efficient resource utilization. The findings of this research, particularly for the Indian automotive sector, align with existing literature, confirming the Stage-Gate framework's suitability for industries where meticulous planning and control are paramount.

The analysis underscores the critical importance of the New Product Development (NPD) process, which emerges as a pivotal dimension influencing the success of newly developed products. According to the findings, the quality of the NPD process directly correlates with the success and quality of the new products. In addition to the NPD process, the dimensions of commercialization, strategy, and research also play vital roles in the successful development and market launch of new products. Each dimension contributes uniquely to ensuring that products are well-conceived, strategically aligned, thoroughly researched, and successfully commercialized. These guidelines on the selection of framework and dimensions will be helpful to provide a practical pathway for Indian manufacturing industries to incorporate new strategies and actions to realign strategies and actions considering success in NPD. This research has successfully demonstrated the use of AHP to evaluate the NPD frameworks and dimensions. The research highlights key practical implications for industry practitioners. The research confirms the Stage-Gate framework’s suitability for the Indian automobile manufacturing sector. Industry practitioners should consider adopting this framework to establish a structured, systematic, and well-defined approach to NPD.

This can help ensure regulatory compliance, effective risk management, and efficient resource allocation throughout the development process. Further, streamlining each stage in the Stage-Gate process can lead to more reliable product outcomes and improve overall product quality, enhancing competitiveness in the market. Besides focusing on the NPD process itself, industry professionals should pay attention to the interconnected dimensions of commercialization, strategy, and research. While the Stage-Gate process offers a clear, linear progression, it’s important for practitioners to balance structure with flexibility. While the Stage-Gate process is the most effective for the Indian automobile industry, businesses should periodically reassess their NPD frameworks to ensure ongoing alignment with industry trends and global best practices to ensure the organization stays competitive and agile, even as the sector evolves. By focusing on the critical dimensions of commercialization, strategy, and research, industry professionals can better address the complexities of the modern automotive market and increase the likelihood of successful product launches. Practitioners should consider using AHP to make more data-driven and informed choices, allowing for better alignment with the company's objectives and the external market environment. Various research avenues can be pursued.

Further research can explore combining AHP with other Multi-Criteria Decision-Making (MCDM) methods such as Technique for Order Preference by Similarity to Ideal Solution (TOPSIS), Decision-Making Trial and Evaluation Laboratory (DEMATEL), or Data Envelopment Analysis (DEA). AHP may be used to evaluate different phases of NPD, such as idea generation and screening, concept development, and product design and testing. Case studies across different industries may be considered to validate the effectiveness of AHP in various NPD contexts, identifying best practices and potential pitfalls. By exploring these directions, researchers can further refine and expand the utility of AHP in NPD, ultimately supporting more effective and innovative product development processes.

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