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New product development process: A conceptual framework for automobile industries

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Abstract

India is emerging as a key destination for global automobile makers, prompting businesses to improve their abilities in product design and development to grow within the technology-focused automobile sector. Managing new product development (NPD) poses significant challenges within the dynamics to remain competitive. A well-defined and proven NPD process in the automobile industry results in high-quality, cost-effective, and timely product delivery to the market. Various frameworks have been proposed in the literature, and limitations highlight the need for a more flexible, integrated, and adaptive NPD model. Utilizing Cooper's highly efficient Stage-Gate framework, this research proposes a new NPD process framework to enhance the performance of the automobile industry. Based on the limitations of existing stages and gates used and a survey among the NPD professionals, detailed activities of the stages and associated gates have been presented.

Keywords: New Product Development, New Product Development Process Framework, Stage-Gate System

1. Introduction

New product development (NPD) is the process of transforming identified market opportunities into a profitable product ready for sale, typically involving a series of steps that companies can utilize to achieve commercialization objectives (Khannan et al., 2021). The literature offers various definitions and explanations regarding the boundaries of NPD. To ensure the effectiveness of NPD, it is crucial to establish seamless coordination among various departments such as manufacturing, engineering, research and development (R&D), marketing, finance, and purchasing. The marketing department takes the lead by conducting an assessment of the new product, followed by the formation of a cross-functional team dedicated to the development of the said product (Gurbuz, 2018). The development of new products is the basis of manufacturing companies as it is the key to leading the market (Rahim & Baksh, 2003). The survival and growth of a company in today's rapidly evolving market heavily rely on the creation of novel and enhanced products (Zhu et al., 2019). Year by year, technological advancements alter the market landscape, causing fluctuating customer demands and increasing market flexibility, which in turn makes NPD more complex to manage. Functional teams are often deployed to streamline the complex tasks involved in NPD, from design to launch (Cano et al., 2021). The true facts are that, out of every seven new product ideas, approximately four undergo development, one and a half are introduced to the market, and only one achieves success (Agrawal & Bhuiyan, 2014). No company likes to develop defective products or cancel the launch because of them. The cancellation of projects in the product development (PD) phase has a negative impact on the industry; such cancellations result in the loss of valuable resources, create a competitive disadvantage by not introducing new or improved products to the market, and lead to overall financial losses (Almeida et al., 2020). Hence, having a systematic NPD process framework is essential for reducing risks, optimizing resources, improving collaboration, and increasing the likelihood of developing successful products.

Intense international competition, driven by rapid technological progress and ever-changing consumer demands, highlights the critical need for companies to develop innovative and competitive new products to succeed. NPD gives organizations an excellent chance to maximize profits and enhance efficiency. To meet the increasing demand for high-quality products that address evolving customer needs, organizations must deliver superior products quickly, leaving no room for errors in the NPD process (Lapunka et al., 2023). Studies consistently show that companies that align their new products with shifting consumer demands are more likely to succeed than those that neglect NPD investments (Brown & Eisenhardt, 1995; Poolton & Barclay, 1998; Yadav et al., 2007). In today's fast-paced business environment, where customer preferences change rapidly, companies must be agile in adapting to these shifts (Singh & Garg, 2015). To succeed, organizations must strengthen their PD capabilities and create products that reflect evolving consumer demands. The NPD process is crucial, especially for companies in markets where product changes happen rapidly (Yadav et al., 2007). Traditional PD methods are slow and prone to significant inefficiencies, with many companies taking three to 4 years to bring a product to market. A study by Anand & Kodali (2008) found that nearly 50% of PD costs are wasted in the NPD process. Furthermore, Rajeshwari (2017) revealed that fewer than 15% of generated ideas succeed in the market, although leading companies achieve an 82.2% success rate, while others only reach 52.9%. These inefficiencies lead to substantial costs, wasted effort, and energy due to high failure rates. While formal NPD processes are standard in most companies and no longer provide a competitive edge (only 6% report lacking such processes), organizations are increasingly adopting flexible, customized approaches tailored to the complexity and size of each project (Brem & Kurzdorfer, 2016). In modern organizations, NPD presents significant risks, but successful companies attribute their success to strong, effective processes that emphasize quality and efficiency.

A well-structured NPD process framework is crucial for guiding functional teams through the product design and development phases with clear, logical, and sequential activities, often illustrated using flowcharts (Yin & Zhang, 2021). When activities are unclear, illogical, or disorganized, it leads to wasted effort, misdirected work, frequent clarification meetings, inaccurate resource and schedule estimates, excessive task dependencies, and ongoing problem-solving, all of which hinder the NPD process. Therefore, it is vital to focus on systematic screening, monitoring, and progression frameworks to address these challenges effectively (Owens & Davies, 2000). Companies continuously refine their frameworks, with a focus on time, cost, and quality, to meet market demands efficiently and reduce the risk of failure. Leading companies consistently leverage robust NPD frameworks to maintain their competitive advantage. Adopting the right framework enhances planning and decision-making, optimizes technology use, allows for evaluation at key milestones, improves cost-efficiency, encourages creativity, strengthens market penetration, boosts revenue, and drives quality improvements. NPD frameworks come in various forms, tailored to the specific needs of different organizations, industries, and products. The choice of framework depends on factors such as product characteristics, market volatility, organizational culture, and the level of innovation desired.

NPD in the automobile industry is a complex and highly competitive process that must consider several key factors due to the industry's rapid technological advancements, evolving consumer preferences, and intense global competition. The nature of competition in the automobile industry influences how companies approach NPD and refine their strategies. According to the 2017 Project Management National Conference in India, the automobile PD process is complicated due to factors such as simultaneous engineering, concurrent activities in PD, the need to introduce the right product to the right market, ensuring each product contributes to overall organizational profitability, and managing the risks associated with running multiple projects or programs concurrently. All these factors make it essential to have a robust process with a continuous plan for improvement. The NPD process must be flexible and adaptable to changing market and customer demands. An efficient, simplified, and flexible NPD process is crucial not only for the survival of a company but also for distinguishing successful firms from less successful ones. As a result, top-performing companies are evolving their NPD processes by incorporating elements of adaptability, agility, and speed into the traditional framework, which is considered rigid (Smolnik & Bergmann, 2020).

The expanding range of NPD frameworks reflects a continuous drive to improve and streamline the process of bringing innovative products to market. The automobile industry has continually worked to improve its PD processes, aiming to reduce failure risks while enhancing efficiency and product quality. The NPD process is essential to this effort, offering a systematic approach to conceptualizing, designing, and launching products. Despite the structured approach, failure cases are not uncommon in the industry, often arising from gaps in the utilization of the NPD framework. The literature review explores the industry scenarios, identifying challenges and analyzing the role of the NPD process in addressing these challenges.

Scholars such as Cooper (2001) have highlighted the Stage-Gate model as a common approach within the industry, emphasizing iterative development and decision-making checkpoints. Effective NPD utilization has been linked to reduced time-to-market, improved product quality, and enhanced customer satisfaction (Clark & Fujimoto, 1991). Failure cases in the automobile industry, such as technical failures, market failures, regulatory failures, and supply chain disruptions, reveal recurring themes of insufficient risk management, inadequate stakeholder engagement, and lack of iterative feedback loops within the NPD process. Despite the popularity of the Stage-Gate framework and efforts to improve NPD performance, innovation failure rates remain high, ranging from 70% to 98%. For an NPD team, Stage-Gate is not merely a process but a series of decision points aimed at aligning resource allocation with business potential. As a result, NPD teams require a more dynamic environment that emphasizes guidance, problem-solving, and knowledge-based risk management, extending beyond the constraints of the traditional Stage-Gate system (Rigen & Welo, 2013). Implementing the Stage-Gate NPD framework can be challenging. It is important not only to modify the Stage-Gate process but also to examine the company's existing business model and capabilities. Companies must take a dynamic approach, continuously reassessing their business models and capabilities, to effectively address challenges and leverage external collaborations (Jaksic et al., 2014).

Stage-Gate is often misunderstood, with one common misconception being that it is a linear and inflexible process (Cooper, 2008). It focuses primarily on internal organizational factors and follows a linear process from exploration to commercialization (Masyhuri, 2022). Common issues with Stage-Gate include:

(1) Too many projects are driven by customer or sales force demands, often leading to quick, uncritical project initiation.
(2) A lack of mechanisms to terminate projects once they have started, resulting in them continuing without clear Go/Kill decision points.
(3) Insufficient criteria for Go/Kill and prioritization decisions, with nearly 50% of firms admitting weaknesses in this area.
(4) Senior management not being sufficiently engaged in the decision-making process, often due to time constraints, lack of understanding, or unpreparedness to make crucial decisions.
(5) The difficulty in terminating projects that seem promising is due to pressure to bring projects to market (Cooper, 2002).

The traditional Stage-Gate process has proven to be cumbersome and less effective in today's complex, unpredictable, non-linear, and interactive market environment (Wind & Mahajan, 1997). Traditional gates are often overly rigid or focused on financial metrics, making the system excessively controlling, bureaucratic, and burdened with unnecessary paperwork, checklists, and tasks that add little value. Consequently, many leading companies are re-evaluating and redesigning their gating systems (Cooper, 2014). 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 (Cooper, 2022). Automobile companies that have modified their Stage-Gate processes tend to report various enhancements, including:

(1) The utilization of virtual teams.
(2) The integration of collaborative and virtual tools for NPD.
(3) The establishment of formal strategies dedicated to NPD.
(4) The adoption of structured procedures to guide the NPD process (Ettlie & Elsenbach, 2007).

By addressing the gaps in NPD utilization and drawing lessons from past failure cases, the automobile industry can enhance its resilience and drive sustainable growth. Both management and engineers view the current process as lacking the flexibility and scalability needed to handle the diverse range of projects undertaken by an automobile company. Consequently, there is a need to study the stages and activities of the NPD process and their alignment with various project types. This analysis aims to pinpoint critical challenges and gather the necessary insights to develop a framework for process improvement. Therefore, the objective of this study is to optimize the existing Stage-Gate NPD process within an automobile company while incorporating cutting-edge practices in automobile PD. To achieve this, the study will focus on the following goals:

(1) Identify best practices in automobile NPD through an in-depth literature review and analysis of industry applications.
(2) Conduct a performance measurement survey to uncover areas for improvement in the current NPD process framework.
(3) Propose an improved NPD process framework that addresses the key areas of improvement identified.

1.1. Challenges of NPD

With the evolution of technology and the growing need for flexibility in response to market demands, products and processes are becoming increasingly intricate. This increased complexity introduces additional risks to the NPD process. The ever-increasing customer demands can be viewed

as a challenge. Another hurdle is related to gaining knowledge and efficiently handling uncertainty to reduce the chances of failure in the PD process (Cooper & Scott, 2003). The focus of the organization has now turned to short-term objectives, leveraging technological advancements such as rapid prototypes, virtual-reality prototypes, digital twins, artificial intelligence, computer animations and simulations, product lifecycle management, product data management, and other tools. This shift has led to a notable rise in the quantity of "small projects" and improvements in NPD methodologies within the development process (Cooper, 2022). Ensuring the transfer of knowledge between different functional areas and during smaller exchanges between individual team members is a fundamental and recurring challenge in NPD (Ringen & Welo, 2013). The current NPD process includes many time-wasting activities with bureaucratic procedures, a lack of focus, and limited learning opportunities (Gronlund et al., 2010). The PD process, when executed in sequence, frequently leads to extended lead times and increased product costs (Kazimierska & Gręboszk-Krawczyk, 2017). The current NPD process is typically outlined in phases and documented in brochures or procedure manuals. However, these documents are often created by central staff not involved in actual development, leading to their perception as mere management procedures. Consequently, project managers and engineers may ignore them, and they quickly become outdated as new practices evolve (Tennant & Roberts, 2003). The existing NPD process also suffers from a lack of various management procedures, well-defined feedback loops for transferring information, and data metrics for assessing and evaluating performance (Ranjan, 2014). Chirumalla (2017) has identified nine significant hurdles in the management of the NPD process. These challenges pertain to resources, time-readiness, and schedule, gated administration, ways of working, communication and time-sharing, learning, business case, coordination and alignment, and competencies. Engineer-to-order companies encounter difficulties in introducing new products due to their customized manufacturing process. These difficulties encompass shorter design cycles, quicker market entry, enhanced product quality, and ongoing cost reductions to maintain competitiveness (Kumar & Wellbrock, 2009). As a result, managing the process of NPD has become increasingly challenging for businesses due to the significant investment of time, finances, and human resources it demands. As per Yang (2016), process complexity is one of the issues in NPD. The NPD process presents a unique set of challenges in comparison to other processes. It requires careful navigation and effective management (Wynn & Clarkson, 2018).

1.2. NPD Process

The NPD process is essential for the success of businesses, especially in today's competitive global market driven by rapid technological progress and evolving consumer preferences. According to Phillips et al. (1999), the product's quality (product performance) is greatly influenced by the quality of the NPD process. To meet the increasing need for high-quality products that meet the changing requirements of customers, organizations must ensure the delivery of improved products within tighter deadlines, allowing no margin for error in the process of NPD. The NPD processes require the participation of essential functional departments within the company, which encompass strategic planning, marketing, product design and development, manufacturing, maintenance, quality, sales, and financial planning. It is organized in a manner that involves engagement with both internal and external stakeholders, including customers and suppliers (Ulrich et al., 2009). The NPD process encompasses all activities involved in bringing a new product to the marketplace, including idea generation, screening, testing, and obtaining customer approval (Wijewardhana et al., 2021). In general, NPD requires eight stages. At the conclusion of every phase, a company must decide whether to proceed to the subsequent phase, abandon PD, or seek additional information. Fig. 1 illustrates the eight stages of the NPD process and is explained below.

(1) Generation of new product ideas: This is the first stage of the NPD process. Various ideas are created using idea-generation techniques, which will help to satisfy needs and examine the evolving technologies. Internal sources, that is, internal departmental members; external sources, that is, customers and competitors; and other sources such as seminars, universities, and investors, are the main sources for idea generation. The survey, which involved 750 interviews with Chief Executive Officers (CEOs) of global businesses, revealed that employees

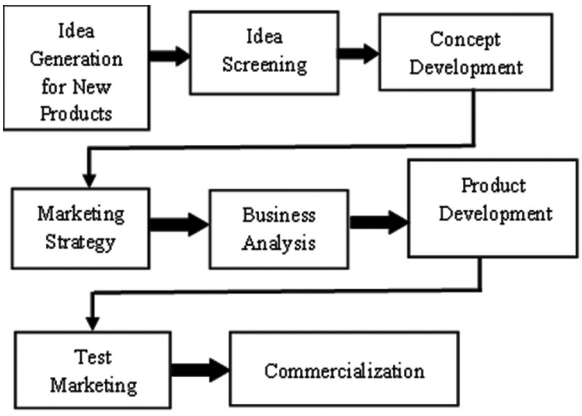

Fig. 1. New product development process

were responsible for generating 41% of new product ideas, customers contributed 36% of ideas, and the R&D department generated only 14% of ideas (Gurbuz, 2018).

(2) Screening and evaluation of ideas: It is a systematic criterion to evaluate the potential of the new product idea. Differentiation between useful and less useful ideas based on various types of feasibility criteria decides the selection of the best ideas.

(3) Concept development and testing: Once the best ideas are selected, product concepts are developed using specific concept selection techniques.

(4) Marketing strategy: At this stage, marketing strategies are determined, including market identification, pricing for the new product, and long-term strategic planning.

(5) Business analysis: It involves studying the estimated economic feasibility of a new product idea, including finalizing the capital and revenue budget based on a make-or-buy decision.

(6) PD: This involves upgrading the product's characteristics to align with customer preferences, along with further development in manufacturing, cost estimation, packaging, and distribution. Prototype development and testing activities are completed, and facilities, tooling, and gauges are designed and developed.

(7) Test marketing: It evaluates major market acceptance through market research, assessing all marketing elements such as the new product concept's target market, market position, advertising, distribution, packaging, and costs.

(8) Commercialization: It involves the actual introduction of the product into the market, including all related resources and decisions. The product launch and associated plans are finalized and executed.

1.3. Review of NPD in The Automobile Industry

The automobile industry's PD process is inherently complex, with varying levels of difficulty depending on the project. Even in the simplest cases, teams must design and develop hundreds, if not thousands, of components. This process must also incorporate customer requirements, design feasibility, performance and safety standards, product quality and reliability, and real-world usage conditions, resulting in an extensive list of factors to consider. Several key factors make this process even more critical: the integration of simultaneous engineering and concurrent activities in vehicle development, the necessity of launching a flawless product in the right market on the first attempt, ensuring that every product contributes to the organization's overall profitability, and effectively managing the risks associated with running multiple projects or programs simultaneously (Koranne & Shende, 2017). PD in automobile NPD differs from other industries due to its complexity, long development cycles, and high regulatory requirements (Ulrich & Eppinger, 2020). Unlike consumer electronics or software, where products can be developed and launched within months, automobile NPD often takes several years due to extensive research, engineering, prototyping, and rigorous safety testing (Thomke & Feinberg, 2006). The process involves collaboration across multiple disciplines, including mechanical, electrical, and software engineering, as modern vehicles integrate advanced technologies such as autonomous driving, electric powertrains, and connectivity features (Nieuwenhuis & Wells, 2015). In addition, automotive NPD must comply with strict government regulations and safety standards across different markets, making testing and validation more intensive than in many other industries. The high costs associated with tooling, manufacturing, and supply chain coordination further differentiate it from industries with lower capital investment requirements (Clark & Fujimoto, 1991). Furthermore, customer expectations for durability, performance, and reliability in automobiles necessitate extensive real-world testing, unlike industries where updates and patches can be released post-launch. These factors make automobile NPD more resource-intensive, risk-prone, and time-consuming compared to many other industries.

An effective 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. India's automobile market was valued at Rs. 10,000 crore in 2021 and is expected to reach Rs. 16,000 crore in 2027, registering a compound annual growth rate of 8.1% over the forecast period 2022 – 2027. As per the Ministry of External Affairs declaration in August 2023, India's auto industry is expected to rank 3rd in the world by 2030. Due to the rise in middle-class income and the rising young population, the Indian automobile market is expected to witness strong growth. In addition, due to the rising demand for automobiles, exports from the country have also seen a significant increase. The automobile sector accounts for 7.1% of India's gross domestic product and 49% of the manufacturing gross domestic product. This industry provides direct and indirect employment to 1.9 crore people in India. As India emerges as a hub for international car manufacturers, businesses are looking to enhance their capabilities in product design

and development within the country to expand their presence in the knowledge-driven automobile industry.

Developing a new product in the automobile industry is a highly complex process. It involves designing and manufacturing hundreds of components, coordinating communication across multiple functions, and ensuring the seamless synchronization of various functional deliverables, each triggering a series of dependent tasks. With this complexity comes inherent risks. These challenges, along with many others, make it crucial to have a well-structured process in place, supported by a continuous improvement plan (Koranne & Shende, 2017). Numerous researchers have previously focused on developing NPD processes tailored to the automobile industry. For instance, the self-assessment NPD process was modified and implemented by Tennant & Roberts (2003) at Land Rover. This led to a notable enhancement in the performance measures of the Freelander compact sport utility vehicle program. Sumantran (2004) conducted a study on Tata Motors' new product introduction process, focusing on the development of a new Sedan Indigo within a span of approximately 20 months. The study highlighted the effectiveness of Tata Motors' approach, which involved a formal vehicle development process, concurrent engineering, math-based simulations, and disciplined manufacturing planning. The implementation of this approach has resulted in significant benefits for the company. A review was conducted on the application of process models, such as the Stage-Gate NPD process framework, to effectively structure and guide the NPD process in the automobile industry. The review concluded with lessons from a benchmarking study on implementing these process models and offered suggestions for future research to enhance their implementation and effectiveness (Chao & Ishii, 2005). An investigative study aimed at enhancing the NPD process in an automobile company, supported by a comprehensive literature review and both qualitative and quantitative research, identified areas for improvement and facilitated the successful implementation, adoption, and adaptation of the process by key drivers (Williams, 2008). The findings of a qualitative meta-analysis involving 16 empirical studies on the success of NPD in the automobile industry reveal a gap between knowledge about the practical relevance of NPD dimensions such as the development process, resources, and strategy and their systematic assessment in practice (Gerhard et al., 2008). A comprehensive PD process (PDP) for the automobile industry was presented, encompassing all stages from market research to sales. This includes customer input, conceptual design, detailed design and engineering, manufacturing process and production, and sales and distribution. The essential features of these five stages were outlined, and specific techniques for their implementation were detailed from a macro perspective with real-life examples (Liang, 2010). A thorough analysis of the six-stage Stage-Gate approach to PD across six different companies found that organizations structured around cross-functional teams tend to favor a low-phased approach, whereas those with a strong functional structure tend to adopt a higher number of phases and gates, indicating a high-phase approach (Phillips et al., 1999). A case study of the Indian automobile industry investigated the impact of original equipment manufacturer collaborations on the convergence of PD processes. It mapped the relationships between automobile companies and other auto original equipment manufacturers in India, concluding that a standardized PD process helps in reducing development cycle time, minimizing platforms, involving suppliers throughout the development stage, promoting cross-functional collaboration, implementing concurrent engineering, and standardizing work practices (Loganathan & Jayakrishnan, 2014). Lean PD was adopted to transform the process of developing Indian automobile products, leveraging foundational lean principles, waste reduction strategies, and a fundamental framework for applying lean practices within the PD process in the Indian automotive industry (Anand et al., 2009). A framework known as Automotive-PDP, developed to oversee the PD process in the automotive industry, was validated through a literature review and a study involving three global automakers from Asia, Europe, and America (Silva & Kaminski, 2017). A study of a small automaker in Malaysia highlighted that its approach to NPD, although aligned with generic NPD processes, integrates concurrent engineering practices. This emphasizes the importance of a structured NPD framework for frequent new product introductions and effective management of risks and uncertainties (Boejang et al., 2017). The following section explores the literature, highlighting the need to redesign NPD process frameworks in the automobile industry.

1.4. The Need for Redesigning The NPD Process Frameworks

Research consistently shows that companies that adapt their new product offerings to meet evolving consumer demands are more likely to succeed than those who fail to invest in NPD initiatives (Brown & Eisenhardt, 1995; Fernandes et al., 2017; Poolton & Barclay, 1998). In every automobile industry, the NPD process has significant value because it greatly influences the whole value chain and decisions on fundamental aspects such as quality, cost, and time. Thus, it is essential to customize the NPD process according to the specific industrial sector. Manufacturing firms within the automobile industry face the challenges of improving their NPD procedure, particularly when operating in markets that demand

innovation, reduced time-to-market, an extensive product portfolio, and superior quality (Fernandes et al., 2017). Today, many automobile companies are redesigning their NPD process to be more agile through better governance and portfolio management practices. Some organizations have also created open innovation modifications to their stage procedures or have shifted toward fully automated systems for NPD. Creating new products presents a more significant obstacle than simply extending product lines. Therefore, it requires a more efficient risk management strategy in the NPD process. By improving their grasp of risks and critical factors that may hinder the success of the NPD process, companies can boost their operational effectiveness and improve their ability to predict potential challenges that may affect NPD process results (Salavati et al., 2016). Hence, it is essential to consider redesigning your NPD process if it has been in place for over 5 years or if your idea-to-launch system does not incorporate current best practices (Cooper, 2008). Many reasons discussed in the literature define the need for redesigning NPD process frameworks. The arrival of multiple foreign companies in the Indian automobile sector has brought about a diverse mix of domestic and international firms through foreign direct investment through greenfield investments, mergers and acquisitions, joint ventures, or contract manufacturing. This has made it necessary to incorporate innovative process improvement techniques in the PD frameworks of these companies (Anand et al., 2009). The expansion of regional and global customer and resource markets due to globalization has increased international competition, leading to significant changes in the competitive landscape and practices across various industries. The collaborations between Indian home-grown automobile companies and major American, European, and Japanese players have brought about significant transformations in the PD processes within the Indian automobile industry (Loganathan & Jayakrishnan, 2014). Manufacturers are in competition to enhance performance by reengineering their processes for NPD to accelerate speed, lower costs, and better meet customer demands (Arnold & Floyd, 1997). The implementation of business strategies such as downsizing, outsourcing, and reengineering has resulted in the creation of more streamlined, cross-functional organizations and has fundamentally changed the relationship between companies, employees, customers, and other stakeholders. This has had a significant impact on all aspects of life and business operations, requiring a reevaluation of NPD process frameworks to adapt to these evolving changes (Wind & Mahajan, 1997). In the current fast-moving environment, upper management demands a shortened NPD cycle, necessitating the immediate delivery of new product projects to the market. However, as highlighted in a Forbes article, speeding up innovation carries risks, it may hinder creativity. Hence, the process must be redesigned instead of just condensing the conventional process (Mayer, 2020). In the automobile industry, NPD is a highly complex process involving numerous part developments, managing communication across functions, synchronizing deliverables, and addressing associated risks, necessitating a robust process with continuous improvement plans (Cooper et al., 2003). Hence, top-performing companies are transforming their NPD processes by incorporating adaptability, flexibility, and speed into the traditional Stage-Gate model, known for its inflexible structure (Smolnik & Bergmann, 2020). The next section focuses on a discussion of the five most used NPD process frameworks, out of which the Stage-Gate process offers several advantages.

2. NPD Process Frameworks

Yin & Zhang (2021) defined the NPD process framework, which represents unambiguous, logical, and clearly defined stages in the form of flow charts that describe the design and development activities of the product to be performed by functional teams. Framework translates theory into practice through systematic means and clearly depicts the leadership goal for the organization (Wang & Kourouklis, 2012). Numerous studies have been undertaken and published about the NPD process frameworks. The crucial task for any organization is to have a proper NPD process framework to guide the NPD team so that quality products are successfully introduced into the market with a reduction in cost and development time. According to Shepherd & Ahmed (2000), a robust NPD framework not only sustains product advantage but also enhances new product success, improves company health, and serves as a significant source of competitive advantage, offering benefits such as reduced PD costs, accelerated time to market for first-mover advantages and new product benefits. The five most used NPD process frameworks are selected for discussion in this section, highlighting the importance of the Stage-Gate NPD process framework as compared to Booz, Allen, and Hamilton (BAH), Lean startup, IDEO, and exploratory PD model (Ex-PD) frameworks.

Table 1 compares these five NPD process frameworks across various aspects, including applicability, implementation process, decision-making, objectives, management, and costs, all of which are critical for the successful execution of NPD. These factors vary depending on the industry, company, product type, and market conditions. The information discussed about each of the five frameworks serves

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Table 1. Comparison of five macro-categories of new product development frameworks

Aspect	**Stage-Gate System** **Cooper (1990)**	**Lean Start-Up** **Ries (2011)**	**IDEO** **David Kelley (1991)**	**BAH** **Booz, Allen and Hamilton (1982)**	**Exploratory product development model (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- initial inquiry, thorough examination, development, testing and validation, production and launch. The product undergoes progressive development and refinement at each step.	It begins with the entrepreneur's vision, taking a leap of faith. The Build-Measure-Learn approach is embraced to test fundamental assumptions or hypotheses. The product undergoes continual modifications based on frequent and early customer feedback.	IDEO structured the product development process into five key steps: understanding/ observing, visualizing/ realizing, evaluating/ refining, implementing/ detailed engineering, and implementing/ manufacturing liaison.	The BAH model unfolds in seven steps: new product strategy, idea generation, screening, business analysis, development, testing, and commercialization.	The Ex-PD approach comprises three interconnected segments within its process: strategy, idea generation and selection, and exploration and creation.
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 operates under the assumption 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 sections of the project.	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	Owners usually double as project managers, with no	The IDEO project team regularly convenes meetings	Implementing a consistent framework that centers	Ex-PD is characterized as a dual-focused, integrated systems approach that requires

(Cont'd...)

Table 1. *(Continued)*

Aspect	**Stage-Gate System Cooper (1990)**	**Lean Start-Up Ries (2011)**	**IDEO David Kelley (1991)**	**BAH Booz, Allen and Hamilton (1982)**	**Exploratory product development model (Ex-PD) Mary Drotar and Kathy Morrissey (2015)**
	the product but not directly managing it, determines each gate.	specifically assigned gatekeepers. Decisions hinge on customer responses to the Minimum Viable Product (MVP).	with clients to gather and incorporate their feedback.	on a comprehensive 360° vision, particularly led by an initial stage entirely dedicated to strategy, allows the process to engage with external networks and the environment.	holistic management, integrating vital elements: strategy, portfolio management, organization/teams/ culture, metrics, market/customer understanding, and process.
Expense	Costs rise with each subsequent gate, and generally, the product does not generate revenue during its development phase.	As the product scales up, expenses grow, but there is a simultaneous generation of revenue during the process.	Costs escalate with rapid prototyping. Generally, the product does not yield revenue during its development phase.	Costs rise at each stage. Generally, the product does not produce revenue during its development.	Costs escalate with each stage. Generally, revenue is not generated during the product's development phase.

as the basis for comparing them against each of these aspects. The comparison reveals that these five NPD process frameworks are well-suited for NPD in Indian industries, and the Stage-Gate NPD process framework proves to be more potent as compared to others. Although other frameworks are effective and useful under certain conditions, the Stage-Gate process offers several advantages.

(1) Performance and operations: The Stage-Gate process provides a highly structured, risk-averse, and systematic approach to NPD, offering clear decision points, quality control, and predictability, making it well-suited for complex projects and large organizations. While BAH, Ex-PD, Lean Startup, and IDEO offer flexibility and rapid iteration, they may lack the formal structure and control that Stage-Gate provides, making them less suitable for projects requiring rigorous oversight and detailed planning.

(2) Documentation and traceability of decisions and progress: The Stage-Gate process stands out in NPD for its rigorous documentation practices that ensure thorough traceability of decisions, progress, and project history. This structured approach supports accountability, auditing, learning from past experiences, and effective communication across teams and stakeholders. In contrast, BAH, Ex-PD, Lean Startup, and IDEO, while offering flexibility and innovation, may not prioritize or achieve the same level of comprehensive documentation and traceability in NPD processes.

(3) Cross-functional collaboration: Stage-Gate excels in fostering structured and formalized cross-functional collaboration through defined stages and gates, clear roles and responsibilities, and formal communication channels. This structured approach helps integrate diverse perspectives and expertise across functions, ensuring alignment and informed decision-making throughout the NPD process. In contrast, while BAH, Ex-PD, Lean Startup, and IDEO also promote collaboration, they may prioritize other aspects such as financial analysis, technical development, customer feedback, or creative design, potentially at the expense of comprehensive cross-functional integration in NPD.

(4) Documentation and regulatory compliance: The Stage-Gate process stands out for its comprehensive documentation and structured approach to regulatory compliance. Its formalized stages and gates ensure that all necessary documentation is in place, making it easier to meet regulatory requirements and maintain a clear audit trail. In contrast, while BAH, Ex-PD, Lean Startup, and IDEO offer valuable approaches to

Table 2. New product development process framework specifications and requirements

Framework specifications	**Framework requirements**
New product development (NPD) framework stages involve lots of technical activities that play an important role in the successful conversion of product ideas into product function	Technical capabilities
Each activity in each stage is completed within the stipulated period	Product production at an appropriate time and cost
Smooth flow of stages, reduced reverse flow, easy to follow	A clear and common understanding of the NPD process
Framework stages emphasize up-front homework	Up-front homework
All new product development framework stages meet consumer needs by the exploitation of new, unique technology	Use of unique technology
Framework stages successfully converted product ideas into product functions quickly and on time	NPD process speed
Deliverables of framework stages include a clear definition of the functions of the product developed	Clear definition of the functions of the product
NPD activities in the framework stages followed all necessary quality standards	Implementation of quality standards
NPD activities in the framework stages followed all necessary regulatory practices	Regulatory practice
Deliverables of framework stages include a clear definition of the functions of the product developed	Clear definition of the functions of the product
NPD activities in the framework stages followed all necessary quality standards	Implementation of quality standards
NPD activities in the framework stages followed all necessary regulatory practices	Regulatory practic
Framework stages emphasize market research and customer involvement	Market research and customer involvement
Deliverables of framework stages include a clear definition of the target market	Clear definition of the target market
Each activity in the framework included a focus on the customer	Focus on the customer
Objectives and deliverables of the NPD framework based on appropriate marketing strategy	Appropriate marketing strategy
Market size defines the objectives of the framework stages	Market size
Senior management provides internal legitimacy and momentum for the new idea and concept	Senior management commitment and involvement
The framework involved cross-functional teams, i.e., marketing, purchasing, sales, after-sales service, design, and manufacturing	Involvement of cross-functional teams
The framework stages used structured new product development activities	Use of structured NPD process
Human factors such as Experience and a dedicated team are used for the successful conversion of product ideas into product function	Dedicated team members with relevant experience in the NPD process and activities
The framework perceives NPD as a strategy for the long term	Long-term vision and strategy
NPD goals that are clearly outlined and visible across the company	Presence of clear goals and milestone measurement
The framework process included effective internal communication with team members and management by properly linking activities	Effective internal communication among team members and management
NPD activities defined in the framework stages support an entrepreneurial culture in the organization	Entrepreneurial culture in the organization
Framework stages aligned with strategy	Alignment of NPD process activities with strategy
Human factors such as teamwork, cooperation, support, and guidance used for the successful conversion of product ideas into product function	Cooperation, support, and guidance within the team

(Cont'd...)

Table 2. *(Continued)*

Framework specifications	Framework requirements
Framework stages support teamwork by maintaining the proper organizational environment	Organizational environment to support teamwork
Each stage of the framework is passed with Go/Kill decision points in the process	Go/Kill decision points in the process
Framework stages considered the time of replacement of the product, considering the product life cycle	The time of replacement, considering the product life cycle
Framework stages utilized the research and development budget for NPD activities	Research and development budget for NPD activities
Project scheduling and monitoring activities are considered as NPD activities in the framework stages	Project scheduling and monitoring
Framework stages support teamwork by maintaining an innovative climate and culture	An innovative climate and culture
Framework stages ensured the availability of project/NPD resources and their management	Availability of project/NPD resources and their management
Framework stages involved innovating ideas in their activities	Innovate idea generation by expert groups
Developing and launching a product within the proper time frame	The right time to launch
The framework stage declared product scoring through the competitor benchmarking tool	Product scoring through benchmarking (competitor)
The framework stage declared product scoring through the internal benchmarking tool	Product scoring through benchmarking (internal)
NPD framework stages require financial resources that play an important role in the successful conversion of product ideas into a product function	Availability of financial resources
NPD framework stages involve lessons learned from past projects that play an important role in the successful conversion of product ideas into product function	Applying lessons learned from past projects
The framework filtered the activities after launch, and lessons learned were captured	Refining a product after launch and having a long-term view
Development of a product within the proper time frame	Time to market
NPD framework stage activities are defined considering social responsibility	Social responsibility
NPD framework stage activities involved statutory and environmental compliance	Statutory and environmental compliance
NPD framework stage activities defined considering Cultural competence	Cultural competence

NPD, they may lack the detailed documentation and formal compliance framework that Stage-Gate provides, potentially complicating regulatory compliance and audit processes.

(5) Specific needs and characteristics of the industry: The Stage-Gate process offers a structured and adaptable framework that can be tailored to meet specific industry needs in NPD, particularly in regulated sectors requiring rigorous risk management, quality assurance, documentation, and cross-functional collaboration. While BAH, Ex-PD, Lean Startup, and IDEO offer innovative approaches to NPD, they may not inherently address the complex requirements and challenges unique to specialized industries without additional customization and integration of industry-specific practices and standards.

A total of 60% of all investigated NPD functions implemented some form of the Stage-Gate process to enhance product innovation (Adams-Bigelow, 2005; Griffin, 1997; Kahn et al., 2012). 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 (Phillips et al., 1999). The Stage-Gate process is characterized by low risk, immediate rewards, and a focus on incremental projects (McDermott & O'Connor, 2002). 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 NPD. The research findings, especially concerning the

Indian automobile sector, support existing literature, confirming the Stage-Gate framework's suitability for industries that prioritize meticulous planning and control. Consequently, the next section investigates identifying the crucial framework requirements and specifications essential for developing the NPD process framework as outlined in this study.

2.1. NPD Process Framework Specifications and Requirements

The NPD process has gradually developed from the implementation of product design and development activities. Hence, the design of the NPD process is greatly impacted by various elements, including technology, maturity, management strategies, business objectives, policies, culture, beliefs, and more. Manufacturing companies typically adjust or utilize current PD procedures based on the operational environment, regulations, and policies in the real world (Yin & Zhang, 2021). Successful companies demonstrate increased awareness of customer needs, prioritize marketing and advertising efforts, excel in PD, actively seek external expertise, and place trust in responsible and experienced employees. Integration of technical, commercial, organizational, marketing, and social factors can be deemed as an important multifunctional management mechanism that boosts the accumulated knowledge exchange, in the success of NPD in all aspects (Kadwe et al., 2017). Effective and repeatable NPD demands a balance between strategic effectiveness, functional excellence, and operational competence (Connell et al., 2001). The framework specifications and requirements, shown in Table 2, are derived from the literature based on seven dimensions delineating NPD success, such as strategy, research, commercialization, NPD process, project climate, company culture, and metrics and performance measurement. These dimensions are shaped by benchmarking studies, aiming to identify the best NPD process framework, expecting companies to adopt and sustain them (Adams-Bigelow, 2005; Barczak et al., 2009; Cooper et al., 2002; Cooper et al., 2004a; 2004b; 2004c).

3. Review on The Importance of The Stage-Gate Approach For NPD in Manufacturing Industries

The Stage-Gate development framework is applied within companies to streamline their PD processes, facilitating the efficient transition of new products from conception to market launch. This integrated approach combines project management principles with necessary processes for product realization, serving as a conceptual model increasingly adopted by organizations to mitigate challenges such as performance issues, rising development costs, and delays, thus minimizing risks associated with NPD. Literature is available on the importance of the Stage-Gate approach for NPD as a best practice in different manufacturing industries. Top-performing companies excel in NPD with an average success rate of 60.2%, while those in the bottom 20% struggle with over 3.5 times the failure rate, highlighting the importance of effective NPD management, leading many firms to adopt Stage-Gate processes as blueprints (Cooper, 1990; Smolnik & Bergmann, 2020). Several organizations have adopted phased-review workflow procedures that cover multiple functions to improve the development of new products. One widely accepted method in this regard is referred to as the "Stage-Gate" process (O'Connor, 1994). Griffin (1997) discovered that a majority of the NPD functions examined utilized a Stage-Gate process to enhance product innovation in manufacturing industries. Barringer & Gresock (2008) found that the acceptance rate of the stage-gate model in the United States industrial sector, currently at 73 percent, emphasizes the valuable advantages of utilizing a solid conceptual model for industrial NPD processes. According to Pietzsch et al. (2009), the primary development model utilized in the medical device industry is the stage-gate process. When the Stage-Gate process was initially introduced, numerous companies such as Procter and Gamble, Polaroid, The Royal Bank of Canada, Lego, and Shell adopted either certain components or the entire process (Broum et al., 2011). Without a Stage-Gate model, managing cross-functional communication, stability, and the efficient handling of NPD processes for a company as large as Ericsson while maintaining synergy between Stage-Gate, lean, and agile processes would be extremely challenging (Davoodi & Aslanzadeh, 2014). According to the findings by Wuest et al. (2014), implementing the Stage-Gate model for manufacturing and assembly processes in industry suggests that an adapted version of this model can significantly support product and process quality improvement. It has been determined that the Stage-Gate model is utilized by 70 – 85% of the prominent companies in the United States to oversee the complete journey of developing and introducing new products or services to the market (Stosic & Milutinovic, 2014). The Stage-Gate system is widely recognized as an efficient tool utilized often by leading companies and is currently regarded as the norm for a structured NPD process in the present market (Kazimierska & Grębosz-Krawczyk, 2017). To address market fluctuations and uncertainty, some companies have adopted a hybrid approach using Stage-Gate and Agile Scrum to reduce time-to-market and respond more swiftly to changing customer requirements (Eljayar & Busch, 2021).

4. Usage of The Stage-Gate Approach in Manufacturing Industries

According to the literature, the Stage-Gate approach is very important for NPD in various manufacturing industries as it enhances efficiency and minimizes the risk of failure, whether it is for launching new products or technologies that can reshape competitive positioning, introducing new products to boost company revenue, or defending market share with significantly improved products. The Stage-Gate model provides a strategic and practical guide for the process of developing new products, starting from the initial idea to the final launch, acting as a blueprint for managing the innovation process to improve productivity and performance. Cooper's Stage-Gate model, the primary focus of this study, can be considered an essential example of this era. The Stage-Gate method divides the innovation process into stages that involve coordinated, cross-functional, and simultaneous tasks, with each stage commencing at a checkpoint accountable for ensuring quality and making Go/Kill/Hold/Recycle decisions (Stosic & Milutinovic, 2014). A typical Stage-Gate model is illustrated in Fig. 2 (Cooper, 1990).

Each stage of the diagram represents a component of the PD process, encompassing a group of activities, while each gate serves as a review point for the preceding stage, where decisions are made based on the information generated. This framework enables the organization to enhance output quality by focusing on the process itself, eliminating non-value-added activities, and reducing risks associated with PD. Many organizations use a type of Stage-Gate process to guide their PD. Table 3 summarizes the Stage-Gate approach implemented in different industries for developing new products. Although similar, each has its own uniqueness in its implementation.

The NPD models of different organizations, as shown in Table 3, show both similarities and differences. The number of stages ranges from four to 11, and the number of gates ranges from 4 to 10. The quantity and titles of the stages might differ among organizations, but they all share a common underlying goal. Based on the number of stages and gates, the process is classified into high Stage-Gate and low Stage-Gate approaches. In most of the processes, the stage numbers are exactly the same or more or less equal to the number of gates. Most of the stages and gates are common for all the models. In some models, the number of activities from idea generation to launch of the product is divided into sub-activities to make the NPD simpler and more effective, which increases the number of stages and gates in the process. Each of the NPD process models mentioned above is unique and is implemented in its own distinct way by companies. All these various NPD process models provide a structured framework with standardized principles and methods for PD, ensuring timely and cost-effective market entry while meeting customer needs. Implementing a model promotes uniformity across an organization, supported by sound management decisions and effective risk management.

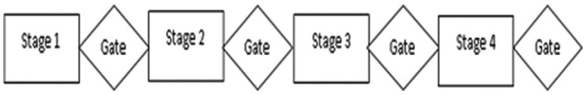

Fig. 2. The Stage-Gate approach

5. The Need to Develop A NPD Process Framework

Observed limitations of this benchmarked NPD process framework are: (i) very rigid and bureaucratic, (ii) stage-wise lead roles are not defined, (iii) all activities from the first stage to the last stage and their one-to-one proper integration is not shown, (iv) lack of functional integration between departments, (v) inadequate flexibility for IT Integration, (vi) lack of feedback process, (vii) lack of involvement of appropriate stakeholders, (viii) lack of generational learning, (ix) lack of organized and structured data, (x) missing management processes, (xi) not designed for rapidly growing and uncertain conditions of the market, (xii) not designed for higher risk initiatives, (xiii) required inputs for each stage are not clearly defined, (xiv) stage-wise deliverables are not clearly defined, (xv) most of the models are based on the traditional Stage-Gate process, and (xvi) coordination complexity.

Launching new and innovative products into the market quickly, cost-effectively, and with minimal risk is essential to meet the targeted demands; companies are consistently upgrading from existing PD models to newer ones that are characterized by increased agility, flexibility, and alignment with their company's structure and operations (Munoli, 2017). Shorter life cycles, changing portfolios of new product opportunities, and associated risks continue to pressure the NPD teams to produce a wider range of products. Shepherd & Ahmed (2000) observed that in many companies, primarily small and medium-sized, the way products are developed is completely unstructured. There is no steady terminology; each company uniquely defines its NPD process framework, even though many are similar. An inconsistent NPD process framework leads to wasted effort, misdirected work, more clarification meetings, failure in estimating resource requirements and schedules, excessive task interdependence, and fire-fighting. To navigate these challenges successfully and efficiently, it is

Table 3. Benchmarking of new product development process frameworks followed by industries (Chao & Ishii, 2005; Phillips et al., 1999; Williams, 2008; Loganathan & Jayakrishnan, 2014)

Company name	Process title	High/low stages	Number of stages	Number of gates
General motor	Product development process	Low	4	-----
Tata motor	New product introduction	High	7	8
Ashok leyland	Genmod	High	6	-----
Daimler's	Commercial vehicle development system	High	8	7
Mitsubishi fuso	Product creation process	High	8	7
Volvo'	Global development process	Low	5	5
Malaysian small-sized automaker	Product development process	Low	4	8
Mahindra and Mahindra	Mahindra product development system	Low	5	13
Renishaw	Renishaw new product development process	High	10	10
ABB	ABB gate model	High	6	7
GE	New product introduction	High	9	10
Lucent	New product introduction	Low	4	8
Rover	Project management guidelines	High	8	-----
BMW	Gateway in new product development	High	7	-----
Chrysler	New product development strategy	Low	4	-----
Ford	Global product development system	High	11	-----
Honda	Programmed milestone philosophy	High	8	-----
IBM	-----	Low	5	-----
Xerox	-----	Low	3	-----
Lucas	Product introduction management	Low	5	-----
Motorola	-----	Low	6	-----
Renault	Project management system	High	6	-----
Toyota	Generic development process	High	9	-----
NASA	Technical design review process	Low	5	-----
Whirlpool Corporation	C2C product creation process	Low	4	4

crucial to focus on systematic screening, monitoring, and progression frameworks. The structured and documented approach provides a clear roadmap for successful NPD (Owens & Cooper, 2001). To remain competitive, best-in-class companies carefully select and use the basic attributes of an effective NPD framework and try for continuous improvements on multiple fronts to retain the leadership position (Griffin, 1997). Implementation of an effective NPD framework improves planning and decision, technology usage, evaluation at key milestones, overhead and labor costs, quality of goods and services, creativity and innovation, need for engineering and design changes, ability to penetrate new markets, revenue and margins, inventory cost, and so on (Shepherd & Ahmed, 2000). Managers managing the introduction of new products within the manufacturing engineering department, as well as other tasks or stages in NPD, face growing pressure to enhance the efficiency of the process. The nature of progress required differs between organizations. The most common and widely cited improvement objectives are as follows: reduced costs and cycle time and increased market share and product quality. In the next section, a structured form is developed to gather the inputs of industrial experts to address the highlighted limitations of existing NPD models and to meet the needs of NPD experts. The initial section gathers fundamental background details regarding the industry and participants (Table 5), while the subsequent section gathers feedback from the participants against the questionnaire (Table 6) based on the scale matrix (Table 4), highlighting the important measures of NPD process frameworks.

5.1. Empirical Investigation to Identify The Need to Address The Modifications of A NPD Framework

Interviews were performed to verify the acceptability and practical use of the NPD process framework specifications and requirements. The interviews were structured as follows: Specific questionnaires for best NPD practice, selection of participants, collection of data, organization of data collected, and presentation and discussion of the results. A set of 37 questions was formed as the foundation for modifications of a PD framework. After answering each of the questions, the average is calculated. High score points are considered as acceptance of framework requirements by industrial experts and are an input in design and development activities for the proposed new theoretical NPD process framework for the automobile Industry.

The selected respondents (Table 5) went through the defined questions (Table 6) and were assigned a scale referring to Table 4.

On reviewing the data presented in Table 6, it is apparent that all survey participants agreed that the NPD process framework for automobile companies should include identified specifications and requirements in design and development activities. In light of this, the proposed NPD process framework effectively addresses the concerns expressed by the participants, as detailed in the following section.

Table 4. Scale matrix

Scale	Definition
5	Strongly agree
4	Agree
3	Neutral
2	Disagree
1	Strongly disagree

6. Proposed NPD Process Framework for The Automobile Industry

Fig. 3 depicts the proposed NPD process framework model, distinguishing between the stages and the gates for the automobile industry. The proposed NPD process framework consists of eleven Stages and Gates across the NPD. The development routines vary from one stage to another. In each stage, there are significant, related main activities that are progressing in parallel with the process as described in Tables 7-17. For each stage, there are gateway(s) indicating activities of monitoring and controlling the ongoing development process. Tables 7-17 show the descriptions of the activities involved in each of the Stages, while Fig. 4 to Fig. 14 shows Stage-Gate NPD activities integration in the form of frameworks.

Each of these eleven stages and gates, as shown in Tables 7-17, is explained as follows;

(1) Stage one, named market research and concept inception, includes the lead role of the marketing department, supported by other departments such as product planning, finance and budgeting, design and development, human resources, launch planning, and the core team. In this stage, an idea is generated after the study and compilation of customer data or customer requirements. The objective of stage one is to complete twenty-one activities. The deliverables of stage one are reviewed in gate one, named idea review, where targets are proposed, and an assessment of affordable alternatives is weighed, including program strategy, product vision, product content, and program goals.

(2) Stage two, named concept verification, includes the lead role of the design department, supported by other departments such as marketing, product planning, development, and the core team. In this stage, the design team develops design features and characteristics after reviewing

Table 5. Profile of respondents

No.	Designation of respondent	Type of company	The sector of the company	Product type
1	Retired manager	Multinational	Automobile/Ancillaries	Highly standardized
2	Vice president	Domestic private	Electrical and 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	Multinational	Others	Standard with custom options
9	Manager	Multinational	Automobile/Ancillaries	Highly standardized
10	Manager	Domestic private	Automobile/Ancillaries	Standard with custom options

Table 6. New product development process survey result analysis

Question	How important is the question? average score
There should be a process for undertaking portfolio management	4.6
New product development (NPD) goals should be clearly defined and visible within the company	4.9
The company should consider NPD as a long-term strategy	4.6
The mission and strategic plan should help to define strategic arenas for new opportunities	4.8
NPD goals should clearly align with the company's mission and strategic plan	4.8
Projects in a portfolio that should be aligned with the NPD strategy	4.6
NPD projects and programs should be reviewed on a regular basis in the company	4.8
Shall Opportunity identification be an ongoing process? and can redirect the strategic plan in real-time to respond to market forces and new technologies	4.5
There should be a ranking or prioritization of NPD projects	4.6
There should be a consideration for balancing the number of projects and available resources	4.7
Concept, product, and market testing should be consistently undertaken and expected with all NPD projects	4.6
Research should be high if any market research is undertaken	4.6
Customer/user should be an integral part of the NPD process	4.7
Studies of customers and users should be focused on both current and future customer needs and problems	4.7
The company should avoid changing marketing budget decisions dramatically and up to the point of launch	4.0
The launch team should be cross-functional in nature	4.7
Cross-functional teams should make decisions concerning manufacturing, logistics, marketing, and sales	4.6
A project post-mortem meeting should be held after the new product is launched	4.3
Commercialization should be a formal part of the NPD process	4.3
Go/No-Go criteria should be clear and pre-defined for each review gate	4.6
The NPD process should be flexible and adaptable to meet the needs, size, and risk of individual projects	4.6
The NPD process should be visible and well-documented	4.8
Information technology (IT) infrastructure with appropriate hardware, software, and technical support should be available to all NPD personnel	4.7
A clear NPD process should exist	4.7
The company should review projects at the point of completion	4.9
The core project team should work on the NPD project from beginning to end	4.8
Each project should have a clearly identifiable stage-wise project leader	4.7
There should be enough formal communication to properly coordinate NPD activities	4.6
The company should appear to have the right number of projects individually assigned to NPD personnel	4.5
NPD should be a Top priority of management	4.4
The company should actively work with customers to identify new product opportunities	4.8
All NPD ideas should welcome those that come from within and outside of the company	4.6
Management should not primarily be focused on operational efficiency and cost savings	4.0
There should be standard criteria for evaluating individual NPD projects	4.6
There should be standard criteria for evaluating individual NPD efforts	4.6
All NPD project evaluations should be stage-wise and by the CFT team	4.3
NPD projects should be killed before they reach launch if they fail to achieve the stage-wise target	3.3

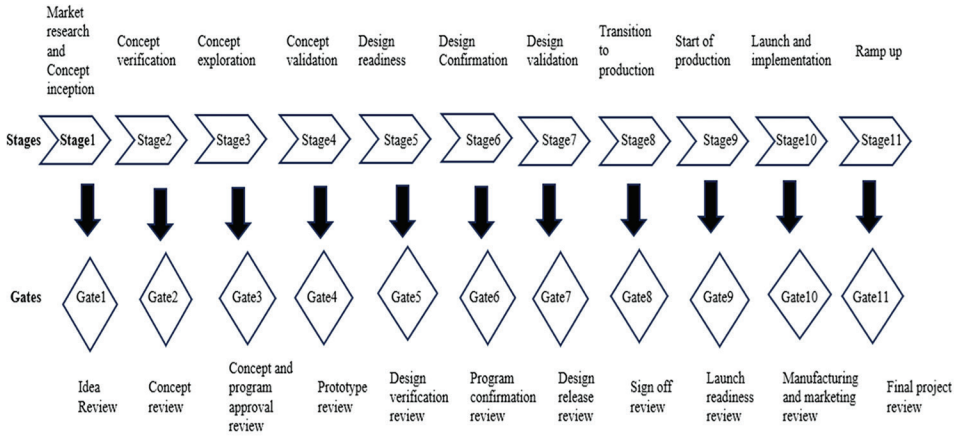

Fig. 3. The proposed new product development process framework model distinguishes between the gates and the stages for the automobile industry

engineering requirements and assessing potential manufacturing problems. The objective of stage two requires completing 20 activities. The deliverables of stage two are reviewed in gate two, named concept review, after gate one (Idea Review) approval, where overall targets are set (Performance, Functional, and Financial), the preliminary project plan is prepared, R&D funds get approved, manufacturing and purchasing opportunities and capacity are reviewed and confirmed, make versus buy decision and manufacturing location confirmed, and project feasibility is confirmed. If found not feasible, the closing report is preserved in the knowledge of the management repository.

(3) Stage three, named concept exploration, includes the lead role of the design department, supported by other departments such as marketing, product planning, development, core team, supplier, launch planning, finance and budget, and manufacturing engineering. In this stage, concept selection and concept analysis activities are completed by the design team. The objective of stage three requires completing 21 activities. The deliverables of stage three are reviewed in gate three, named concept and program approval review, after gate two (concept review) approval, where product specification and styling are frozen, program cost target is frozen, and project budget code is created, and quality and reliability targets are signed off.

(4) Stage four, named concept validation, includes the lead role of the design and development department, supported by other departments such as product planning, HR, supplier, launch planning, finance and budget, and manufacturing engineering. In this stage, design features and characteristics are finalized after reviewing engineering requirements and assessing potential manufacturing problems, and comprehensive and effective manufacturing systems are developed, ensuring that the manufacturing system meets customer requirements. The objective of stage four requires completing 20 activities. The deliverables of stage four are reviewed in gate four, named prototype review after gate three (concept and program approval review) approval, where based on the voice of the customer and customer requirements, technical specifications are developed in the form of PDB, safety data sheet and design input, and customer input requirements and preliminary drawings under PPRF number are released.

(5) Stage five, named design readiness, includes the lead role of the design department, supported by other departments such as product planning, HR, supplier, development, launch planning, and manufacturing engineering. In this stage, a detailed design is ready. The objective of stage five requires completing 15 activities. The deliverables of stage five are reviewed in gate five, named as design verification review, after gate four (Prototype Review) approval, where based on the EP build and test experience, drawings are released for procurement of new parts under PPRF number and final BOM is prepared thus confirming the designs for further activity of facility and process planning.

(6) Stage six, named design confirmation, includes the lead role of the design and development department, supported by other departments such as product planning, HR, supplier, launch planning, and manufacturing engineering. The objective of this stage is design analysis, simulation, and manufacturing planning (FTG planning). The objective of stage six requires completing 14 activities. The deliverables of stage six are reviewed in gate six, named

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Table 7. Stage 1 and Gate 1 new product development activities

Stage-Gate NPD Activities	**Stage-Gate Objectives, Lead Roles, Inputs and Deliverables**		
Stage 1 – Market research and concept inception	Objectives- (1) To define an idea (2) To determine customer needs (3) To define a quality program		
Gate 1 – Idea review	Objectives – Based on inputs from the voice of the customer (VOC), Market Research, High Priority Customer Wants, and Competitive Benchmark, targets are proposed, and an assessment of affordable alternatives is weighed. The idea review gateway includes (1) Program strategy, (2) Product vision, (3) Product content, and (4) Program goals.		
NPD activities	Lead role	Inputs	Deliverables
(1) Market research (2) Market survey of existing products and similar products (3) Decide Market Segment and Volume (4) Refer J. D. Power (Consumer Survey) and related inputs in the similar segment (5) Identify competitor product (6) Decide benchmark and benchmark testing (7) Receive strategy from management (8) Collate the voice of the customer (VOC) (9) Convert VOC into customer requirements (10) Initiate and obtain QFD (11) Identify competitor vehicle (12) Generation of Product Request Form (13) Collect data on- Market volumes, segment, competition, Design Input, Customer Inputs, Business intent, Business Environment, Financials, Selection of partners, Resources, etc. (14) Decide benchmark and conduct benchmarking studies (15) Creation of ideas (16) Development of the concept based on the requirement request (17) Search for Patents	(1) Product planning/Program management (2) Top management (3) Customer (4) Marketing (5) Finance and Budgeting (6) Design and Development (7) Human resource (8) Core team (9) Launch planning service and training	(1) Voice of the Customer (2) Business Plan/Marketing Strategy (3) Product/Process Benchmark Data (4) Product/Process assumptions (5) Product Reliability studies (6) Customer inputs	(1) Product intent (2) Direction from Top Management (3) Collation of Voice of Customer (Corporate, Regulatory, Final Customer, Manufacturing etc.) (4) Market intelligence inputs considered (5) Limited CFT in place (6) QFD analysis leading to Concepts (7) Forecasting techniques (volume) (8) Product specifications outlined on the Product Request Form (9) Required Job1 date indicated (10) Overall “Boundary levels Targets” for Costs, Weights, and Investments set

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Table 7. *(Continued)*

Stage-Gate NPD Activities	**Stage-Gate Objectives, Lead Roles, Inputs and Deliverables**		
(18) Product Portfolio analysis (19) Collect data for the Business Case (20) Gateway review meetings (21) Register as a new development program			

Abbreviations: CFT: Cross-functional team; J1: Job 1; PRF: Product Request Form; QFD: Quality function deployment; VOC: Voice of customer.

Table 8. Stage 2 and Gate 2 new product development activities

Stage-Gate NPD Activities	**Stage-Gate Objectives, Lead Roles, Inputs and Deliverables**		
Stage 2 – Concept verification	Objectives- (1) To develop design features and characteristics. (2) To critically review engineering requirements and assess potential manufacturing problems, if any		
Gate 2 – Concept review	Objectives – Based on Gate 1 (Idea Review) approval, (1) Overall "Targets" are set (Performance, Functional and Financial), (2) Preliminary project plan prepared, (3) R&D funds are approved, (4) Manufacturing and purchasing opportunities and capacity reviewed and confirmed – make v/s buy decision and manufacturing location confirmed,		

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Table 8. *(Continued)*

Stage-Gate NPD Activities	**Stage-Gate Objectives, Lead Roles, Inputs and Deliverables**		
	(5) Product content is sufficiently detailed to drive the project and (6) Project feasibility is confirmed. If found not feasible, the closing report is preserved in the Knowledge Management Repository.		
NPD activities	Lead role	Inputs	Deliverables
(1) Refer to QFD and translate to technical specifications (2) Design Review Concept – DR0 (3) Creation of Unique Selling Points (USPs) (4) Styling options and Concept layout completed (5) Buck components made; Static buck build started – "Mock" ready for approval (6) Buck evaluation (7) Define the scope of the project (Product and Process – Vehicle Level Assumptions), initiate PDB/VDS/SDS development (8) Identify Technology options (Concept Ready and Implementation Ready) (9) Identify powertrain options (10) Identify Regulatory and Product Liability requirements (11) Refer to Lessons learned from previous projects (12) Evaluate the feasibility and revision of the Product Request Form (13) Identify consultants, as applicable (14) Check manufacturing feasibility, competency, and capacity (In-house/vendor) (15) Declare the project team (ensure representation from essential functions) (16) Initiate timing plan (17) Make/buy decision (18) Prepare a business case with a sensitivity analysis (19) Prepare project budget (20) Gateway review meetings	(1) Customer (2) Management (3) Marketing (4) Product design (5) Order management (6) Program Management	(1) Voice of the Customer (2) Business Plan/Marketing strategy (3) Product/Process Benchmark Data (4) Product/Process assumptions (5) Product Reliability studies (6) Customer inputs	(1) Concept (layout) frozen (along with SWOT analysis), Product Request Form Sign-off (2) Manufacturing Musts and Wants Submitted (3) Functional Image targets set based on signed-off Product Request Form (4) Engine, transmission, and Axle options selected (5) Consultants, if any, are identified (6) DR0 (Concept) conducted and outputs recorded (7) Project/Program Team declared; Prod. Launch Manager Identified (8) High Impact-High Risk vendors identified and are on board (9) Mock-up approved (10) Preliminary Project Plan outlined, including firm Job1 date (11) Project key deliverables frozen, including reusability targets (12) Assumptions for PDB (Product Description Book), Concept Styling, Functional Image Targets evolved (13) Product Cost target, Manufacturing Location, make v/s Buy Decision, volume commitment, including cannibalization, decided (14) Business Case details collated, including sensitivity analysis (15) Investments, IRR and Business Case Approved

Abbreviations: DR: Design review; IRR: Internal rate of return; NPD: New product development; PALS: Product attribute leadership strategy; PCF: Process flow chart; PDB: Product data book; SDS: System design specification; SWOT: Strengths, weaknesses, opportunities, and threats; TCE: Teamcenter engineering; VDS: Vehicle design specification.

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Table 9. Stage 3 and Gate 3 new product development activities

Stage-Gate NPD Activities	**Stage-Gate Objectives, Lead Roles, Inputs and Deliverables**		
Stage 3 – Concept exploration	Objectives- 1. Concept selection, 2. Concept analysis		
Gate 3 – Concept and Program approval review	Objectives – Based on Gate 2 (Concept review), the program is approved. 1. Product specification and styling are frozen 2. The Program Cost target is frozen, and the project budget code is created 3. Quality and Reliability targets signed off		
NPD activities	Lead role	Inputs	Deliverables
(1) Sign-off targets for functional image, cost, quality, durability, reliability, warranty, time, etc. (2) Decide reusability strategy for facilities, parts, technology, resources, etc. (3) Identify and release hardpoints (4) Identify and complete RWUP (5) Finalize Product Specifications (VDS and SDS, as applicable) (6) Ensure EP readiness of Powertrain (for new development) (7) Internal and external (supplier) manufacturing and assembly objectives consistent with the timing, resource, and investment targets of the vehicle (8) Complete PDB (Product Description Book) and sign-off (9) Make/Buy decision (10) Identify the scope, budget, resource plan, and timing for verification/validation (11) Verify feasibility for CMVR/Homologation and safety (12) Prepare development timing plan and Work Breakdown Structure (WBS) (13) Identify the critical activity path (14) Complete and present Project Budget, Resource Plans, Timing Plans, Deliverables, Benefits, and Business Case for Approval of Corporate Projects (15) Preliminary decision on allocation of manufacturing responsibilities (16) Investigation of necessary production capacity (17) Initiate DFA/MA analysis, as applicable (18) Go ahead/Hold decision for design (19) Creation of budget code (20) Lessons learned recorded (21) Gateway review meetings conducted	(1) Product design (2) Product development (3) Program Management	(1) Voice of the Customer (2) Business Plan/ Marketing Strategy (3) Product/Process Benchmark Data (4) Product/Process Assumptions (5) Product Reliability studies (6) Customer inputs	(1) Define and complete RWUP (2) Quality and Reliability Targets Signed Off (3) Project budget approved by Corporate Projects and budget code created (4) Engine, Transmission and Axle EP ready (if under development) (5) Cost targets for VDS and SDS defined (6) Baseline Plan including Work Breakdown Structure/PDB Signed Off (7) Lessons Learnt Recorded

Abbreviations: APQP: Advanced product quality planning; CMVR: Central motor vehicle regulation; CP: Clay prototype; DFA: Design for assembly; DMA: Design for manufacturing.; EBOM: e-Bill of material; EP: Engineering prototype; FTG: Facility tooling gauge; HIHR: High-risk high impact; IPR: Intellectual property rights; P&H: Packaging and hard point; PALS: Product attribute leadership strategy; PDB: Product data book; PR: Prototype request; RFQ: Request for quotation; RWUP: Real-world usage pattern; SAM: Serviceability, accessibility, and maintainability; SDS: System design specification; SOR: Statement of requirement; TCF: Teamcenter engineering; VDS: Vehicle design specification; WBS: Work breakdown structure.

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Table 10. Stage 4 and Gate 4 new product development activities

Stage-Gate NPD Activities	**Stage-Gate Objectives, Lead Roles, Inputs and Deliverables**		
Stage 4 – Concept validation	Objectives- 1. To finalize design features and characteristics. 2. To critically review engineering requirements and assess potential manufacturing problems, if any 3. To develop a comprehensive and effective manufacturing System. 4. To ensure that the manufacturing system meets customer requirements		
Gate4 – Prototype review	Objectives – Based on the VOC and Customer Requirement (CR) converted to technical specification in the form of PDB, SDS, Design Input, and Customer Input Requirement, the design teams prepare the preliminary drawings under the PPRF number		
NPD activities	Lead role	Inputs	Deliverables
(1) Preparation of preliminary Bill of Materials and add-delete list (2) Cascade vehicle design specifications to system and component levels. Document SDS and CDS. (3) Initiate and complete DFMEA with recommended actions (4) Vehicle, system, and sub-system level layouts ready (5) Develop and release System and Component level designs (PPRF drawings) for EP (6) MP level build and MP testing (7) Record MP learnings (8) Design Review (Product Design) – DR1 (9) Verify specifications and update PDB based upon SDS	(1) Customer (2) Management (3) Marketing (4) Product design (5) Order management (6) Program Management	(1) Design goals (2) Reliability and quality Goals (3) Preliminary Bill of Material (4) Preliminary process flow chart (5) Preliminary listing of special product and process Characteristics (6) Product Assurance Plan (7) Management support (8) Design failure mode and effects analysis (DFMEA) (9) Design for manufacturability and Assembly (10) Design verification	(1) Availability of preliminary BOM/ “Add-Delete” list (2) Cascading of VDS - SDS – CDS (3) Develop Customer Input Requirements (4) MP preparation (if required) (5) Design Review (Product)-DR1 and recommendations available (6) DFMEAs Initiated and Completed with recommended actions (7) QFD - system level completed for the identified system (8) Vehicle-level design ready

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Table 10. *(Continued)*

Stage-Gate NPD Activities	**Stage-Gate Objectives, Lead Roles, Inputs and Deliverables**		
(10) EP development planned (11) Customer Input Requirement finalization (include performance, functional, appearance, regulatory, reliability, capacity, serviceability, manufacturability, warranty, etc., targets) (12) Prepare concept model for CAE (13) Selection of high-risk-high Impact Suppliers (Sourcing decision) (14) Release specific Customer Input Requirements to the supplier (15) Initiation of APQP at HI-HR suppliers (Prepare Quality Plan) (16) System-level and Component-level DVP completed (17) CAE Analysis complete		(11) Design review (12) Prototype Build – Control Plan (13) Engineering drawings (Including Math Data) (14) Engineering Specifications (15) Material specifications (16) Drawing and specification changes (17) New Equipment, Tooling, and Facilities Requirements (18) Special Product and Process Characteristics (19) Gages/Testing Equipment Requirements (20) Team Feasibility, commitment, and management support	(9) Systems and subsystem-level layouts are ready (10) SDS, CDS level designs ready for release (11) System Level DVP (12) Component Level DVP ready (13) Completion of CAE Analysis (14) MP learnings recorded (15) Long lead tooling and Facilities identified (16) Sourcing Decision [HI-HR] made and APQP initiated for suppliers and in-house. (17) PPRF released for new parts. (18) Preliminary BOM

Abbreviations: APQP: Advance product quality planning; BOM: Bill of material; CAE: Computer-aided engineering; CDS: Component design specification; CIR: Customer input requirement; CP: Clay prototype; DFMEA: Design failure mode effect analysis; DMU: Digital mock-up; DR: Design review; DVP: Design verification plan; EP: Engineering prototype; FTG: Facility, tooling, gauge; HIHR: High-risk high impact; MIMR: Medium risk medium impact; MP: Mechanical prototype; PPRF: Prototype request form; QFD: Quality function deployment; RFQ: Request for quotation; SAM: Serviceability, accessibility, and maintainability; SAP: System applications and products in data processing; SDS: System design specification; VDS: Vehicle design specification; VP: Validation prototype; WBS: Work breakdown structure.

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Table 11. Stage 5 and Gate 5 new product development activities

Stage-Gate NPD Activities	**Stage-Gate Objectives, Lead Roles, Inputs and Deliverables**		
Stage 5- Design readiness	Objectives – 1. Detailed design readiness		
Gate 5 – Design verification review	Objectives – Based on the EP build and test experience, drawings are released for procurement of new parts under the PPRF number, and the final BOM is prepared, thus confirming the designs for further activity of facility and process planning		
NPD activities	Lead role	Inputs	Deliverables
(1) Updating technical specifications and features w. r. t. current competition and new market scenario (Review QFD) (2) Driveline performance analysis (3) Updating drawings to conform to design guidelines (4) Identify SC/CC (5) Final Engineering bill of materials ready in metaphase (6) Develop Appearance including colour and trim (7) Design Review DR-2 (Process Design) (8) Update CAE Analysis – strength, durability, and kinematics (9) Price negotiation/Finalize price (10) Release of PO (11) Receive aggregates/components for EP (12) Product launch manager identified for M2, M4 projects (13) EP build as per prototype control plan (14) Initiation of Process design and Process FMEAs (15) Identify resource requirement	(1) Product design (2) Product development (3) Program Management	(1) Design Goals (2) Reliability and Quality Goals (3) Preliminary Bill of Material (4) Preliminary Process Flow Chart (5) Preliminary Listing of Special Product and Process Characteristics (6) Product Assurance Plan (7) Management support (8) Design Failure Mode and Effects Analysis (DFMEA) (9) Design for Manufacturability and Assembly (10) Design Verification (11) Design Reviews (12) Prototype Build – Control Plan (13) Engineering Drawings (Including Math Data)	(1) Availability of preliminary BOM/"Add-Delete" list (2) Cascading of VDS - SDS – CDS (3) Develop Customer Input Requirements (4) MP preparation (if required) (5) Design Review (Product)-DR1 and recommendations available (6) DFMEAs Initiated and Completed with Recommended actions (7) QFD – system level completed for identified system (8) Vehicle-level Design ready (9) Systems and subsystem level layouts ready (10) SDS, CDS level designs ready for release (11) System Level DVP (12) Component Level DVP ready

Abbreviations : AIAG: Automotive industry action group; APQP: Advance product quality planning; BOM: Bill of material; CAE: Computer-aided engineering; CC: Critical characteristics; CDS: Component design specification; CIR: Customer input requirements; CP: Clay prototype; DFMEA: Design failure mode effect analysis; DR: Design review; DVP: Design verification plan; DVP&R: Design verification plan and report; EBOM: e-Bill of material; ELV: End of life of a vehicle; EP: Engineering prototype; FMEA: Failure mode effect analysis; FTG: Facility, tooling, gauge; M2, M4 Projects: Minor and major modification projects; MP: Mechanical prototype; PFMEA: Process failure mode effect analysis; PO: Purchase order; QFD: Quality function deployment; SAP: System applications and products in data processing; SC: Significant characteristics; SDS: System design specification; TCE: Team center engineering; VDS: Vehicle design specification; VP: Validation prototype; Ys YCS: Failure modes.

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Table 12. Stage 6 and Gate 6 new product development activities

Stage-Gate NPD Activities	**Stage-Gate Objectives, Lead Roles, Inputs and Deliverables**		
Stage 6 – Design confirmation	Objectives- 1. Design analysis and simulation 2. Manufacturing planning (FTG planning)		
Gate 6 – Program confirmation review	Objectives- 1. Final design release 2. Long lead tooling signs off		
NPD activities	Lead role	Inputs	Deliverables
(1) Marketing Launch team in place (2) EP concern resolution and changes incorporated in drawings (3) EN drawings released for VP build (4) Preparation of Installation drawings (5) Identified vendors' commitment preparedness for J1 (All vendors signed off) (6) Select/Design, Develop, and Procure new Facilities, Tools and Gauges (7) Prepare Process Flow Chart based on FTG, Floor Plan Layout (8) Process FMEA completed (9) Review resource requirement (10) Manufacturing Launch Team in place (11) Review and confirm Business case (12) Go ahead/Hold decision for manufacturing and marketing (13) Lessons learnt recorded (14) Gateway review meeting	(1) Product planning/Program Management (2) Supplier (3) Manufacturing engineering/ Facility creation (4) Design and development (5) HR (6) Marketing (7) Launch planning/service and training	(1) Design goals (2) Reliability and Quality goals (3) Preliminary Bill of Material (4) Preliminary Process Flow Chart (5) Preliminary Listing of Special Product and Process Characteristics (6) Product Assurance Plan (7) Management support (8) Design Failure Mode and Effects Analysis (DFMEA) (9) Design for Manufacturability and Assembly (10) Design Verification (11) Design Reviews (12) Prototype Build – Control Plan (13) Engineering Drawings (Including Math Data) (14) Engineering Specifications (15) Material Specifications (16) Drawing and Specification Changes (17) New Equipment, Tooling, and Facilities Requirements (18) Special Product and Process Characteristics (19) Gages/Testing Equipment Requirements (20) Team Feasibility commitment and management support	(1) Revalidate Business Case assumptions and confirm Business Case (2) Go/Kill decision given (3) Identification and Deployment of additional and requisite resources (4) EN released for VP build (5) Team Feasibility Commitment (6) Preliminary Process BOM (7) All vendors signed off (8) Vehicle available for customer validation (9) Lessons Learnt Recorded

Abbreviations: AIAG: Automotive industry action group; APQP: Advance product quality planning; BOM: Bill of material; CMVR: Central motor vehicle regulation; DFMEA: Design failure mode effect analysis; DVP and R: Design verification plan and report; EN: Engineering notice; EP: Engineering prototype; FMEA: Failure mode effect analysis; FTG: Facility, tooling, gauge; J1: Job1; SAP: System applications and products in data processing; VP: Validation prototype.

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Table 13. Stage 7 and Gate 7 new product development activities

Stage-Gate NPD Activities	**Stage-Gate Objectives, Lead Roles, Inputs and Deliverables**		
Stage 7 – Design validation	Objectives- 1. Tooled up parts trial 2. Crash test 3. Aggregate test 4. Detail costing		
Gate 7 – Design release review	Objectives – 1. Design release 2. Long lead tooling signs off 3. Component reliability plan 4. Business case validation		
NPD activities	Lead role	Inputs	Deliverables
(1) Marketing launch budget prepared and strategy finalized (2) Dealer selection completed (3) Concern resolution for VP build trial (4) Design Review (DR-3) for Validation completed (5) Tuning of performance, Internal jury evaluation (6) Review the supplier PSW status (7) Tooled-up parts received (8) Application for CMVR Certification (and Homologation) prepared (9) Reliability, durability tests, and key life testing of VP vehicles start as per DVP (Vehicle and Rig) (10) Emission tuning trials (regulation) (11) Install new tools/facilities (12) Operator process instructions (SOP) prepared (13) Operator training initiated (14) Process (SAP) BOM available (15) Manufacturing process sheets initiated (16) VP build control plan completed (17) VP and/or static build ready from Make-like production (including timing verification, BOM Validation) (18) Production Validation Test plan ready (19) NOVA-C evaluation of EP vehicles with scores completed (20) Gateway review meeting conducted	(1) Product planning/Program Management (2) Supplier (3) Manufacturing engineering/ Facility creation (4) Design and development (5) HR (6) Marketing (7) Launch planning/service, and training	(1) Design Goals (2) Reliability and Quality Goals (3) Preliminary Bill of Materials (4) Preliminary Process Flow Chart (5) Preliminary Listing of Special Product and Process Characteristics (6) Product Assurance Plan (7) Management support (8) Design Failure Mode and Effects Analysis (DFMEA) (9) Design for Manufacturability and Assembly (10) Design Verification (11) Design Reviews (12) Prototype Build –Control Plan (13) Engineering Drawings (Including Math Data) (14) Engineering specifications (15) Material Specifications (16) Drawing and Specification Changes (17) New Equipment, Tooling, and Facilities Requirements (18) Special Product and Process Characteristics (19) Gages/Testing Equipment Requirements (20) Team Feasibility, commitment, and management support	(1) VP tooling and parts development (2) Review Supplier PSW status (3) Operator Training initiated (4) BOM Validation (5) VP and/or Static Build ready from “Make-like” Production Process (6) NOVA-C evaluation and scores for EP (7) Dealer selection done (8) Tooled-up parts received (9) Functional Image Targets met through Internal Jury (10) Design Review (Validation)-DR 3 (11) DVP for VP (12) Testing of VP vehicles commences (13) SAP BOM available (14) Application for homologation. (15) PV Test plans ready

Abbreviations: APQP: Advance product quality planning; BOM: Bill of material; CMVR: Central motor vehicle regulation; DFMEA: Design failure mode effects analysis; DR: Design review; DVP: Design verification plan; EP: Engineering prototype; FEU: Field evaluation unit; MSA: Measurement system analysis; NOVA-C: New overall vehicle audit – complete; PFMEA: Process failure mode effects analysis; PDB: Product data book; PO: Purchase order; PP: Production prove out; PSW: Part submission warrant; PTR: Production trail run; PV: Production validation; SAP: System applications and products in data processing; SOP: Standard operating process; VR: Validation prototype.

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Table 14. Stage 8 and Gate 8 new product development activities

Stage-Gate NPD Activities	**Stage-Gate Objectives, Lead Roles, Inputs and Deliverables**		
Stage 8 – Transition to production	Objectives- 1. To validate the manufacturing process 2. To ensure that customer requirements will be met		
Gate 8 – Sign off review	Objectives – Formal acknowledgment that all aspects of product design are completed as per intent and verified		
NPD activities	Lead role	Inputs	Deliverables
(1) Plan product profile (variant/configuration) (2) Plan for media launch (Selection of advertising agency) (3) Identify and initiate the development of a dealership (4) Concern resolution for VP test trial reports and incorporate changes (5) Update the CAE model based on durability results (6) Verify the part quality (7) Reliability, Durability tests, Key life testing, VP testing completed (Vehicle and Rig) (8) Tool and facility try-out and Production Trial Run completed (9) PP build initiated (10) Review Team feasibility commitment (11) Measurement system evaluation starts (12) Preliminary process capability study starts (13) Dealer development initiated (14) Gateway review meetings (15) Jury and Management evaluation for Functional Image (16) Production of promotional material (17) Production of sales aids (18) Preparation of sales person/centers (19) Reconfirm the CAE results (20) Re-affirm performance targets based on Jury evaluation (21) Verify specifications on performance (22) Engineering sign-off (Design and performance targets (23) Concern resolution for field trails (24) Facilitate supplier PPAP (25) Production trial run at supplier (26) Final component price available (27) Verify receipt of PSW for supplier provided parts	(1) Product planning/ Program Management (2) Supplier (3) Manufacturing engineering/ Facility creation (4) Design and development (5) HR (6) Marketing (7) Launch planning/ service, and training (8) Finance and Budgeting	(1) Packaging Standards (2) Product/Process Quality System Review (3) Process Flow Chart (4) Floor Plan Layout (5) Characteristics Matrix (6) Process Failure Mode and Effects Analysis (PFMEA) • Pre-Launch Control Plan (7) Process Instructions (8) Measurement Systems Analysis Plan (9) Preliminary Process Capability Study Plan (10) Packaging Specifications (11) Management Support	(1) Review Supplier PSW status (2) Dealer development initiated (3) Tool Try-out (TTO) completed (4) Process validation completed (5) Production Trial Run (PP) completed (6) Manufacturing Facility ready, including logistics (7) Results of Reliability, VP Tests available (8) Reliability analysis complete (9) Product Cost/Time performance details available. (10) CAE updated based on VP results. (11) Review Team Feasibility Commitment (12) Field Evaluation Units/Pilot lot build commencement for early user feedback (13) PVT involvement begins (14) Production Validation Testing initiated (15) External Jury Evaluation (16) Final component price available (17) Certification for homologation (18) Performance Targets re-affirmed through External Jury (19) Operator training completed (20) Engineering Sign off by:

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Table 14. *(Continued)*

Stage-Gate NPD Activities	Stage-Gate Objectives, Lead Roles, Inputs and Deliverables		
(28) CMVR/Homologation testing complete (Present vehicle to authorities and obtain certificate) (29) Initiation of FEU/Pilot builds for early user feedback using Prelaunch control plan (30) Process FMEA Complete (31) High priority manufacturing issues sorted out (32) Facilities, tools, and gages completion (33) Logistics in place (34) Finalize process (M/C Availability/ capacity/capability) (35) Operator training completed and resources deployed (36) Review and update in-plant indicators (37) Perform production validation testing (38) Verify process capability (PPk) (39) PVT involvement starts (40) Field trials (41) Decide warranty policy (42) Identify and develop a service network (43) Conduct weekly launch meetings (44) Product price (BNDP) available (45) Capture and collate Lessons learned (46) Go ahead/hold the decision for full-scale production (47) Gateway review meetings			Customer Management, Product Development, Vendor Management (21) Mfg. Issues (High Priority) sorted out (22) Design and Performance Signed Off and frozen (23) Product Price (BNDP) Available (24) Logistics in place (25) Lessons Learnt Recorded (26) Supplier PSW complete

Abbreviations: APQP: Advance product quality planning; BNDP: Net dealer price before taxation; BOM: Bill of material; CAE: Computer-aided engineering; CMVR: Central motor vehicle regulation; FEU: Field evaluation units; FMEA: Failure mode effects analysis; FTR: Fitment trial run report; IPR: Intellectual property rights; J1: Job1; PFMEA: Process failure mode effects analysis; PIPC: Percentage of indices process capable; PIST: Percentage of inspection points that satisfies specified tolerance; PP: Production prove out; PPAP: Production part approval process; PPk: Process capability index; PSW: Part submission warrant; PTR: Production trail run; PVT: Plant vehicle team; SAM: Serviceability, accessibility, maintainability; TAKT: Total activity completion time; TTO: Tooling try outs; VP: Validation prototype.

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Table 15. Stage 9 and Gate 9 new product development activities

Stage-Gate NPD Activities	**Stage-Gate Objectives, Lead Roles, Inputs and Deliverables**		
Stage 9 – Start of production	Objectives- 1. To validate the manufacturing process 2. To ensure that customer requirements will be met		
Gate 9 – Launch readiness review	Objectives – Start production of new vehicle, at the manufacturing location, at the TAKT time by the production operators		
NPD activities	Lead role	Inputs	Deliverables
(1) Product Pricing Strategy finalized (2) Advertisement, Exhibitions and demonstrations material ready (3) Distribution network identified (4) Marketing launch plan ready (5) Concern monitoring and resolution on FEUs initiated (6) Design Review (DR-4) for Production (7) Complete the Suppliers' PSW and start material procurement (8) Evaluation of packaging and logistics completed (9) Initiate and finalize ramp-up plan (10) Final variant production plan ready (11) Manufacturing sign off completed (12) Final process (SAP) BOM completed (13) Manufacturing Process Sheets completed (14) Manufacturing PSW complete (15) Complete Production Validation Tests (16) Quality Planning Sign-off (17) Production build control plan prepared (18) Review NOVA-C audits and Update NOVA C targets (19) Field trials continued (20) Develop special service tools (21) Field support plan preparation (22) Dealer development completed (23) Service engineer and Dealer training completed	(1) Product planning/ Program Management (2) Supplier (3) Manufacturing engineering/Facility creation (4) Design and development (5) HR (6) Marketing (7) Launch planning/ service, and training	(1) Production Trial Run (2) Measurement Systems Evaluation (3) Preliminary Process Capability Study (4)Production Part Approval (5) Production Validation Testing (6) Packaging Evaluation (7) Production Control Plan (8) Quality planning sign-off and management support	(1) Service and Dealer Training completed (2) Parts catalog/PAB and operator manual available (3) Quality Planning Sign off completed (4) Ramp-up planning initiated and finalized (5) Spares' Kit and Costing available with dealers (6) Production Validation Testing completed (7) Manufacturing Sign-off completed (8) Packaging and logistics evaluation complete (9) Marketing Launch Plan (Media etc.) ready (10) Final variant production plan ready (11) Action plan on feedback from FEU initiated (12) Manufacturing PSW Complete

(Cont'd...)

Table 15. *(Continued)*

Stage-Gate NPD Activities	Stage-Gate Objectives, Lead Roles, Inputs and Deliverables		
(24) Preparation of Parts and Accessories Bulletin (25) Preparation of Parts Catalogue and Owner's Manual (26) Spare kit, spare pricing, preparation, and distribution (27) Compute product costing (28) Conduct regular launch meetings (29) Gateway review meeting			(13) Distribution network identified (14) Final SAP BOM completed (15) Dealer Development completed (16) Design Review-DR4 completed

Abbreviations: APQP: Advance product quality planning; BOM: Bill of material; DR: Design review; FEU: Field evaluation unit; IPR: Intellectual property rights; MOST: Meynord operation sequence technique; NOVA C: New overall vehicle audit - complete; PSW: Part submission warrant; PV: Production validation; PVT: Plant vehicle team; SAP: System applications and products in data processing; SOP: Start of production; TAKT: Total activity completion time.

Table 16. Stage 10 and Gate 10 new product development activities

Stage-Gate NPD Activities	Stage-Gate Objectives, Lead Roles, Inputs and Deliverables		
Stage 10 – Launch and implementation	Objectives- Introduction of the product into the market		
Gate 10 – Manufacturing and market review	Objectives- Manufacturing and Market launch		
NPD activities	Lead role	Inputs	Deliverables
(1) Market launch events (Event Management at identified markets) (2) Resolution of "A" concerns reported from FEUs completed (3) Availability of components for production quantity as per the ramp-up plan (4) Component ownership transferred to respective supply module(s) (5) Durability tracking study on FEUs continues (6) First run process capability established (Pp, PPk targets) (7) Line balancing and TAKT on production batch achieved	(1) Product planning/Program Management (2) Supplier (3) Manufacturing engineering/ Facility creation (4) Design and development (5) HR (6) Marketing	(1) Production Trial Run (2) Measurement Systems Evaluation (3) Preliminary Process Capability Study (4) Production Part Approval (5) Production Validation Testing	(1) All "A" concerns resolved (2) NOVA-C target achieved (3) Production on line stabilized (4) Ramp-up planning and deployment (5) Concern Management (6) Early field concern resolution (7) First lot of Saleable products

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Table 16. *(Continued)*

Stage-Gate NPD Activities	Stage-Gate Objectives, Lead Roles, Inputs and Deliverables		
(8) Man61ufacture and roll down production batch as per Production Control Plan (9) Initiate Launch Sampling Plan and long-duration vehicle road tests (10) Verify achievement of NOVA-C targets (11) Verify ongoing process capability (CPk) (12) Conduct weekly launch meetings (13) Gateway review meetings	(7) Launch planning/service and training	(6) Packaging Evaluation (7) Production Control Plan (8) Quality Planning Sign-off and management support	(8) Distribution of product (9) Launch form filled (10) Build quantity for nationwide launch (11) Event management for Launch

Abbreviations: APQP: Advanced product quality planning; CDS: Component design specification; DFMEA: Design failure mode effect analysis; DVP: Design verification plan; FEU: Field evaluation unit; J1: Job1; MOST: Meynord operation sequence technique; NOVA-C: New overall vehicle audit - complete; PFMEA: Process failure mode effect analysis; PSW: Part submission warrant; SDS: System design specification; TAKT: Total activity completion time.

Table 17. Stage 11 and Gate 11 new product development activities

Stage-Gate NPD Activities	Stage-Gate Objectives, Lead Roles, Inputs and Deliverables		
Stage 11 – Ramp up	Objectives- Ramp up of production as per the marketing schedule		
Gate 11 – Final Project review	Objectives- Formal closing of the project and the team disbanded.		
NPD activities	Lead role	Inputs	Deliverables
(1) Event Management (Market Launch in different territories) (2) Record and update variance to targets (Q, C, F, T, etc) (3) Update the generic SDS in the reference library (4) Continuous improvements on field concerns (5) Ramp up builds (6) Capture and analyze early customer feedback (USVR) (7) Based on the ramp-up plan and feedback from the field, alternate source development was initiated	(1) Product planning/Program Management (2) Supplier (3) Manufacturing engineering/ Facility creation (4) Design and development	(1) Production Trial Run (2) Measurement Systems Evaluation (3) Preliminary Process Capability Study (4) Production Part Approval (5) Production Validation Testing	(1) Capturing early Customer Feedback (2) Durability tracking study (3) Second Source development (4) Lessons learnt recorded in the format (5) Project variance recorded with real time cost, quality and time

(Cont'd...)

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Table 17. *(Continued)*

Stage-Gate NPD Activities	Stage-Gate Objectives, Lead Roles, Inputs and Deliverables	
(8) Durability tracking study completed (9) Monitor NOVA-C (10) PVT owns the responsibility for the model (11) Capture and collate Lessons Learnt, Update knowledge base (12) Project Closing Report (13) Final Project closing review meeting (14) Evaluate team performance	(6) Packaging Evaluation (7) Production Control Plan (8) Quality Planning sign-off and management support	(6) CAE updated based on Production Validation Test results (7) Customer Survey Process initiated [IQS] (8) Project inventory disposed off (9) CFT disbanded, PVT takes over

Abbreviations: APQP: Advance product quality planning; CAE: Computer-aided engineering; CFT: Cross-functional team; Q, C, F, T: Quality, cost, function, time; IQS: Initial quality study; J1: Job 1; MM: Materials management; NOVA C: New overall vehicle audit – complete; PSW: Part submission warrant; PVT: Plant vehicle team; SDS: System design specification; USVR: User security verification routine.

Program confirmation review, after gate five (Design Verification Review) approval, where the final design is released and long lead tooling is signed off.

(7) Stage seven, named design validation, includes the lead role of the design and development department, supported by other departments such as product planning, HR, supplier, marketing, launch planning, and manufacturing engineering. The objective of this stage is a trial for tooled-up parts, crash tests, aggregate tests, and detailed costing. The objective of stage seven requires completing 20 activities. The deliverables of stage seven are reviewed in gate seven, named as design release review, after gate six (Program Confirmation Review) approval, where the final design is released, long lead tooling is signed off, the component reliability plan is ready, and the business case is validated.

(8) Stage eight, named transition to production, includes the lead role of the design, development, and manufacturing department, supported by other departments such as product planning, HR, supplier, launch planning, finance, budgeting, and manufacturing engineering. The objective of this stage is to validate the manufacturing process and to ensure that customer requirements will be met. The objective of stage eight requires completing 47 activities. The deliverables of stage eight are reviewed in gate eight, named Sign-off review, after gate seven (Design Release Review) approval, where formal acknowledgment is made that all aspects of product design are completed as per intent and verified.

(9) Stage nine, named the start of production, includes the lead role of the manufacturing department supported by other departments such as product planning, design and development, HR, supplier, launch planning, marketing, and manufacturing engineering. The objective of this stage is to validate the manufacturing process and to ensure that customer requirements will be met. The objective of stage nine requires completing 29 activities. The deliverables of stage nine are reviewed in gate nine, named launch readiness review, after gate eight (Sign Off Review) approval, where production of the new vehicle starts at the manufacturing location at the total activity completion time by the production operators.

(10) Stage 10, named launch and implementation, includes the lead role of the launch planning and marketing department, supported by other departments such as product planning, design and development, HR, supplier, and manufacturing engineering. The objective of this stage is the

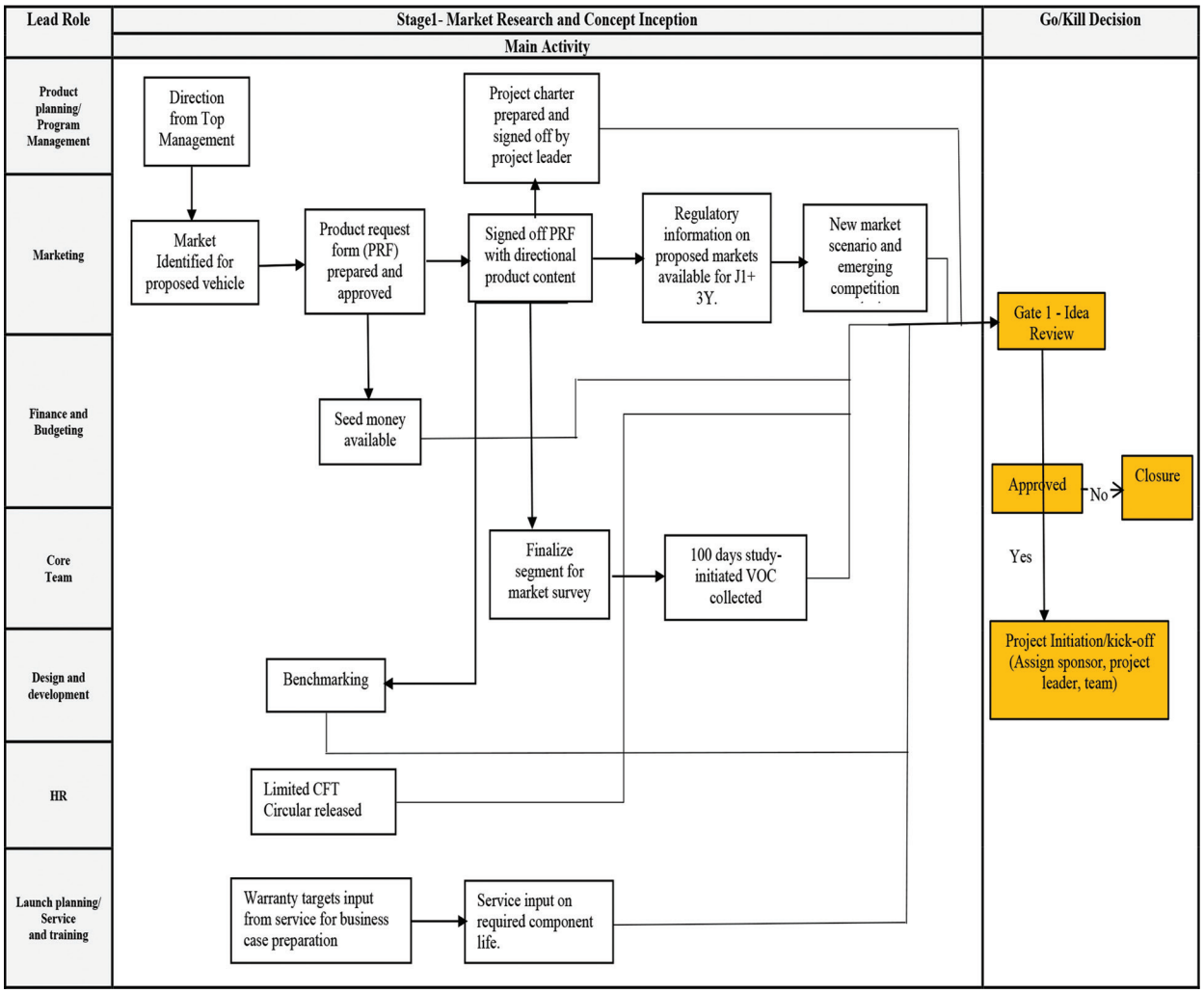

Fig. 4. Proposed new product development process framework for Stage 1 and Gate 1 new product development activities

introduction of the product into the market. The objective of stage ten requires completing 13 activities. The deliverables of stage 10 are reviewed in gate 10, named manufacturing and market review, after gate nine (Launch Readiness Review) approval, where the product is launched.

(11) Stage 11, named ramp-up, includes the lead role of manufacturing, launch planning, and marketing department, supported by other departments such as product planning, design and development, supplier, and manufacturing engineering. The objective of this stage is to ramp up production as per the marketing schedule. The objective of Stage 11 requires completing 14 activities. The deliverables of stage eleven are reviewed in Gate 11, named final project review, after gate 10 (Manufacturing and Market Review) approval, where the formal closing of the project and team is disbanded.

The proposed NPD framework has the following hallmarks as compared to the existing frameworks:

(1) The common stages across all available frameworks include marketing, design, development, manufacturing, and product launch. To simplify and enhance the effectiveness of this framework, each main stage of the NPD process is further divided into sub-stages.

(2) The number and titles of stages and gates are modified to align with specific objectives and deliverables.

(3) Each activity is defined in a structured format, specifying the lead role and its integration within the framework.

(4) This framework is applicable to projects that are new to design and development.

(5) Each stage emphasizes the involvement of both external and internal customers, enhancing cross-functional interaction.

(6) A more disciplined approach to cross-functional meetings and communication in NPD activities involves clear agendas that focus on specific deliverables and criteria, keeping discussions on

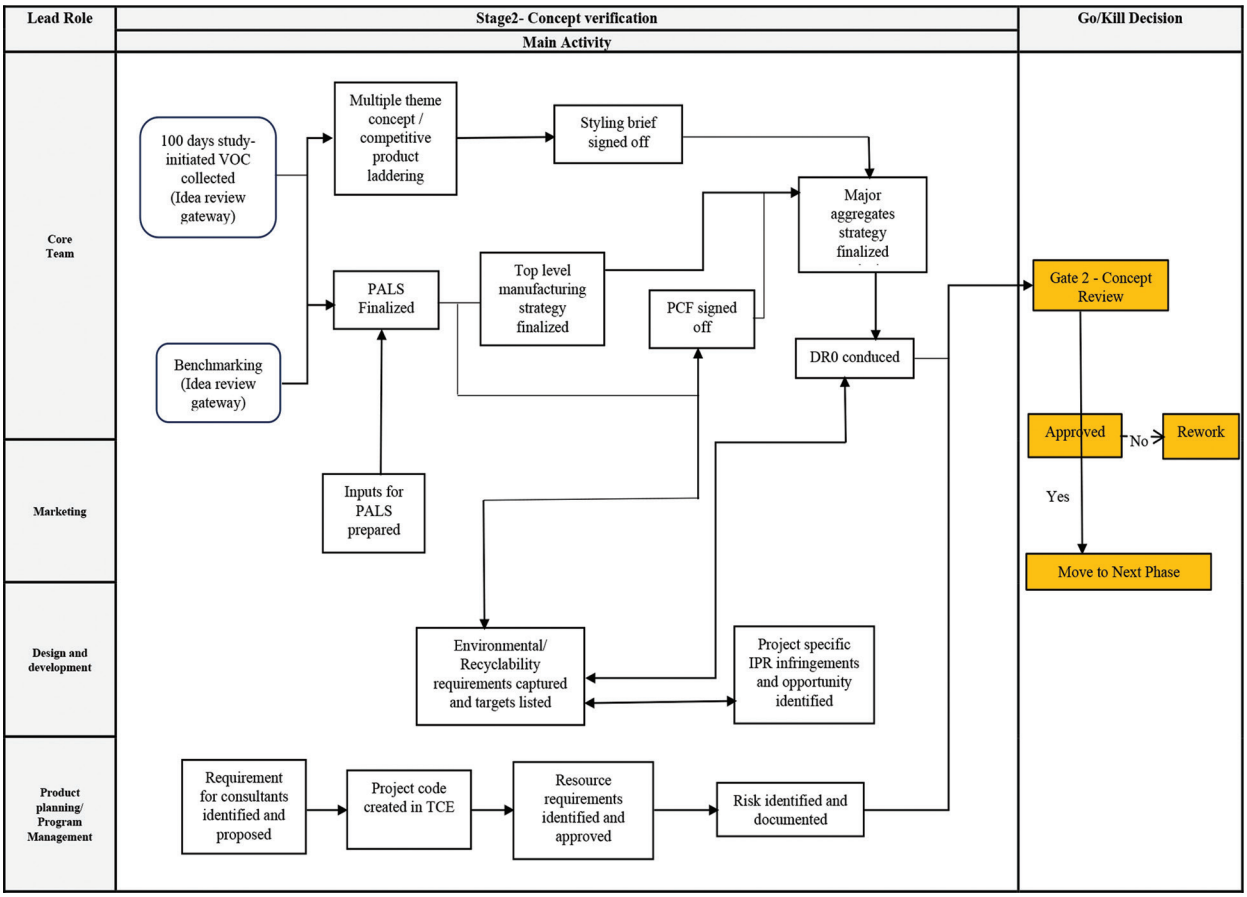

Fig. 5. Proposed new product development process framework for Stage 2 and Gate 2 new product development activities

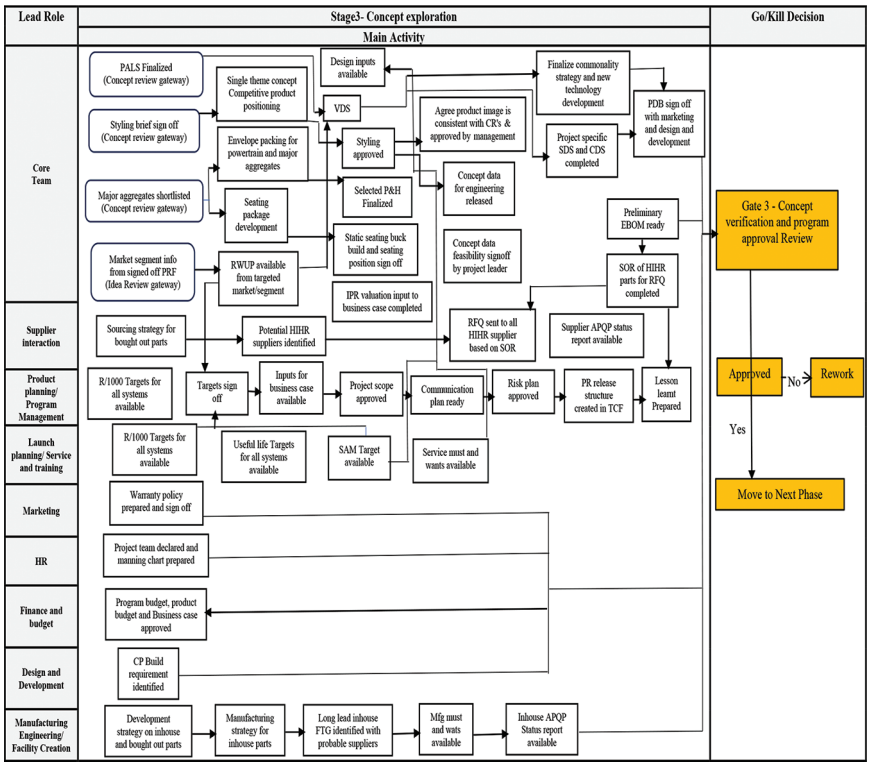

Fig. 6. Proposed new product development process framework for Stage 3 and Gate 3 new product development activities

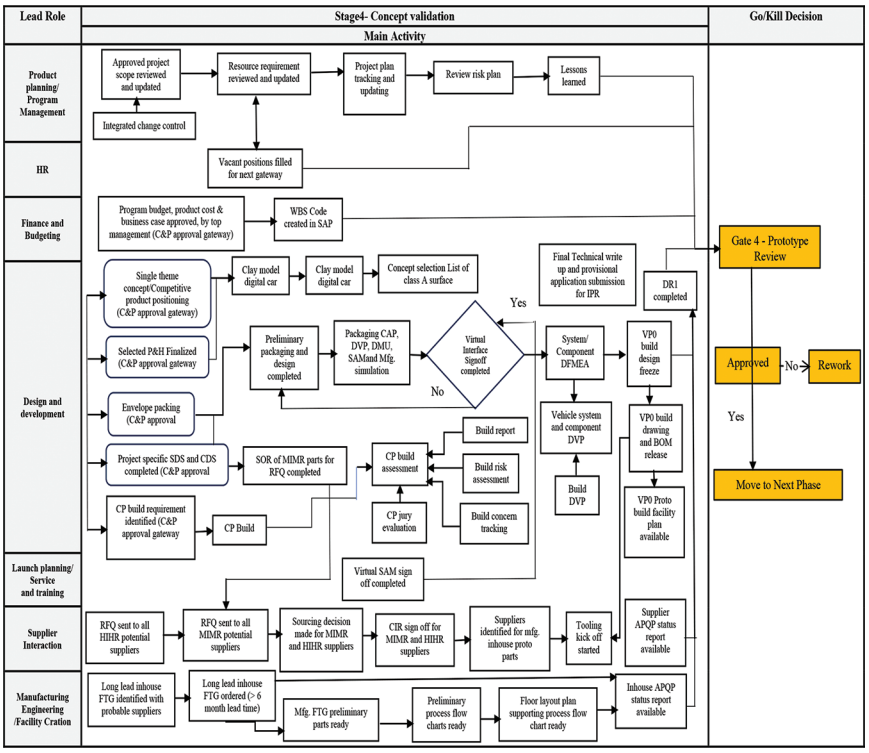

Fig. 7. Proposed new product development process framework for Stage 4 and Gate 4 new product development activities

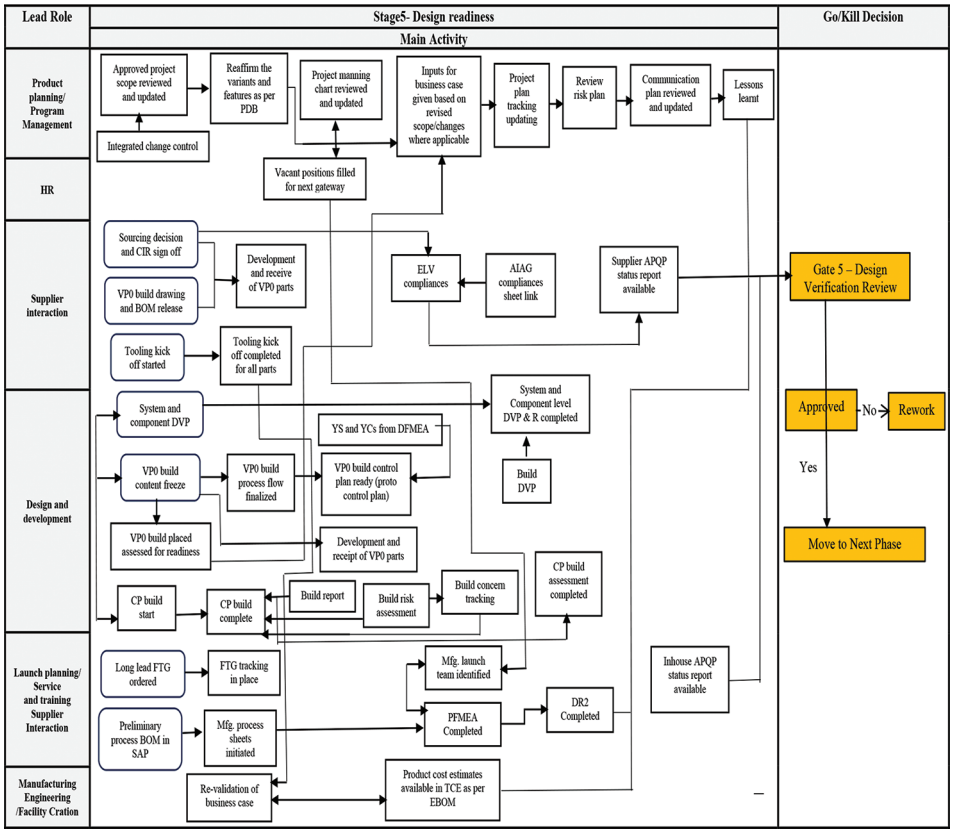

Fig. 8. Proposed new product development process framework for Stage 5 and Gate 5 new product development activities

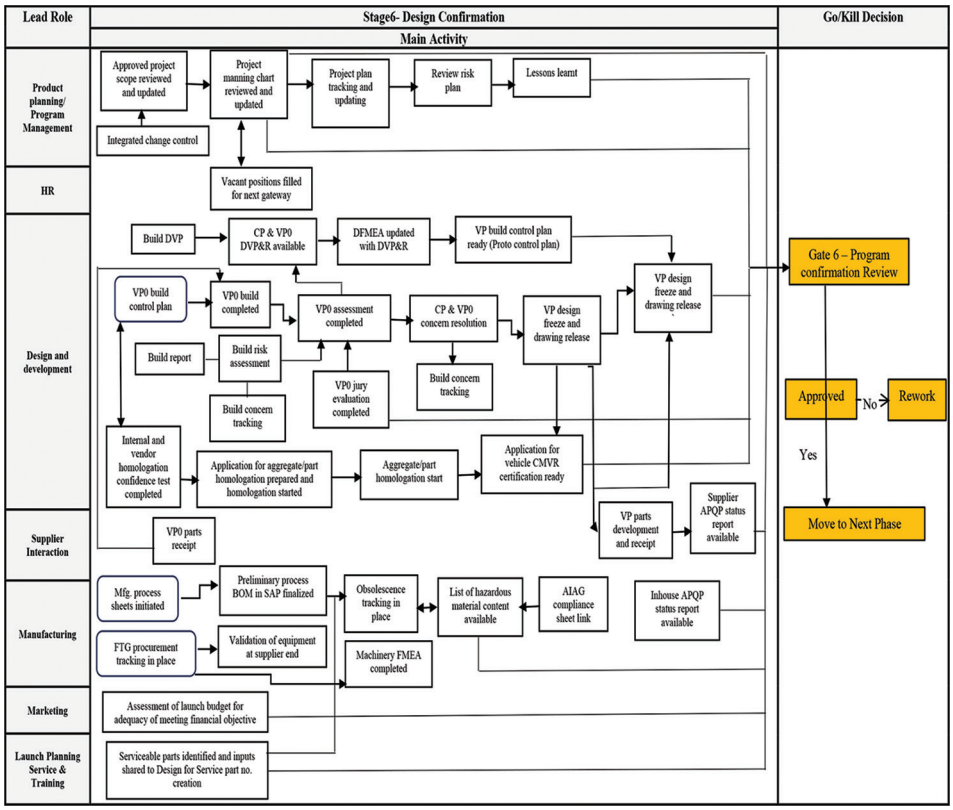

Fig. 9. Proposed new product development process framework for Stage 6 and Gate 6 new product development activities

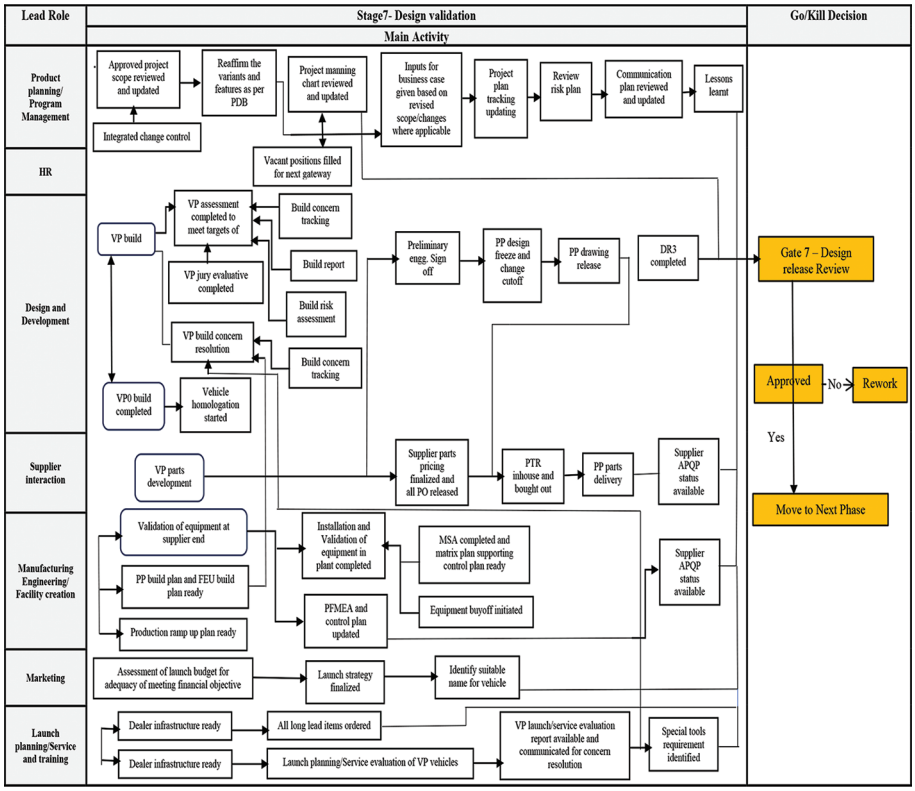

Fig. 10. Proposed new product development process framework for Stage 7 and Gate 7 new product development activities

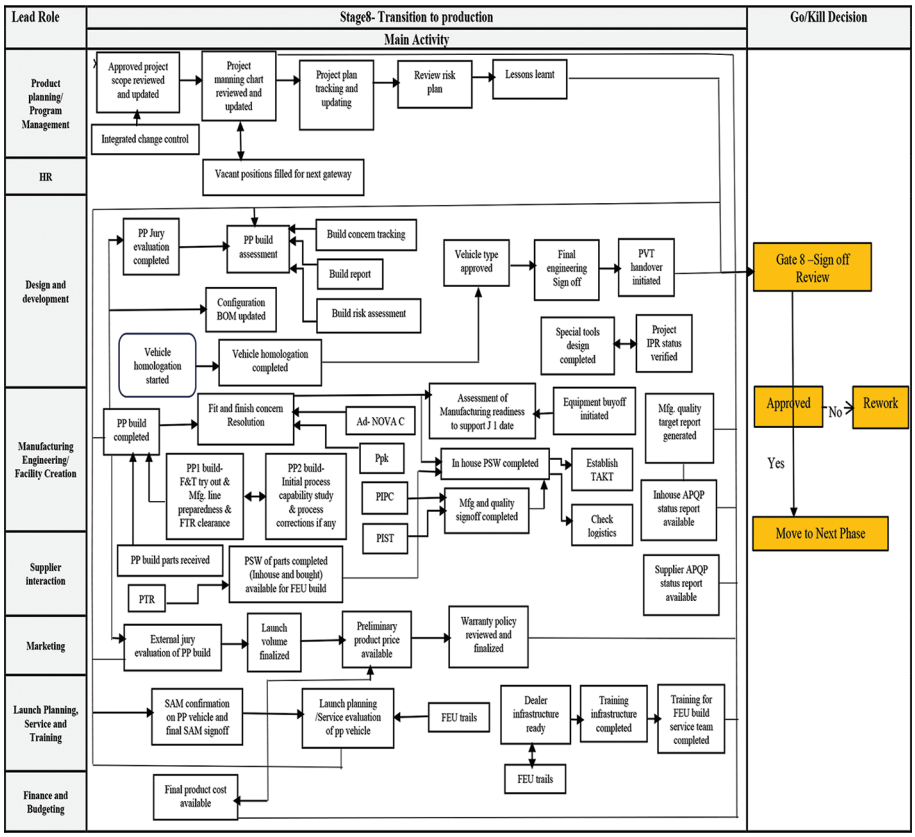

Fig. 11. Proposed new product development process framework for Stage 8 and Gate 8 new product development activities

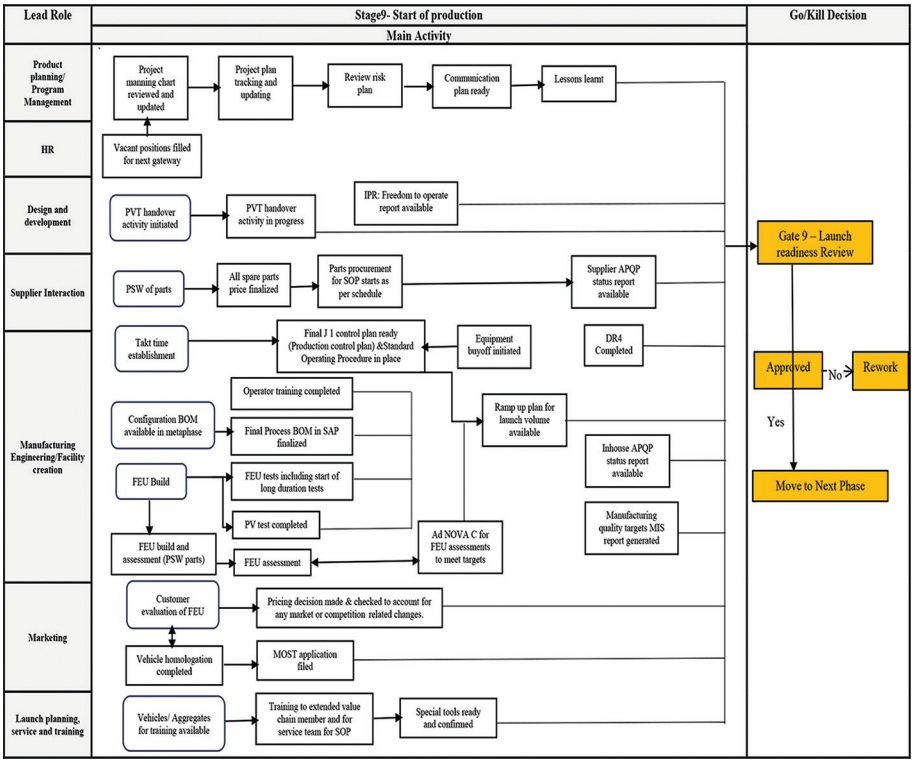

Fig. 12. Proposed new product development process framework for Stage 9 and Gate 9 new product development activities

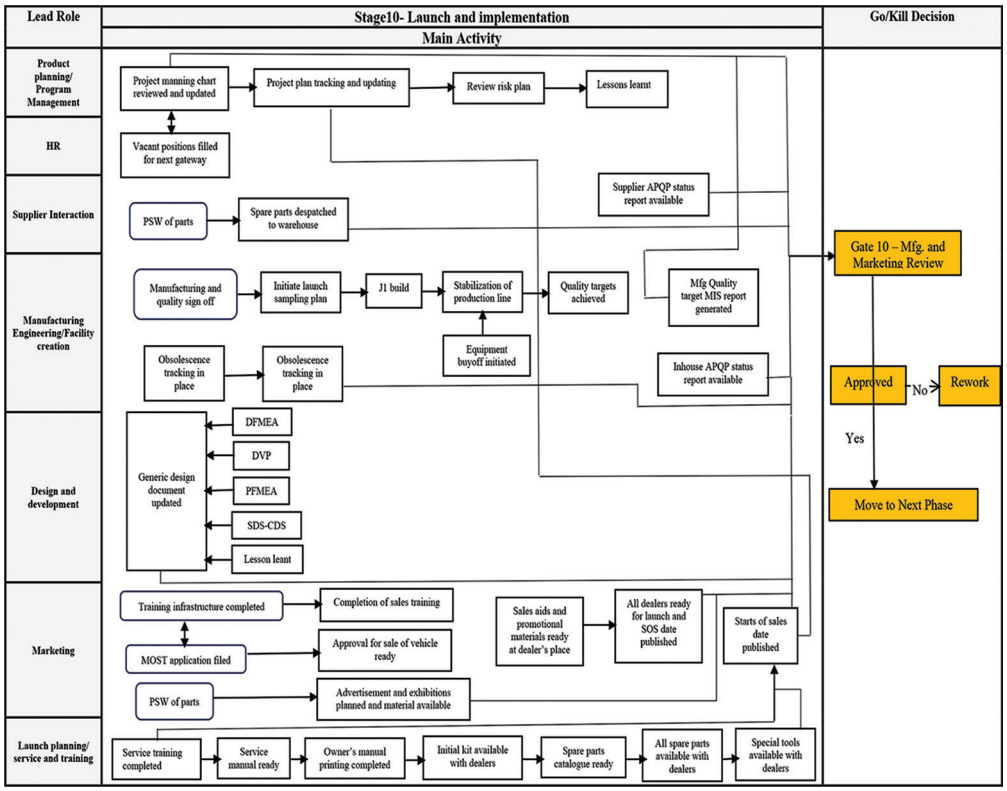

Fig. 13. Proposed new product development process framework for Stage 10 and Gate 10 new product development activities

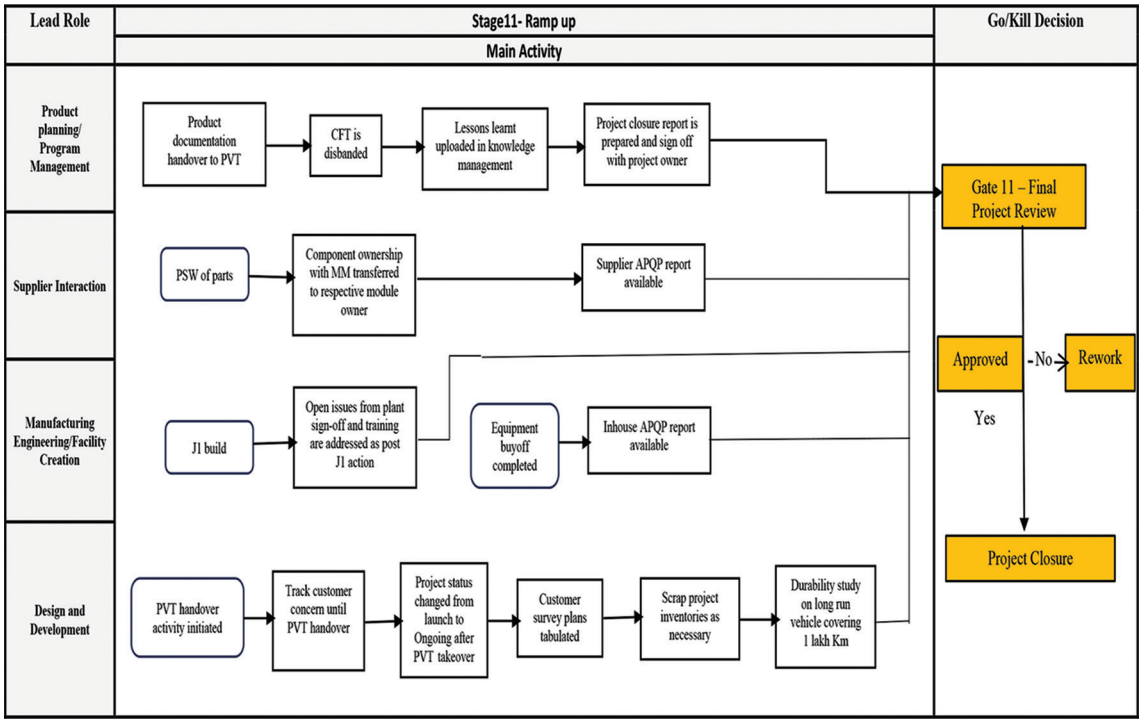

Fig. 14. Proposed new product development process framework for Stage 11 and Gate 11 new product development activities

track and efficient.

(7) Cross-functional teams frequently incorporate diverse perspectives and expertise, promoting proper teamwork and active participation from

all stakeholders throughout the project.

(8) A proper feedback mechanism is maintained by clear communication, making the framework efficient and a straightforward change control procedure. This structured framework ensures that changes are evaluated, approved, and implemented systematically, minimizing disruptions and maintaining NPD activities' alignment with objectives.

(9) The framework includes robust cost control mechanisms, such as periodic review activities, which enhance cost planning, tracking, and control.

(10) This framework allows for incremental progress and avoids overwhelming the team with unrealistic expectations. Criteria-based evaluation, cross-functional inputs, continuous feedback, adequate resources, and a realistic timeframe make the milestones achievable and realistic.

(11) Customized to meet automobile needs.

(12) Cross-functional team collaboration enhances interdepartmental communication and knowledge sharing.

(13) It is highly effective in data management for input and delivery processes due to its structured and systematic approach. It ensures comprehensive data collection through meticulous requirements gathering, integrates data from various functional areas, and maintains high data quality and consistency through standardization and validation.

(14) Checks such as the use of standardized templates and guidelines, training for data collection and documentation, and regular audits are incorporated for data compatibility and consistency.

(15) Structured review and performance metrics of the framework. Improve system feedback on deliverables (met/not met).

(16) Standardization across frameworks is achieved through the use of consistent processes, ensuring uniformity and efficiency. This standardization helps in aligning main activities and deliverables with the objectives, facilitating clear planning and execution.

(17) Non-value-added activities are minimized, which shifts the work culture from reactive to proactive mode.

(18) This framework is notably flexible in handling various projects due to its iterative and adaptable nature. The framework's cross-functional collaboration encourages diverse perspectives and expertise, enhancing its ability to address unique challenges across different projects. In addition, the process often includes stages for regular review and adjustment, which supports its adaptability to various project demands and uncertainties.

7. Conclusion

The literature study has identified several common challenges in NPD, including market uncertainty, resource allocation, time management, technical challenges, regulatory compliance, cross-functional collaboration, risk management, innovation management, customer feedback, supply chain coordination, cost control, quality assurance, and post-launch issues. The review of the NPD process in the automobile industry emphasized its critical role in overcoming these challenges and concluded that there is a need to redesign the NPD process framework. In alignment with existing literature, particularly regarding the Indian automobile sector, it has been confirmed that the Stage-Gate framework is the most suitable for industries that prioritize meticulous planning and control. The identified limitations of benchmarked NPD process frameworks, followed by the Stage-Gate approach implemented by automobile and supporting companies, and specifications and requirements by a survey among the NPD professionals, were considered in the design and development of the proposed NPD process framework, followed by some hallmarks as compared to the existing frameworks.

8. Future Scope

It is advisable to verify the proposed NPD process framework by conducting case studies to evaluate its NPD performance. With the imminent industrial revolution and the rise of new technologies and digital transformations, the mapping and integration of the proposed NPD process framework with emerging technologies such as AI/DS, PDM, PLM, IoT, Machine Learning, and TRIZ has the potential to boost innovation, shorten development cycles, and enhance product quality.

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