



Accelerating Automotive Innovation Through Adaptive Product Development Processes

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ARTICLE HISTORY

Received	Revised	Accepted	Published
19 June 2026	27 July 2026	20 August 2026	30 September 2026

ABSTRACT

Escalating competition and rapid technological change have made development execution a critical source of automotive competitiveness. As vehicle architectures increasingly combine electrification, software, connectivity, intelligent systems, and sustainability requirements, manufacturers must coordinate complex technical and organizational activities while preserving cost efficiency, quality, speed, and customer value. This article examines how effective development processes contribute to new product development success in the automotive industry. It focuses on process structure, cross functional integration, digital technologies, customer and supplier involvement, process agility, and sustainability as the principal dimensions shaping development performance. The analysis identifies several constraints, including procedural rigidity, fragmented knowledge coordination, difficulties in integrating advanced digital technologies, complex external relationships, and pressure to accelerate development without compromising product integrity. In response, the article highlights adaptive process governance, integrated knowledge sharing, digitally enabled decision making, strategically managed external collaboration, and early integration of sustainability considerations. Collectively, these mechanisms strengthen the ability of automotive firms to anticipate development problems, improve technical and commercial decisions, reduce costly iterations, accelerate organizational learning, and respond more effectively to technological and market uncertainty. Effective development processes therefore represent a strategic organizational capability that transforms innovation potential into superior product outcomes and sustained competitive performance.

Keywords: Automotive, Development, Innovation, Integration, Sustainability

HOW TO CITE

Author1, A. A., & Author2, B. B. (20XX). Title of the article.
International Journal of Business and Management Advancement,
X(X), xx-xx. <https://doi.org/10.xxxx/ijbma.xxxxx>

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1. INTRODUCTION

Competitive conditions in the automotive industry have changed substantially as manufacturers confront rapid technological advancement, shorter product life cycles, shifting customer expectations, and increasing pressure to deliver innovative vehicles at competitive cost. Electrification, connected mobility, advanced driver assistance systems, digital technologies, and software intensive vehicle architectures have expanded the scope and complexity of product development activities. Consequently, competitive advantage increasingly depends not only on the ability to generate innovative product ideas but also on the capability to transform those ideas into commercially viable products through disciplined and responsive development processes. Cooper (2019) argues that successful new product development is strongly influenced by the quality of project execution, customer orientation, organizational support, and the systems used to manage development activities. More recent research similarly demonstrates that contemporary product development requires greater integration between people, digital technologies, production activities, sustainability considerations, and external partnerships (Aniceski et al., 2025). Within the automotive context, these requirements are particularly significant because product development involves complex interactions among engineering, manufacturing, marketing, procurement, suppliers, quality management, and technology specialists. Effective development processes therefore provide the organizational structure necessary to coordinate these activities and convert technological opportunities into products capable of achieving market and operational success. This automotive emphasis is reinforced by Yusof and Salleh (2021), who position innovation-driven NPD as a strategic route to stronger industry performance.

The development process represents a critical mechanism through which automotive firms organize the progression of a product from initial opportunity identification to design, engineering, validation, industrialization, and eventual market introduction. Rather than functioning merely as a sequence of technical activities, an effective process establishes decision points, responsibilities, information requirements, evaluation criteria, and coordination mechanisms throughout the development cycle. Shinde et al., (2025) emphasize that a well structured and proven new product development process can contribute to high quality, cost effective, and timely product delivery in automobile industries. Their findings also indicate that contemporary automotive environments require development frameworks that are sufficiently flexible, integrated, and adaptive to accommodate changing technological and market conditions. This perspective extends the established argument of Cooper (2019), who identifies robust systems and processes as important drivers of superior new product performance. A carefully managed development process can reduce uncertainty by ensuring that technical feasibility, customer requirements, commercial potential, manufacturing capability, and resource commitments are progressively evaluated before substantial investments are made. For automotive manufacturers, such discipline becomes particularly important because development failures can generate substantial financial losses, delayed vehicle launches, engineering modifications, quality problems, and weakened competitive positioning. Digital capability is similarly connected with NPD success by Yusof, Salleh, and Zahari (2020a). The practical value of this approach lies in reducing avoidable iteration while preserving enough flexibility to respond to new technical information, market signals, and changing project conditions.

At the same time, automotive development processes are becoming increasingly dependent on digital technologies that improve information availability, simulation capability, collaboration, and decision

quality across development stages. Industry 4.0 technologies have created opportunities for organizations to integrate product development more closely with marketing, operations, manufacturing, and customer information. Arromba et al., (2021) identify numerous benefits associated with Industry 4.0 within product development, including improved understanding of customer preferences, greater decision making agility, stronger alignment among organizational functions, and improved management of product and service life cycles. In automotive development specifically, digital technologies can support earlier identification of design problems and enable development teams to evaluate alternatives before committing resources to physical prototypes. Smeets et al., (2023), for example, demonstrate the relevance of digital twins for automotive development by highlighting their potential to connect vehicle usage information with development activities and improve understanding of customer requirements. Similarly, Huang et al., (2022) explain that digital twin based validation can support rapid product development by connecting design, validation, and manufacturing activities. These capabilities strengthen development effectiveness because engineers and managers can obtain more timely information, conduct virtual evaluations, and improve decisions throughout increasingly complex development programmes. The alignment of NPD process and strategy is also emphasised by Yusof, Salleh, and Zahari (2020b). Effective execution therefore depends on clear responsibilities, shared information, and decision mechanisms that allow specialised functions to resolve interdependencies before they become costly development delays.

Effective development processes also depend heavily on coordination across organizational functions because automotive products integrate numerous technical systems that must satisfy customer, regulatory, manufacturing, cost, safety, and performance requirements simultaneously. Fragmented development practices can create communication barriers, conflicting priorities, duplicated activities, and delayed decisions, particularly when departments operate with limited information sharing. Recent automotive evidence reinforces the strategic importance of overcoming these functional boundaries. Silva et al., (2026), through a study in the heavy vehicle sector, found that combining cross functional integration with Industry 4.0 technologies can optimize product development processes, improve productivity and agility, strengthen competitiveness, reduce time to market, and support a stronger culture of innovation. These findings suggest that development effectiveness emerges not simply from technological sophistication but from the organizational capacity to coordinate knowledge and decisions across specialised functions. Earlier research similarly established that product development success is influenced by organizational arrangements, management commitment, innovation strategy, and effective execution practices (Cooper, 2019). In automotive firms, where engineering decisions can directly affect sourcing, production systems, quality requirements, cost structures, and launch schedules, integrated development processes allow potential problems to be identified earlier and addressed collectively. Cross functional coordination therefore becomes a fundamental process capability rather than an administrative activity. Recent Malaysian automotive evidence from Yusof et al., (2024) further supports the performance importance of coordinated NPD practices.

The involvement of suppliers further increases the importance of well coordinated development processes because automotive manufacturers depend extensively on external organizations for components, technologies, engineering expertise, materials, and specialised systems. Supplier capabilities can significantly influence product quality, technological feasibility, development cost,

and the ability to meet targeted launch schedules. Petersen et al., (2005) demonstrate that integrating suppliers into new product development can contribute to shorter development times, improved quality, reduced product costs, and smoother product introduction when integration is effectively managed. Their research further shows that appropriate supplier selection and joint establishment of technical and business performance targets can strengthen development team effectiveness. These considerations remain highly relevant to contemporary automotive development, where increasingly sophisticated vehicle technologies require collaboration among manufacturers and specialised technology partners. Aniceski et al., (2025) similarly identify partnerships and vertical and horizontal integration as prominent dimensions of new product development in the Industry 4.0 environment. Effective development processes should therefore establish clear mechanisms for determining when suppliers participate, what responsibilities they assume, how information is exchanged, and how technical expectations are coordinated. Without such mechanisms, external collaboration may create additional complexity rather than improving development performance, particularly when product architectures and technologies are rapidly evolving. The need for unified organisational effort in automotive NPD is likewise highlighted by Yusof (2025a). When these elements are coordinated early, development teams can identify trade-offs more clearly and make decisions that protect product integrity without unnecessarily slowing innovation.

2. LITERATURE REVIEW

New product development success in the automotive industry is increasingly shaped by the effectiveness of the processes used to transform ideas, technologies, and market requirements into commercially viable products. As automotive products become more technologically complex, development activities require stronger coordination, faster information exchange, systematic decision making, and greater integration across organizational boundaries. Cooper (2019) emphasizes that effective development systems and strong project execution remain fundamental to successful product innovation, while Aniceski et al., (2025) demonstrate that contemporary new product development increasingly integrates digital technologies, human capabilities, partnerships, production activities, and sustainability considerations. Recent automotive research also indicates that cross functional integration and Industry 4.0 technologies can improve development agility, productivity, competitiveness, and time to market (Silva et al., 2026). Accordingly, this literature review examines five interconnected dimensions that explain how effective development processes contribute to new product development success in the automotive industry: development process structure, cross functional integration, digital technologies, customer and supplier integration, and process agility and sustainability.

2.1 Development Process Structure Driving New Product Development Success

An effective development process provides the structural foundation through which new product ideas are transformed into technically feasible and commercially valuable outcomes. Contemporary research increasingly views new product development as an integrated system of activities rather than a rigid sequence of isolated stages. Khannan et al., (2021) demonstrate that development methods have evolved substantially, with organizations combining structured frameworks, iterative practices, and context specific approaches to address increasing innovation complexity. This perspective is reinforced by Srisathan et al., (2024), who argue that the effectiveness of a new product development process is shaped by contextual conditions, including organizational resources, technological characteristics, market circumstances, and the nature of innovation. Consequently,

development processes must provide sufficient discipline to maintain project control while retaining flexibility to respond to uncertainty. Cooper (2019) similarly emphasizes that successful product innovation requires robust development systems supported by strong execution, customer orientation, strategic alignment, and management commitment. Within automotive firms, these characteristics are especially significant because vehicle development involves numerous interdependent activities that must satisfy engineering, safety, cost, quality, production, and market requirements. A coherent process therefore strengthens project visibility, clarifies responsibilities, establishes meaningful evaluation points, and enables resources to be directed toward projects with stronger technical and commercial potential. Related automotive research by Yusof et al., (2025a) links stronger NPD practices with innovation and growth. Accordingly, development effectiveness should be evaluated through the combined quality of coordination, learning, responsiveness, and strategic control across the full product development cycle.

The value of process structure becomes more apparent when automotive development is considered within an environment characterized by electrification, software integration, connectivity, advanced electronics, and increasingly sophisticated customer requirements. Development teams must coordinate numerous technical decisions while preventing excessive bureaucracy from slowing innovation. Recent literature therefore advocates adaptable process architectures capable of combining systematic evaluation with rapid learning and iteration. Aniceski et al., (2025), following a review of 192 peer reviewed studies, demonstrate that Industry 4.0 technologies increasingly support activities across predevelopment, development, and postdevelopment stages, indicating that modern NPD processes are becoming more connected and information intensive. Development effectiveness consequently depends on how successfully firms integrate technologies, organizational practices, partnerships, production activities, and human capabilities throughout the process. Magnacca and Giannetti (2024) further show that management control and accounting mechanisms contribute to NPD by supporting resource allocation, performance assessment, and decision making under innovation uncertainty. In automotive organizations, development process quality should therefore be understood as the capability to organize complex activities without suppressing experimentation and responsiveness. When appropriate governance, evaluation mechanisms, information flows, and development routines operate cohesively, organizations can reduce unnecessary rework, identify weaknesses earlier, improve resource utilization, and increase the probability that promising concepts progress successfully toward market introduction. Sustainability-oriented innovation is also evident in Jamaludin et al., (2025) through their analysis of PROTON's automotive initiatives.

2.2 Cross Functional Integration Strengthening Development Coordination Capabilities

Cross functional integration represents a fundamental component of effective development processes because new product development requires knowledge distributed across engineering, manufacturing, marketing, purchasing, quality management, finance, information technology, and supply chain functions. The value of integration extends beyond communication because it enables specialized knowledge to be combined when resolving development problems and making critical project decisions. Silva et al., (2026) provide direct evidence from the heavy vehicle sector that high levels of cross functional integration supported by digital technologies can optimize product development processes, improve productivity and agility, increase competitiveness, reduce time to market, and strengthen innovation culture. These findings are particularly relevant to automotive

development, where decisions made by one functional area can generate significant consequences for other activities. Engineering changes, for example, may alter manufacturing requirements, supplier specifications, product cost, validation procedures, or launch schedules. Effective integration allows such implications to be recognized earlier and managed collectively rather than sequentially. Cooper (2019) similarly identifies effective execution and organizational support as central conditions for stronger new product performance. Accordingly, development processes should establish shared responsibilities, transparent information flows, coordinated decision mechanisms, and regular interaction among participating functions. These practices create a development environment in which functional expertise contributes collectively to project objectives instead of remaining confined within departmental boundaries. More broadly, Yusof (2025b) associates technology adoption with innovation and digital sustainability.

The effectiveness of cross functional collaboration is also influenced by organizational behaviour, leadership practices, and the willingness of development participants to exchange knowledge and challenge established assumptions. Zhou et al., (2024) demonstrate that leadership conditions can influence new product development performance through employee autonomy and creativity, although an organizational culture characterized by strong error aversion may weaken these benefits. This finding is important because automotive development teams frequently operate under substantial pressure to meet technical standards, quality expectations, budgets, and launch deadlines. Excessive fear of mistakes can discourage experimentation and constrain the collaborative problem solving required for innovative development. At the same time, integration requires mechanisms that prevent autonomy from producing fragmented decisions or inconsistent project priorities. Silva et al., (2026) indicate that organizations implementing advanced digital technologies should simultaneously develop workforce capabilities and a culture that supports interaction between people and technology. This suggests that effective development coordination depends on both structural integration and behavioural readiness. Automotive firms should therefore create development processes in which technical specialists can contribute expertise openly while remaining aligned with shared project objectives. When cross functional relationships are supported by appropriate leadership, clear decision authority, common information, and collaborative routines, organizations are better positioned to resolve complex development challenges and maintain project momentum throughout the development cycle. Leadership remains complementary to process capability, as Yusof (2026) links digital and entrepreneurial leadership with organisational performance.

2.3 Digital Technologies Enabling Intelligent Product Development Processes

Digital transformation has fundamentally expanded the technological capabilities available for managing new product development. Digital twins, artificial intelligence, advanced simulation, data analytics, virtual validation, and integrated information systems allow development teams to evaluate alternatives more rapidly and obtain deeper insight before substantial resources are committed to physical development. Zhang et al., (2023) establish that digital transformation can improve new product development performance through different configurations of digital resources, organizational structures, and capabilities, demonstrating that technology creates stronger outcomes when accompanied by appropriate organizational arrangements. Within automotive applications, digital twin technology has received particular attention because it enables physical products, operating environments, and development information to be represented digitally. Liu et

al., (2023), through a systematic review of digital twin applications in the automotive field, identify substantial opportunities across the automotive industry, transportation systems, and battery applications. These technologies can strengthen development processes by facilitating simulation, monitoring, testing, and continuous information exchange between physical and virtual environments. Their strategic value therefore extends beyond automation because digital technologies can reshape how development knowledge is generated and applied. For automotive manufacturers managing increasingly sophisticated vehicle architectures, digital integration can enhance process transparency, improve technical analysis, reduce dependence on repeated physical experimentation, and enable development decisions to be supported by richer and more timely information. Supplier and operational coordination also matters because Abdullah et al., (2020) connect strategic warehouse management with supply chain performance.

Virtual validation further illustrates how digital capability can improve the efficiency and responsiveness of development processes. Huang et al., (2022) propose a digital twin based validation framework that integrates product design, validation, and manufacturing to support rapid product development. Such integration is particularly valuable within automotive engineering because physical prototypes and repeated testing can require substantial time, financial resources, and specialized facilities. Digital validation allows alternative configurations and potential performance problems to be investigated earlier, thereby increasing opportunities for corrective action before costly downstream commitments occur. Artificial intelligence is also extending these capabilities. Vallé et al., (2026), through a systematic review of 98 studies, conclude that artificial intelligence is reconfiguring information processing and decision making across new product development, with its influence differing according to the stage of the process. Zhang et al., (2021) similarly explain that artificial intelligence can contribute to NPD success by strengthening analytical and decision capabilities. These developments suggest that digital technologies should not be treated merely as isolated technical tools. Their contribution depends on integration with established development activities, data structures, employee capabilities, and decision responsibilities. Automotive firms that successfully embed intelligent technologies throughout development can accelerate learning, improve validation accuracy, reduce avoidable iterations, and create development processes capable of responding more effectively to increasing technological complexity. Performance accountability is strengthened when decision processes remain transparent, a relationship also examined by Azahari and Mohamed Suhaimi (2023).

2.4 Customer Supplier Integration Strengthening Product Development Collaboration

Effective development processes require organizations to incorporate knowledge beyond their internal boundaries because both customers and suppliers possess information that can significantly influence product relevance and technical feasibility. Customer involvement is particularly important when market preferences evolve rapidly and organizations must identify requirements before committing substantial resources to product concepts. Lu et al., (2024) distinguish between customers participating as information sources and customers acting as codevelopers, demonstrating that these forms of involvement can influence NPD performance differently across development stages. Their findings indicate that digitally involving customers as information sources positively affects performance, while extensive codevelopment can produce diminishing benefits when involvement becomes excessive. Dean et al., (2024) similarly demonstrate that customer participation in problem solving and decision making generates different effects on product

innovativeness and development speed. These findings highlight the importance of designing development processes that incorporate customer knowledge selectively rather than assuming that greater participation will automatically produce superior outcomes. In automotive development, customer information can influence vehicle functionality, comfort, connectivity, safety expectations, styling, digital interfaces, and environmental preferences. Effective processes should therefore determine what customer information is needed, when it should enter development, and how it should be translated into engineering and commercial decisions without creating uncontrolled complexity. Customer information has growing strategic value in digital markets, as illustrated by Zaini et al., (2026) through consumer review perception and spending behaviour.

Supplier participation represents an equally important external dimension because contemporary vehicles depend on extensive networks of component manufacturers, software developers, technology specialists, and engineering partners. Suppliers often possess specialized knowledge that automotive manufacturers cannot efficiently reproduce internally, making their involvement valuable during design, engineering, testing, and industrialization. Petersen et al., (2005) established that effective supplier integration into NPD can contribute to improved product quality, lower costs, shorter development time, and smoother product introduction, particularly when organizations carefully select suppliers and establish shared technical and business objectives. More recent literature strengthens the broader importance of collaborative development. Aniceski et al., (2025) identify partnerships and integration as major themes within new product development under Industry 4.0, demonstrating that innovation increasingly occurs through interconnected organizational environments. Zhang and Zhou (2025) likewise show that technology based cooperation can influence organizational research and new product development outcomes, although the benefits depend on the configuration and intensity of collaboration. Automotive development processes must consequently provide mechanisms for early supplier participation, secure information exchange, coordinated specifications, joint problem solving, and performance monitoring. When external knowledge is integrated systematically rather than introduced reactively, firms can strengthen technical feasibility, reduce late engineering modifications, improve component compatibility, and create more resilient development programmes. For automotive managers, this means that process design must connect technical discipline with timely managerial judgement rather than treating governance as a purely administrative requirement.

2.5 Process Agility Sustainability Driving New Product Development Performance

Development process effectiveness increasingly depends on the capacity to balance speed, flexibility, quality, sustainability, and commercial discipline. Competitive pressure encourages automotive manufacturers to shorten development cycles, yet acceleration without appropriate coordination can increase engineering errors, resource inefficiency, and costly redesign. Research therefore suggests that development speed should emerge from better information, faster learning, stronger integration, and more efficient decision making rather than from simply compressing project schedules. Zhu et al., (2019) demonstrate that the relationship between open innovation and new product development speed depends on alignment with the firm's business model, indicating that development acceleration is contingent on organizational configuration rather than a universally beneficial practice. Lyu et al., (2024) further show that competitive intensity can encourage firms to accelerate NPD through knowledge integration, while market orientation influences the strength of this relationship. These findings are highly relevant to automotive firms facing rapidly changing

technologies and intensifying competition because process agility requires the capacity to mobilize knowledge quickly without sacrificing technical integrity. Effective development processes should therefore support rapid information exchange, timely decisions, iterative learning, and early identification of problems. When these mechanisms function effectively, automotive organizations can respond more quickly to technological and market changes while protecting product quality and development reliability. The practical value of this approach lies in reducing avoidable iteration while preserving enough flexibility to respond to new technical information, market signals, and changing project conditions.

Sustainability has simultaneously become an essential consideration within contemporary development processes, requiring environmental and commercial objectives to be addressed together rather than sequentially. Hunger et al., (2025) emphasize that sustainability considerations should be incorporated during the early stages of new product development because decisions made during these phases can strongly determine environmental consequences throughout the product life cycle. Their review highlights the value of structured decision tools for evaluating multiple sustainability dimensions when product concepts remain sufficiently flexible for meaningful modification. This requirement is particularly significant in the automotive industry, where material selection, battery technologies, energy efficiency, manufacturing processes, recyclability, vehicle weight, and component design can produce substantial environmental implications. Aniceski et al., (2025) similarly identify sustainable development as a major theme shaping NPD within the Industry 4.0 environment. Effective automotive development processes must therefore integrate sustainability criteria into concept selection, engineering evaluation, supplier decisions, validation, and production planning while maintaining attention to cost, quality, customer value, and development speed. Collectively, the literature indicates that new product development success is strengthened when process structure, cross functional integration, digital capability, external collaboration, agility, and sustainability operate as interconnected development capabilities rather than as independent managerial initiatives. Effective execution therefore depends on clear responsibilities, shared information, and decision mechanisms that allow specialised functions to resolve interdependencies before they become costly development delays.

3. STRUCTURAL INTEGRATION BARRIERS CONSTRAINING AUTOMOTIVE PRODUCT DEVELOPMENT PERFORMANCE

The automotive industry is experiencing substantial transformation as product development becomes more technologically intensive, interconnected, and exposed to rapidly changing market requirements. Although structured development processes can strengthen new product development performance, their effectiveness is frequently constrained by organizational fragmentation, technological integration difficulties, external coordination problems, increasing sustainability requirements, and pressure to accelerate development. These challenges are particularly significant because automotive development involves extensive interdependence among engineering, manufacturing, suppliers, customers, digital systems, and strategic decision makers. Wu et al., (2024) demonstrate that cross functional and external integration can influence NPD performance, while Silva et al., (2026) show that digital technologies and functional integration are increasingly interconnected within automotive product development. Consequently, weaknesses in any part of the development process can generate wider implications for development cost, quality, speed, and

market performance. The following sections examine five critical issues corresponding directly with the development process dimensions established in the literature review.

3.1 Development Process Rigidity Creating Structural Complexity Challenges

A major issue confronting automotive firms is the difficulty of maintaining structured development processes without creating excessive rigidity and administrative complexity. Formal processes are essential for controlling technical requirements, project expenditure, quality standards, regulatory compliance, and development schedules, yet excessive procedural control can restrict responsiveness when market or technological conditions change. This tension becomes increasingly problematic as automotive manufacturers develop electric vehicles, connected systems, advanced electronics, and software intensive products that require frequent learning and technical adjustment. Aniceski et al., (2025) demonstrate that contemporary NPD incorporates numerous interconnected dimensions, including technology, people, production, partnerships, and sustainability, substantially expanding the managerial scope of development processes. Lyu et al., (2024) further establish that competitive intensity creates pressure for organizations to accelerate NPD, particularly through stronger knowledge integration. Under such conditions, development structures designed for relatively predictable environments may become inefficient when teams must respond rapidly to new information. Excessive approval requirements can delay decisions, while overly standardized procedures may prevent teams from adapting activities to the characteristics of particular projects. Automotive organizations therefore face a fundamental process challenge in maintaining sufficient control to protect development quality while creating enough flexibility to accommodate uncertainty, experimentation, technological changes, and evolving customer expectations. This perspective is especially important in automotive programmes because design choices can quickly influence sourcing, manufacturing readiness, quality assurance, customer value, and launch performance.

Development complexity is intensified by the growing number of technical dependencies that must be coordinated across the product architecture. A modification to one vehicle system can create consequences for manufacturing processes, component specifications, software interfaces, safety validation, sourcing requirements, and project costs. Consequently, development processes may experience repeated iterations when decisions are made without adequate consideration of downstream implications. Magnacca and Giannetti (2024) indicate that management control mechanisms play an important role in NPD by supporting resource allocation, monitoring, and decision making under conditions of innovation uncertainty. However, control mechanisms that are poorly designed can increase procedural burden without necessarily improving development outcomes. Wu et al., (2024) similarly identify potential adverse effects associated with excessive structural empowerment, illustrating that organizational mechanisms intended to improve development may produce unintended consequences when their configuration is inappropriate. These findings suggest that the issue is not simply whether automotive firms possess formal development processes, but whether those processes are appropriately configured for the complexity of contemporary vehicle development. Ineffective structures may create unclear decision authority, duplicated evaluations, unnecessary documentation, and delayed escalation of technical problems. Such weaknesses can extend development cycles and reduce the organization's ability to transform promising concepts into successful products within commercially acceptable timeframes. When

these elements are coordinated early, development teams can identify trade-offs more clearly and make decisions that protect product integrity without unnecessarily slowing innovation.

3.2 Cross Functional Fragmentation Creating Knowledge Coordination Challenges

Cross functional fragmentation remains a significant obstacle because automotive product development depends on the coordinated contribution of multiple specialized functions. Engineering teams may prioritize technical performance, manufacturing units may emphasize process feasibility, procurement functions may focus on cost and supplier capacity, while marketing teams concentrate on customer requirements and competitive positioning. These priorities are individually legitimate but can generate conflicting decisions when development processes do not provide effective integration mechanisms. Wu et al., (2024) demonstrate that cross functional integration contributes to NPD performance partly through customer and supplier involvement, illustrating the importance of connecting internal and external development activities. Silva et al., (2026) similarly find that high cross functional integration supported by digital technologies can improve productivity, agility, competitiveness, and time to market within the heavy vehicle sector. The implication is that insufficient integration can produce the opposite effects, including slower information flows, repeated engineering modifications, delayed problem resolution, and inconsistent development priorities. The issue becomes particularly serious when departments possess different performance measures or information systems because development participants may optimize functional objectives rather than overall project performance. Fragmented decision making therefore reduces the ability of automotive firms to identify interdependencies early and coordinate responses before problems become costly. Accordingly, development effectiveness should be evaluated through the combined quality of coordination, learning, responsiveness, and strategic control across the full product development cycle.

Knowledge coordination presents an additional challenge because effective integration requires more than placing representatives from different functions within the same development team. Participants must be willing and able to exchange specialized knowledge, interpret information generated by other disciplines, and incorporate that information into their own decisions. Zhou et al., (2024) demonstrate that employee autonomy and creativity can contribute to NPD performance, while organizational conditions such as error aversion may weaken these benefits. This issue has important implications for automotive development because employees operating within highly controlled environments may hesitate to challenge established solutions, communicate emerging problems, or experiment with alternative approaches. Silva et al., (2026) further emphasize the importance of workforce capabilities and organizational culture when digital technologies are integrated with cross functional development. Accordingly, functional integration may remain superficial when organizations implement collaborative structures without addressing behavioural and knowledge barriers. Engineering expertise, customer intelligence, manufacturing experience, and supplier knowledge can remain disconnected even when formal coordination meetings exist. The resulting knowledge gaps can cause development teams to discover technical incompatibilities or manufacturing constraints relatively late in the process. Automotive firms therefore confront the challenge of creating development environments where knowledge moves effectively across functional boundaries and contributes meaningfully to collective decision making. For automotive managers, this means that process design must connect technical discipline with timely managerial judgement rather than treating governance as a purely administrative requirement.

3.3 Digital Integration Complexity Creating Technology Implementation Challenges

Digital technologies offer considerable opportunities to strengthen automotive product development, yet their implementation introduces significant organizational and technical challenges. Digital twins, artificial intelligence, simulation platforms, data analytics, and integrated product lifecycle systems generate value only when information can move reliably across development activities. In practice, automotive organizations may operate numerous legacy systems developed for different functions, technologies, and generations of products, creating difficulties in data compatibility and process integration. Silva et al., (2026) acknowledge that organizations implementing advanced technology packages must address challenges surrounding employee capabilities and the effective interaction between people and digital technologies. Digital transformation therefore involves considerably more than purchasing advanced software. It requires appropriate data structures, process redesign, workforce competence, and clear understanding of how digital outputs contribute to development decisions. When these conditions are weak, organizations may accumulate sophisticated technological tools without achieving corresponding improvements in development performance. Fragmented digital environments can also force engineers to reconcile information manually across separate platforms, increasing the possibility of inconsistent data and duplicated activities. The central issue is therefore the ability to establish an integrated digital development environment in which technological capabilities reinforce rather than complicate existing product development processes. The practical value of this approach lies in reducing avoidable iteration while preserving enough flexibility to respond to new technical information, market signals, and changing project conditions. This strengthens development discipline and managerial responsiveness across the programme.

The increasing use of digital models also raises concerns regarding model reliability, validation quality, data governance, and the appropriate balance between virtual and physical testing. Liu et al., (2023) identify extensive opportunities for digital twins across automotive applications but also highlight continuing challenges associated with their development and implementation. Huang et al., (2022) demonstrate that digital twin based validation can connect design, validation, and manufacturing to facilitate rapid product development, yet such benefits depend heavily on accurate models and reliable information flows. Artificial intelligence introduces additional complexity because algorithmic outputs may influence development decisions without always providing complete transparency regarding how conclusions were generated. Zhang et al., (2021) argue that artificial intelligence can support NPD through enhanced analytical capabilities, but successful application requires complementary organizational capabilities. Consequently, automotive manufacturers face the risk of technological investment advancing faster than their capacity to govern and integrate these technologies effectively. Poor quality data or disconnected digital platforms can generate misleading analyses and reduce confidence among development personnel. Digitalization may therefore become an additional layer of complexity unless firms align technology adoption with process requirements, employee competencies, validation standards, and decision responsibilities throughout the development lifecycle. Effective execution therefore depends on clear responsibilities, shared information, and decision mechanisms that allow specialised functions to resolve interdependencies before they become costly development delays. This strengthens development discipline and managerial responsiveness across the programme.

3.4 Customer Supplier Integration Creating External Coordination Difficulties

External integration creates another significant challenge because automotive development processes must capture valuable customer and supplier knowledge without allowing excessive involvement to complicate decision making. Customer participation can improve understanding of market expectations, but the usefulness of customer information varies according to development stage and type of involvement. Wu et al., (2024) demonstrate that customer and supplier involvement can mediate the relationship between cross functional integration and NPD performance, emphasizing that external participation is closely connected with internal organizational integration. However, customer expectations are increasingly diverse, particularly as vehicle buyers demand different combinations of connectivity, safety, environmental performance, personalization, convenience, and digital functionality. Development teams may therefore receive contradictory signals regarding which product attributes deserve priority. Translating these preferences into stable technical specifications becomes difficult when customer expectations change faster than traditional automotive development cycles. Excessive responsiveness to individual preferences can also generate product complexity, increase engineering workload, and weaken project focus. Automotive firms must consequently determine which customer information represents strategically meaningful demand rather than temporary preferences. Without disciplined mechanisms for evaluating external market knowledge, customer integration can produce additional uncertainty rather than providing the clarity required for successful development decisions. This perspective is especially important in automotive programmes because design choices can quickly influence sourcing, manufacturing readiness, quality assurance, customer value, and launch performance. When these elements are coordinated early, development teams can identify trade-offs more clearly and make decisions that protect product integrity without unnecessarily slowing innovation.

Supplier involvement generates different but equally significant coordination problems. Automotive manufacturers increasingly rely on specialized suppliers for electronics, software, battery systems, sensors, materials, and other technologically sophisticated components. Although supplier expertise can strengthen development capability, deeper integration creates knowledge interdependencies that require careful coordination. Donmez and Norheim Hansen (2024) explain that supplier integration into product development creates coordination difficulties across product, supplier, and buyer supplier levels, particularly when knowledge interdependencies are complex. Delgado Verde and Díez Vial (2024) likewise show that supplier involvement can support NPD, while emphasizing the role of broader research and development collaboration in obtaining external knowledge. These relationships become challenging when organizations differ in technical capabilities, priorities, development schedules, information systems, or willingness to share proprietary knowledge. Zhang and Zhou (2025) further indicate that technology based cooperation does not automatically generate equivalent innovation outcomes because its effectiveness depends on how collaboration is configured. For automotive manufacturers, ineffective supplier coordination can result in specification misunderstandings, component incompatibility, delayed engineering changes, and disrupted validation activities. Development processes must therefore balance the benefits of external expertise with the managerial complexity created by extensive interorganizational dependence. When these elements are coordinated early, development teams can identify trade-offs more clearly and make decisions that protect product integrity without unnecessarily slowing innovation. Supplier involvement findings are also supported by Delgado-Verde and Díez-Vial (2024).

3.5 Development Acceleration Creating Sustainability Product Integrity Pressures

Automotive manufacturers are increasingly pressured to accelerate product development as technological change and competitive intensity shorten the period during which innovations can generate market advantage. However, pursuing development speed without sufficient process capability can create substantial operational risks. Lyu et al., (2024) demonstrate that competitive intensity can encourage firms to increase NPD speed through knowledge integration, indicating that rapid development requires effective use of organizational knowledge rather than simple schedule compression. Automotive firms face particular difficulty because shortening development cycles must occur while products continue to satisfy demanding requirements for safety, quality, durability, manufacturing feasibility, and regulatory compliance. Development teams may therefore encounter conflicting expectations to complete engineering activities rapidly while simultaneously conducting extensive testing and validation. Excessive schedule pressure can encourage premature decisions, incomplete information sharing, insufficient technical evaluation, and greater dependence on corrective action during later development stages. Silva et al., (2026) show that digital technology and cross functional integration can contribute to reduced time to market, suggesting that development speed should result from improved processes rather than from eliminating essential development activities. The challenge for automotive firms is therefore to increase responsiveness without allowing time pressure to undermine development discipline and ultimately compromise product performance. Accordingly, development effectiveness should be evaluated through the combined quality of coordination, learning, responsiveness, and strategic control across the full product development cycle.

Sustainability requirements further complicate this challenge because environmental considerations must increasingly be incorporated into development decisions that are already constrained by cost, quality, performance, and time objectives. Hunger et al., (2025) identify important gaps and challenges in integrating multiple sustainability dimensions during the early stages of NPD, where decisions can strongly influence environmental performance across the product lifecycle. Delaney and Liu (2024) similarly demonstrate that implementing environmental sustainability during product design involves complex decision processes and interaction among different organizational stakeholders. Within the automotive industry, Rosienkiewicz et al., (2024) show the importance of incorporating environmental assessment into product lifecycle management so that environmental performance can be evaluated alongside business objectives during development. Nevertheless, competing development priorities can make sustainability difficult to operationalize consistently. Engineers may face tradeoffs involving material selection, vehicle weight, production cost, recyclability, energy efficiency, and technical performance, while managers remain responsible for maintaining commercially viable development schedules. Sustainability therefore introduces additional evaluation requirements into an already complex process. The critical issue is ensuring that environmental objectives become embedded within development decisions rather than being treated as supplementary requirements after fundamental product characteristics have already been established. For automotive managers, this means that process design must connect technical discipline with timely managerial judgement rather than treating governance as a purely administrative requirement. This strengthens development discipline and managerial responsiveness across the programme.

4. ORGANISATIONAL CAPABILITIES STRENGTHENING HIGH PERFORMANCE AUTOMOTIVE PRODUCT DEVELOPMENT

Automotive innovation increasingly depends on the ability of manufacturers to transform complex ideas into marketable products through development processes that are responsive, integrated, technologically capable, and strategically controlled. The transition toward electrification, connected vehicles, intelligent systems, and software intensive products has increased the amount of knowledge that must be coordinated throughout product development. Consequently, development effectiveness is no longer determined primarily by completing prescribed activities but by the quality of decisions, interactions, information flows, and learning occurring throughout the process. Lu et al., (2024) demonstrate that the contribution of customer involvement to new product development performance varies according to the nature of participation and the development stage, illustrating the importance of managing development activities contextually rather than uniformly. Digital technologies are also reshaping information processing and decision making across different NPD stages (Vallé et al., 2026). At the same time, sustainability considerations are becoming increasingly important during early product development because fundamental design decisions can determine long term environmental consequences (Hunger et al., 2025). Effective development processes must therefore integrate organizational discipline with adaptability, functional knowledge, digital intelligence, external collaboration, development speed, and sustainability to create stronger new product outcomes.

4.1 Adaptive Development Governance Strengthening Strategic Process Control

Development process effectiveness begins with the ability to maintain sufficient structure for managerial control while preserving the flexibility required to address uncertainty. Automotive projects involve substantial investment, extensive engineering requirements, safety obligations, manufacturing considerations, and demanding commercialization schedules. These conditions make formal processes necessary, but excessive standardization can become counterproductive when technological assumptions or market requirements change during development. Cooper (2019) emphasizes that successful product innovation requires robust development systems accompanied by strong execution, customer orientation, and organizational support. This suggests that process discipline should facilitate development rather than create procedural barriers that prevent timely responses to new information. Automotive firms should consequently differentiate development intensity according to project complexity, technological novelty, commercial uncertainty, and potential risk. Projects involving established technologies may require relatively predictable development pathways, whereas electric, connected, or intelligent vehicle innovations may require greater experimentation and iterative learning. An adaptive process provides this flexibility while maintaining common expectations for technical feasibility, quality, investment justification, and market potential. Such an approach enables development teams to respond constructively to uncertainty without weakening accountability, allowing organizational resources to be concentrated on activities that create meaningful technical and commercial value. The practical value of this approach lies in reducing avoidable iteration while preserving enough flexibility to respond to new technical information, market signals, and changing project conditions. This strengthens development discipline and managerial responsiveness across the programme.

Strategic control remains essential because flexibility without clear governance can generate unstable priorities, repeated design modifications, and inefficient resource allocation. The objective

is therefore not to eliminate formal development controls but to ensure that controls correspond with the significance of individual decisions. Major commitments involving product architecture, safety, manufacturing investment, technology selection, and commercialization should receive rigorous evaluation, while routine technical decisions can be delegated closer to development teams. This distinction becomes particularly important as automotive products incorporate increasingly interconnected technologies and development activities. Smeets et al., (2023) explain that shortening product lifecycles and rising customer demands require manufacturers to improve the efficiency and effectiveness of product development, particularly through stronger connections between real world product information and development activities. Such information can enable teams to reassess assumptions more intelligently rather than following predetermined decisions when evidence indicates that modification is necessary. Effective governance should therefore establish clear decision rights, escalation mechanisms, evaluation criteria, and opportunities for informed iteration. When flexibility operates within a transparent governance architecture, automotive manufacturers can reduce unnecessary administrative delays while maintaining technical integrity. Development processes consequently become more capable of accommodating uncertainty without allowing experimentation to undermine project direction, cost control, product quality, or commercialization objectives. Effective execution therefore depends on clear responsibilities, shared information, and decision mechanisms that allow specialised functions to resolve interdependencies before they become costly development delays.

4.2 Cross Functional Integration Strengthening Knowledge Coordination Capabilities

Cross functional integration becomes increasingly important as vehicle development requires specialized knowledge from engineering, manufacturing, procurement, marketing, quality management, information technology, and other organizational functions. These areas frequently evaluate development priorities from different perspectives, creating potential conflict when decisions are made independently. Engineering teams may prioritize technical performance, manufacturing personnel may emphasize production feasibility, procurement specialists may concentrate on component cost and supplier capability, while marketing teams focus on customer value and competitive differentiation. Effective development processes must therefore create mechanisms through which these perspectives can be reconciled before major commitments are finalized. Customer participation research also demonstrates that development proficiency influences the value generated through external participation, reinforcing the importance of internal organizational capability in utilizing market knowledge (Zarbi et al., 2024). Cross functional integration should consequently extend beyond periodic meetings and become embedded within project decisions, technical reviews, problem solving, and performance evaluation. Earlier functional participation can expose manufacturing limitations, sourcing risks, customer concerns, and quality requirements before they become embedded within product designs. This reduces the probability that localized decisions generate costly consequences during later development stages and improves the overall coherence of the development programme. This perspective is especially important in automotive programmes because design choices can quickly influence sourcing, manufacturing readiness, quality assurance, customer value, and launch performance. When these elements are coordinated early, development teams can identify trade-offs more clearly and make decisions that protect product integrity without unnecessarily slowing innovation.

Knowledge coordination represents the deeper purpose of functional integration because organizational performance depends on whether specialized information is transformed into collective understanding and action. Simply increasing interaction among departments does not guarantee better development outcomes when participants continue to defend individual functional priorities. Automotive firms require shared development objectives that encourage teams to evaluate decisions according to overall product performance rather than isolated departmental measures. Lu et al., (2024) demonstrate that the effectiveness of customer involvement differs according to the stage of NPD, suggesting that development knowledge must be integrated at the appropriate time and in a form suitable for specific development decisions. This principle also applies internally. Manufacturing knowledge creates greater value when incorporated before critical design decisions become difficult to modify, while marketing information becomes particularly valuable during opportunity identification and concept formulation. Effective development processes should therefore determine when particular knowledge is required, who should contribute it, and how disagreements should be resolved. Integrated information systems, multidisciplinary reviews, shared performance objectives, and explicit decision responsibilities can strengthen these connections. When knowledge coordination is embedded systematically throughout development, automotive firms can improve technical decisions, anticipate downstream consequences, reduce repeated engineering work, and create products that achieve stronger alignment between customer expectations and operational capabilities. When these elements are coordinated early, development teams can identify trade-offs more clearly and make decisions that protect product integrity without unnecessarily slowing innovation.

4.3 Digital Technology Integration Strengthening Development Intelligence Capabilities

Digital technologies are fundamentally changing how automotive organizations generate, analyse, exchange, and apply development information. Digital twins, artificial intelligence, advanced simulation, data analytics, and virtual testing enable firms to evaluate product alternatives with greater analytical depth and potentially lower dependence on repeated physical experimentation. Nevertheless, the strategic contribution of these technologies depends on their integration with development processes rather than their isolated implementation. Smeets et al., (2023) demonstrate that digital twins can strengthen automotive development by connecting vehicle usage information with development activities, allowing manufacturers to derive more comprehensive customer requirements from real world data. This capability represents an important advancement because development teams can gain insight into how products perform under actual operating conditions and incorporate this knowledge into future development decisions. Digital technologies therefore strengthen development when they create continuous learning between physical products, virtual environments, and organizational decision making. Automotive manufacturers should consequently view digitalization as an information capability rather than merely an automation initiative. When digital platforms are connected with engineering, validation, manufacturing, and market information, they can increase development visibility, expose technical problems earlier, improve evaluation accuracy, and provide development teams with stronger evidence for selecting among competing design alternatives. Accordingly, development effectiveness should be evaluated through the combined quality of coordination, learning, responsiveness, and strategic control across the full product development cycle. This strengthens development discipline and managerial responsiveness across the programme.

Artificial intelligence extends these capabilities by enabling increasingly sophisticated processing of development information. Vallé et al., (2026), through a systematic review of 98 studies, establish that artificial intelligence is reconfiguring information processing and decision making throughout NPD, with its effects varying according to development stage. This finding demonstrates that AI should not be applied uniformly because different phases require different forms of information, analysis, and managerial judgement. Early development may benefit from technologies capable of analysing market information and generating alternatives, while later phases may employ AI for engineering analysis, testing, optimization, and validation. However, technological sophistication cannot compensate for unreliable data or weak organizational readiness. Development teams must understand the assumptions and limitations underlying digitally generated information, particularly when decisions involve product safety, technical reliability, or substantial investment. Digital governance therefore becomes an integral element of effective development processes. Automotive firms require reliable data architectures, validation standards, clear ownership of information, and personnel capable of combining digital insights with professional expertise. When these conditions are established, digital technologies can enhance rather than complicate development, creating a more intelligent process capable of accelerating learning, improving analytical precision, and supporting higher quality decisions. For automotive managers, this means that process design must connect technical discipline with timely managerial judgement rather than treating governance as a purely administrative requirement. This strengthens development discipline and managerial responsiveness across the programme.

4.4 Customer Supplier Integration Strengthening Collaborative Development Capabilities

External knowledge can substantially strengthen automotive product development, but its contribution depends on how selectively and systematically it is incorporated into development decisions. Customer involvement is particularly valuable because manufacturers must understand changing expectations concerning vehicle performance, safety, connectivity, comfort, environmental characteristics, and digital functionality. However, greater customer involvement does not automatically produce superior outcomes. Lu et al., (2024) found that digitally involving customers as information sources positively influences NPD performance, while customer involvement as codevelopers exhibits an inverted U shaped relationship with performance. Their research further demonstrates that these relationships differ across NPD stages. These findings indicate that customer integration should be strategically calibrated rather than maximized. During ideation, broad customer information can help automotive firms recognize unmet requirements and identify attractive opportunities. As development becomes more technically intensive, however, excessive customer intervention may create conflicting requirements or complicate engineering decisions. Zarbi et al., (2024) similarly demonstrate that the outcomes associated with customer participation depend on product development proficiency and task uncertainty. Automotive firms should therefore design customer involvement around specific information requirements, ensuring that customer knowledge enriches development decisions without destabilizing technical priorities or expanding product complexity beyond commercially sustainable levels. The practical value of this approach lies in reducing avoidable iteration while preserving enough flexibility to respond to new technical information, market signals, and changing project conditions.

Supplier involvement requires equally careful management because technological transformation has increased the importance of specialized external expertise throughout the automotive value

network. Manufacturers frequently depend on suppliers for batteries, semiconductors, sensors, electronic systems, software, advanced materials, and numerous other technologies that influence vehicle functionality. Earlier supplier involvement can therefore strengthen technical feasibility and enable specialized knowledge to enter development before fundamental product decisions are finalized. However, collaboration creates additional coordination requirements because suppliers may possess different priorities, information systems, technological capabilities, and commercial interests. Effective supplier integration should consequently be differentiated according to component complexity, strategic importance, technological uncertainty, and the level of knowledge interdependence involved. Critical technology suppliers may require intensive participation in design reviews, validation activities, and engineering changes, while standardized component suppliers may require less extensive involvement. Development processes should establish clear technical specifications, information sharing protocols, responsibilities, milestones, and change management procedures to support these relationships. Customer and supplier integration should ultimately complement internal development capabilities rather than substitute for them. When automotive firms possess strong internal coordination and deliberately manage external participation, valuable market and technological knowledge can be incorporated without creating excessive development complexity, strengthening product relevance, technical feasibility, and commercialization potential. Effective execution therefore depends on clear responsibilities, shared information, and decision mechanisms that allow specialised functions to resolve interdependencies before they become costly development delays. Customer co-development outcomes are further examined by Zaefarian et al., (2025).

4.5 Development Agility Strengthening Sustainability Product Integrity Capabilities

Competitive automotive markets increasingly reward organizations capable of introducing technologically advanced products rapidly, but development speed should emerge from process effectiveness rather than indiscriminate schedule reduction. Eliminating essential engineering or validation activities may shorten individual project phases while increasing the probability of redesign, quality problems, or commercialization delays later. Automotive manufacturers should instead accelerate development by improving information availability, reducing unnecessary waiting, resolving problems earlier, and coordinating interdependent activities more effectively. Digital technologies can contribute substantially to this objective. Smeets et al., (2023) demonstrate the potential of digital twins to improve the efficiency and effectiveness of automotive development by creating stronger connections between manufacturers and vehicles in use. Vallé et al., (2026) similarly show that artificial intelligence is transforming information processing and decision making throughout NPD. Together, these capabilities can reduce the time required to generate and evaluate development knowledge when they are appropriately integrated with organizational processes. Faster development should therefore represent the outcome of superior learning and decision making rather than reduced technical discipline. This distinction allows automotive firms to respond rapidly to technological and competitive changes while preserving the validation, safety, quality, and manufacturing requirements essential for successful product introduction. This perspective is especially important in automotive programmes because design choices can quickly influence sourcing, manufacturing readiness, quality assurance, customer value, and launch performance. This strengthens development discipline and managerial responsiveness across the programme.

Sustainability further strengthens the need for development processes capable of making high quality decisions early because environmental characteristics are frequently determined before products reach detailed engineering. Hunger et al., (2025) emphasize that sustainability integration during the early stages of NPD is critical for innovation and long term competitive advantage. Their review demonstrates the importance of incorporating multiple sustainability dimensions while alternative product concepts remain sufficiently flexible for meaningful modification. This principle has substantial relevance for automotive manufacturers because early decisions involving materials, vehicle architecture, battery systems, manufacturing processes, energy consumption, recyclability, and component selection can influence environmental performance throughout the product lifecycle. Treating sustainability as a late development requirement can generate costly redesign and conflict with established technical specifications. Instead, environmental criteria should be incorporated alongside technical feasibility, customer value, cost, quality, and manufacturing considerations during major development decisions. Such integration also demonstrates that sustainability and development speed do not necessarily represent opposing objectives. Early environmental evaluation can prevent later corrective activities and improve decision quality before resources become committed. Effective automotive development processes should therefore combine speed, sustainability, and product integrity as interconnected performance requirements, enabling manufacturers to achieve competitive market timing while developing technologically robust, commercially viable, and environmentally responsible products. When these elements are coordinated early, development teams can identify trade-offs more clearly and make decisions that protect product integrity without unnecessarily slowing innovation.

5. STRATEGIC PATHWAYS ADVANCING AUTOMOTIVE NEW PRODUCT DEVELOPMENT PERFORMANCE

Sustaining successful new product development in the automotive industry requires manufacturers to continuously strengthen the processes through which technological opportunities, market knowledge, engineering expertise, and organizational resources are converted into commercially viable products. Development improvement should therefore extend beyond isolated attempts to reduce project duration or introduce advanced technologies. Greater attention must be directed toward creating adaptive development structures, strengthening cross functional knowledge integration, embedding digital intelligence into decision processes, improving customer and supplier participation, and incorporating sustainability without compromising product integrity. Recent evidence demonstrates that digital transformation can enhance new product development performance when technological resources are effectively combined with organizational structures and capabilities (Zhang et al., 2023). Wu et al., (2024) similarly establish that cross functional integration contributes to NPD performance through customer and supplier involvement, while Lyu et al., (2024) emphasize the importance of knowledge integration for accelerating development under competitive pressure. Sustainability must also be incorporated earlier because decisions during initial development stages can strongly influence environmental performance and long term competitiveness (Hunger et al., 2025). Automotive manufacturers should consequently pursue coordinated process improvements that strengthen development effectiveness across the entire product development cycle.

5.1 Adaptive Risk Based Development Process Implementation Strategies

Automotive manufacturers should establish adaptive development processes that differentiate project requirements according to technological novelty, product complexity, investment exposure, market uncertainty, and regulatory risk. Applying an identical development pathway to every project can create unnecessary administrative burden for incremental products while providing insufficient learning opportunities for highly innovative programmes. Cooper (2019) argues that contemporary innovation systems require greater flexibility, adaptability, acceleration, and customer orientation while retaining appropriate governance. This principle is particularly applicable to automotive firms developing products ranging from minor platform modifications to electric, connected, autonomous, and software intensive vehicles. Development management should therefore classify projects at an early stage and determine the appropriate level of technical review, experimentation, documentation, customer validation, and executive oversight. Highly uncertain projects should receive greater opportunities for iterative learning before substantial resources are committed, whereas lower risk projects should follow streamlined procedures that eliminate unnecessary activities. Such differentiation can preserve development discipline without allowing standardized procedures to restrict innovation. A risk based process architecture would also enable automotive firms to allocate managerial attention according to the significance of development uncertainty, improving resource efficiency while ensuring that critical technical and commercial decisions receive sufficient evaluation before projects progress toward industrialization and market introduction. Automotive firms should additionally institutionalize iterative learning throughout the development cycle rather than limiting learning to formal reviews or postproject evaluations.

Greater process adaptability should be accompanied by clearly defined decision rights and evidence based evaluation criteria. Development teams require sufficient authority to resolve routine technical matters rapidly, but decisions involving substantial investment, safety, fundamental product architecture, regulatory compliance, and market positioning should remain subject to systematic review. Wu et al., (2024) demonstrate that structural empowerment can generate adverse effects when applied excessively, suggesting that autonomy must be balanced with organizational control. Automotive manufacturers should consequently establish decision matrices that specify who possesses authority for different categories of development decisions and the conditions under which matters must be escalated. Gate reviews should focus on evidence concerning technical maturity, customer value, manufacturing feasibility, supplier readiness, financial viability, and emerging risk rather than becoming documentation exercises. Magnacca and Giannetti (2024) similarly emphasize the relevance of management control mechanisms for supporting resource allocation and decision making within NPD environments. Combining managerial control with delegated operational authority can create a more responsive process in which teams act rapidly without losing strategic direction. This configuration can also reduce approval bottlenecks, prevent unnecessary escalation, and ensure that senior management attention is concentrated on decisions capable of materially influencing product performance, development investment, and commercialization success. Development uncertainty cannot always be eliminated during initial planning because customer expectations, technologies, engineering constraints, and competitive conditions may change after projects begin.

5.2 Integrated Cross Functional Development Team Capability Building Strategies

Automotive manufacturers should strengthen cross functional development by establishing integrated teams with meaningful participation from engineering, manufacturing, procurement, marketing, quality, finance, information technology, and supply chain functions from the early stages of development. Functional representation should not be postponed until individual departments become responsible for downstream implementation because many product decisions become expensive to reverse once detailed engineering has progressed. Wu et al., (2024) demonstrate that cross functional integration can enhance NPD performance indirectly through stronger customer and supplier involvement, confirming that internal integration creates an important foundation for utilizing external knowledge. Development teams should consequently evaluate major product decisions collectively and consider their implications for technical performance, manufacturing feasibility, component availability, customer value, cost, quality, and commercialization. Earlier integration can identify conflicting requirements before they become embedded within product architecture. For example, procurement knowledge can expose supplier constraints while manufacturing expertise can identify production difficulties associated with proposed engineering solutions. Marketing knowledge can simultaneously clarify whether additional technical complexity generates meaningful customer value. Cross functional integration therefore improves development not simply by increasing communication but by ensuring that diverse knowledge influences decisions at the moment when it can create the greatest value. Knowledge integration should further be supported by formal mechanisms for capturing and transferring development experience across projects. However, this knowledge may remain within individual teams and disappear when projects conclude or personnel move to other responsibilities.

Shared development objectives should also be established to prevent functional performance measures from generating conflicting priorities. Development participants frequently evaluate success according to departmental responsibilities, potentially encouraging decisions that optimize one function while creating difficulties elsewhere. Automotive firms should therefore implement common project measures covering product quality, target cost, development timing, manufacturing readiness, customer value, technical performance, and innovation objectives. Lyu et al., (2024) demonstrate that knowledge integration represents an important mechanism connecting competitive intensity with faster NPD, emphasizing that organizational knowledge must be combined effectively rather than remaining separated within individual functions. Cross functional teams should consequently use common information platforms, integrated project reviews, and joint problem solving routines to establish shared understanding. Leadership should encourage technical disagreement when it improves decision quality but ensure that disagreements are resolved according to evidence and project objectives. This arrangement can reduce departmental bargaining and strengthen collective ownership of development outcomes. When functional specialists recognize that overall project performance determines success, they are more likely to share knowledge proactively, identify emerging problems, and cooperate in developing solutions that optimize the complete product development system rather than individual organizational activities. Automotive manufacturers frequently conduct multiple development programmes simultaneously, creating valuable knowledge concerning technologies, suppliers, customer responses, validation failures, manufacturing constraints, and successful engineering practices. Systematic knowledge retention reduces repeated mistakes and allows successful development practices to accumulate as organizational capability.

5.3 Integrated Digital Development Ecosystem Implementation Governance Strategies

Automotive manufacturers should create an integrated digital development ecosystem in which digital twins, artificial intelligence, simulation technologies, analytics, product lifecycle management systems, and engineering data operate within a coherent information architecture. Implementing these technologies separately can create fragmented digital environments that increase rather than reduce development complexity. Zhang et al., (2023) demonstrate that digital transformation contributes to NPD performance through configurations of resources, structures, and organizational capabilities, indicating that technological investment alone is insufficient. Chandrasekaran and Rajesh (2025) further demonstrate the relevance of digital twin enabled product design specifically within the automotive industry. Automotive firms should therefore develop digital strategies based on the information requirements of the complete development process rather than allowing individual functions to acquire disconnected applications independently. A common digital architecture can enable development participants to access consistent product information, compare engineering alternatives, monitor technical maturity, and understand how modifications influence downstream activities. Connecting design, simulation, validation, manufacturing, and lifecycle information can substantially improve development visibility. This integrated approach can also create a reliable digital thread across development stages, reducing duplicated data entry and ensuring that decisions are based on current and consistent technical information. Digital capability development must simultaneously include workforce development because advanced technologies cannot improve product development when employees lack the competence to use and interpret them effectively. Automotive manufacturers should therefore develop multidisciplinary digital competencies among engineers, project managers, manufacturing specialists, and other development personnel.

Artificial intelligence should be introduced selectively according to the information processing requirements of particular development stages. Vallé et al., (2026), based on a systematic review of 98 studies, establish that AI applications influence NPD differently across front end activities, development and testing, and later stages. Automotive manufacturers should therefore avoid implementing AI merely because the technology is available and instead identify development activities where analytical augmentation can generate measurable value. During early development, AI can support analysis of customer information, technology trends, and alternative concepts. During engineering and testing, it can assist optimization, pattern identification, predictive analysis, and interpretation of complex technical data. Human expertise should nevertheless retain responsibility for consequential decisions, particularly those involving product safety, ethical considerations, regulatory requirements, and uncertain technical assumptions. Vallé et al., (2026) also identify data availability, governance, and organizational readiness as important boundary conditions affecting AI effectiveness. Automotive firms should consequently establish data quality standards, model validation procedures, access controls, and clear accountability for technology supported decisions. Such governance can strengthen confidence in AI outputs while ensuring that technological acceleration does not weaken professional judgement or technical responsibility. Aniceski et al., (2025) identify people, technologies, partnerships, production, and sustainable development as interconnected dimensions of NPD within the Industry 4.0 environment. Firms should also establish specialist roles capable of connecting engineering expertise with data science and digital architecture.

5.4 Strategic Customer Supplier Collaboration Institutionalisation Governance Strategies

Automotive manufacturers should develop stage specific customer involvement strategies that determine what customer knowledge is required and when it should influence development. Treating customer participation as universally beneficial can introduce excessive complexity, particularly when customers are asked to contribute to highly technical decisions beyond their expertise. Lu et al., (2024) demonstrate that customers acting as information sources positively influence NPD performance, while customer codevelopment displays an inverted U shaped relationship with performance. Their findings also establish that these effects vary according to the development stage. Automotive firms should therefore obtain extensive customer information during opportunity identification and concept formulation, when preferences concerning functionality, comfort, connectivity, sustainability, safety, and digital experiences can meaningfully shape product direction. As projects move into detailed engineering, customer participation should become more focused on validating defined solutions rather than continuously expanding product requirements. Dean et al., (2024) similarly demonstrate that different forms of customer participation can produce distinct consequences for innovativeness and development speed. A carefully calibrated involvement strategy can therefore preserve customer orientation while protecting development teams from unstable specifications and excessive feature proliferation. Customer knowledge becomes most valuable when it informs clearly defined development decisions rather than continuously redirecting the project. External collaboration should additionally be connected with organizational mechanisms that allow automotive firms to absorb and apply knowledge obtained from customers, suppliers, universities, technology partners, and other external actors.

Supplier involvement should similarly be differentiated according to the strategic and technological importance of the supplier's contribution. Contemporary automotive products depend on specialized knowledge involving battery systems, electronics, software, semiconductors, sensors, materials, and advanced manufacturing technologies. Delgado Verde and Díez Vial (2024) demonstrate the importance of supplier involvement in NPD and highlight how research and development collaboration with supporting organizations can contribute to external knowledge acquisition. Donmez and Norheim Hansen (2024) further show that supplier integration involves knowledge interdependencies at product, supplier, and buyer supplier levels, requiring different forms of coordination. Automotive manufacturers should consequently segment suppliers according to component criticality, knowledge specialization, technological uncertainty, and interface complexity. Strategic technology suppliers should participate earlier in concept and engineering activities, while standardized suppliers can be integrated through more conventional coordination mechanisms. Joint technical milestones, shared problem solving processes, transparent change procedures, and clear intellectual property arrangements should support deeper relationships. Such differentiation allows manufacturers to obtain specialized knowledge where it creates substantial value without imposing unnecessary coordination costs across the entire supply network. Early supplier participation can also identify technical feasibility concerns before product architectures become difficult to modify. External knowledge has limited value when organizations cannot interpret, combine, and convert it into development decisions. Outside-in open innovation and knowledge sharing are further connected with performance by Bagherzadeh et al., (2020).

5.5 Development Acceleration Sustainability Product Integrity Integration Strategies

Automotive firms should accelerate development by eliminating process inefficiencies rather than reducing essential engineering, testing, and validation activities. Competitive pressure can encourage organizations to compress schedules aggressively, but apparent speed achieved by postponing unresolved technical problems can generate expensive redesign and quality difficulties later. Lyu et al., (2024) demonstrate that knowledge integration mediates the relationship between competitive intensity and NPD speed, indicating that faster development can be achieved through superior knowledge utilization. Automotive manufacturers should consequently map development processes to identify waiting periods, duplicated approvals, repeated information entry, unnecessary handovers, and late functional involvement. Parallel development activities should be introduced where technical dependencies allow them, while digital simulation and virtual validation can reduce development time where sufficient model reliability exists. Process performance should be measured using both cycle time and downstream consequences such as engineering changes, validation failures, launch quality, and manufacturing readiness. This prevents development teams from achieving schedule targets by transferring unresolved problems to later stages. Development speed should ultimately represent the organization's capability to learn, decide, coordinate, and execute efficiently. When acceleration emerges from improved process quality, automotive firms can achieve competitive market timing without sacrificing the technical reliability expected from complex vehicle products. Product lifecycle management should finally be strengthened to connect sustainability objectives with measurable technical and business decisions throughout automotive development. This approach allows sustainability to contribute to innovation rather than merely constrain it.

Sustainability criteria should be incorporated during concept development rather than introduced after major product characteristics have already been established. Hunger et al., (2025) emphasize that integrating sustainability into early NPD stages is critical for innovation and long term competitive advantage, particularly because early decisions determine substantial environmental consequences. Delaney and Liu (2024) similarly demonstrate that implementing environmental sustainability during product design involves complex decision processes among designers and organizational stakeholders. Automotive firms should therefore establish sustainability requirements alongside traditional targets for cost, quality, technical performance, customer value, and development timing. Concept evaluations can include material intensity, energy consumption, recyclability, manufacturing implications, carbon impact, product durability, and end of life considerations. Sustainability specialists should participate in major development decisions rather than operating separately from engineering teams. This integration enables environmental concerns to influence product architecture while alternatives remain technically and economically adjustable. It can also reduce the probability of expensive redesign when environmental requirements emerge during later validation or regulatory assessment. Sustainability consequently becomes an inherent dimension of product development quality rather than an additional obligation imposed upon an established design. Molasy et al., (2024) demonstrate an automotive focused approach for assessing product greenness during the NPD phase while considering business goals, illustrating how environmental assessment can be incorporated into product lifecycle management. Effective execution therefore depends on clear responsibilities, shared information, and decision mechanisms that allow specialised functions to resolve interdependencies before they become costly development delays.

6. CONCLUSION

Competitive advantage in contemporary automotive markets increasingly rests on the capability to convert technological opportunities and market knowledge into products that achieve technical excellence, commercial relevance, and timely market introduction. This article establishes that the effectiveness of the development process is central to this capability because new product development involves far more than progressing a concept through a predetermined sequence of activities. Successful development requires an adaptive architecture capable of maintaining strategic control while accommodating technological uncertainty, changing customer expectations, and complex engineering requirements. Cross functional integration further strengthens this architecture by connecting specialized knowledge from engineering, manufacturing, procurement, marketing, quality, supply chain, and other organizational functions. When these capabilities operate cohesively, automotive manufacturers can identify development problems earlier, improve the quality of technical and commercial decisions, minimize unnecessary iterations, and achieve stronger alignment between product concepts and organizational capabilities. Development process effectiveness should therefore be recognized as a strategic organizational capability that determines how efficiently firms transform knowledge, resources, technologies, and innovative ideas into products capable of generating sustainable competitive value.

Digital intelligence and external collaboration further expand the strategic potential of effective development processes. Digital twins, artificial intelligence, simulation technologies, analytics, and integrated information systems provide opportunities to strengthen experimentation, validation, information visibility, and decision quality across development stages. Their contribution, however, depends on reliable data, appropriate governance, workforce competence, and effective integration with established development activities. At the same time, customers and suppliers provide valuable knowledge that can improve market relevance and technical feasibility, although their participation must be carefully calibrated according to development requirements. Customer involvement should generate meaningful insight without creating unstable product requirements, while supplier integration should provide access to specialized technological expertise without weakening coordination or strategic control. The combined management of internal expertise, digital capability, customer intelligence, and supplier knowledge creates a more connected development environment in which information can be transformed into informed action. Such connectivity is particularly valuable in automotive development, where mechanical, electronic, digital, manufacturing, and commercial considerations are becoming increasingly interdependent.

Looking forward, the pursuit of development speed must remain compatible with product integrity and sustainability rather than becoming an isolated performance objective. Shorter development cycles create strategic value only when acceleration results from superior coordination, faster organizational learning, improved information flows, and more efficient decision making. Reducing essential validation or engineering activities may generate temporary schedule advantages while increasing the possibility of quality failures, redesign, additional costs, and commercialization difficulties. Sustainability should likewise be incorporated from the earliest stages so that environmental considerations influence product architecture, material selection, manufacturing requirements, energy performance, recyclability, and lifecycle decisions while meaningful alternatives remain available. Ultimately, automotive manufacturers that integrate adaptive governance, cross functional knowledge, digital intelligence, purposeful external collaboration,

process agility, sustainability, and rigorous product validation will be better positioned to navigate the increasing complexity of new product development. Effective development processes consequently provide more than operational efficiency. They create the strategic foundation through which automotive firms can continuously deliver innovative, reliable, environmentally responsible, and commercially compelling products while strengthening long term competitiveness in a rapidly evolving global industry.

DECLARATIONS

1. Acknowledgement

The authors gratefully acknowledge the academic support provided by the Institute of Graduate Studies, Universiti Poly-Tech Malaysia (UPTM). Appreciation is also extended to the scholars whose published works provided the intellectual foundation for the development of this conceptual article.

2. Conflict of Interest

The authors declare that they have no conflict of interest related to the authorship or publication of this article.

3. Author Contribution Statement

Mohd Hadli Shah Mohamad Yunus: Conceptualization, literature review, conceptual development, and original manuscript preparation.

Norreha Othman: Supervision, intellectual guidance, critical review, and manuscript refinement.

Both authors contributed to the development of the conceptual arguments presented in the article, reviewed the manuscript, and approved the final version for publication.

4. Ethics Statement

This article is conceptual in nature and is based exclusively on published literature. It does not involve human participants, animals, surveys, interviews, experiments, or the collection of primary data. Therefore, ethical approval and informed consent were not applicable. All scholarly sources used in developing the conceptual arguments were appropriately acknowledged and cited.

REFERENCES

- Abdullah, F. I., Yusof, M. S., & Abu Seman, S. (2020). Strategic warehouse management and supply chain performance in a changing business environment. *The Asian Journal of Professional & Business Studies*, 1(2), 73–89. <https://doi.org/10.61688/ajpbs.v1i2.155>
- Aniceski, T. A., Canciglieri, A. B., Canciglieri Junior, O., Nara, E. O. B., & Benitez, G. B. (2025). New product development in the Industry 4.0 era: A literature review and research agenda. *Production Planning & Control*. Advance online publication. <https://doi.org/10.1080/09537287.2025.2570209>
- Arromba, I. F., Martin, P. S., Ordoñez, R. E. C., Anholon, R., Rampasso, I. S., Santa Eulalia, L. A., & Quelhas, O. L. G. (2021). Industry 4.0 in the product development process: Benefits, difficulties and its impact in marketing strategies and operations. *Journal of Business & Industrial Marketing*. <https://doi.org/10.1108/JBIM-01-2020-0014>
- Azahari, J., & Mohamed Suhaimi, Y. (2023). The influence of financial transparency and corporate social responsibility transparency on the performance of public listed companies in Malaysia. *Journal of Harbin Engineering University*, 44(11), 920–928.

- Bagherzadeh, M., Markovic, S., Cheng, J., & Vanhaverbeke, W. (2020). How does outside in open innovation influence innovation performance? Analyzing the mediating roles of knowledge sharing and innovation strategy. *IEEE Transactions on Engineering Management*, 67(3), 740–753.
- Chandrasekaran, M., & Rajesh, P. K. (2025). Conceptualisation of digital twin enabled new product design framework for the automotive industry. *Journal of Engineering Design*. Advance online publication. <https://doi.org/10.1080/09544828.2025.2504852>
- Cooper, R. G. (2019). The drivers of success in new product development. *Industrial Marketing Management*, 76, 36–47. <https://doi.org/10.1016/j.indmarman.2018.07.005>
- Dean, T., Zhang, H., & Xiao, Y. (2024). Customer involvement in co development: Problem solving and decision making in new product development. *European Journal of Marketing*, 58(6), 1520–1542. <https://doi.org/10.1108/EJM-12-2022-0917>
- Delaney, E., & Liu, W. (2024). Insights into environmental sustainability implementation during the design stage of new product development: An industry perspective. *Journal of Engineering and Technology Management*, 71, 101803. <https://doi.org/10.1016/j.jengtecman.2024.101803>
- Delgado-Verde, M., & Díez-Vial, I. (2024). New product development and supplier involvement: The role of R&D collaboration with supporting organisations. *The Journal of Technology Transfer*, 49(2), 518–541. <https://doi.org/10.1007/s10961-023-09998-6>
- Donmez, M., & Norheim-Hansen, A. (2024). Unlocking effective coordination: A knowledge based multilevel perspective on supplier integration into product development. *Journal of Supply Chain Management*, 60(2), 22–38. <https://doi.org/10.1111/jscm.12317>
- Huang, S., Wang, G., Lei, D., & Yan, Y. (2022). Toward digital validation for rapid product development based on digital twin: A framework. *The International Journal of Advanced Manufacturing Technology*, 119, 2509–2523. <https://doi.org/10.1007/s00170-021-08475-4>
- Hunger, T., Arnold, M. G., Engesser, S., & van den Boogaart, K. G. (2025). Integrating sustainability facets into the early stages of new product development using multi criteria tools: A critical review. *Journal of Cleaner Production*, 517, 145834. <https://doi.org/10.1016/j.jclepro.2025.145834>
- Jamaludin, A., Yusof, M. S., Othman, N., Izzwi, D., Manan, A., & Abidin, Z. Z. (2025). Green innovation for competitive advantage in PROTON's automotive sustainability initiatives. *Journal of Information Systems Engineering and Management*, 10(27s).
- Khannan, M. S. A., Tontowi, A. E., Herliansyah, M. K., & Sudiarso, A. (2021). New product development method trends and future research. *Jurnal Teknik Industri*, 23(1), 11–24. <https://doi.org/10.9744/jti.23.1.11-24>
- Lu, K., Zou, T., & Du, J. (2024). Two forms of customer involvement and new product development performance in the digital context: The moderating role of new product development stage. *Technovation*, 134, 103023. <https://doi.org/10.1016/j.technovation.2024.103023>
- Lyu, C., Bao, Y., Zhang, F., Wang, H., Tuo, X., Ou, J., & Lin, D. (2024). How competitive intensity drives firms to speed up new product development? The mediating effect of knowledge

- integration and the moderating effect of market orientation. *R&D Management*, 54(3), 664–681. <https://doi.org/10.1111/radm.12665>
- Magnacca, F., & Giannetti, R. (2024). Management accounting and new product development: A systematic literature review and future research directions. *Journal of Management and Governance*, 28, 651–685. <https://doi.org/10.1007/s10997-022-09650-9>
- Petersen, K. J., Handfield, R. B., & Ragatz, G. L. (2005). Supplier integration into new product development: Coordinating product, process and supply chain design. *Journal of Operations Management*, 23(3–4), 371–388. <https://doi.org/10.1016/j.jom.2004.07.009>
- Rosienkiewicz, M., Helman, J., Cholewa, M., Molasy, M., Oleszek, S., & Berselli, G. (2024). Green PLM: Business goals-oriented algorithm assessing the greenness of a product in the new product development phase for the automotive industry. *Annals of Operations Research*. <https://doi.org/10.1007/s10479-024-06014-4>
- Shinde, B. G., Sanap, S. B., Pawar, S. S., & Wakchaure, V. D. (2025). New product development process: A conceptual framework for automobile industries. *International Journal of Systematic Innovation*, 9(3), 31–74. [https://doi.org/10.6977/IJoSI.202506_9\(3\).0004](https://doi.org/10.6977/IJoSI.202506_9(3).0004)
- Silva, S. F., Pimenta, M. L., Oprime, P., & Fodra, M. (2026). Cross-functional integration 4.0 in product development processes: A case study in the heavy vehicle sector. *Business Process Management Journal*, 32(2), 467–486. <https://doi.org/10.1108/BPMJ-08-2024-0759>
- Smeets, J., Öztürk, K., & Liebich, R. (2023). Digital twins for automotive development: Two wheelers application. *Advanced Engineering Informatics*, 56, 101982. <https://doi.org/10.1016/j.aei.2023.101982>
- Vallé, R., Seitz, J., Kanbach, D. K., & Schuhmacher, M. C. (2026). The use of artificial intelligence in new product development: A systematic literature review, conceptual framework, and future research agenda. *Technovation*, 153, 103541. <https://doi.org/10.1016/j.technovation.2026.103541>
- Wu, D., Lin, X., Liu, T., & Li, J. (2024). Cross functional integration and new product development performance: Assessing mediating role of customer supplier involvement and moderating role of structural empowerment. *Technological Forecasting and Social Change*, 208, 123658. <https://doi.org/10.1016/j.techfore.2024.123658>
- Yusof, M. S. (2025b). Technology adoption in small and medium enterprises and its impact on business growth, innovation, and digital sustainability. *International Journal of Advanced Research in Economics and Finance*, 7(3), 84–100. <https://doi.org/10.55057/ijaref.2025.7.3.7>
- Yusof, M. S. (2026). Integrating digital and entrepreneurial leadership: A framework for SME performance in emerging economies. *Jurnal Evolusi*, 7(1), 62–77. <https://doi.org/10.61688/jev.v7i1.568>
- Yusof, M. S. B. (2025a). Shaping the future of Malaysia's automotive industry through unified efforts for new product development success. *Veredas do Direito*, 22(6), e223925–e223925.
- Yusof, M. S., & Salleh, M. N. (2021). Beyond manufacturing towards innovation-driven new product development in Malaysia's automotive industry. *The Asian Journal of Professional & Business Studies*, 2(1), 35–52. <https://doi.org/10.61688/ajpbs.v2i1.152>

- Yusof, M. S., Salleh, M. N., & Zahari, F. M. (2020a). The relationship between information technology capability and new product development success: A conceptual framework. *International Journal of Business and Technology Management*, 2(1), 98–112.
- Yusof, M. S., Salleh, M. N., & Zahari, F. M. (2020b). The relationship between NPD process and NPD strategy toward NPD success in Malaysian automotive industry. *Asian Journal of Research in Business and Management*, 2(1), 11–26.
- Yusof, M. S., Wahid, A., Seman, S. A., Jusoh, Z. S. M., & Razali, H. (2024). An empirical analysis of new product development success among automotive industry vendors in Malaysia. *International Journal of Religion*, 5(6), 836–847.
- Yusof, M. S., Zaini, A. F. A., Othman, N., Jali, M. N., Manan, D. I. A., Seman, S. A., & Abidin, Z. Z. (2025a). Advancing new product development practices for innovation and growth in Malaysia's automotive industry. *Journal of Posthumanism*, 5(4), 1369–1383.
- Zaefarian, G., Katsikeas, C. S., Najafi-Tavani, Z., & Robson, M. J. (2025). Unpacking when and how customer involvement as co developer affects supplier new product performance. *Journal of the Academy of Marketing Science*, 53(3), 876–906. <https://doi.org/10.1007/s11747-024-01066-1>
- Zaini, A. F. B. A., Yusof, M. S. B., Jamaludin, A., Yunus, M. H. S. M., & Hashim, F. (2026). Consumer review perception and its impact on Generation Z online spending behaviour in modern digital commerce. *Veredas do Direito*, 23(1), e234304–e234304.
- Zarbi, H., Mansour, S., & Mosadegh, H. (2024). Customer participation in new product development: The contingent effects of product development proficiency and task uncertainty. *Engineering Management Journal*. Advance online publication. <https://doi.org/10.1080/10429247.2024.2398957>
- Zhang, D., Hou, X., & Guo, J. (2023). How does digital transformation improve new product development performance from the perspective of resource orchestration? Analysis based on configuration. *PLOS ONE*, 18(11), e0291652. <https://doi.org/10.1371/journal.pone.0291652>
- Zhang, X., & Zhou, N. (2025). How technology coopetition affects firms' scientific research and new product development? Evidence from Chinese pharmaceutical industry. *Technology Analysis & Strategic Management*. Advance online publication. <https://doi.org/10.1080/09537325.2025.2515466>
- Zhou, J., He, P., Zhu, S., & Yin, L. (2024). Can empowering leadership increase new product development performance in China: The destructive role of error aversion culture. *SAGE Open*. <https://doi.org/10.1177/21582440241300345>
- Zhu, X., Xiao, Z., Dong, M. C., & Gu, J. (2019). The fit between firms' open innovation and business model for new product development speed: A contingent perspective. *Technovation*, 86–87, 75–85. <https://doi.org/10.1016/j.technovation.2019.05.005>