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An Enhanced CPI-Based Framework for Risk Management in New Energy Vehicle Development

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Abstract

The rapid expansion of the global new energy vehicle (NEV) industry has introduced unprecedented technical, operational, and systemic risks, driven by increasing system complexity and intelligent connectivity features. This study critically examines prevailing risk management practices in NEV development and evaluates the effectiveness of existing qualitative risk assessment approaches used by automakers. The analysis reveals significant methodological limitations, particularly in consistency, standardization, and decision-support capability. To address these gaps, this paper develops an enhanced Criticality Priority Index (CPI) framework that integrates maturity assessment into a structured three-dimensional risk evaluation model. By embedding technological maturity and process readiness into CPI calculations, the proposed approach strengthens the analytical rigor and comparability of qualitative risk assessments. The study validates the enhanced framework through empirical case applications, demonstrating its superiority over conventional qualitative methods in risk classification accuracy and managerial usability. Furthermore, the findings show that the enhanced CPI model improves risk-level discrimination, supports more precise resource prioritization, and enhances project-level decision-making under uncertainty. Overall, the research advances risk management methodology for complex engineering projects and provides a practical, multi-dimensional assessment tool tailored to the technologically intensive environment of NEV development.

Keywords

NEV Project, Risk Management, Risk Qualitative Assessment, Three-Dimensional Assessment

1. Introduction

Global climate change concerns and sustained technological innovation have accelerated the rapid expansion of the new energy vehicle (NEV) industry over the past decade. The International Energy Agency (IEA) projects that global NEV stock will exceed 85 million units by 2025—approximately sixteen times the 2018 level. While this extraordinary growth signals industrial transformation and market acceptance, it also amplifies systemic risks and intensifies the complexity of risk governance across the NEV value chain.

Unlike traditional internal combustion engine vehicles, NEVs integrate advanced battery technologies, high-efficiency electric drive systems, power electronics, and intelligent connectivity architectures. These innovations enhance vehicle performance and user experience but simultaneously introduce intricate technical interdependencies. In particular, battery degradation dynamics, electrochemical instability, electromagnetic compatibility issues, and tightly coupled software-hardware systems significantly increase the uncertainty embedded in research and development (R&D) processes. As a result, automakers must manage not only component-level reliability risks but also cross-system integration risks that evolve throughout the product life-cycle.

Although manufacturers widely implement structured risk management frameworks, unexpected malfunctions and safety incidents continue to occur in both conventional and new energy vehicles. Risk uncertainty, incomplete information, and qualitative bias in assessment processes often weaken early-stage detection and prioritization. These failures generate substantial financial losses, trigger recalls, erode consumer trust, and slow broader NEV market adoption. Strengthening methodological rigor in risk evaluation, therefore, remains a strategic imperative for sustainable industry development.

This paper addresses these challenges by developing an enhanced Criticality Priority Index (CPI)-based risk assessment framework tailored to complex engineering projects such as NEV development. Traditional qualitative risk analysis typically evaluates risk using probability and impact as two primary dimensions. However, this two-dimensional structure inadequately captures technological readiness and process capability, both of which critically influence project outcomes. To overcome this limitation, the proposed framework introduces maturity as a third evaluative dimension, integrating technological and organizational readiness into CPI calculations. This three-dimensional structure refines risk quantification, reduces subjectivity, and improves prioritization accuracy.

By embedding maturity assessment into the CPI model, the study enables project teams to identify high-leverage risk factors earlier, allocate resources more strategically, and implement targeted mitigation strategies across the vehicle development lifecycle. The subsequent sections analyze current risk management practices within the NEV industry and employ case-based validation to demonstrate how the enhanced CPI method achieves more precise risk discrimination and superior prioritization performance compared with traditional CPI approaches.

2. Literature Review

This section synthesizes the principal determinants of risk in new energy vehicle (NEV) project development and reviews the theoretical foundations of project risk management. By integrating domain-specific industry insights with established risk management theory, the section establishes a structured conceptual basis for systematic risk identification and assessment in future NEV development initiatives.

2.1. NEV Project Development

Over the past decade, the rapid technological evolution and global policy emphasis on decarbonization have accelerated the development of NEVs. As this sector expands, project architectures have grown increasingly complex, requiring more rigorous and standardized risk assessment systems. Effective evaluation frameworks must now address not only traditional project constraints—such as cost, schedule, and scope—but also emerging uncertainties related to technological integration, regulatory volatility, and supply chain interdependence.

To construct a comprehensive understanding of these risks, this study conducts a narrative review of domestic and international literature on NEV project risk factors. The review identifies a broad spectrum of threats that can impede successful project delivery, ranging from technical feasibility challenges to market adoption uncertainty. To strengthen the practical relevance of the analysis, the study also incorporates structured input from five domain experts specializing in NEV engineering and project management. This combined methodological approach enhances both theoretical rigor and applied validity.

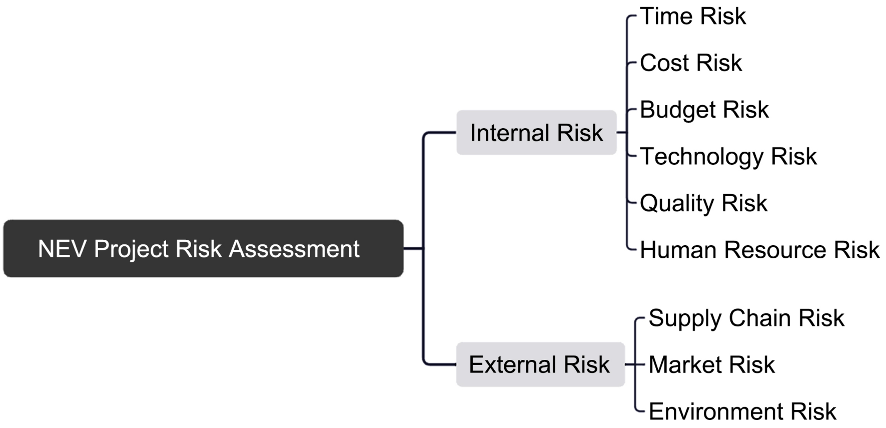

Figure 1. Framework of risk assessment for new energy vehicles (NEV).

Based on this integrated analysis, the study classifies NEV development risks into two primary categories: internal and external risks. Internal risks arise from within the project organization and directly affect execution performance. These include schedule delays, cost overruns, budget misallocation, technological immaturity, quality control deficiencies, and human resource constraints. In contrast, external risks originate from the broader operational environment and typically lie beyond direct managerial control. These risks include supply chain instability, market demand fluctuations, competitive pressures, regulatory shifts, and macro-environmental uncertainties.

This structured categorization clarifies causal pathways between risk sources and project outcomes while providing a foundation for multidimensional risk assessment modeling. **Figure 1** presents the resulting risk assessment framework, which integrates internal and external risk dimensions into a unified analytical structure for NEV project evaluation.

2.2. Project Risk Management

Risk management constitutes a core discipline within project management and directly determines project performance and long-term success (Fang & Marle, 2012). Since practitioners formalized risk management practices in the United States in the 1950s, organizations worldwide have applied structured risk frameworks to control uncertainty in increasingly complex projects (Dionne, 2013). In the automotive sector—particularly within the rapidly evolving new energy vehicle (NEV) industry—project managers must address escalating technological complexity, compressed development cycles, and intensified market competition. Under these conditions, risk management becomes not merely supportive but central to strategic execution. However, when evaluated against contemporary theoretical standards, many tools currently used in practice reveal conceptual and methodological limitations.

1) *Definition of risk management*

Project risk management refers to the structured and continuous process through which organizations identify, analyze, evaluate, and respond to uncertainties throughout the project life cycle (Cervone, 2006). The latest version of ISO 31000:2023 defines risk management as “coordinated activities of an organization to direct and control risk” emphasizing integration, governance alignment, and systematic control (Barghi & Shadrokh Sikari, 2020). The standard further defines risk as ‘the effect of uncertainty on objectives’ highlighting its dual nature: uncertainty can generate both threats and opportunities.

The PRINCE2 framework characterizes project risk management as an iterative cycle of identification, assessment, planning, and response to uncertain events that may influence objectives. This perspective prioritizes proactive decision-making and structured anticipation over reactive mitigation (Tomanek & Juricek, 2015).

Similarly, China’s GB/T 23694-2024 standard—aligned with ISO principles—defines risk management as coordinated organizational activities that direct and control risk, reinforcing its governance-oriented and systematic attributes (Xu & Shi, 2025).

Taken together, these frameworks converge on three core principles. First, risk includes both negative threats and positive opportunities. Second, uncertainty forms the analytical foundation of risk assessment. Third, organizations must embed structured identification, evaluation, and response mechanisms before and during project execution. Effective risk management, therefore, seeks not only to reduce adverse outcomes but also to enhance value creation under uncertainty. Furthermore, in technologically intensive industries such as NEVs, this balanced perspective becomes critical to sustaining competitiveness and innovation.

2) *Risk management process*

Organizations implement risk management through a dynamic and cyclical process that integrates identification, assessment, response planning, monitoring, and control. Risk identification techniques commonly include SWOT analysis, expert workshops, brainstorming sessions, Delphi studies, and cause-and-effect (fish-bone) diagrams. These tools enable teams to surface potential uncertainties across technical, financial, and organizational dimensions.

In NEV development, practitioners generally classify risk analysis methods into qualitative, quantitative, and hybrid approaches. Qualitative methods rely on expert judgment to evaluate risk probability and impact, often operationalized through risk matrices or indices such as the Criticality Priority Index (CPI). These approaches facilitate rapid assessment but depend heavily on subjective interpretation.

Quantitative methods, by contrast, apply mathematical modeling to estimate probability distributions and impact magnitudes. For example, project teams frequently use Monte Carlo simulations to model complex interactions among uncertain variables, enabling probabilistic forecasting of schedule and cost outcomes (Virine, 2013). These techniques enhance analytical precision and support evidence-based decision-making by translating uncertainty into measurable distributions.

Throughout the project life-cycle, teams typically maintain a risk register to document identified risks, assign ownership, track mitigation actions, and monitor status changes. As projects evolve, managers dynamically adjust response strategies to reflect new information, shifting priorities, or emerging uncertainties. This adaptive capability distinguishes effective risk governance from static compliance-based approaches.

3) *Limitation of qualitative risk assessment*

Despite its widespread use, qualitative risk assessment faces significant conceptual and practical constraints. Scholars such as Lincoln and Guba (1985) and Schwandt (1989) argue that qualitative and quantitative paradigms rely on fundamentally different epistemological foundations (Ochieng, 2009). In contrast, other researchers contend that experienced analysts can integrate both approaches effectively, highlighting an ongoing methodological debate within risk research.

As project environments grow more complex, the number and interdependence of risk variables expand significantly. Huang (2025) notes that multivariate risk structures in complex systems often exceed the analytical capacity of simplified qualitative tools. Furthermore, Cox Jr. et al. (2005) demonstrate that many qualitative rating systems lack sufficient resolution to distinguish meaningfully between risks with vastly different quantitative magnitudes. As a result, evaluators may assign identical qualitative labels (e.g., "high risk") to scenarios whose actual impacts differ by several orders of magnitude, thereby weakening prioritization accuracy.

To address such deficiencies, Cagno et al. (2007) propose a multi-level risk mapping model that incorporates multiple classification dimensions to improve granularity and strategic targeting. Their approach underscores the need for structured, multidimensional frameworks in complex project environments.

Although the traditional CPI-based qualitative approach remains simple, accessible, and efficient for cross-functional teams, its analytical depth proves increasingly insufficient for high-technology industries such as NEVs. As project architectures integrate advanced batteries, intelligent software systems, and interconnected supply networks, risk inter-dependencies intensify. Under these conditions, purely two-dimensional qualitative models struggle to capture maturity, integration readiness, and systemic vulnerability. Therefore, advancing beyond conventional CPI calculations becomes necessary to achieve greater precision, discrimination, and strategic relevance in risk prioritization.

3. Risks in the NEV Industry

3.1. Project Risk Categories

Table 1. Risks in the development of NEV.

Risk Category	Subcategories	Representative Examples
Internal	Time Risk	Project development plan delayed
	Cost Risk	Over costs of component
	Budget Risk	Over budgets
	Technology Risk	Battery system thermal runaway and capacity decay
		Motor demagnetization, inverter failure, reducer oil leakage
		Controller software bugs, functional failure
	Quality Risk	Component assembly defects, welding quality
	Human Resource Risk	Team conflicts and resignations
External	Supply Chain Risk	Lack of components
	Market Risk	Market environment changes
	Environment Risk	Changes in regulations, earthquakes, tsunamis

New energy vehicle development involves multidimensional and continuously evolving risk structures. Drawing on industry practice and empirical analysis of NEV project data, this study classifies risks into two overarching categories: internal and external risks. Internal risks originate within the project organization and relate to execution capability, technological readiness, cost control, schedule management, and resource allocation. External risks arise from market volatility, supply chain disruptions, regulatory uncertainty, environmental factors, and competitive dynamics.

Each category contains multiple sub-dimensions that generate distinct managerial challenges and require differentiated mitigation strategies. **Table 1** summarizes these risk classifications and outlines corresponding countermeasures tailored to the NEV development context.

3.2. Common Project Risks

1) *Time risk*

Project teams encounter time-related risks throughout both the development and operational phases of NEV projects. Managers must align resource allocation between R&D and production, ensure that milestones remain realistic and achievable, and verify that project execution meets technical and commercial targets within scheduled timelines. They must also evaluate whether projected order volumes will materialize after production launch, whether pre-production orders can be delivered on time, whether downstream suppliers can meet contractual commitments, and whether the project team's structure and technical capabilities adequately support R&D complexity.

Jones (1994) identifies scope expansion and the attempt to complete excessive tasks within compressed time-frames as major contributors to declining quality and escalating costs under schedule pressure. These findings suggest that effective time risk management requires more than monitoring deadlines. Project leaders must rigorously assess the feasibility and logical coherence of development plans, ensuring that timelines reflect technological maturity, integration complexity, and organizational capacity.

2) *Financial risk*

Financial risk emerges when project investment decisions fail to align with anticipated revenue streams. Managers must balance fixed asset investments, material costs, development expenditures, and mass production plans against projected sales performance. At the same time, they must incorporate marketing expenditures and commercialization uncertainties into financial forecasting models.

Battery systems significantly influence vehicle cost structures. Because batteries occupy substantial physical space and contribute heavily to total vehicle weight, engineers frequently adjust technical configurations to reduce mass and enhance efficiency. However, such adjustments may increase manufacturing complexity and short-term costs. Although lithium iron phosphate and ternary lithium battery technologies offer long-term cost-reduction potential, raw material price volatility, technological constraints, and supply limitations complicate forecasting. Moreover, solid-state batteries remain commercially immature, limiting immediate cost-optimization opportunities. These interacting uncertainties heighten financial exposure during both development and scaling phases.

3) *Technology risk*

NEV technologies possess a shorter operational history than traditional internal combustion systems, which increases technological uncertainty. The electric powertrain—comprising the battery, motor, and electronic control system—represents a relatively new technological architecture within the automotive industry. This architecture evolves rapidly, creating both innovation opportunities and integration risks.

However, continuous technological iteration in battery chemistry, power electronics, intelligent control systems, and vehicle software demands sustained R&D investment and system-level coordination. Simultaneously, hybrid vehicle platforms compete for strategic focus and resource allocation. These overlapping technological pathways generate uncertainty in long-term development direction, increase integration challenges, and elevate the risk of obsolescence or design rework.

4) *Supply chain risk*

As automobile firms expand domestically and internationally, they rely on geographically dispersed supplier networks. NEVs contain highly complex systems, diverse component categories, and large part volumes, often sourced across multiple countries. Dias et al. (2020) identify delayed deliveries, supply interruptions, and quality deficiencies as primary supply chain risks facing automotive manufacturers.

Yan et al. (2020) further note that China's NEV industry faces distinctive vulnerabilities stemming from rapid policy adjustments and shifting technological trajectories. These dynamics amplify supplier uncertainty and complicate coordination across tiers. Consequently, firms must strengthen supplier evaluation mechanisms, diversify sourcing strategies, and enhance visibility across supply networks to mitigate cascading disruptions.

5) *Market risk*

NEVs address environmental and energy efficiency concerns by replacing fossil fuel consumption with electricity. In China and other major markets, governments initially accelerated adoption through targeted subsidies and regional support policies. However, national policy frameworks evolve dynamically in response to macroeconomic conditions and industrial strategy adjustments. Companies must continuously adapt pricing, production, and investment strategies to align with regulatory changes. Failure to anticipate policy shifts can generate significant financial losses.

As governments phase out subsidies, NEVs increasingly compete within fully market-driven environments. Firms must secure market share through cost leadership, technological differentiation, brand positioning, and strategic alliances. At the same time, they face intensifying competition, fluctuating consumer preferences, geopolitical uncertainty, and other force majeure events. These external pressures create volatile demand conditions and heighten exposure to market-based risks.

4. Traditional Risk Analysis Methods and Limitations

4.1. Traditional CPI Calculation Method

The Criticality Priority Index (CPI) serves as a foundational tool in qualitative risk assessment within automotive engineering. Practitioners traditionally calculate CPI by multiplying two parameters: probability and impact. Equation (1) presents the conventional formulation:

$$\mathrm{CPI} = \mathrm{P} \times \mathrm{I} \tag{1}$$

In Equation (1), P represents the probability of risk occurrence, and I represents the impact of the risk event.

For the first dimension, P (probability of occurrence) is based on the scoring criteria proposed by Kendrick (2015). The second dimension, I (impact or severity), is derived from the research of Lansdowne (1999), which employs a five-point scale to assess risk impact. The definitions of each index value are presented in **Table 2** and **Table 3** below.

Table 2. Definitions of probability index value.

Index (P)	Value	Value definition
High probability	5	Probability of occurrence ≥ 80%
Medium-high probability	4	Probability of occurrence 60% - 80%
Medium probability	3	Probability of occurrence 40% - 60%
Medium-low probability	2	Probability of occurrence 20% - 40%
Low probability	1	Probability of occurrence ≤ 20%

Table 3. Definitions of impact index value.

Index (I)	Value	Value definition
Major risk	5	Will lead to project failure.
Serious risk	4	Will cause significant cost or schedule increases, and secondary requirements may not be met.
Moderate risk	3	Will lead to moderate cost/schedule increases, but important requirements can still be met.
Minor risk	2	Only causes minor cost/schedule increases.
Negligible risk	1	No substantial impact on cost or schedule.

The primary advantage of the traditional CPI method lies in its operational simplicity and intuitive structure. Project teams can apply the model with minimal specialized training, and engineers can easily interpret its results. By generating risk priority values ranging from 1 to 25, the method allows practitioners to rank risks quickly and allocate mitigation resources in a structured and practical manner. Its accessibility has therefore contributed to its widespread adoption in automotive project management.

4.2. Limitations of the Application

Despite its popularity, the traditional CPI method reveals substantive limitations when applied to the technological and organizational complexity of NEV development.

In conventional qualitative risk analysis, practitioners calculate the CPI as the product of probability and impact, thereby estimating a basic level of risk exposure. However, this two-dimensional risk matrix framework overlooks critical factors such as risk recognition, evolutionary dynamics, organizational preparedness, and management maturity. As a result, the method simplifies inherently dynamic and systemic risks into static numerical representations, which restricts its explanatory and predictive power.

To address these theoretical and practical shortcomings, this study develops an enhanced CPI model that introduces risk maturity as a third evaluative dimension. The revised framework draws on multidimensional comprehensive risk evaluation theory, risk maturity theory, and contemporary principles of qualitative risk analysis. In complex engineering projects, the actual severity of risk depends not only on the likelihood of occurrence and magnitude of impact, but also on whether the organization fully understands the risk, has identified its root causes, and has developed robust mitigation strategies.

Vehicle development projects often involve hidden, gradual, and transmissive risk mechanisms. Technical issues may remain latent during early stages and escalate rapidly once integration begins. The traditional CPI model frequently fails to detect such low-maturity but high-volatility risks, leading to potential underestimation or misclassification. Conversely, it may overestimate highly visible risks that are already well-controlled. By incorporating maturity as a structural dimension, the enhanced CPI model improves discrimination accuracy, strengthens early warning capability, and offers greater theoretical completeness.

From an industry perspective, effective automotive risk management requires organizations to anticipate and contain low-maturity risks before they propagate across interconnected systems. The traditional CPI framework cannot adequately capture this transmission dynamic. The enhanced CPI model directly addresses this gap, enabling firms to prioritize structurally vulnerable risks and allocate management resources more strategically.

5. AN Enhanced Risk Assessment Framework

5.1. Basic Theory

To overcome the analytical constraints of traditional qualitative assessment, this study proposes an enhanced three-dimensional risk evaluation framework tailored to NEV development. The model retains the conventional Probability (P) and Impact (I) dimensions while introducing risk event Maturity (M) as an additional evaluative factor. This extension integrates theoretical insights from risk management literature with empirical evidence from vehicle engineering projects and structured expert interviews. Although developed within the NEV context, the framework can be generalized to other complex engineering, manufacturing, and technology-intensive development programs. The enhanced CPI formula is defined as:

$$\mathrm{CPI} = \mathrm{P} \times \mathrm{I} \times \mathrm{M} \tag{2}$$

where:

P: Measures the likelihood of occurrence using a five-point scale (1 = very low probability; 5 = very high probability).

I: Assesses severity using a five-point scale (1 = negligible impact; 5 = critical impact).

M: As a combined construct, M represents technology readiness, supplier/process readiness, or management preparedness. Evaluates the technological and organizational maturity of the risk source, considering factors such as design readiness, production capability, and process stability (1 = fully mature and well-controlled; 5 = early-stage, exploratory, or highly uncertain).

By expanding the risk matrix into a three-dimensional structure, the enhanced framework captures both uncertainty and preparedness. It preserves the usability and clarity of qualitative assessment methods while significantly improving analytical depth and differentiation capacity.

5.2. Implementation Methods

Table 4 presents the qualitative assessment scale developed for the enhanced framework. The study constructed this scale by referencing established qualitative risk assessment principles from the A Guide to the Project Management Body of Knowledge (PMBOK Guide) and adapting them to align with the multidimensional theoretical structure proposed here. This calibration ensures conceptual consistency with recognized project management standards while maintaining practical relevance to real-world NEV development environments.

Table 4. Qualitative risk assessment scale.

Probability (P)		Impact (I)		Maturity (M)	
Index	**Value**	**Index**	**Value**	**Index**	**Value**
5	High probability	5	Major risk	5	Early development
4	Medium-high probability	4	Serious risk	4	Testing and verification phase
3	Medium probability	3	Moderate risk	3	Small-scale applications
2	Medium-low probability	2	Minor risk	2	Mass production and application
1	Low probability	1	Negligible risk	1	Fully mature

6. Case Application Analysis

To scientifically and rigorously verify the practical effectiveness of the improved CPI framework, this study conducts empirical analysis combining structured expert interviews with real-world vehicle development cases, so as to ensure the professionalism and practical applicability of evaluation outcomes derived from the framework. Two senior industry specialists with over ten years of experience in new energy vehicle (NEV) project development are selected for interviews to deliver authoritative practical input for framework dimension formulation and quantitative scoring, substantially improving the authenticity and reliability of research findings. The interviewed experts boast expertise spanning core vehicle development sectors with functionally complementary and representative job roles: one is a powertrain manager specializing in electric drive system R&D, who has long been in charge of risk management and control for key component development; the other works as a project director overseeing full-process vehicle development and excels at risk assessment across the complete vehicle R&D life-cycle. Together, they can cover diverse risk scenarios in NEV development from two hierarchical perspectives: critical individual components and complete vehicle systems.

Each single interview lasts approximately 30 minutes, centering on persistent challenges, high-frequency risk factors in NEV development as well as inherent drawbacks of prevailing risk management tools, with systematic collection of the experts' hands-on experience and professional analytical conclusions. Post-interview, standardized sorting and formal conversion of valid interview data are implemented in two phases. First, standardized risk categories compatible with the improved CPI framework are summarized based on development pain points and potential hazards mentioned by experts alongside corresponding risk occurrence scenarios, impact dimensions and control attributes, which optimizes the framework's risk classification system. Second, grounded on experts' empirical judgments concerning risk occurrence probability and consequence severity, practically oriented scoring criteria are established to convert qualitative experiential assessments into quantifiable numerical ratings. Such quantitative risk evaluation of practical vehicle development cases furnishes solid empirical data to validate the efficacy of the improved CPI framework.

Based on the interview findings, the study identified two high-probability risks commonly encountered during NEV development. It then applied both the traditional CPI method and the enhanced CPI model to these cases to enable a structured comparative evaluation.

6.1. Comparative Risk Assessment

To test the practical value of the enhanced qualitative framework, the study selected one internal risk (quality risk) and one external risk (supply chain risk). Each case study compares and contrasts traditional CPI and enhanced CPI to assess how each calculation method differentiates risk severity and supports management decisions. The traditional CPI risk level of 1-25 is assessed using two dimensions: probability of occurrence and impact. The enhanced CPI, by introducing a third dimension of "maturity", has a risk level range of 1-125. The comparison evaluates how each calculation method differentiates risk severity and supports managerial decision-making. In case 1 and 2 analysis, the P and I values are based solely on experts judgment.

1) *Case* 1

Risk item: During the prototype manufacturing stage, engineers were unable to install the high-voltage wiring harness in the engineering prototype vehicle.

This issue represents a component-level quality risk. When using the traditional CPI method, the assessment and CPI are as follows.

P: 4 (Based on industry quality problem data, this indicates a medium-to-high likelihood of occurrence).

I: 3 (Requires assessment in conjunction with the overall project development plan. Based on recorded industry quality problem data, the issue may delay project milestones and increase procurement or redesign costs, representing a moderate impact).

$$\text{Traditional CPI} = 4 \times 3 = 12 \tag{3}$$

Based on the above P and I assessment values, the enhanced framework incorporates a third dimension: M.

M: 4 (Based on the case, the project remains in the engineering prototype trial production phase, and the maturity of the high-voltage wiring harness is still undergoing testing and validation).

$$\text{Enhanced CPI} = 4 \times 3 \times 4 = 48 \tag{4}$$

Under the traditional CPI calculation method, the risk value is 12, and under the enhanced CPI calculation method, the risk value is 48. Given the traditional CPI risk value range of 1 to 25, assuming this range represents 0% to 100% risk severity, a value of 12 corresponds to 48% of the overall risk range, indicating a moderate risk. However, when the enhanced CPI risk value range lies between 1 and 125, and assuming this range represents 0% to 100%, a value of 48 corresponds to 38.4% of the overall risk range, indicating a low-to-medium risk level.

Therefore, the enhanced CPI more accurately reflects the practical context: although the probability and impact are notable, the organization recognizes the technical immaturity at this stage and actively manages it during testing. The dimensional breakdown directs engineers to concentrate mitigation efforts on design validation and component quality control during verification.

2) *Case* 2

Risk item: Battery delivery was delayed during the prototype vehicle trial production phase.

This issue constitutes a supply chain risk. When using the traditional CPI method, the assessment and CPI are as follows.

P: 5 (Based on industry data, this indicates a high likelihood of delivery delays).

I: 4 (Requires assessment in conjunction with the overall project development plan. Based on recorded industry data, delays can significantly disrupt development schedules and increase costs, denoting a serious risk level).

$$\text{Traditional CPI} = 5 \times 4 = 20 \tag{5}$$

Based on the above assessed values of P and I, the enhanced framework adds the third dimension: M.

M: 4 (Based on this case, the project is in the engineering prototype trial production phase. During the prototype stage, battery technology and supplier processes typically remain in testing and validation phases).

$$\text{Enhanced CPI} = 5 \times 4 \times 4 = 80 \tag{6}$$

When normalized, the traditional method classifies this as high risk, while the enhanced method places it at a medium-to-high level. Under the traditional CPI calculation method, the risk value is 20. Under the enhanced CPI calculation method, the risk value is 80. Given the traditional CPI risk value range of 1 to 25, assuming this range represents 0% to 100% risk severity, a value of 20 corresponds to 80% of the overall risk range, indicating a high risk. However, the enhanced CPI risk value range is 1 to 125, and assuming this range represents 0% to 100%, a value of 80 corresponds to 64% of the overall risk range, indicating a medium-high risk.

Similarly, the enhanced CPI provides a more accurate risk assessment. In the actual development process of new energy vehicles, battery delivery delays frequently occur during the prototype stage and are highly correlated with the overall project development cycle and the maturity of the power battery technology employed. Consequently, project teams typically prioritize timely component delivery and identify risks early in the project, aligning with the overall development plan. During project execution, engineers closely monitor the likelihood of such risks and respond promptly.

Thus, although the probability and impact assessments for battery delivery delay are high, the low maturity of the components leads the development team to implement early risk mitigation measures and maintain heightened vigilance throughout the development process. As a result, the actual risk level in project execution is closer to medium-high, rather than the high risk indicated by the traditional CPI method.

In practice, development teams anticipate battery delivery uncertainty at the prototype stage and implement early monitoring mechanisms. Engineers integrate delivery risk into scheduling buffers and maintain close coordination with suppliers. Although probability and impact remain high, proactive mitigation and awareness reduce the effective exposure during execution. The enhanced CPI captures this maturity-adjusted reality more accurately than the traditional approach.

6.2. Analysis of Comparative Evaluation Results

The case analyses demonstrate several advantages of the enhanced CPI framework. First, the model improves assessment accuracy. By incorporating maturity as a third dimension, the framework aligns risk scoring more closely with actual project conditions in NEV development. It captures not only likelihood and consequence but also organizational preparedness and technological readiness.

Second, the enhanced model strengthens resource optimization. In complex projects, multiple risks often receive identical traditional CPI scores, limiting prioritization precision. The additional maturity dimension increases differentiation among risks, reduces score clustering, and minimizes the risk of systematic overestimation or underestimation.

Finally, improved discrimination supports more rational allocation of human resources, budget, time, and managerial attention. By identifying structurally vulnerable yet manageable risks, project teams can design more efficient development plans and improve overall project success rates in technologically intensive NEV environments.

7. Conclusion

7.1. Research Findings and Summary

Project risk management requires organizations to systematically identify and evaluate factors that may threaten project objectives. This study confirms that effective risk governance plays a decisive role in NEV project development, where technological complexity, supply chain interdependence, and rapid iteration amplify uncertainty. Through structured analysis of industry risk categories, the research demonstrates that traditional qualitative assessment methods—particularly two-dimensional CPI models—often misclassify risks in complex engineering environments, leading to underestimation or overestimation of actual exposure.

To address these deficiencies, this study develops an enhanced CPI framework that incorporates maturity as a third evaluative dimension alongside probability and impact. By integrating technological and organizational readiness into the assessment structure, the refined model improves discrimination accuracy while preserving the operational simplicity of qualitative risk analysis. The case studies confirm that the enhanced CPI method produces risk priorities that better align with real-world project dynamics and support more strategic allocation of managerial attention and development resources. These findings underscore the relevance of multidimensional evaluation in the context of modern NEV development.

7.2. Theoretical and Practical Significance

This research advances both academic theory and industry practice.

Theoretical contributions: The study extends qualitative risk assessment theory by introducing a structured multidimensional evaluation model tailored to complex project environments. By embedding maturity into the probabilistic framework, it establishes a conceptual mechanism for capturing dynamic risk evolution and organizational preparedness. This contribution enhances analytical depth and provides a clearer foundation for differentiating risk levels in technologically intensive systems.

Practical implications: For NEV manufacturers and component suppliers, the enhanced CPI framework offers a practical and scalable decision-support tool. It strengthens project safety and reliability while enabling more precise prioritization of mitigation actions. Compared with the traditional CPI approach, the enhanced model requires minimal incremental analytical effort yet delivers significantly improved assessment accuracy. As a result, firms can allocate human resources, budgets, and technical oversight more effectively across the development life-cycle.

7.3. Limitations and Future Research

Although the study validates the advantages of enhanced qualitative risk assessment, several limitations warrant further investigation.

First, the framework relies on expert judgment to assign probability, impact, and maturity scores, which may introduce subjective bias. Future research should refine the scoring system by developing standardized evaluation criteria and integrating quantitative performance indicators where feasible. Such advancements could support the construction of a hybrid qualitative-quantitative multidimensional assessment system.

Second, the empirical validation relies on a limited number of representative cases. Expanding the analysis across additional vehicle subsystems, development stages, and manufacturers would strengthen external validity. Longitudinal studies that apply the enhanced CPI continuously throughout the full project life-cycle would provide deeper evidence of its predictive and managerial effectiveness.

In conclusion, as the NEV industry accelerates technological innovation and market expansion, organizations must adopt more sophisticated and structurally sensitive risk management frameworks. The enhanced qualitative risk assessment model proposed in this study provides a multidimensional perspective capable of capturing both uncertainty and maturity effects. By applying this approach, automotive firms can improve risk transparency, enhance product reliability, and promote sustainable development within increasingly complex engineering ecosystems.

Future research should test the enhanced CPI model using larger datasets across multiple NEV platforms and development phases. Besides, incorporating cross-company or cross-regional comparisons would increase generalizability and external validity.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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