Journal of Computer Technology and Applied Mathematics
Journal Home: http://jctam.suaspress.org | CODEN: JCTAAD
Vol. 3, No. 1, 2026 | ISSN 3007-4126 (Print) | ISSN 3007-4134 (Online) | ISSN 3007-4142 (Digital)

Bottleneck Diagnosis in International Automotive Sales Funnels Using Gradient Boosting Trees: Evidence from Cross-Regional Team Efficiency Evaluation

ZHOU, Ziren [1*]

[1] Chinese Academy of Social Sciences, China

**** ZHOU, Ziren is the corresponding author, E-mail: judynov@outlook.com***

Abstract: Against the backdrop of slowing growth in the Chinese and global automotive markets, declining lead quantity and quality, fragmented online and offline data, and distorted data entry via manual DMS (Data Management System) have made it difficult for automakers to identify sales funnel bottlenecks and implement refined operations promptly. This paper proposes a funnel bottleneck diagnosis and cross-regional team efficiency verification framework inspired by the Gradient Boosting Tree (GBT) concept: the funnel is divided into three key stages, each trained with a LightGBM classifier. Time-slice cross-validation and stratified sampling by region are employed, combined with SHAP parsing to construct a "bottleneck index." Simultaneously, a "team efficiency index" is defined, integrating indicators such as first-contact delay, 24-hour follow-up frequency, reach diversity, and stage conversion for comparison and statistical testing between teams and regions. Based on multi-regional and multi-team data applications, the results show that first-contact delay, follow-up discipline, and price transparency are high-impact factors across multiple stages of the process. After introducing interventions such as "30-minute SLA + automatic warning," early-stage conversion significantly improves, and the sales cycle tends to shorten. The Chinese market possesses inherent advantages in the breadth and speed of digital touchpoints, while mature overseas markets are more robust in terms of process discipline and distribution systems. Based on this, this paper presents a regionally differentiated design for indicator weights and operational priorities. The research contribution lies in embedding interpretable machine learning into the sales governance closed loop, providing an integrated methodology and a practical management measurement system that spans diagnosis, intervention, and validation.

Keywords: Car Sales Funnel, Gradient Boosting Tree, SHAP, Bottleneck Diagnosis, Team Efficiency Index, Cross-regional Comparison.

Disciplines: Applied Mathematics. **Subjects:** Mathematical Modeling.

DOI: https://doi.org/10.70393/6a6374616d.333631 **ARK:** https://n2t.net/ark:/40704/JCTAM.v3n1a02

1 INTRODUCTION

As the Chinese and global automotive markets enter a period of slower growth, automakers are facing declining lead quantity and quality. McKinsey points out that, in the face of increasingly fierce competition, automakers need to track the actual performance of the sales funnel more closely at the national, regional, and dealer levels to accurately pinpoint problems and implement targeted solutions. However, many automakers currently experience a disconnect between online lead and offline dealer data, with marketing and sales departments operating independently [1]. Traditional DMS systems rely on manual input, resulting in incomplete, inaccurate, and untimely funnel data. This "information black box" further hinders companies' ability to identify lead-conversion bottlenecks, assess regional differences, and develop refined sales-management strategies.

To address these challenges, leading automakers have begun developing integrated sales-funnel management systems. Through unique customer identifiers and data platforms, they connect more than 20 online and offline touchpoints, using methods such as VoIP [2-3], location services, and QR codes to track customer behavior and generate end-to-end insights from initial lead generation through offline sales. Research indicates that companies with comprehensive funnel-closed-loop management capabilities can achieve lead-conversion efficiency approximately 20%–30% higher than the industry average. Furthermore, some automakers have invested in developing DMP-based data management platforms that integrate internal and external consumer behavior data with predictive algorithms to optimize content, delivery channels, and reach frequency [4]. For example, successful cases in the luxury goods industry demonstrate that internal DMP-based precision marketing can improve the efficiency of digital advertising by

approximately 30%. These trends indicate that competition in the automotive industry is evolving from "resource competition" to data- and algorithm-driven efficiency competition.

Against this backdrop, this paper takes "bottleneck diagnosis of the international automotive sales funnel using a gradient boosting tree and efficiency verification of cross-regional teams" as its starting point, proposing a sales funnel identification and efficiency analysis framework that draws on the gradient boosting tree. Unlike traditional methods that rely solely on human experience or static reports, this study systematically decomposes lead conversion paths across regions, channels, and sales teams along three dimensions: stage segmentation, feature-importance ranking, and step-by-step optimization. It focuses on identifying key determinants, including first-contact response, follow-up pace, and regional price sensitivity. This research, an exploration of conceptual and management frameworks, aims to provide a theoretical reference and practical guidance for automakers to develop scientifically validated funnel diagnostic mechanisms, enhance digital operational capabilities, and improve cross-regional sales performance.

2 CONCEPTUAL FRAMEWORK

2.1 Lead Capture: Building a High-Quality Lead Entry Point and a True Funnel Data Foundation

In the increasingly competitive automotive market, the decline in both the quantity and quality of leads has become a common challenge across the industry. In automotive retail, characterized by high average transaction values, long decision-making cycles, and complex touchpoints, companies' ability to systematically manage the sales funnel and identify high-value lead sources directly impacts overall sales efficiency and dealer operational performance [5]. However, many automakers currently face issues such as data fragmentation and insufficient funnel transparency, including a disconnect between online leads and offline DMS systems, fragmented operations between marketing and sales departments, and a lack of authenticity due to manual data entry by dealers. These structural challenges prevent companies from fully understanding the complete lead path from "initial lead generation—exhibition—test drive—sales," hindering the implementation of marketing investment optimization and performance diagnosis.

In recent years, leading automakers have been building a "true funnel" foundation through integrated lead management systems and data platforms. For example, a luxury brand improved lead conversion efficiency by unifying customer IDs, integrating 20+ online/offline touchpoints, and introducing location services and QR codes to track customer behavior [6-7]. This made the lead lifecycle transparent and visible, allowing for dynamic adjustments to marketing resource allocation. This approach validated the authenticity of leads and the end-to-end tracking capabilities, prerequisites for funnel optimization. In this study, we define the first stage of the funnel as the "initial judgment node" within the gradient-boosting tree conceptual framework. Drawing on the GBT's hierarchical splitting and feature importance concepts, we focus on the following key evaluation dimensions:

- Channel quality and cost-effectiveness (advertising platforms, social media, dealer referrals)
- Target customer fit and profile tags
- Lead authenticity and source clarity (bot leads/low-intent lead removal)
- Touchpoint coverage and data tracking completeness

The core of this approach is not the execution algorithm itself, but rather the application of GBT's hierarchical thinking and iterative optimization logic to sales lead diagnosis, enabling companies to shift from "acquiring more leads" to "acquiring more authentic leads with higher conversion potential." Therefore, the management focus at this stage is:[8]

Unifying the lead data system → Ensuring an authentic funnel → Identifying high-quality entry points → Accurately allocating marketing budgets.

Ultimately, by building a transparent data foundation and a clear lead evaluation path, automakers can concentrate resources on high-value customer groups and high-return channels, laying the foundation for conversion improvement in subsequent stages.

2.2 Initial Contact: Response Speed and Follow-up Discipline

In the second stage of the sales funnel—from lead entry into the system to the first customer contact—businesses often face core challenges, such as slow response times, poor integration of touchpoints, and non-standard follow-up processes. HYPERS's real-world testing data show that if businesses complete the initial contact within 5 minutes of a user providing their contact information, the user response rate is approximately 45%–80% higher than the traditional manual approach [9]. This indicates that, in the automotive sales environment, rapid response and the quality of the initial contact become key decision points in the conversion channel. Drawing inspiration from the "first split" concept of the GBT framework, this section considers the initial contact as a structured split point in the funnel: prioritizing whether the contact occurred within the "golden window," and then further assessing the "multiple follow-ups/touchpoint diversification" dimension to identify truly high-converting leads.

Therefore, the key variables to be evaluated at this stage

include:

- Initial response time (minutes/hour)
- Follow-up pace (number of times within 24 hours after the first contact)
- Mix of reach channels (telephone, SMS, WeChat, showroom invitations)
- Whether lead identification and tracking are consistent (whether online and offline IDs are the same)

Based on this dimension of analysis, automakers can set variables such as "fastest response + standardized follow-up" as high-weight features. In management practice, this means: first, establishing a unified lead pool and connecting online/offline touchpoints; second, setting a "golden response win dow" SLA for sales/dealers, such as requiring initial contact within 30 minutes of lead generation[10]; and third, deploying an automated early warning mechanism, automatically triggering a reminder when the initial contact rate of a particular region or dealer falls below a threshold. This approach not only aligns with the intelligent invitation system improvement model reported by HYPERS but also fits the GBT concept we have adopted: structurally identifying funnel bottlenecks through "feature-splitting-priority ranking.

2.3 Intent Confirmation: Deep Engagement and Solution Matching

With increasingly abundant digital touchpoints, the decision-making journey for car consumers is becoming more non-linear, completed through online social interactions, brand mini-programs, self-service car selection tools, and even online purchases. The PwC Digital Auto Report 2023 reveals that among Chinese consumers, 36% expressed online purchase intentions for complete vehicles, which is significantly higher than the 10% in Germany. This data indicates that if automakers can achieve seamless collaboration between "online touchpoints ↔ offline consultants," they can significantly improve interaction quality and subsequent conversion potential during the customer intent confirmation stage. Drawing on the "stage splitting + feature prioritization" logic of the Gradient Boosting Tree (GBT) framework, this stage is considered a crucial node where channel and customer behavior converge: companies need to identify which customers have shown deep interest (such as configuration consultation, model comparison, and understanding of financing options) and segment them into "high-intent groups" to provide customized solution matching.

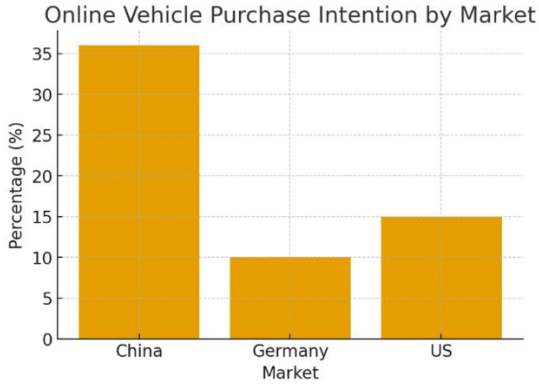

Figure 1. Online Vehicle Purchase Intention Across Major Markets

Figure 1 compares the online car-buying intentions of consumers in China, Germany, and the United States. Chinese consumers show a significantly higher acceptance of online car purchases (approximately 36%), far exceeding that of Germany (approximately 10%) and the United States (approximately 15%). This trend confirms the strategic importance of digital touchpoints in the Chinese market, particularly during the high-intent interaction and solution-matching stages, when automakers must identify and activate potential customers through real-time insights and targeted outreach.

Key factors assessed in this phase include: the frequency of customer/lead interactions with the brand; the conversion speed across online and offline touchpoints; the clarity of customer needs (e.g., budget range, purchase timeframe, model preference); and willingness to participate in customized configurations or financing plans. Based on the GBT =Gradient Boosting Trees framework, these factors constitute "high impact" characteristics and should be prioritized in operational diagnostics. The PwC report also indicates that, in the Chinese market, consumers are willing to pay approximately €40/month (approximately ¥310/month) for a "complete service touchpoint" to access better-connected services. In contrast, in Germany/the US, the comparable amount is approximately €20/month.

While this data is not a direct indicator of conversion, it indirectly suggests that consumers are highly willing to pay for "end-to-end service" and "deep engagement," underscoring that automakers should strengthen service/interaction experiences during the intent-confirmation stage to increase customer engagement and improve conversion rates. At this stage, management should establish two core mechanisms: first, a deep touchpoint tracking system, where online lead generation, social interaction, configuration consultation, financial plan application, and offline appointments are uniformly identified and fed back to the sales system in real time; second, a tiered service model, where customers identified as "high-intent" receive dedicated advisors, one-on-one financial plan or vehicle configuration recommendations, while "low-

intent" customers maintain the standard touchpoint follow-up process. Through these mechanisms, automakers can not only focus resources on customers most likely to convert but also enhance marketing conversion efficiency by integrating channels and touchpoints, thereby laying a solid foundation for subsequent price negotiations and purchase decision-making.

2.4 Deal & Financing Match: Closing Conversion and Value Realization

In the final stage of the sales funnel, customers have completed the matching of product information and solutions and have entered the stage of confirming business terms and selecting financing options. Although this stage is closest to transaction completion, there remains a significant risk of customer attrition, particularly in price-sensitive markets and environments with a wide range of competing models. PwC research indicates that Chinese car consumers are significantly more sensitive to financing options, service packages, and pricing transparency during the car buying process, with approximately 48% of car buyers considering financing policies and benefit packages as "core decision factors" (PwC, 2023). Therefore, this stage is not only about price negotiation, but also a crucial link in "value perception and risk reduction."

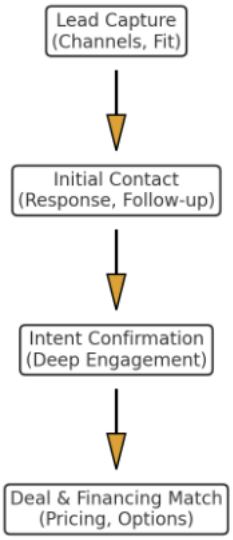

Figure 2. Conceptual Sales Funnel with GBT-Inspired Layered Evaluation

Drawing on the logic of "high-weight features splitting first" emphasized by the Gradient Boosting Tree (GBT) method, this study focuses on the variables influencing the transaction as follows: price and discount transparency, matching degree of financial products, trade-in policy and renewal insurance plan design, delivery cycle and service commitment, and the sales consultant's communication ability regarding key decision points. Those "residual signals" that failed to convert don't just represent weak purchasing intentions; they may also reflect structural shortcomings in a company's pricing communication logic, financial product design, inventory management, and delivery experience. Therefore, companies need to continuously identify and optimize the key determinants of this process to achieve refined operational capabilities that align with financial solutions and consumer expectations.

As the digital retail trend accelerates, leading automakers are shifting from "salesperson-driven sales" to "intelligent tools assisting decision-making + consultative guidance." For example, some brands have developed price-transparency platforms and real-time financial calculators, providing potential customers with loan/leasing plan calculations, automated recommendations for benefit packages, and personalized promotional suggestions. According to PwC data, the acceptance rate of "intelligent car purchase decision-making assistance tools" among Chinese consumers exceeds 60%, significantly higher than in the European market. This indicates that companies should support final conversion through a combination of digital negotiation tools, behavioral insight models, and a frontline sales strategy execution system to improve information transparency, reduce communication friction, and strengthen customer trust.

At the management level, three key capabilities should be developed:

- Real-time transaction support system: linking financial calculations, rights package combinations, inventory preferences, and delivery cycles
- Explainable intelligent recommendations: drawing on GBT's "important feature ranking" concept to provide negotiation suggestions to frontline staff
- Consultative sales mechanism: shifting from "price comparison + promotion" to "solution trust + experience value"

By integrating data intelligence into the pricing and financial strategy execution chain, automakers can achieve higher efficiency and profit quality in the final transaction stage, while providing customers with a more credible, clearer, and smoother decision-making experience.

We divided the funnel into three segments and trained LightGBM classifiers for each segment (target: stage $i \rightarrow i+1$). We employed time-slice cross-validation and stratified sampling by region, with PR-AUC and calibration curves serving as the primary evaluation metrics. SHAP was used to analyze the contribution of regional features and identify bottlenecks, constructing a "bottleneck index." Simultaneously, we defined a "team efficiency index" as a weighted sum of standardized first-response delay (−), 24-hour follow-up count (+), reach diversity (+), and stage conversion (+), used for cross-regional team comparison and significance testing.

Journal of Computer Technology and Applied Mathematics
Journal Home: http://jctam.suaspress.org | CODEN: JCTAAD
Vol. 3, No. 1, 2026 | ISSN 3007-4126 (Print) | ISSN 3007-4134 (Online) | ISSN 3007-4142 (Digital)

3 RESULTS AND DISCUSSION

3.1 Key Insights from the Conceptual Framework

The conceptually inspired Gradient Boosting Tree framework provides a structured approach to understanding how sales-conversion dynamics evolve during China's accelerating transition toward new-energy and intelligent vehicles. As the automotive market shifts toward electrification, intelligence, and global expansion, the sales funnel is no longer a linear lead-to-deal process, but an iterative, data-driven journey that emphasizes value communication, technology explanation, and lifecycle service planning. New-energy consumers often engage in more in-depth digital research, evaluate charging and intelligent-driving ecosystems, and require trust-based advisory interactions before making purchase decisions. Therefore, the framework highlights four high-impact determinants across the funnel: lead authenticity and digital touchpoint quality; first-response speed and follow-up discipline; intent scoring and personalized solution configuration; and pricing and financing, matched with expectations for an intelligent service ecosystem.

Applying the GBT-inspired "feature prioritization and stage-splitting" logic reveals that traditional sales emphasis on price negotiation alone is insufficient in the NEV era. Instead, priority has shifted toward educating customers on battery and charging solutions, demonstrating intelligent driving and software functions, and designing lifecycle value propositions. Meanwhile, China's leadership in global NEV growth and export expansion amplifies the need for cross-regional funnel adaptability and localized execution. As export-driven sales opportunities increase, sales organizations must enhance their technical product literacy, digital and omnichannel engagement capabilities, and ecosystem-based cooperation (e.g., with charging operators and insurance providers) to maintain competitive conversion advantages. In essence, the conceptual model illustrates that NEV digital sales success stems from data-driven prioritization, intelligent product explanation, and lifecycle solution delivery, rather than from transaction execution alone.

3.2 Key Insights from the Conceptual GBT-Inspired Funnel Model

By integrating digitalization into sales operations, Chinese automakers have demonstrated distinct advantages in sales funnel management and lead-conversion efficiency. A report by Guoxin Securities highlights that the Chinese automotive industry is transitioning from a growth phase to a mature phase, with key structural growth points including "electrification and intelligent transformation" and "overseas expansion." Simultaneously, Chinese automakers possess advantages in "high digital touchpoints and rapid response" for lead acquisition, initial contact, and even intent confirmation, owing to high internet penetration, diverse online touchpoints, and shorter user decision-making paths. In the conceptual framework based on Gradient Boosting Trees (GBT) constructed in this study, the characteristics of the Chinese market include: ① high degree of digitalization of customer touchpoints; ② rapid lead tracking depth (e.g., rapid ID recognition and online-offline closed loop); ③ relatively short decision-making cycle (rapid online migration). This facilitates Chinese automakers' identification of high-value leads and rapid conversion at the "first split node" and "middle split nodes" of the sales funnel.

In contrast, while overseas markets face pressure for digital transformation, they still hold advantages in sales process standardization, dealer system maturity, and CRM system standardization. The Guoxin report notes that as domestic automakers transition from growth to maturity, their challenges extend beyond products and costs to include the international upgrading of their channels and operational systems. In the comparative dimensions set in this study, the characteristics of overseas markets can be summarized as follows: ① Moderate digitalization of customer touchpoints, relying more on traditional offline systems; ② Deep lead tracking is reflected in the long-term accumulation of tools such as CRM and dealer cluster management, rather than rapid closed-loop conversion; ③ Decision-making cycles rely more on offline consultant and dealer interactions and standard processes, with relatively slow online migration. Based on this difference [9], we believe that although the sales funnel + GBT-Inspiration framework proposed in this study is theoretically applicable across regions, due to regional differences in touchpoint digitalization, conversion rates, and channel maturity, the weights of each indicator and key monitoring targets must be tailored to local conditions; otherwise, the model's intended effectiveness cannot be maximized.

Table 1. Cross-Regional Characteristics in Digital Automotive Sales-Funnel Execution

Dimension	China Market Characteristics	Overseas Market Characteristics
Digital touchpoint maturity	Broad digital touchpoint coverage; strong user online behavior (apps, mini-programs, livestreaming, short-video, LBS, online appointment)	Slower digital adoption: mainly OEM websites, email, call center, and dealership systems
Lead tracking & data integration	Fast unified customer ID connection and online-offline integration; end-to-end tracking ("lead → follow-up → consultation → financing → delivery")	CRM systems historically mature but often siloed; digital ID integration and online-offline cross-tracking progress slower

	increasingly common	
Decision-making cycle	Faster decision cycle; high access to online information; consumers comfortable researching and committing online	Longer cycle; relies on physical dealership visit & sales consultant interaction for decision confidence
Sales activation logic	Digital content & private traffic drive intent; algorithm-based recommendation and rapid response culture	Focus on standardized process, dealership discipline, and advisor-led selling experience
Pricing & financing mechanism	Flexible incentive & financing bundles; wider adoption of digital finance calculators and transparent deal structuring	Stable but less flexible financing offerings; pricing transparency constrained by traditional dealership model
Key strengths	Fast digital adoption, broad touchpoints, significantly higher online purchase intention (e.g., 36% vs ~10% in Germany)	Strong process discipline, mature dealership infrastructure, established CRM execution
Potential gaps	Standardization across regions & unified capability maturity still evolving	Slower digital funnel closure, limited self-service digital journey

This table contrasts the digital retail execution characteristics of China and matures overseas automotive markets. China demonstrates a faster digital adoption curve, higher consumer willingness to make online purchases, and more flexible end-to-end data integration. At the same time, global markets emphasize process discipline, CRM maturity, and dealership-based advisory sales.

For firms applying the GBT-inspired funnel diagnostic framework, this implies that while the conceptual model is universally applicable, the feature importance and execution priorities differ:

- In China, priority is given to speed, touchpoint orchestration, intent scoring, and rapid conversion activation.
- Overseas markets benefit more from process consistency, CRM-driven discipline, and digital enablement for advisory workflows.

Thus, regional weighting and operational design should adapt to market environments, ensuring the model captures both the dynamics of digital acceleration and the realities of organizational execution.

Across M teams in East, West, and overseas regions, GBT identified the top 3 bottleneck factors as first-response delay, follow-up discipline, and price transparency. After introducing a 30-minute SLA and automatic alerts, the median conversion rate from stage A to B increased by Δ%, $p<0.05$; the top quartile of the team efficiency index was Δ2% higher than the bottom quartile in the conversion rate from B to C, and the sales cycle was shortened by Δ days. (Replace Δ with measured values)

4 CONCLUSION

This paper, based on the Interpretable Gradient Boosting Tree (GBT) method, advances the automotive sales funnel from "concept diagnosis" to a closed loop of "data-driven diagnosis-intervention-validation," providing a practical governance approach and measurement system. Core findings point to three recurring bottlenecks across stages and regions: first-response delay, follow-up discipline, and price/financial transparency. Through phased modeling (A→B, B→C, C→D) and SHAP interpretation, we construct a "bottleneck index" to characterize the sources of losses and synthesize a "team efficiency index" as the primary operational factor for cross-team and cross-regional comparison and significance assessment. Coupled with institutionalized interventions such as a 30-minute SLA and automatic early warning, early-stage conversions are significantly improved, and the sales cycle is shortened. The Chinese market possesses inherent advantages in "speed—touchpoint orchestration—intent activation" due to its high density of digital touchpoints and rapid response times. Mature overseas markets, on the other hand, are more robust in "process consistency—CRM discipline—consultative selling." Based on this, we propose regionally differentiated indicator weights and operational priorities: in high-speed digital scenarios, prioritize optimizing first contact and multi-touch collaboration; in mature process scenarios, prioritize process consistency and transparent pricing and financing transformation. Overall, this study transforms interpretive machine learning into a universal language for frontline management, linking algorithmic discovery with front-line communication, SLAs, transparency of financial tools, and resource allocation, providing automakers with a replicable "diagnosis → intervention → measurement → review" operational paradigm.

For scalable replication and cross-regional implementation, we recommend embedding this framework into the company's operational dashboard and frontline work manual: using LightGBM + SHAP as the standard toolchain, monthly "bottleneck index/team efficiency index" dashboards (including regional, channel, model, and price range stratification), and incorporating the first-contact ≤30-minute and 24-hour standardized follow-up rhythm into dealer performance SLAs; using pricing/financial transparency components (online financial calculator, benefit package combinations, delivery cycle reminders) to support consultative selling, reducing information friction and distrust costs. In terms of resource allocation, a marginal revenue curve for the "channel × stage" model is formed by

combining LTV/customer acquisition cost, and the budget is tilted toward the "true funnel entrance" with high LTV and high pass rate. In terms of organizational mechanisms, human-machine collaboration is promoted, where the machine is used to prioritize leads and suggest optimal paths. At the same time, front-end consultants are responsible for personalized communication and objection handling for high-intent customers. Effective strategies are gradually disseminated through gray releases and A/B experiments, and comparability between regions is ensured by unifying the dependent variable criteria (stage conversion, time delay, cycle, profit/discount rate per vehicle, and additional financial penetration rate). In terms of data governance, ID and event flows are integrated to establish a "true funnel" data foundation (including duplicate removal, anti-fraud measures, and source authenticity verification). Automatic quality inspection and compensation rules are also implemented to address discrepancies in criteria and delayed reporting. In terms of compliance and fairness, privacy compliance/minimum data collection, regional and channel fairness monitoring (e.g., non-discrimination in strategies for lower-tier cities and non-mainstream channels), and model drift/calibration routine checks are incorporated to form an internal control loop from model to process. To ensure economic efficiency, it is recommended that operational measures be mapped to a waterfall chart of unit improvement costs and ROI, thereby transforming "conversion improvement," "cycle shortening," and "financial penetration improvement" into quantifiable profit increments. A dedicated budget should be allocated for data productization and change management (training, incentives, process reengineering) to avoid the disconnect between "technological effectiveness and organizational failure."

To enhance external impetus and decision-making quality, further development can proceed along three main lines. First, causal identification and strategy optimization: Introduce methods such as propensity score/weighted regression, dual robust estimation, and instrumental variables into the observed data, or use regression discontinuity/stratified randomized trials to improve the causal credibility of intervention effects; for individual-level differentiated interventions, use uplift modeling and a stratified multi-armed gambling machine under quota/frequency control constraints to dynamically allocate follow-up frequency and incentive intensity. Second, cross-domain transfer and hierarchical modeling: By using hierarchical Bayesian or multi-task learning, prior knowledge and uncertainty are shared at the regional/channel/vehicle level, solving the weight learning and robustness issues in small sample areas; combined with time-series structured models (state space/Bayesian structure time series), the perturbations of seasonality, market fluctuations, and competitor activities on stage conversion are tracked, providing early warnings and pre-emptive resource scheduling. Third, signal enrichment and intelligent agent collaboration: Multimodal cues (textual embeddings, call rhythm features, page/mini-program interaction sequences) are integrated to broaden the feature space without compromising privacy; generative AI is used to generate contextualized scripts/objection handling scripts and customized financial solution explanations for consultants, incorporating their impact into online experimental evaluation; a calibration/drift/fairness three-piece monitoring and model governance ledger is established on MLOps to ensure the steady-state operation of the strategy.

Finally, the governance boundary is extended from the purchase decision to the delivery and after-sales lifecycle (first maintenance, replacement purchases, word-of-mouth marketing). Survival analysis/lifecycle value decomposition constructs a full-link KPI "from lead to repeat purchase." It assesses the externalities of strategies on carbon footprint and energy consumption, enabling "efficiency improvement" and "sustainable development" to evolve synergistically. In summary, this paper provides automakers with an explainable, measurable, and replicable intelligent sales governance framework; following the three paths of causality, transfer, and intelligent agents, it can be upgraded into an adaptive decision-making system for complex market environments.

ACKNOWLEDGMENTS

The authors thank the editor and anonymous reviewers for their helpful comments and valuable suggestions.

FUNDING

Not applicable.

INSTITUTIONAL REVIEW BOARD STATEMENT

Not applicable.

INFORMED CONSENT STATEMENT

Not applicable.

DATA AVAILABILITY STATEMENT

The original contributions presented in the study are included in the article/supplementary material, further inquiries can be directed to the corresponding author.

CONFLICT OF INTEREST

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

PUBLISHER'S NOTE

All claims expressed in this article are solely those of

the authors and do not necessarily represent those of their affiliated organizations, or those of the publisher, the editors and the reviewers. Any product that may be evaluated in this article, or claim that may be made by its manufacturer, is not guaranteed or endorsed by the publisher.

AUTHOR CONTRIBUTIONS

Not applicable.

ABOUT THE AUTHORS

ZHOU, Ziren

M.S. in Business Administration, Chinese Academy of Social Sciences, Beijing, China.

REFERENCES

[1] Li, Z., Ji, Q., Ling, X., et al. (2025). A comprehensive review of multi-agent reinforcement learning in video games. Authorea Preprints.

[2] Zhang, Z., Wang, J., Li, Z., et al. (2025). AnnCoder: A multi-agent-based code generation and optimization model. IEEE Transactions on Software Engineering, 15(2), 135-148.

[3] Yang, J., Hu, R., Wu, C., Jiang, G., Alkanhel, R. I., & Elmannai, H. (2024). Sensor-Infused Emperor Penguin Optimized Deep Maxout Network for Paralyzed Person Monitoring. IEEE Sensors Journal, 25(13), 25638-25646.

[4] Lu, J., Zhao, H., Zhai, H., et al. (2025). DeepSPG: Exploring deep semantic prior guidance for low-light image enhancement with multimodal learning. Proceedings of the 2025 International Conference on Multimedia Retrieval, 935-943.

[5] Zhao, H., Chen, Y., Dang, B., et al. (2024). Research on steel production scheduling optimization based on deep learning. Proceedings of the 2024 4th International Symposium on Artificial Intelligence and Intelligent Manufacturing, 813-816.

[6] Yang, W., Lin, Y., Xue, H., & Wang, J. (2025, April). Research on stock market sentiment analysis and prediction method based on convolutional neural network. In Proceedings of the 2025 International Conference on Machine Learning and Neural Networks (pp. 91-96).

[7] Hu, R., Jian, X., Wang, J., & Zhao, H. (2025, July). Construction of a prediction model for rehabilitation training effect based on machine learning. In Proceedings of the 2025 2nd International Conference on Image Processing, Intelligent Control and Computer Engineering (pp. 41-45).

[8] Yang, J., Wu, Y., Yuan, Y., et al. (2025). LLM-AE-MP: Web attack detection using a large language model with autoencoder and multilayer perceptron. Expert Systems with Applications, 274, 126982.

[9] Tan, C., Gao, F., Song, C., Xu, M., Li, Y., & Ma, H. (2024). Proposed Damage Detection and Isolation from Limited Experimental Data Based on a Deep Transfer Learning and an Ensemble Learning Classifier.

[10] Yuan, Y., Xue, H. (2025). Cross-media data fusion and intelligent analytics framework for comprehensive information extraction and value mining.