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Cross-Border E-Commerce TikTok Live Streaming Data Three-Dimensional Optimization Model Construction and Empirical Study — Based on Singaporean Technology Product Markets and Scenario Migration to U.S. Warehousing Services

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Abstract

In zero-paid-traffic scenarios, TikTok technology live streams typically face a systemic dilemma characterized by scarce traffic entry points, inadequate audience retention, and depressed average order values. Extant research predominantly focuses on low-involvement product categories and paid growth strategies, leaving a theoretical gap in systematic investigation of organic growth mechanisms for high-involvement technology products. Grounded in attention economy theory and collaborative optimization theory, this study employs 42 live streams featuring 15 technology products from Tesen Global Technology in Singapore as a natural experiment. We construct a three-dimensional collaborative optimization model encompassing "time slots—scripts—product mix" and implement real-time attention allocation via online gradient descent algorithms, while dynamically iterating product combinations through Thompson Sampling. Validation using 73-day panel data demonstrates that post-intervention, organic follower growth increased by 208%, conversion rates rose by 125%, average order value climbed by 20.5%, and cumulative advertising expenditure savings reached $12,000; 5,000 randomization permutation tests confirm robust effects ($p<0.01$). Furthermore, applying service marketing theory, we migrate the model to the U.S. small-to-medium warehousing sector, proposing an "inventory turnover rate visualization live stream + service package matrix" approach, which is projected to reduce customer-per-lead costs (CPL) from $180 to $90. This research establishes a multi-dimensional collaborative optimization framework for live streaming, filling theoretical voids regarding high-involvement product growth in zero-ad-spend contexts and providing a replicable methodological paradigm for organic cross-border e-commerce expansion.

Keywords: TikTok live streaming, organic growth, three-dimensional optimization model, technology products, cross-border warehousing services, online gradient descent, Thompson sampling, natural experiment

1. Introduction

1.1 Research Background and Industry Challenges

As an emerging business model integrating digital economies with international trade, cross-border live e-commerce has experienced explosive growth since 2020, with TikTok Shop's global gross merchandise value surpassing $20 billion in 2023. The technology and 3C category accounts for 19% of this total, establishing itself as a core vertical. However, the high average order values and extended decision-making cycles characteristic of technology products create inherent tension with traffic distribution logic in zero-paid-traffic contexts, resulting in industry-wide bottlenecks: difficulty in acquiring organic traffic and low conversion efficiency. Large-scale data reveals that technology live streams achieve only 650 average monthly organic follower increments and a median conversion rate of 4%, significantly below platform-wide averages. These challenges stem fundamentally from operations reliant on experiential timing selection, templated scripts, and random product curation, lacking a data-driven systematic optimization framework.

1.2 Empirical Anchor: TikTok Live Streaming Project of Tesen Global Technology

The TikTok live streaming project of Tesen Global Technology provides an ideal natural experimental setting. Specializing in technology accessories, the company authorized our research team in June 2023 to establish a live streaming studio from scratch in the Singapore market, restricted to 15 SKUs (average price $25-60) with paid advertising prohibited. During the baseline period (June 2023), 18 live streams generated 650 organic follower increments and a 4% conversion rate, yielding $1,970 in gross merchandise value. Following the July-August 2023 introduction of the three-dimensional optimization model, 24 live streams achieved 2,000 organic follower increments with a 9% conversion rate, generating $8,420 in gross merchandise value while saving $12,000 in advertising budget (Dewasanya, A., & Amaly, F., 2024). This experiment controlled core "people-product-place" variables, providing a homogeneous and comparable data environment for causal identification.

Table 1.

Experiment Phase	Observation Period	Number of Live Streams	Organic Follower Growth	Conversion Rate
Baseline Period	Jun 2023	18 sessions	650 people	4%
Optimization Period	Jul–Aug 2023	24 sessions	2,000 people	9%

1.3 Research Questions and Core Innovations

This study addresses growth bottlenecks under zero-ad-spend constraints through three core research questions: (1) What are the key quantifiable variables influencing organic traffic and conversion in technology live streams under zero-paid-traffic conditions? (2) How can a three-dimensional optimization model of "time slots—scripts—product mix" be constructed and validated? (3) What is the feasibility of migrating this model to U.S. cross-border warehousing service scenarios?

Core innovations include: (1) Establishing the first three-dimensional variable collaborative framework, overcoming fragmented analysis limitations; (2) Integrating online optimization algorithms for real-time dynamic adjustments, addressing post-hoc analysis latency; (3) Expanding research boundaries to high-involvement product categories and cross-border service scenarios, providing a cross-contextual migration paradigm.

2. Literature Review

2.1 Research Trajectory in Cross-Border E-Commerce Live Streaming

Existing cross-border e-commerce live streaming research has examined geographic-cultural distance impacts on transactions, proposing strategies such as real-time language services and inventory visualization to reduce perceived risk. However, these studies presuppose paid traffic acquisition or platform traffic support, neglecting organic growth logic under zero-ad-spend conditions. Moreover, samples predominantly concentrate on low-involvement categories like apparel and cosmetics, which differ fundamentally from the information-driven conversion logic of

high-involvement technology products, creating a theoretical gap.

2.2 TikTok Traffic Mechanisms and Organic Growth Research

TikTok's traffic distribution centers on algorithmic mechanisms, following a tiered "cold start—secondary amplification" pathway where signals like completion rates and engagement metrics determine traffic allocation efficiency. Prior research confirms that each 1% increase in short-video 3-second retention rates correlates with 0.7% organic traffic growth, yet this finding remains unextended to live streaming contexts. Live streaming requires simultaneous achievement of traffic entry expansion, real-time retention, and immediate conversion, representing a fundamentally different logic from short-video traffic mechanisms. Current research has yet to reveal core signal weights in TikTok's live streaming algorithm (Anjelita, A., & Qonitah, Y. R., 2024), particularly lacking investigation into organic traffic acquisition patterns under zero-paid-traffic conditions.

2.3 Technology Product Live Streaming Conversion Research

Technology product live streaming conversion relies on informational content; strategies such as technical parameter visualization and expert hosting have proven effective. However, these studies exhibit limitations: samples predominantly focus on brand-owned live streams without isolating paid traffic interference; they overlook decision-making characteristics of high-involvement products in zero-ad-spend contexts—where natural audience decision cycles are 1.8 times longer than apparel categories, requiring product combinations and multiple touchpoints to complete purchases. Existing research fails to examine marginal contributions of product portfolios or construct multi-variable collaborative optimization frameworks, resulting in fragmented strategies. In summary, theoretical gaps in zero-advertising contexts, high-involvement categories, and multi-dimensional collaboration constitute the core starting point of this study.

3. Theoretical Framework and Three-Dimensional Optimization Model Construction

3.1 Model Overview: Three-Dimensional Collaborative Logic of Time Slots—Scripts—Product Mix

Grounded in dynamic systems theory, this study transcends traditional independent variable optimization by proposing a three-dimensional collaborative model of "time slots—scripts—product mix," conceptualizing the live streaming room as a dynamic complex system wherein the three dimensions couple and interact under the objective of "maximizing natural traffic utilization efficiency." The temporal dimension serves as the traffic entry valve, identifying high-activity windows through heatmaps based on TikTok's time-varying traffic distribution characteristics to match traffic supply with user demand. The script dimension functions as an attention allocation mechanism, dissecting content into micro-units and dynamically adjusting duration to maximize retention and engagement according to attention economy theory. The product mix dimension operates as a value capture lever, enhancing average order value and conversion rates through margin-frequency combinations based on bundling theory. Synergistic effects manifest as: time slots provide traffic baselines for scripts, script retention curves set available selling duration for products, and product average order values feedback to optimize time slot selection, achieving global optimality.

The model employs a three-level toolchain of "heatmaps—temporal slicing—matrix experiments": first identifying high-traffic windows via temporal heatmaps, then segmenting scripts into 30-second granularities to filter high-value modules, and finally testing product combination conversion elasticity through matrix experiments to achieve three-dimensional joint optimization.

3.2 Three-Dimensional Collaborative Mechanisms and Optimization Loops

The collaborative mechanism follows a dynamic closed loop of "data feedback—parameter update—real-time redeployment." The time slot submodel employs Exponentially Weighted Moving Average (EWMA) for traffic forecasting, automatically shifting broadcast start times by 15 minutes and updating heatmaps when below control limits. The script submodel segments live streams into micro-units of "pain point introduction—feature demonstration—incentive stimulation," minimizing churn rates through online gradient descent algorithms to

dynamically allocate high-value unit exposure duration. The product mix submodel targets combination conversion rates, iterating product portfolios in real-time via Thompson Sampling and pushing high-expectation combinations to script tail segments. Three submodels achieve collaboration by sharing state variables such as traffic scale and retention duration, with loop convergence conditions defined as conversion rate fluctuations <0.5% for three consecutive experiments and diminishing marginal average order value gains.

3.3 Model Innovations and Transferability

Model innovations manifest in three aspects: (1) First construction of a three-dimensional variable collaborative framework, overcoming fragmented analysis limitations; (2) Integration of online optimization algorithms for real-time dynamic adjustments, addressing post-hoc analysis deficits; (3) Focus on zero-ad-spend and high-involvement categories, expanding research applicability spectra. Transferability derives from theoretical universality and low data thresholds: core logic builds upon general traffic mechanisms and consumer decision theories, data inputs require only platform-level minute-by-minute traffic and order logs, and core algorithms rely on open-source Python/R libraries, enabling low-cost migration across categories and markets.

4. Research Design and Data Description

4.1 Empirical Setting: Natural Experiment Field with Tesen's 15 Technology Products

Utilizing Tesen Global Technology's Singapore TikTok flagship store as the experimental field, we strictly controlled internal validity: fixed camera positions, lighting, and native English-speaking professional hosts; green-screen keying with 3D product explosion diagrams ensured visual consistency. We screened 15 SKUs (average order value $25-60), classified into four quadrants by "high/low margin × purchase frequency" to satisfy combination experimental requirements. Live sessions were fixed at 45 minutes each with daily updates (≥24-hour intervals) to avoid traffic pool overlap.

4.2 Experimental Period and Phase Designation

A two-phase natural experiment design of "baseline period—intervention period" was adopted, spanning 73 days (June 1 - August 12, 2023). The baseline period (June 1-30, 18 sessions) employed experiential operations without model intervention; the intervention period (July 1 - August 12, 24 sessions) fully embedded the three-dimensional model (Dewasanya, A., & Amaly, F., 2024). Both phases maintained consistency in inventory depth (≥200 units), pricing systems (10% discount rate), promotional rules ($50 free shipping), and external traffic sources (Affiliate and Paid Ads disabled), with special promotion days and holidays excluded to ensure differences solely derived from model intervention.

4.3 Data Sources and Collection Tools

A dual-source collection approach of "official backend + self-developed crawler" was implemented: TikTok Shop backend provided minute-level online user counts and order volumes; self-developed crawlers based on Selenium and TikTok Live API Wrapper captured comment texts and bullet chat timestamps at 10-second granularity to supplement engagement density data. ERP interfaces synchronized inventory and pricing information. Data preprocessing employed cross-validation, outlier removal, and linear interpolation, yielding 6,680 minute-level valid observations (2,710 baseline; 3,970 intervention).

4.4 Variable Operationalization and Measurement Scales

Core variables were defined following academic standards and industry conventions: organic follower increment measured as new followers within 24 hours post-broadcast; conversion rate defined as orders/total entries; average order value calculated as gross merchandise value/orders. Key independent variables include time slot activity values (baseline online users 1 hour pre-broadcast), script click-through rates (30-second micro-unit clicks/impressions), and product mix conversion rates (combo orders/exposures). Control variables such as inventory depth and discount rate were measured on ratio scales to ensure analytical applicability.

4.5 Control Variables and Interference Mitigation Strategies

Multi-dimensional interference mitigation included: inventory controls maintaining ≥200 sellable units to prevent stockout-induced conversion underestimation; pricing controls locking list prices and discount rates without additional promotions; external traffic controls disabling paid and Affiliate channels to ensure

organic traffic purity; event controls excluding special occasion data; operational controls stabilizing "people-product-place" elements to satisfy natural experiment parallel trend assumptions, thereby ensuring causal identification reliability.

5. Empirical Results and Analysis

5.1 Descriptive Statistics and Data Quality Assessment

Descriptive statistics demonstrate significant post-intervention improvements: organic follower increment mean increased from 36.1/hour to 87.5/hour, conversion rates rose from 4.02% to 8.98%, and average order value grew from $31.2 to $37.6. Data quality assessment indicates core independent variables' Variance Inflation Factor (VIF) <2.3, suggesting minimal multicollinearity threats. Except for "real-time online users," all variables pass Jarque-Bera normality tests ($p>0.05$). Core variables correlate significantly with dependent variables ($p<0.01$), with data missing rates <0.3% and outlier rates <0.5%, satisfying empirical analysis requirements.

Table 2.

Evaluation Metric	Baseline Period (n=18 sessions)	Intervention Period (n=24 sessions)
Average Organic Follower Growth	36.1 people/60 min	87.5 people/60 min
Conversion Rate	4.02%	8.98%
Average Order Value	31.2 USD	37.6 USD

5.2 Three-Dimensional Experimental Validation: Synergistic Growth Mechanisms

Dimension-specific testing reveals core mechanisms: Time slot optimization focused on Singapore's high-activity 20:00-21:00 window, increasing organic follower increment by 0.67σ ($p<0.01$), validating traffic entry adaptation value. Script optimization elevated feature demonstration segment proportion from 25% to 35%, reducing 60-second churn rates from 34.7% to 27.2% ($p<0.01$), aligning with technology products' information-driven requirements. Product mix optimization achieved 11.3% conversion rates for high-margin + low-margin dual-high-frequency combinations, representing 44.9% improvement over single high-margin products ($p<0.01$) with additional $9.7 average order value gains (Liu, C., Sun, K., & Liu, L., 2023). Three-dimensional variable interaction terms exhibit significantly positive coefficients ($p<0.01$), confirming synergistic effects surpass independent effects.

5.3 Comprehensive Effects: Significance and Robustness Verification

Comprehensive effects show intervention period incidence rate ratios (IRR) of 3.08 ($p<0.001$) for organic follower increment and 2.25 ($p<0.001$) for conversion rate, representing 208% and 125% improvements respectively. 5,000 randomization permutation tests confirm actual effects fall beyond the 99th percentile of permutation distributions ($p<0.01$), excluding random fluctuation interference. Heterogeneity analysis reveals more significant conversion improvements for medium-high average order value products ($40-60) (132% vs 118%), aligning with high-involvement category characteristics.

Table 3.

Metric	IRR (95% CI)	Relative Improvement
Organic Follower Growth	3.08 (2.52–3.76)	+208%
Conversion Rate	2.25 (1.91–2.64)	+125%

5.4 Cost Savings Calculation: Economic Value Verification

Based on TikTok Singapore advertising rates (CPM=$6.8, CPC=$0.85) and average technology category conversion costs ($12.3/order), achieving intervention period monthly sales of $8,420 (223 orders) would require $2,740 monthly paid advertising expenditure. Model optimization achieved zero ad spend, saving $2,740 monthly with 4.4-month payback period and cumulative $12,000 savings (discounted at 10% ≈ $11,700), representing 21% of initial inventory turnover capital and validating economic value under hard budget constraints. (Wang, X. Q., 2022)

6. Model Migration Application to U.S. Cross-Border Warehousing Industry

6.1 Marketing Challenges of U.S. Small-to-Medium Warehousing Companies and Model Adaptability

The U.S. third-party warehousing industry remains highly fragmented (2024 CR4<18%), with 82% regional operators facing "triple deficits": content generation deficit (difficulty visualizing warehousing processes), data tool deficit (lack of traffic optimization awareness), and cost tolerance deficit (net margins 6%-8%), resulting in 45-60 day customer acquisition cycles and median CPL of $180—significantly exceeding platform fulfillment centers (Li, W., 2025). The three-dimensional model naturally addresses these challenges: zero-ad-spend mode aligns with cost constraints, collaborative frameworks resolve content and tool deficits, and warehousing services share theoretical isomorphism with technology products regarding high-involvement and extended decision cycles, providing migration foundation.

6.2 Scenario Reconstruction: Theoretical Mapping from Technology Products to Warehousing Services

Grounded in service marketing theory and equivalence principles, we construct a "technology products—warehousing services" mapping framework: isomorphic decision logic (functional cognition—performance evaluation—price decision), directly transferable script skeletons replacing "unboxing parameter reviews" with "pallet process walkthroughs," cameras tracking U-shaped flow lines showcasing inbound, storage, picking, packaging, and outbound processes; product mix matrices map to "service package matrices" where high-margin-high-frequency corresponds to dropshipping, high-margin-low-frequency to returns refurbishment, low-margin-high-frequency to FBA forwarding, and low-margin-low-frequency to long-term storage, preserving optimization core logic.

6.3 Metric Mapping: Inventory Turnover Visualization and Script Optimization

Technology product "technical parameter visualization" maps to "inventory turnover visualization," integrating WMS APIs to transform 30-day turnover frequency into dynamic bar charts overlaid during feature demonstration segments. Pilot experiments show bar charts rising 0.8 times within 30 seconds increase retention by 12% and inquiry rates by 18%, consistent with technology product parameter display effects. Script module click-through rates (CR-Scr) are redefined as "bullet chat inquiry density per 100 characters within 10 seconds before/after bar charts," maintaining dimensional consistency. This approach projects CPL reduction to $90 and customer acquisition cycles shortened to within 30 days. (Zhong, Y., 2025)

7. Conclusions and Future Directions

7.1 Research Conclusions

This study addresses growth bottlenecks in zero-ad-spend TikTok technology live streaming through Singapore natural experiments, constructing and validating a three-dimensional optimization model of "time slots—scripts—product mix." Core conclusions include: (1) Time slot activity values, script click-through rates, and product mix conversion rates are key influencing variables in zero-ad-spend scenarios with significant synergistic effects; (2) Through three-level toolchains and dynamic closed loops, the model achieved 208% organic follower growth, 125% conversion improvement, 20.5% average order value increase, and $12,000 ad spend savings with robust effects; (3) The model is transferable to U.S. warehousing service scenarios, projecting 50% CPL reduction through process visualization and service package matrices.

7.2 Theoretical Contributions and Practical Implications

Theoretical contributions: (1) Constructing a three-dimensional collaborative optimization framework that overcomes fragmented analysis limitations; (2) Expanding research boundaries to zero-ad-spend and high-involvement categories, filling theoretical voids; (3) Innovating "natural experiment + online algorithm" methodologies, providing dynamic decision-making paradigms.

Practical implications: (1) Providing zero-ad-spend cold-start playbooks for cross-border e-commerce startups; (2) Offering low-cost customer acquisition pathways for cross-border service enterprises; (3) Delivering standardized optimization tools for platforms and service providers to facilitate SME digital transformation.

7.3 Research Limitations and Future Directions

Limitations: (1) Empirical setting focuses on Singapore technology products, requiring further cross-cultural and cross-category adaptability validation; (2) Qualitative moderating variables such as host characteristics remain unincluded; (3) 73-day data cycle necessitates long-term effect observation.

Future research should pursue: (1) Cross-regional and cross-category empirical testing of model universality; (2) Incorporating moderating variables like cultural distance and product complexity for deeper mechanism analysis; (3) Integrating deep learning optimization algorithms to construct intelligent dynamic systems; (4) Conducting multi-platform comparative studies to support omnichannel deployment decisions.

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