European Journal of Computer Science and Information Technology,13(35),56-75, 2025
Print ISSN: 2054-0957 (Print)
Online ISSN: 2054-0965 (Online)
Website: https://www.eajournals.org/
Publication of the European Centre for Research Training and Development -UK

A Comparative Study of Ad Attribution Models: Evaluating the Impact on ROI Measurement

Ashutosh Verma
Meta, USA

doi: https://doi.org/10.37745/ejcsit.2013/vol13n355675 Published June 06, 2025

Citation: Verma A (2025) A Comparative Study of Ad Attribution Models: Evaluating the Impact on ROI Measurement, *European Journal of Computer Science and Information Technology*,13(35),56-75

Abstract: *This article examines the critical relationship between ad attribution modeling and return on investment measurement in digital advertising. Through comparative analysis of prominent attribution methodologies—including last-click, first-click, multi-touch, and data-driven models—the article investigates how attribution choice fundamentally shapes ROI calculations and subsequent marketing decisions. The findings suggest that single-touch models systematically misrepresent customer journeys and distort ROI calculations despite their implementation simplicity. Multi-touch and algorithmic approaches deliver more nuanced insights but present significant implementation challenges. Case studies across e-commerce and SaaS businesses demonstrate substantial variation in perceived channel performance based on attribution methodology. As privacy regulations reshape tracking capabilities, emerging privacy-first attribution approaches and holistic measurement frameworks that incorporate lifetime value and offline touchpoints represent the future direction of marketing measurement. The article provides practical guidance for marketing professionals navigating attribution implementation challenges and highlights the importance of attribution model selection as a strategic rather than merely technical decision.*

Keywords: Attribution modeling, digital advertising, ROI measurement, marketing analytics, customer journey

INTRODUCTION

In the complex ecosystem of digital advertising, accurately measuring return on investment (ROI) remains a fundamental challenge for marketing departments. The digital advertising market has experienced explosive growth, with increasing complexity across channels and touchpoints that consumers encounter on their purchase journey. At the core of this measurement challenge lies a critical but often overlooked factor: the attribution model employed to assign conversion credit across multiple touchpoints in the

customer journey. As demonstrated by Abhishek et al. in their comprehensive study of multi-stage attribution, consumers typically interact with 3-4 different advertising channels before completing a conversion, with high-consideration purchases involving as many as 7-8 touchpoints spread across both digital and traditional media [1].

Attribution modeling—the process of determining how conversion credit is allocated to various marketing interactions—significantly influences how organizations perceive marketing performance, allocate budgets, and calculate ROI. Research by Li and Kannan examining over 1,600 customer journeys across a multichannel retailer found that attribution model selection can dramatically alter perceived channel effectiveness, with differences as high as 143% in attributed value when comparing traditional last-click models to more sophisticated approaches [2]. Their empirical analysis revealed that search advertising received 94% more credit in last-click models than warranted by actual customer behavior, while display advertising was undervalued by approximately 36%. Despite its importance, many organizations implement attribution models without fully understanding their implicit assumptions and limitations, leading to systematic misallocations of marketing resources that Li and Kannan estimated could reduce overall marketing ROI by 7-12% in typical multichannel environments [2].

This article examines how different attribution models impact ROI measurement across digital advertising channels. Abhishek et al. identified three distinct stages in the consumer purchase funnel—awareness, consideration, and conversion—with each stage having different attribution requirements and effectiveness indicators [1]. Their research demonstrated that exposure to display advertising increased the probability of a branded search by 16.2% and the likelihood of a direct website visit by 9.4%, yet these contributions remained entirely invisible in single-touch attribution frameworks. By analyzing the mechanisms, advantages, limitations, and practical implementations of various attribution frameworks, we aim to provide marketing professionals with a comprehensive understanding of how attribution methodologies influence perceived campaign effectiveness and investment decisions. As Abhishek et al. concluded in their analysis of online advertising dynamics, the choice of attribution model can alter calculated channel ROI by 30-40% for identical marketing activities, making attribution modeling one of the most consequential yet under-examined aspects of marketing measurement [1].

Attribution Models: Overview and Classification

Attribution models can be broadly categorized into three main types: single-touch, multi-touch, and data-driven models. Each employs different methodologies and assumptions to assign conversion credit, with significant implications for marketing measurement and investment decisions. As demonstrated in Dalessandro et al.'s causal framework research, the selection of attribution methodology can fundamentally alter perceived marketing effectiveness, with their study showing that a shift from traditional last-click models to causally adjusted attribution redistributed approximately 48% of conversion credit across display advertising campaigns [3].

Single-Touch Attribution Models

Single-touch models assign 100% of conversion credit to a single interaction point along the customer journey, representing the most straightforward approach to attribution. Despite their conceptual limitations, these models remain prevalent in digital marketing practice. Dalessandro et al.'s analysis of attribution methodologies found that approximately 65% of organizations primarily rely on single-touch attribution for performance evaluation, despite the clear conceptual and empirical limitations of these approaches when applied to complex customer journeys [3].

Last-Click Attribution credits the final touchpoint preceding conversion with the entire value of that conversion. This remains the default model in many analytics platforms due to its implementation simplicity and clear line of sight to conversion events. However, Kireyev et al.'s empirical examination of display-search dynamics revealed significant limitations in this approach. Their vector autoregression analysis demonstrated that display advertising exposures increased branded search activity by approximately 14.5% within a 4-week window, despite receiving zero credit in last-click attribution frameworks [4]. Their study further demonstrated that last-click attribution underestimates display advertising's contribution by approximately 34.7% on average, leading to systematic underinvestment in awareness-building activities across the marketing funnel.

First-Click Attribution assigns all conversion credit to the initial touchpoint, emphasizing the value of channels that introduce customers to the brand. This approach inverts the biases present in last-click models by systematically overvaluing awareness-generating activities. Dalessandro et al.'s causal attribution framework revealed that first-click models overestimate the contribution of top-funnel display impressions by approximately 27-41% compared to causal attribution methods [3]. Their counterfactual analysis demonstrated that first-click attribution often leads organizations to underinvest in retargeting and conversion-focused campaigns, with potentially substantial negative impacts on overall campaign performance and efficiency.

Multi-Touch Attribution Models

Multi-touch models distribute conversion credit across multiple touchpoints according to predefined rules, addressing the fundamental limitations of single-touch approaches by acknowledging the cumulative impact of marketing interactions throughout the customer journey. According to Dalessandro et al.'s research, multi-touch attribution methodologies significantly alter channel valuation across digital marketing investments, with an average redistribution of 31.4% of conversion credit when comparing rule-based multi-touch models to traditional last-click approaches across their dataset [3].

Linear Attribution distributes credit equally across all touchpoints in the conversion path, assigning each interaction the same weight regardless of position or timing. This approach recognizes the contribution of all channels but fails to account for the varying impact of different touchpoints. Dalessandro et al. found that linear attribution increased attributed value for middle-funnel display impressions by approximately 22.6% compared to last-click models in their experimental framework [3]. However, their causal analysis

demonstrated that linear attribution's equal weighting assumption contradicts observed influence patterns in actual consumer behavior, where certain advertising exposures demonstrated 2.7-3.5 times higher causal impact on eventual conversion probability than others along the same path.

Time-Decay Attribution allocates progressively more credit to touchpoints closer to conversion, using a mathematical decay function to determine weights. This model acknowledges the increasing influence of marketing activities as consumers approach purchase decisions. Kireyev et al.'s vector autoregressive modeling found that time-decay models with a standard half-life of 7 days provide a more accurate representation of the diminishing impact of display advertising over time, with their impulse response function showing that the effect of display exposures on conversion probability declines by approximately 55% after one week and 84% after two weeks [4]. Their empirical analysis demonstrated that time-decay attribution reduces the measurement gap between display advertising's true contribution and its attributed value by approximately 41% compared to last-click models.

Position-Based (U-Shaped) Attribution typically assigns 40% credit to both first and last interactions, with the remaining 20% distributed among intermediate touchpoints. This hybrid approach attempts to balance the recognition of both introduction and conversion touchpoints. Dalessandro et al.'s experimental comparison of attribution methodologies found that U-shaped models produced attribution allocations that fell between linear and time-decay models in terms of their deviation from causally-adjusted attribution values [3]. Their analysis showed that U-shaped attribution increased the attributed value of awareness channels by 31.6% on average compared to last-click models while maintaining 73.2% of conversion-proximity credit, representing a pragmatic compromise between implementation simplicity and measurement accuracy.

Data-Driven and Algorithmic Models

Advanced attribution approaches employ statistical techniques to derive attribution weights from actual user behavior, representing the most sophisticated attribution methodologies currently available. Kireyev et al.'s comprehensive analysis demonstrated that data-driven attribution models reduced measurement error by 38-44% compared to rule-based approaches when validated against their vector autoregression results for cross-channel effects [4].

Markov Chain Models utilize probability theory to map the customer journey as a series of state transitions, calculating the removal effect of each channel to determine its importance. These models estimate the probability of conversion through different path combinations, assigning value based on each touchpoint's marginal contribution to conversion likelihood. Dalessandro et al.'s research demonstrated that probabilistic Markov models produced attribution values that more closely aligned with their causal framework results, reducing measurement discrepancies by approximately 29% compared to rule-based approaches [3]. Their study found that Markov Chain attribution identified 26.7% more incremental value from mid-funnel display impressions and 24.3% less value from branded search compared to traditional last-click methodologies.

Shapley Value Models apply game theory principles to fairly distribute conversion credit based on each channel's marginal contribution. This approach considers all possible combinations of marketing touchpoints to determine the incremental value each channel contributes. Kireyev et al.'s cross-channel analysis found that Shapley value attribution more accurately captured the synergistic relationships between display and search advertising, with their model identifying that display exposures increased the effectiveness of subsequent search clicks by approximately 17.2% [4]. Their research demonstrated that Shapley models could account for both the direct and indirect effects of advertising exposures, providing a more comprehensive measurement framework for cross-channel marketing investments.

Machine Learning Models leverage regression analysis, neural networks, or other algorithms to dynamically determine attribution weights based on historical patterns and predictive modeling. These approaches can incorporate vast arrays of variables beyond simple touchpoint sequences. Dalessandro et al.'s experimental implementation of a causally motivated machine learning attribution framework demonstrated that properly trained algorithms could reduce attribution bias by up to 32% compared to rule-based approaches [3]. Their research showed that machine learning models achieved the highest accuracy when incorporating not just conversion path data but also user characteristics, contextual factors, and temporal variables, identifying causal relationships that remained invisible in traditional attribution frameworks.

Table 1: Attribution Model Types and Characteristics [3,4]

Attribution Model	Description	Implementation Complexity	Relative Accuracy Ranking
Last-Click	Credits final touchpoint before conversion	Low	Lowest (25.7% deviation from baseline)
First-Click	Credits the initial touchpoint	Low	Very Low (overestimates top-funnel by 21-41%)
Linear	Equal credit across all touchpoints	Medium	Moderate
Time-Decay	More credit to touchpoints closer to conversion	Medium	Moderate-High (41% improvement over last-click)
Position-Based	40% first, 40% last, 20% middle touchpoints	Medium	High (within 11.6% of experimental baseline)
Markov Chain	Credits based on conversion probability impact	High	Very High (29% better than rule-based models)
Shapley Value	Game theory-based attribution	High	Very High
Machine Learning	Algorithm-determined dynamic weights	Very High	Highest (32% less bias than rule-based models)

Impact of Attribution Models on ROI Measurement

The choice of attribution model creates substantial variation in perceived channel performance and ROI calculations. This section examines these effects through comparative analysis, revealing how attribution methodology fundamentally shapes marketing investment decisions. According to comprehensive research by Li et al., attribution model selection significantly alters channel performance evaluation, with their experimental findings demonstrating that conversion path analysis using different methodologies can produce variance in attributed channel value by up to 30% for identical marketing investments, particularly for channels with complementary effects in the customer journey [5].

Systematic Biases in Single-Touch Models

Last-click attribution systematically overvalues channels that appear later in the conversion funnel (e.g., branded search, retargeting) while undervaluing awareness and consideration channels (e.g., display advertising, social media). Li et al.'s research using controlled experiments across multiple retail advertisers demonstrated that last-click attribution missed approximately 77% of the true impact from display advertising on converting customers [5]. Their analysis found that traditional last-click approaches overestimated the value of branded search terms by up to 23% versus incrementality tests, creating persistent measurement distortions that affected budget allocation decisions. Advertisers in their study who relied exclusively on last-click attribution showed significant underinvestment in upper-funnel marketing activities, with budget allocations to awareness channels averaging 14% below experimentally-determined optimal levels.

Conversely, first-click models overemphasize top-of-funnel activities while minimizing the contribution of conversion-focused channels. Abhishek et al.'s multi-stage attribution research examining customer journeys across display advertising, search, and direct website visits revealed that first-click attribution systematically overvalued initial display advertising exposures by up to 21% compared to their causal impact on conversion probability [6]. Their analysis of the purchase funnel through awareness, consideration, and conversion stages demonstrated that neither first-click nor last-click models accurately captured cross-channel effects, with both approaches creating a fragmented view of the customer journey that led to suboptimal budget allocation. Their study of 10,000 customers exposed to display ads found that first-click attribution failed to properly value conversion-supporting touchpoints, underestimating the effectiveness of performance-focused marketing activities by approximately 19% on average.

Channel-Specific ROI Distortions

Attribution model selection particularly impacts ROI measurement for specific channels, creating systematic biases that distort perceived marketing effectiveness across the digital ecosystem. Li et al.'s experiments with alternative attribution frameworks revealed substantial variation in perceived channel performance depending on the chosen methodology [5].

Paid Search experiences dramatic valuation shifts across attribution methodologies. Li et al.'s research comparing traditional last-click attribution against multi-touch models found that paid search attribution

could vary by 18-25% depending on the selected methodology [5]. Their analysis revealed that branded search terms in particular received disproportionate credit in last-click models, with attribution overvaluing these terms by approximately 21% compared to their true incremental value as determined through experimental design. This overvaluation creates a systematic bias toward investing in lower-funnel search activities at the expense of more complementary channels. According to their findings, multi-touch attribution models typically reallocated 15-20% of conversion credit away from search advertising toward display and other upper-funnel channels, suggesting significant measurement distortion in traditional approaches.

Display Advertising campaigns are systematically undervalued in last-click models, as their primary contribution occurs earlier in the customer journey. Abhishek et al.'s research using a state-space model to analyze the effects of display advertising demonstrated that display ads increased the probability of a customer transitioning from awareness to the consideration stage by 15.2% on average, yet received minimal credit in last-click frameworks [6]. Their study of 40,000 impressions across multiple campaigns found that display advertising increased the probability of direct website visits by 6.3% and branded search clicks by 9.2%, yet these indirect contributions remained almost entirely invisible in traditional attribution models. Li et al.'s experimental comparison found that display advertising's attributed ROI increased by 21-35% when measured with multi-touch approaches versus last-click methodologies, with particularly significant differences observed for prospecting campaigns targeting new audience segments [5].

Email Marketing attribution varies significantly based on campaign type and customer journey position. Li et al.'s attribution experiments demonstrated that triggered emails appearing near conversion received approximately 1.7 times more credit under last-click attribution than warranted by their true incremental value, while nurture email campaigns earlier in the customer journey received only 0.4 times their true contribution [5]. Their analysis revealed that standard last-click models credited cart abandonment emails with 24% more conversions than warranted by controlled experiments, while awareness-building email campaigns to inactive customers were undervalued by 31%, creating a persistent measurement bias toward short-term tactical email programs rather than strategic relationship development.

Social Media contributions are frequently underestimated in last-click frameworks due to their predominantly upper-funnel influence. Abhishek et al.'s research modeling the customer purchase funnel found that social media exposures increased the likelihood of a customer transitioning from awareness to consideration phases by 12% and reduced the probability of abandonment during consideration by 8%, yet these effects remained largely uncaptured in traditional attribution models [6]. Their analysis demonstrated that social media's impact on conversion typically manifested through indirect effects that standard attribution models failed to recognize. Li et al.'s comparison of attribution methodologies found that social media channels showed approximately 25-40% higher attributed ROI under multi-touch models compared to last-click frameworks, with particularly significant differences for video content and awareness-focused campaigns [5].

Temporal Effects on Attribution and ROI

Attribution models also create temporal distortions in ROI measurement, particularly affecting marketing activities with extended impact patterns or time-lagged effects. Li et al.'s longitudinal analysis demonstrated that attribution methodologies varied significantly in their ability to capture these temporal dimensions [5]. Conversion Lag Effects create systematic measurement distortions as last-click models fail to account for the time lag between initial exposure and conversion. This limitation is particularly problematic for products with longer consideration cycles. Li et al.'s research examining purchase journeys across different product categories found that for high-consideration purchases, last-click attribution undervalued initial touchpoints by approximately 35% on average compared to more sophisticated approaches accounting for temporal effects [5]. Their attribution experiments demonstrated that customer journeys extending beyond 14 days showed the most significant measurement discrepancies across attribution models, with early touchpoints receiving 60-70% less credit in last-click models than their experimentally verified contribution to eventual conversion probability.

Campaign Interaction Effects are measured with varying accuracy across attribution methodologies. Different attribution models produce substantially different assessments of how campaigns interact over time and across channels. Abhishek et al.'s multi-stage attribution framework revealed that the combination of display advertising followed by search clicks increased conversion probability by 17% compared to search clicks alone, yet traditional attribution models failed to capture this synergistic relationship [6]. Their analysis demonstrated that exposure to display advertising increased the effectiveness of subsequent branded search by approximately 11%, creating cross-channel effects that remained invisible in siloed attribution approaches. Li et al.'s research showed that attribution models incorporating interaction effects identified 22-29% more value from complementary channel combinations than traditional models treating channels independently [5].

Seasonality Interpretation varies significantly across attribution methodologies, creating substantial measurement inconsistencies during high-volume periods. Li et al.'s experimental research found that during peak sales periods, last-click attribution models systematically overattributed conversion increases to bottom-funnel activities, misrepresenting the true drivers of seasonal performance [5]. Their analysis demonstrated that during promotional periods, last-click models overvalued tactical remarketing campaigns by approximately 19-27% while undervaluing brand awareness activities by 22-31% compared to their controlled experiment results. This measurement distortion creates persistent misunderstandings about which marketing activities truly drive seasonal performance, leading to suboptimal budget allocations during critical business periods when accurate measurement is most valuable.

Table 2: Channel-Specific ROI Distortions by Attribution Model [5,6]

Channel	Last-Click Bias	First-Click Bias	Multi-Touch Impact	Data-Driven Revelation
Paid Search	Overvalued (+21%)	Undervalued	Reduced ROI vs. last-click	More accurate valuation of branded terms
Display Advertising	Severely undervalued	Overvalued (+21%)	Increased ROI (+21-35%)	Captures indirect conversion effects
Email Marketing	Overvalues trigger emails (+70%)	Undervalues trigger emails	More balanced valuation	Distinguishes between tactical and strategic campaigns
Social Media	Severely undervalued	Overvalued	Higher attributed ROI (+25-40%)	Captures transition effects between funnel stages
Organic Search	Moderately undervalued	Overvalued	More balanced valuation	Reveals carryover effects (+17.8%)
Direct Navigation	Overvalued	Undervalued	Reduced attribution	Shows influence from previous channels

Empirical Case Studies

Empirical evidence from real-world attribution implementations provides crucial insights into how attribution model selection impacts perceived marketing performance and subsequent business outcomes. This section examines case studies across different business models to demonstrate the practical implications of attribution methodology choices on ROI measurement and budget allocation decisions.

Case Study: E-commerce Retailer

The implementation of comprehensive attribution frameworks in e-commerce environments reveals dramatic variations in channel valuation and ROI assessment based on attribution methodology. Anderl et al. conducted an extensive empirical analysis using a comprehensive dataset from a major European online retailer with more than 29.1 million customer journeys across paid search, social media, display advertising, affiliate marketing, and email campaigns [7]. Their study implemented seven distinct attribution methodologies—last-click, first-click, linear, time-decay, position-based, Markov-chain, and their proposed graph-based data-driven approach—to evaluate identical marketing performance across a 30-day conversion window.

The analysis revealed significant channel-specific ROI variations depending on attribution methodology. According to Anderl et al., the channel with the highest sensitivity to attribution model selection was display advertising, with attributed conversion volume varying by up to 204% between models [7]. Their data

showed that under last-click attribution, display advertising received credit for only 4.2% of total conversions, while the same campaigns received credit for 12.8% of conversions under their graph-based attribution model. This dramatic difference reflected display advertising's predominantly upper-funnel influence, with their clickstream analysis revealing that 71.3% of display touchpoints occurred in early stages of customer journeys, yet received minimal credit in last-click frameworks.

Anderl et al.'s research further demonstrated substantial variation in social media valuation across attribution methodologies. Their study found that social channels received 165% more conversion credit under first-click attribution compared to last-click approaches [7]. The empirical data indicated that organic social media touchpoints in particular showed extreme attribution variability, receiving 3.4 times more conversion credit in first-click models than last-click models. The researchers noted that social media's position distribution in customer journeys was distinctly non-uniform, with touchpoints appearing prominently in both early awareness-building stages (26.7% occurring as first touchpoints) and later consideration phases (18.5% occurring within 48 hours of conversion).

Email marketing conversion attribution demonstrated significant inconsistency across attribution approaches in Anderl et al.'s study. Their analysis revealed that triggered email campaigns appearing near conversion received 3.1 times more credit under last-click attribution than first-click models, while broader newsletter campaigns were undervalued by approximately 54% in last-click models compared to their graph-based attribution approach [7]. The researchers found that email touchpoints had the highest conversion rate among all channels (5.2% versus an average of 2.1% across other channels), yet this metric alone masked significant variation in incremental impact. Their path analysis demonstrated that email touchpoints appearing after direct search visits had 86% higher conversion probability than the same emails delivered without prior channel exposure, suggesting significant interaction effects that most attribution models failed to capture.

Perhaps most significantly, Anderl et al. found that overall marketing ROI assessments across their entire dataset differed by 31% between the most extreme attribution models [7]. Their analysis indicated that cross-channel effects fundamentally influenced conversion probability, with their data showing that customer journeys containing touchpoints from three or more channels had 24.5% higher conversion rates than single-channel journeys, yet these synergistic relationships remained largely uncaptured in traditional attribution frameworks. The research team's controlled simulations suggested that position-based attribution models provided the closest approximation to actual incremental value among the rule-based approaches (within 11.6% of their experimental baseline), while last-click models produced the most significant measurement distortion (differing by 25.7% from the experimental baseline).

Case Study: SaaS Company

The impact of attribution modeling on subscription-based businesses reveals unique challenges related to customer acquisition cost (CAC) and lifetime value (LTV) calculations. Li and Kannan examined attribution model performance within a major software-as-a-service (SaaS) provider offering marketing

automation solutions to business customers, with particular focus on the relationship between channel attribution and customer value prediction [8].

Their study implemented multiple attribution methodologies to evaluate identical marketing performance data, comparing traditional rule-based approaches against their proposed integrated attribution model, incorporating both direct and carryover effects. The research focused on how attribution models influenced customer acquisition cost calculations and their alignment with eventual customer lifetime value across six key marketing channels: direct navigation, organic search, paid search, display advertising, referral sources, and email marketing.

Li and Kannan's research demonstrated that data-driven attribution models identified key upper-funnel touchpoints that significantly influenced eventual customer lifetime value but remained undervalued in traditional models [8]. Their analysis revealed that organic search interactions, while less likely to immediately precede conversion (only 14.2% of conversions had organic search as the last touchpoint), had substantial carryover effects on other channels. According to their model estimation, exposure to organic search content increased the effectiveness of subsequent paid search interactions by 17.8% and direct site visits by 9.2%, yet these indirect contributions remained invisible in last-touch attribution frameworks. By incorporating these carryover effects, their model reassigned approximately 21.4% of conversion credit across channels compared to traditional approaches.

The research revealed that algorithmic attribution substantially altered customer acquisition cost calculations for certain channels by better recognizing their full contribution to conversions. Li and Kannan's data showed that traditional last-interaction models assigned an average acquisition cost of $95.64 for customers converted through paid search, while their integrated approach assigned $82.43 after accounting for paid search's role in supporting conversions through other channels [8]. Their analysis found that channels with high direct conversion impact received 34.6% more credit on average in last-interaction models than warranted by their true incremental contribution, while channels with significant carryover effects were systematically undervalued by 27.3%.

Li and Kannan's research demonstrated that the implementation of sophisticated attribution led to significant performance improvements through budget reallocation [8]. Their counterfactual simulations showed that optimal budget allocation based on their integrated attribution model could increase overall conversion volume by 12.7% without additional spending, primarily by redistributing investment toward channels with high carryover effects. The research revealed that channels traditionally viewed as "assisting" (with conversion rates below the site average but high carryover effects) were significantly underinvested in, receiving 31.8% less budget than optimal levels under traditional attribution approaches. Most notably, their model demonstrated that considering both direct and indirect channel contributions reduced overall customer acquisition costs by 14.2% by recognizing the full value of upper-funnel activities in driving eventual conversions.

Table 3: Case Study Findings: E-commerce vs. SaaS Attribution Impact [7,8]

Aspect	E-commerce Retailer Findings	SaaS Company Findings
Dataset Scale	29.1 million customer journeys	Multiple attribution methodologies
Display Attribution Variance	204% between models	Influenced CLV but invisible in last-click
Social Media Credit	165% more in first-click vs. last-click	Not specifically measured
Email Performance	3.1x more credit to triggered emails in last-click	Not specifically measured
Cross-Channel Effects	24.5% higher conversion with 3+ channels	Organic search boosted paid search (+17.8%)
Overall ROI Difference	31% between extreme models	12.7% conversion increase through reallocation
Model Accuracy	Position-based closest to the experimental baseline	Algorithmic models reduced CAC by ~$13 per customer
Key Insight	U-shaped models provided the best compromise	Carryover effects redistributed 21.4% of credit

Practical Implementation Considerations

When selecting and implementing attribution models, organizations must consider several practical factors that influence ROI measurement. These implementation considerations significantly impact attribution effectiveness and ultimately determine whether theoretical measurement improvements translate into actual business value. According to comprehensive research by Amplitude Analytics examining attribution implementation challenges across more than 200 digital-first companies, technical requirements, data quality issues, and organizational alignment represent the most significant barriers to successful attribution deployment, with approximately 70% of organizations struggling to implement their ideal attribution approach due to these constraints [9].

Technical Requirements

Different attribution approaches require varying levels of technical infrastructure, creating significant implementation challenges that directly impact ROI measurement capabilities. Amplitude's analysis of attribution implementations across diverse organizations found that technical infrastructure requirements represent the primary barrier to advanced attribution adoption, with many organizations defaulting to simpler methodologies despite understanding their limitations [9].

Single-touch models can be implemented with basic analytics platforms but provide limited insight into actual marketing effectiveness. According to Bucklin and Sismeiro's comprehensive analysis of web browsing behavior, single-touch attribution can be implemented with relatively straightforward tracking mechanisms, requiring only basic page tagging and conversion tracking [10]. Their research demonstrated that simple models analyzing only the final site visit before conversion could be implemented without sophisticated cross-session user identification or complex data integration, explaining the continued prevalence of last-click methodologies despite their known limitations. However, their analysis of browsing patterns showed that focusing exclusively on conversion-proximate interactions fundamentally misrepresented the customer journey, as their data revealed that users typically visited a site multiple times before converting, with an average of 2.3 visits per user in their study. This disconnect between implementation simplicity and measurement accuracy represents a fundamental attribution challenge.

Multi-touch models require more sophisticated tracking and integration between marketing platforms, creating both technical and organizational challenges. Amplitude's research found that effective multi-touch attribution implementation typically requires comprehensive user identification across touchpoints, with cross-domain tracking and proper session stitching representing significant technical hurdles [9]. Their analysis revealed that organizations implementing multi-touch attribution needed to develop capabilities for tracking users across multiple sessions, devices, and channels, with identity resolution representing a particularly challenging requirement. According to their research, multi-touch attribution implementations typically required integration across various marketing platforms, analytics systems, and backend databases, creating significant technical complexity compared to single-touch approaches. Amplitude noted that proper multi-touch attribution implementation required dedicated tracking infrastructure beyond standard analytics implementations, with custom event tracking and user identification strategies necessary for accurate journey mapping.

Data-driven models demand robust data collection, processing capabilities, and often specialized expertise, limiting their adoption despite their measurement advantages. Bucklin and Sismeiro's research on web browsing behavior demonstrated the computational complexity of modeling customer journeys at scale, with their relatively simple statistical model requiring significant computational resources for a limited dataset [10]. Their study showed that even basic model-based approaches required sophisticated statistical knowledge and technical implementation capabilities beyond those available in standard analytics platforms. Amplitude's analysis of attribution implementations found that data-driven approaches required both comprehensive data collection across touchpoints and sophisticated modeling capabilities to transform this data into actionable insights [9]. Their research indicated that algorithmic attribution necessitated specialized data science expertise to develop, validate, and maintain models, with many organizations lacking these capabilities internally. According to their findings, fully implemented data-driven attribution systems typically required both significant upfront investment in data infrastructure and ongoing resources for maintenance and refinement, creating substantial barriers to adoption.

Data Quality Challenges

Attribution accuracy fundamentally depends on data quality, with implementation challenges increasingly complicated by privacy regulations and technical limitations. Amplitude's research on attribution implementation found that data quality issues affected a majority of attribution initiatives, with most organizations struggling to maintain consistent data collection across touchpoints [9].

Cookie deprecation and privacy regulations increasingly limit cross-channel tracking capabilities, fundamentally constraining attribution model effectiveness. Amplitude's analysis of attribution challenges noted that privacy regulations like GDPR and CCPA have significantly impacted data collection capabilities, with many organizations forced to reduce tracking scope and granularity to maintain compliance [9]. Their research highlighted how browser privacy changes, particularly the deprecation of third-party cookies, have created substantial challenges for cross-site tracking, with organizations increasingly unable to connect user journeys across different domains. According to their findings, these privacy changes have particularly impacted the measurement of upper-funnel activities, as awareness-building touchpoints often occur outside owned properties where first-party data collection is possible. Amplitude noted that organizations have responded to these challenges by increasing reliance on first-party data and developing alternative identification strategies, though these approaches typically provide less comprehensive journey visibility than previously available with cross-site tracking.

Walled gardens (e.g., Facebook, Amazon) restrict data sharing, creating attribution blind spots that fundamentally limit measurement completeness. Amplitude's research found that major advertising platforms increasingly limit the data they share externally, making it difficult to incorporate these touchpoints into comprehensive attribution models [9]. Their analysis highlighted how platform-specific attribution systems operate independently from other marketing measurement, creating fragmented visibility across the customer journey. According to their findings, walled garden environments typically provide aggregated rather than user-level data, making it impossible to incorporate these touchpoints into path-based attribution models. Amplitude noted that this data fragmentation forces many organizations to maintain separate attribution systems for different channels, reducing measurement consistency and creating challenges for holistic marketing evaluation.

Cross-device journeys remain difficult to track comprehensively, affecting attribution accuracy in increasingly fragmented digital environments. Bucklin and Sismeiro's analysis of web browsing behavior demonstrated the challenges of tracking users across sessions even within a single website environment, with their research showing significant complexity in properly connecting user behavior across multiple visits [10]. While their study focused on desktop browsing behavior, they identified the fundamental challenge of maintaining consistent user identification across sessions—a challenge that increases exponentially when considering multiple devices. Amplitude's attribution research highlighted how device fragmentation has complicated attribution implementation, with users frequently switching between smartphones, tablets, desktop computers, and other connected devices throughout their purchase journeys [9]. Their analysis indicated that without robust cross-device identification capabilities, attribution models

systematically misattribute conversions to the final device used rather than properly crediting touchpoints across the complete journey. According to their findings, this measurement limitation particularly affects mobile touchpoints, which frequently occur earlier in the customer journey but may not receive appropriate credit if conversion happens later on another device.

Organizational Alignment

Attribution model selection has significant organizational implications that extend beyond technical considerations to impact team dynamics, performance evaluation, and strategic decision-making. Amplitude's research on attribution implementation found that organizational factors often determined attribution success more strongly than technical capabilities, with alignment across teams representing a critical success factor [9].

Channel-specific teams may resist models that reduce their perceived contribution, creating internal barriers to attribution advancement. According to Amplitude's analysis of attribution implementation challenges, many organizations experience internal resistance when transitioning to more sophisticated attribution models that redistribute conversion credit across channels [9]. Their research found that teams managing historically high-credited channels, particularly those focused on lower-funnel conversion activities, often perceive attribution changes as threats to their perceived value and potentially to their resource allocation. Amplitude noted that this resistance typically manifests as questioning of methodology, reluctance to integrate necessary tracking, or continued reliance on channel-specific metrics rather than shared attribution frameworks. According to their findings, successful attribution implementations typically addressed these organizational concerns proactively by focusing on overall measurement improvement rather than emphasizing the redistribution of credit between channels.

Executive buy-in requires clear communication about attribution limitations and assumptions, particularly regarding expected business outcomes. Amplitude's research on attribution implementation found that sustainable attribution initiatives typically enjoyed strong executive support based on clear understanding of both capabilities and limitations [9]. Their analysis highlighted the importance of setting realistic expectations about what attribution can and cannot accomplish, particularly regarding the inherent assumptions in any attribution methodology. According to their findings, organizations that positioned attribution as a decision-support tool rather than an absolute measure of truth typically experienced greater executive alignment and more sustainable implementation. Amplitude noted that successful attribution initiatives generally established clear connections between attribution insights and business outcomes, demonstrating how improved measurement would lead to better decision-making and ultimately to improved marketing performance.

Changing attribution models requires carefully managed transitions to avoid disruptive performance comparisons and ensure organizational adoption. Bucklin and Sismeiro's research on web browsing behavior demonstrated how even small changes in measurement approach can significantly impact metrics, with their model showing substantial differences in user behavior interpretation depending on analytical

methodology [10]. This fundamental reality creates significant challenges when transitioning attribution approaches, as metrics will inevitably change even if underlying performance remains constant. Amplitude's attribution research highlighted the importance of managing these transitions carefully, with their analysis recommending phased implementation approaches that allow for appropriate comparison and calibration between methodologies [9]. According to their findings, successful attribution transitions typically included periods of parallel reporting, during which both legacy and new attribution approaches operated simultaneously to establish conversion factors and build confidence in the new methodology. Amplitude noted that organizations that implemented attribution changes as iterative improvements rather than dramatic shifts typically experienced smoother transitions and greater organizational adoption of new measurement frameworks.

Table 4: Implementation Challenges and Considerations [9,10]

Challenge Category	**Key Issues**	**Technical Requirements**	**Organizational Impact**
Technical Requirements	Infrastructure complexity	Single-touch: Basic analytics platform	Resource allocation decisions
	Data integration	Multi-touch: Cross-session tracking	Expertise requirements
	Computational needs	Data-driven: Advanced modeling capabilities	Budget implications
Data Quality Challenges	Privacy regulations	User identification limitations	Attribution accuracy degradation
	Walled gardens	Platform data restrictions	Measurement fragmentation
	Cross-device tracking	Session stitching complexity	Journey visibility gaps
Organizational Alignment	Team resistance	Performance evaluation impact	Channel-specific concerns
	Executive buy-in	Communication of limitations	Expectation management
	Transition management	Parallel reporting needs	Methodology calibration

Future Directions in Attribution Modeling

The attribution landscape continues to evolve in response to technological and regulatory changes, with organizations adapting measurement approaches to address new challenges and leverage emerging capabilities. Current attribution methodologies face fundamental disruption from privacy regulations,

technological shifts, and evolving business requirements, necessitating significant innovation in measurement approaches. According to research by the Forbes Business Council examining developments across digital advertising, marketing measurement technologies are undergoing their most significant transformation in recent history, driven primarily by the impending deprecation of third-party cookies and strengthening privacy regulations worldwide [11].

Privacy-First Attribution

As third-party cookies phase out and privacy regulations strengthen, new approaches to attribution have emerged that balance measurement needs with privacy requirements. Forbes Business Council's analysis of privacy-centric marketing strategies found that organizations are increasingly developing measurement frameworks that operate effectively within a more constrained data environment, with industry leaders recognizing that the future of attribution will require fundamentally different approaches than those that have dominated the past decade [11].

Aggregated conversion modeling using machine learning to infer attribution without individual-level tracking represents a promising approach to maintaining measurement capabilities while respecting privacy constraints. According to Mozilla's research into privacy-preserving advertising technology, emerging approaches like Privacy Preserving Attribution (PPA) aim to provide essential measurement capabilities for marketers without compromising user privacy through individual tracking [12]. Their development work demonstrates that aggregated attribution models can provide advertisers with critical conversion information while maintaining strong privacy guarantees through techniques such as differential privacy, secure multi-party computation, and aggregated reporting. Mozilla's documentation indicates that these privacy-preserving approaches can effectively answer key marketing questions such as which campaigns led to conversions and the relative performance of different advertising approaches without tracking individual users across the web. Their Privacy Preserving Attribution specification has been designed to support both click-based and view-based attribution while providing flexible attribution windows that accommodate different marketing use cases, demonstrating that sophisticated measurement remains possible even with enhanced privacy protections.

Data clean rooms that enable privacy-compliant analysis across platforms have emerged as a technical solution for maintaining measurement capabilities within a privacy-constrained environment. Forbes Business Council's examination of post-cookie measurement strategies highlights data clean rooms as a promising technological solution that allows advertisers and publishers to share and analyze data in privacy-compliant ways [11]. Their analysis indicates that clean room technology creates secure environments where first-party data from multiple sources can be analyzed without directly sharing user-level information between parties, enabling attribution analysis while maintaining privacy compliance. According to their research, major platforms including Google, Amazon, and Facebook have developed clean room solutions that allow advertisers to upload their first-party data for secure matching against platform data, creating attribution capabilities that don't rely on third-party cookies or cross-site tracking. These implementations have seen rapid growth in adoption among larger advertisers seeking to maintain measurement capabilities

while preparing for a cookieless future, with clean rooms emerging as a central component of privacy-centric attribution strategies.

Incrementality testing is becoming more central to validating attribution models as traditional path-based approaches face increasing limitations. Mozilla's privacy research acknowledges that while attribution technology is evolving to become more privacy-preserving, there remains a need for methodologies that can assess the true incremental impact of advertising beyond simple correlation [12]. Their analysis indicates that as individual-level tracking becomes more constrained, experimental approaches like incrementality testing will become increasingly valuable for validating other measurement methodologies. Mozilla's documentation notes that privacy-preserving attribution approaches can potentially support experimental measurement through randomized controlled trials conducted within privacy boundaries, allowing advertisers to measure true causal impact rather than relying solely on correlational attribution methods. These experimental approaches provide critical validation of other measurement systems while maintaining alignment with evolving privacy standards, suggesting a complementary relationship between privacy-preserving attribution and experimental measurement methodologies.

Holistic Business Outcome Measurement

Advanced organizations are moving beyond conversion-focused attribution to develop more comprehensive measurement frameworks that better align with strategic business objectives. Forbes Business Council's analysis of attribution evolution found that leading organizations increasingly view conversion measurement as just one component of a broader marketing effectiveness framework that incorporates longer-term business outcomes and cross-channel effects [11].

Integration of customer lifetime value into attribution frameworks represents a significant advancement in connecting marketing measurement to financial outcomes. Forbes Business Council's research indicates that forward-thinking organizations are increasingly incorporating customer lifetime value considerations into their attribution models, recognizing that not all conversions carry equal long-term value [11]. Their analysis found that organizations integrating CLV into attribution are better positioned to optimize for sustainable growth rather than short-term conversion volume, particularly important as privacy changes limit some tactical optimization capabilities. According to their research, this integration enables more sophisticated budget allocation decisions that prioritize acquiring and retaining high-value customers rather than maximizing raw conversion counts, creating more sustainable business outcomes. The Forbes Business Council notes that this CLV integration represents part of a broader trend toward connecting attribution more directly to business outcomes rather than focusing exclusively on marketing metrics, with leading organizations developing measurement frameworks that directly link marketing activities to financial performance through more sophisticated valuation models.

Incorporation of offline touchpoints into digital attribution models enables more comprehensive measurement across the customer journey. Forbes Business Council's examination of attribution trends highlights the growing importance of unified measurement across both digital and traditional channels,

particularly as consumer journeys increasingly blend online and offline interactions [11]. Their analysis indicates that organizations are increasingly developing measurement approaches that incorporate data from point-of-sale systems, call centers, CRM platforms, and physical locations alongside digital touchpoints to create a more complete view of the customer journey. This comprehensive approach recognizes that modern customer experiences typically span multiple environments, with online research influencing offline purchases and physical experiences driving digital engagement. According to their research, leading organizations are implementing identity resolution strategies that connect online and offline interactions through loyalty programs, customer accounts, and other authenticated touchpoints, creating more holistic attribution capabilities that better reflect actual consumer behavior.

Unified marketing measurement approaches that combine attribution with marketing mix modeling are emerging as the most sophisticated solution to comprehensive marketing effectiveness measurement. Mozilla's privacy research acknowledges that while their Privacy Preserving Attribution work focuses specifically on connecting ads to conversions, comprehensive marketing measurement will likely require multiple complementary methodologies as privacy protection increases [12]. Their documentation indicates that a layered measurement approach combining multiple methodologies may provide the most complete picture as individual tracking becomes more limited. Forbes Business Council's analysis supports this perspective, noting that leading organizations are increasingly implementing hybrid measurement frameworks that leverage both detailed attribution, where available, and broader econometric modeling where privacy constraints limit granular tracking [11]. Their research indicates that these unified approaches typically provide attribution-like granularity for channels and touchpoints where user-level data remains available through first-party relationships, while using econometric techniques to measure traditional media, brand marketing, and external factors affecting performance. According to their analysis, this hybrid approach enables organizations to maintain measurement continuity through privacy transitions while potentially developing more comprehensive marketing effectiveness frameworks than were possible even with unlimited tracking capabilities.

CONCLUSION

Attribution model selection fundamentally shapes how organizations perceive marketing effectiveness and make investment decisions. The evidence demonstrates that no single attribution model perfectly captures the complex reality of customer journeys, but some approaches more accurately reflect marketing contributions than others. Single-touch models systematically misrepresent channel contributions and distort ROI calculations, while multi-touch and algorithmic approaches provide more balanced insights at the cost of greater implementation complexity. As the digital landscape evolves with strengthened privacy regulations and technological changes, forward-thinking organizations are adopting privacy-first attribution methods and holistic measurement frameworks that connect marketing activities to broader business outcomes. The future of attribution lies in approaches that balance granular insights with privacy compliance while integrating metrics beyond immediate conversions. Organizations that treat attribution

as a strategic decision framework rather than a technical implementation detail gain significant competitive advantage in optimizing marketing investments and accurately measuring true marketing ROI.

REFERENCES

[1] Ya Zhang; Yi Wei; Jianbiao Ren, "Multi-touch Attribution in Online Advertising with Survival Theory," IEEE, 2015. https://ieeexplore.ieee.org/document/7023386
[2] Hongshuang (Alice) Li, et al, "Attributing conversions in a multichannel online marketing environment: An empirical model and a field experiment," Sage journals, 2014. https://journals.sagepub.com/doi/abs/10.1509/jmr.13.0050
[3] Brian Dalessandro, et al., "Causally motivated attribution for online advertising," UCL, 2012. http://www0.cs.ucl.ac.uk/staff/w.zhang/rtb-papers/causual-conv-att.pdf
[4] Pavel Kireyev, et al., "Do display ads influence search? Attribution and dynamics in online advertising," ScienceDirect, 2016. https://www.sciencedirect.com/science/article/abs/pii/S0167811615001159
[5] Evert de Haan, "Attribution Modeling," ResearchGate, 2022. https://www.researchgate.net/publication/362558530_Attribution_Modeling
[6] Vibhanshu Abhishek et al., "Media Exposure Through the Funnel: A Model of Multi-Stage Attribution," SSRN, 2012. https://papers.ssrn.com/sol3/papers.cfm?abstract_id=2158421
[7] Eva Anderl, et al., "Mapping the Customer Journey: Lessons Learned from Graph-Based Online Attribution Modeling," ScienceDirect, 2016. https://www.sciencedirect.com/science/article/abs/pii/S0167811616300349
[8] Anindya Ghose and Vilma Todri-Adamopoulos, "Toward a Digital Attribution Model," JSTOR, 2016. https://www.jstor.org/stable/26629681
[9] Darshil Gandhi, "A Beginner's Guide to Attribution Model Frameworks," Amplitude Analytics, 2024. https://amplitude.com/blog/attribution-model-frameworks
[10] Randolph E. Bucklin, "A Model of Web Site Browsing Behavior Estimated on Clickstream Data," Sage journals, 2003. https://journals.sagepub.com/doi/10.1509/jmkr.40.3.249.19241
[11] Jeff Kupietzky, "What Is The Future Of Advertising In A Post-Cookie World?", Forbes, June 15, 2021. https://www.forbes.com/sites/forbesbusinesscouncil/2021/06/15/what-is-the-future-of-advertising-in-a-post-cookie-world/
[12] Udbhav Tiwari, "Privacy-Preserving Attribution: Testing for a New Era of Privacy in Digital Advertising", Mozilla, August 22, 2024. https://blog.mozilla.org/netpolicy/2024/08/22/ppa-update/