

Short Video Advertisement Optimization

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1 Problem Motivation

Short video platforms like TikTok and Instagram have become essential channels for advertising, given their large and highly engaged user bases. Leveraging these platforms, along with advanced shipping logistics, merchants have found that livestreaming to sell products or placing ads with top influencers can significantly boost their order volumes. According to *The Information*, since July of this year, TikTok Shop's monthly sales have exceeded \$1 billion, with the total product sales in the U.S. expected to reach \$17.5 billion by the end of the year. Short video advertising has a huge and widespread market. However, for new merchants looking to capitalize on this wave of short video-driven sales, efficiently allocating resources across multiple platforms, targeting the right audiences at the right times, while also avoiding ad fatigue, is a significant challenge. This project seeks to develop an optimization model to identify the optimal strategy for ad placements that maximizes engagement and conversions while considering various platform constraints.

2 Discussion of Mathematical Model

The core of the problem is formulated as a *linear optimization* model or not, depending on the relationship between decision variables and objective function. The goal is to maximize engagement and conversion across multiple platforms by adjusting decision variables like budget allocation, ad timing, frequency, and audience targeting. These decision variables and constraints are just examples. We can delete, add, or adjust them later.

2.1 Decision Variables

We could include several decision variables or more to allow for more complex and realistic optimization:

- **Budget Allocation:** Proportion of the total budget allocated to different platforms and audience segments $x_{i,j}$, where i represents the platform, and j represents the audience segment.
- **Ad Timing:** Time slots for ads to appear, such as morning, afternoon, or evening.
- **Ad Frequency:** The number of ad impressions per user in a given time period $f_{i,j}$, where i is the platform and j is the audience segment.
- **Platform Distribution:** Proportion of total ad impressions on each platform p_i , accounting for daily active users (DAU) on each platform.

2.2 Objective Function

We could maximize the following weighted sum of engagement metrics (likes, comments, follows, purchases):

$$\text{maximize } \sum_{i=1}^M \sum_{j=1}^N (w_1 \cdot \text{Likes}_{i,j} + w_2 \cdot \text{Comments}_{i,j} + w_3 \cdot \text{Follows}_{i,j} + w_4 \cdot \text{Purchases}_{i,j})$$

Where w_1, w_2, w_3, w_4 are the weights assigned to each metric and the values of $\text{Likes}_{i,j}$, $\text{Comments}_{i,j}$, $\text{Follows}_{i,j}$, $\text{Purchases}_{i,j}$ are functions of the decision variables like $x_{i,j}$, $f_{i,j}$, p_i . For example:

$$\text{Likes}_{i,j} = f_1(x_{i,j}, f_{i,j}, p_i, \dots)$$

$$\text{Comments}_{i,j} = f_2(x_{i,j}, f_{i,j}, p_i, \dots)$$

If the function f_1 that relates the decision variables to the engagement metrics is linear, the problem remains a linear optimization problem.

If f_1 is nonlinear, the problem becomes a nonlinear optimization problem.

2.3 Constraints

- **Budget Constraint:**

$$\sum_{i=1}^M \sum_{j=1}^N x_{i,j} \leq B$$

The total budget B must not be exceeded.

- **Frequency Constraint:**

$$f_{i,j} \leq f_{\max} \quad \forall i, j$$

Ads can only be shown a maximum number of times per user to avoid ad fatigue.

- **Time Constraint:**

$$t_{\text{start}} \leq t_i \leq t_{\text{end}} \quad \forall i$$

Ads can only be shown within specific time windows.

- **Audience Coverage:**

$$c_{i,j} \geq c_{\min} \quad \forall i, j$$

Each audience segment must reach a minimum number of users.

- **Platform Capacity:**

$$p_i \cdot \text{DAU}_i \leq \text{Impression Limit}_i$$

This means that the proportion of ads allocated to platform i (denoted by p_i) multiplied by the number of daily active users (DAU_i) on that platform must not exceed the platform's ad serving capacity ($\text{Impression Limit}_i$).

3 Proposed Analysis

Several analyses might be conducted to understand the effectiveness of the proposed optimization model:

- **Sensitivity Analysis:** Vary the weights w_1, w_2, w_3, w_4 to observe how changes in advertiser priorities (e.g., favoring purchases over likes) affect the optimal strategy. This will help identify trade-offs between different objectives.
- **Scenario Analysis:** Introduce different budget levels or audience engagement patterns to test how the model responds to external factors, such as seasonal trends or new competitor ads.

4 Data Gathering Plan

In fact, I don't know where to find the data. I'm just suggesting some platforms where we might find the data we need.

- **Ad Platform Data:** TikTok Ads Manager, Instagram Insights, and Meta Business Suite.
- **User Behavior Data:** Hootsuite, Sprout Social, or Socialbakers.
- **Market Research Data:** Statista and eMarketer.