

MEDIA AND ECONOMICS: ADVERTISING OPTIMIZATION IN THE DIGITAL AGE

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Keywords: media, economics, digital advertising, optimization, budget allocation

Abstract: Digitalizacija je značajno promijenila ekonomiju medija, planiranje kampanja i mjerenje efikasnosti oglašavanja. Ovaj rad ispituje optimalnu raspodjelu resursa za oglašavanje između tradicionalnih i digitalnih medija. Formulisan je model cjelobrojnog linearnog programiranja s ciljem minimiziranja ukupnih troškova kampanje, uz ostvarivanje ciljanog dosega od najmanje 1,5 miliona ljudi i poštovanje gornjih ograničenja učestalosti kampanje specifičnih za pojedine medijske kanale. Model je implementiran pomoću programa Microsoft Excel Solver i analiziran kroz tri scenarija: tradicionalne medije, digitalne medije i strateški odabranu kombinaciju tradicionalnih i digitalnih medija. Rezultati pokazuju da, uz pretpostavljene troškove i parametre dosega, scenario tradicionalnih medija ostvaruje ciljani doseg uz najniže troškove (13.875 €). Digitalni scenario bez ograničenja minimalne zastupljenosti pojedinačnih kanala zahtijeva 15.000 €, dok raznovrsna kombinacija digitalnih medija, u kojoj se svaki kanal koristi najmanje četiri puta, košta 17.400 €. Strateški odabrana kombinacija televizije, radija, YouTubea i LinkedIna, takođe uz ograničenja minimalnog korišćenja, ostvaruje doseg od 1,505 miliona ljudi uz ukupan trošak od 15.800 €. Rezultati pokazuju da matematička optimizacija može unaprijediti transparentnost i kontrolu troškova prilikom raspodjele budžeta za oglašavanje. Međutim, prilikom praktičnog planiranja medijske kampanje potrebno je uzeti u obzir i preklapanje publike, kvalitet dosega, ciljeve brenda, troškove proizvodnje sadržaja i opadajuće marginalne prinose.

MEDIJI I EKONOMIJA: OPTIMIZACIJA OGLAŠAVANJA U DIGITALNOM DOBU

Ključne riječi: mediji, ekonomija, digitalno oglašavanje, optimizacija, raspodjela budžeta

Sažetak: Digitalizacija je značajno promijenila ekonomiju medija, planiranje kampanja i mjerenje efikasnosti oglašavanja. Ovaj rad ispituje optimalnu raspodjelu resursa za oglašavanje između tradicionalnih i digitalnih medija. Formulisan je model cjelobrojnog linearnog programiranja s ciljem minimiziranja ukupnih troškova kampanje, uz ostvarivanje ciljanog dosega od najmanje 1,5 miliona ljudi i poštovanje gornjih ograničenja učestalosti kampanje specifičnih za pojedine kanale. Model je implementiran u programu Microsoft Excel Solver i analiziran kroz tri scenarija: tradicionalne medije, digitalne medije i odabranu kombinaciju medija. Rezultati pokazuju da, uz pretpostavljene troškove i parametre dosega, scenario tradicionalnih medija ostvaruje ciljani doseg uz najniže troškove (13.875 €). Neograničeni digitalni scenario zahtijeva 15.000 €, dok raznovrsna kombinacija digitalnih medija, u kojoj se svaki

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kanal koristi najmanje četiri puta, košta 17.400 €. Strateški odabrana kombinacija televizije, radija, YouTubea i LinkedIna, takođe uz ograničenja minimalnog korišćenja, ostvaruje doseg od 1,505 miliona ljudi uz trošak od 15.800 €. Rezultati pokazuju da matematička optimizacija unapređuje transparentnost i kontrolu troškova, ali da praktične odluke moraju uzeti u obzir i preklapanje publike, kvalitet dosega, ciljeve brenda, troškove sadržaja i opadajuće prinose.

1. Introduction

In the contemporary business environment, media play an important economic and communication role by connecting companies with consumers, increasing market visibility, and influencing sales performance. At the same time, the growing number of available media channels makes it increasingly difficult for companies to determine where to advertise, how frequently to communicate with their target audiences, and how to allocate advertising budgets efficiently.

Companies therefore no longer choose only among traditional media such as television, radio, newspapers, and direct mail. Their media planning decisions increasingly include social media platforms, video-sharing platforms, professional networking platforms, and collaborations with influencers and other content creators. This expansion of available advertising channels has created new opportunities for audience targeting, but has also increased the complexity of media planning and budget allocation.

Digitalization has enabled more precise audience targeting, real-time monitoring of user responses, and rapid reallocation of advertising budgets. However, it has not eliminated the importance of traditional media. Traditional channels can still provide broad audience reach, credibility, and a strong impact on brand awareness. Consequently, the economic problem is not simply a choice between traditional and digital media, but rather the identification of an appropriate media mix that achieves the desired communication objective at the lowest possible cost while satisfying predefined campaign constraints.

The subject of this paper is the optimization of advertising budget allocation across traditional and contemporary digital media channels. The aim of the paper is to develop and apply an integer linear programming model using Microsoft Excel Solver in order to determine the cost-optimal combination of media channels while achieving a minimum target reach of 1.5 million people and respecting the maximum permitted number of campaigns for each channel. In addition to cost minimization, the analysis examines how diversification requirements affect the structure and total cost of the optimal media mix.

In accordance with the aim of the paper, the following research questions are formulated:

1. Which combination of media channels enables the target reach to be achieved at the lowest possible cost?
2. How do the costs of traditional, digital, and combined media mixes differ?
3. How do constraints related to maximum campaign frequency and minimum channel representation affect the optimal solution?
4. Under which assumptions is a combined traditional and digital media mix economically and strategically justified?

The analysis is based on three scenarios. The first considers traditional media, the second examines digital media, and the third evaluates a strategically selected combination of

traditional and digital channels. By comparing these scenarios, the paper seeks to demonstrate how mathematical optimization can support advertising budget allocation and provide a transparent basis for media planning decisions.

2. Traditional and Contemporary Advertising Channels

2.1. Traditional Media

Traditional media include television, radio, print media, direct mail, and outdoor advertising. Their common characteristic is the ability to deliver standardized messages to large audiences, although they generally provide fewer opportunities for precise individual targeting and immediate measurement of audience response than digital media. Their primary value is particularly evident in campaigns aimed at rapidly increasing brand awareness, building consumer trust, and reaching broad and demographically diverse audiences.

Television combines images, sound, motion, and storytelling, enabling advertisers to deliver emotionally engaging and persuasive messages. However, its effectiveness depends on several factors, including the creative concept, broadcasting time, program context, and frequency of exposure. Tellis et al. (2000) demonstrate that the effects of television advertising vary considerably depending on where, when, and how frequently advertisements are presented. Shapiro et al. (2021) further emphasize that broad reach does not necessarily guarantee profitability and that diminishing marginal effectiveness may occur beyond a certain level of advertising exposure.

Radio generally involves lower production and broadcasting costs than television and enables geographic and interest-based targeting according to listener profiles. Its limitations include the short-lived nature of advertising messages, divided audience attention, and relatively limited opportunities for immediate measurement of advertising effectiveness. Newspapers and magazines allow for more detailed presentation of products and services and potentially longer message retention, although their reach is traditionally assessed primarily through circulation and readership data. Direct mail can be precisely targeted and personalized, but its effectiveness depends on the quality of the recipient database and may involve significant printing and distribution costs.

The advantages of traditional media may also arise from their complementary use. Naik and Raman (2003) identified synergistic effects between television and print advertising, suggesting that the combined impact of multiple media channels may exceed the sum of their individual effects. Consequently, advertising optimization should consider not only the individual costs and estimated reach of each medium, but also potential interactions and synergies among different channels.

2.2. Contemporary Digital Media

Digital media include social networking platforms, search engines, video-sharing platforms, mobile applications, display advertising, and collaborations with influencers and other content creators. Their key advantages include precise audience targeting, flexible budget management, interactivity, and access to detailed performance analytics. Kannan and Li (2017) conceptualize digital marketing as an adaptive process of value creation

across different stages of the customer relationship, ranging from initial contact to purchase and post-purchase communication.

Facebook and Instagram enable audience segmentation based on variables such as age, location, interests, and user behavior, while TikTok emphasizes short, dynamic, and authentic video formats. YouTube combines some characteristics of mass audiovisual media with the targeting capabilities of digital advertising. Advertising effectiveness may vary substantially across platforms because users engage with individual platforms for different purposes. Consequently, the same advertising message may produce different effects depending on the platform through which it is delivered (Voorveld et al., 2018).

Digital channels enable advertisers to monitor impressions, reach, clicks, views, engagement, and conversions. Nevertheless, the availability of a large number of performance metrics does not eliminate the attribution problem. A purchase may result from several advertising touchpoints, while the same individual may be reached across multiple platforms. Consequently, simply adding the reported reach of individual channels may overestimate the actual number of unique users reached by a campaign. More advanced optimization models should therefore account for audience overlap, saturation effects, and the diminishing marginal effectiveness of repeated advertising exposure.

Influencer marketing is largely based on perceived credibility, trust, and the relationship between content creators and their audiences. Pan et al. (2025) demonstrate that influencer marketing can positively affect consumer attitudes and behavior, although its effectiveness depends on factors such as the fit among the influencer, content, audience, and promoted product. Similarly, De Veirman et al. (2017) show that a large number of followers does not, by itself, guarantee more favorable attitudes toward a brand. From a methodological perspective, it is therefore appropriate to distinguish between the costs of content production and the costs associated with content distribution.

A concise comparison of traditional and contemporary advertising channels is presented in Table 1.

Characteristic	Traditional Channels	Contemporary Digital Channels
Reach	Mass reach, with less precise targeting	Global reach and more precise targeting
Costs	Higher initial costs and lower flexibility	More flexible budgets and rapid reallocation
Measurability	Estimates of reach and frequency	Detailed analytics and conversion tracking
Interactivity	Predominantly one-way communication	Two-way communication and engagement
Speed of adjustment	Slower	Rapid and almost real-time
Main limitations	High costs and weaker attribution	Saturation, algorithms, privacy issues, and audience overlap

Table 1. Comparison of Traditional and Contemporary Advertising Channels

3. Research problem and methodology

The research problem addressed in this paper concerns the optimal allocation of advertising resources across different media channels under predefined budgetary and communication constraints. The analysis considers a company seeking to achieve a total advertising reach of at least 1.5 million people. For each media channel, three parameters are specified: the estimated reach per campaign, the cost per campaign, and the maximum permitted number of campaigns.

The model assumes that advertising campaigns are purchased as discrete units. Consequently, the decision variables are defined as non-negative integers representing the number of campaigns allocated to each media channel. Creative content production costs are excluded from the model. This distinction is important because the analysis focuses exclusively on the optimization of media placement costs rather than on the total cost of developing and executing an advertising campaign.

The optimization problem is formulated as an integer linear programming model. The objective is to minimize the total cost of advertising while satisfying the minimum target-reach requirement and the channel-specific constraints on the maximum number of campaigns. The model is implemented using Microsoft Excel Solver.

Indicator	TV	Radio	Direct Mail	Newspapers
Reach per campaign	50,000	25,000	20,000	15,000
Cost per campaign	€500	€200	€250	€125
Maximum number of campaigns	20	15	10	15

Table 2. Input Data for Traditional Media

Indicator	Facebook and Instagram	TikTok	YouTube	LinkedIn	Influencers
Reach per campaign	50,000	40,000	60,000	20,000	35,000
Cost per campaign	€500	€400	€700	€450	€600
Maximum number of campaigns	20	15	12	10	8

Table 3. Input Data for Contemporary Digital Media

The analysis covers three scenarios: (1) traditional media, (2) digital media, and (3) a strategically selected combined media mix consisting of television, radio, YouTube, and LinkedIn. In the second and third scenarios, an additional diversification constraint is considered, according to which each included channel must be used at least four times. This prevents a solution that is mathematically inexpensive but excessively concentrated on a small number of channels.

For the first scenario, the objective function is defined as follows:

$$\min Z = 500x_1 + 200x_2 + 250x_3 + 125x_4$$

subject to the reach constraint:

$$50.000x_1 + 25.000x_2 + 20.000x_3 + 15.000x_4 \geq 1.500.000$$

and the constraints: $0 \leq x_1 \leq 20$, $0 \leq x_2 \leq 15$, $0 \leq x_3 \leq 10$ i $0 \leq x_4 \leq 15$, where all variables are integers.

The models for the remaining two scenarios were formulated according to the same principle, using the corresponding costs, reach values, and limits for the individual channels.

4. Computer-Supported Optimisation Model

To enable the direct illustration and practical application of the model, Table 4 presents the optimisation problem for Scenario 3, formulated in a Microsoft Excel spreadsheet and solved using the Solver add-in. The model includes the additional constraint that each advertising medium must be used at least four times.

6	Requirement					
7		TV	Radio	YouTube Ads	LinkedIn Ads	
8	Audience size per campaign	50.000	25.000	60.000	20.000	
9	Cost per campaign	500 €	200 €	700 €	450 €	
10	Maximum number of campaigns	20	15	12	10	
11						
12	Investment Plan					
13		TV	Radio	YouTube Ads	LinkedIn Ads	Total
14	Cost	\$7.500	\$3.000	\$3.500	\$1.800	\$15.800
15	Number of advertisements	15	15	5	4	
16	Total reach	750.000	375.000	300.000	80.000	1.505.000

Table 4. Spreadsheet-Based Optimisation Model

4.1. Spreadsheet Structure

In each scenario, the input parameters are arranged in three rows: reach per campaign, cost per campaign, and the maximum number of campaigns. The decision variables represent the number of campaigns for each individual channel. Reach and cost by channel are calculated using formulas, while total reach and total cost are obtained by summing the values of all included channels.

Model element	Example cell	Formula/content	Role
Target reach	F16	1,500,000	Minimum total reach that the campaign must achieve
Decision variables	B14	Integer values	Number of campaigns per channel
Reach by channel	B16	=B15*B8	Reach per campaign × number of campaigns
Cost by channel	B14	=B15*B9	Cost per campaign × number of campaigns

Model element	Example cell	Formula/content	Role
Total reach	F16	=SUM(B16:E16)	Left-hand side of the reach constraint
Total cost	F14	=SUM(B14:E14)	Objective function to be minimised

4.2. Setting Up the Solver Model

1. In the **Set Objective** field, the total cost cell is selected and the **Min** option is chosen.
2. In the **By Changing Variable Cells** field, the row containing the number of campaigns by channel is selected.
3. A constraint is added specifying that the total reach must be greater than or equal to the target reach.
4. Lower and upper bounds are defined for each variable, representing the minimum and maximum number of campaigns.
5. The decision variables are specified as integers, while **Simplex LP** is selected as the solving method.

This formulation is clearer than a model in which monetary investments are used as decision variables because it directly optimises the number of campaigns. It therefore avoids non-integer solutions, such as 16.1 television campaigns, which cannot be implemented in an actual media purchasing plan.

5. Results and Discussion

5.1. Scenario 1: Traditional Media

The optimal solution includes 18 television campaigns, 15 radio campaigns, and 15 newspaper advertisements, while direct mail is not used. This combination achieves exactly 1,500,000 contacts at a minimum cost of €13,875. The solution uses the maximum permitted number of lower-cost radio and newspaper advertisements, while the remaining reach is achieved through television. Direct mail is not included because it has a less favourable cost-to-reach ratio than the other available traditional channels.

5.2. Scenario 2: Digital Media

Without the diversification requirement, the optimal digital solution consists of 18 campaigns on Facebook and Instagram and 15 campaigns on TikTok. The total reach is 1,500,000 people, while the total cost amounts to €15,000. The solution is concentrated on the two channels with the lowest cost per contact. However, such concentration increases the risk of audience overlap and dependence on the algorithms of individual platforms.

When the constraint requiring each of the five digital channels to be used at least four times is introduced, the optimal mix consists of 9 campaigns on Facebook and Instagram, 15 campaigns on TikTok, and 4 campaigns each on YouTube, LinkedIn, and through influencers. The total reach is 1,500,000 people, while the total cost amounts to €17,400. Diversification increases the cost by €2,400, or 16%, but it simultaneously increases the number of customer touchpoints and reduces concentration risk.

5.3. Scenario 3: Combined Media Mix

The combined scenario was designed for a campaign targeting both the general public and business users. Television and radio were included because of their mass reach, YouTube because of its ability to demonstrate products, and LinkedIn because it provides access to professionals, managers, and decision-makers. Subject to the condition that each channel must be used at least four times, the optimal integer solution includes 15 television campaigns, 15 radio campaigns, 5 YouTube campaigns, and 4 LinkedIn campaigns.

This combination achieves a reach of 1,505,000 people at a cost of €15,800. The solution is €1,925 more expensive than the exclusively traditional scenario, but €1,600 less expensive than the fully diversified digital scenario. At the same time, it combines mass reach with the possibility of more precise targeting of business audiences.

Scenario	Optimal structure	Reach	Cost
1. Traditional	TV 18; radio 15; newspapers 15; direct mail 0	1,500,000	€13,875
2A. Digital without minimum-use constraints	Facebook/Instagram 18; TikTok 15	1,500,000	€15,000
2B. Digital, minimum of 4 per channel	Facebook/Instagram 9; TikTok 15; YouTube 4; LinkedIn 4; influencers 4	1,500,000	€17,400
3. Combined, minimum of 4 per channel	TV 15; radio 15; YouTube 5; LinkedIn 4	1,505,000	€15,800

Table 5. Comparison of Optimal Solutions

The results provide answers to the research questions. Under the specified parameters, the traditional scenario achieves the lowest cost. A digital media mix is not automatically less expensive: its advantages depend on unit costs, targeting quality, and additional constraints. Minimum channel representation increases the total cost, but it may be strategically justified in order to diversify the campaign, cover different stages of the customer journey, and reduce dependence on a single medium.

Nevertheless, the results should be interpreted as an illustration of the application of an optimisation model rather than as a universal recommendation. The model assumes linear and additive reach, although the audiences of different channels may overlap. It does not account for differences in contact quality, conversion probability, creative effectiveness, production costs, broadcasting time, or synergies between media. In practice, these elements should be estimated on the basis of data from the specific advertising campaign.

6. Conclusion

The aim of this paper was to demonstrate how the allocation of advertising budgets across different media channels can be formulated and solved using integer linear programming. The proposed model enables media selection decisions to be based on clearly defined parameters, including campaign cost, estimated reach, the maximum number of campaigns per channel, and, where applicable, minimum channel representation. Its principal value lies in transforming a complex media planning problem into a transparent, systematic, and verifiable decision-making procedure.

Under the specified assumptions and input parameters, the traditional media scenario proved to be the most cost-effective, achieving the target reach of 1.5 million at a total cost of €13,875. The digital media scenario without diversification constraints requires €15,000, whereas the introduction of a minimum-use requirement for all digital channels increases the total cost to €17,400. The combined media mix consisting of television, radio, YouTube, and LinkedIn achieves a modeled reach of 1.505 million at a cost of €15,800. It therefore represents an intermediate solution between minimum-cost efficiency and greater strategic channel diversification.

The findings indicate that minimizing advertising costs should not be regarded as the sole criterion for selecting an appropriate media mix. Media planning decisions should also be aligned with the characteristics of the target audience, stages of the customer journey, product characteristics, and communication objectives. Traditional media may provide advantages when broad audience coverage and brand visibility are priorities, whereas digital channels offer greater opportunities for precise targeting, interactivity, flexibility, and performance measurement. A combined approach may therefore be strategically justified when a campaign seeks to achieve broad visibility while simultaneously reaching specific audience segments through more targeted communication.

The findings should nevertheless be interpreted within the limitations of the proposed model. The analysis assumes linear and additive reach and does not explicitly account for audience overlap across channels. Consequently, the modeled reach should not necessarily be interpreted as the number of unique individuals exposed to the campaign. Furthermore, the model does not incorporate differences in contact quality, conversion probability, creative effectiveness, content production costs, media synergies, or diminishing marginal returns from repeated advertising exposure. These factors may substantially influence the effectiveness and economic justification of a media plan in practice.

Future research should therefore extend the model by incorporating audience overlap, diminishing marginal returns, conversion probabilities, content production costs, synergies among media channels, and uncertainty in estimated reach. Further development could also include multi-criteria or stochastic optimization models that evaluate not only campaign costs but also reach quality, conversion potential, sales outcomes, and risk. Despite these limitations, the proposed model provides a practical framework for more rational advertising planning and demonstrates how mathematical optimization can contribute to a more effective integration of marketing objectives and the economic evaluation of advertising investments.

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