PLANNING THE DIGITAL MARKETING BUDGET: COMPUTER MODELLING FOR DECISION MAKING

Liudmyla Dorokhova¹, Andres Kuusik², Radi Dimitrov³
Kristian Pentus⁴, Oleksandr Dorokhov⁵, Mariana Petrova⁶

¹, ², ⁵University of Tartu, Tartu, Estonia
³ University of Telecommunications and Post, Sofia, Bulgaria
⁶ St. Cyril and St. Methodius University of Veliko Tarnovo, Veliko Tarnovo, Bulgaria

e-mails: ¹liudmyla.dorokhova@ut.ee, ²andres.kuusik@ut.ee, ³r.dimitrov@utp.bg, ⁴kristian.pentus@ut.ee,
⁵oleksandr.dorokhov@ut.ee, ⁶m.petrova@ts.uni-vt.bg

Received: 13 December 2022   Accepted: 3 March 2023   Online Published: 15 March 2023

ABSTRACT

Objectives: The rational distribution of the advertising budget in conducting an advertising campaign using digital marketing tools is very relevant and tricky. The possibility of computer simulation of the results of the joint use of various Internet advertising tools and their impact on buyers is considered. Methods/Approach: It is proposed to use approaches based on simulation of the long-term impact of digital advertising on potential consumers. Three primary states of awareness and actions of consumers are distinguished and modelled: an uninformed consumer, a consumer who is aware of the product, a buyer, and a regular buyer. We study the dynamics of changes in the number of consumers in each group during exposure to various components of a digital advertising campaign. Results: A computer simulation model has been developed to change consumers’ states during an advertising campaign. It numerically simulates the sequential transition of potential consumers to the state of regular buyers and back under the influence of the considered means of online advertising. Conclusions: The developed approach makes it possible to predict the dynamics of changes in the number of consumers and its relationship with the ratio of elements of an advertising campaign over time. The proposed model is simple to use and has good opportunities for further development.

Keywords: internet marketing, medicines consumers, social media modelling, marketing budget, decision making, computer simulation

JEL classification: M31, M37, D12

Paper type: Case Study.


INTRODUCTION

The development of information Internet technologies opens fundamentally new, revolutionary opportunities and tools for solving various marketing and management problems (Gams, 2022). This is especially true in the context of a pandemic and the transition of a significant part of sales to the Internet, confirmed by the number of scientific publications.

Thus, the survey (Pluta, 2018) describes the development of integrated marketing Internet communications models and the configuration of their various tools. In (Yu & Jin, 2020), the necessity and components of
modelling the marketing influence on the purchasing behaviour of a fast-growing segment of users of online stores are substantiated. The article (Liping & Chih, 2020) qualitatively describes Internet users as potential consumers, their interaction in social networks, and their mutual influence. Oral Internet communication, the quality of relationships, and information exchange are considered in detail. Summarizing these and similar sources, we can conclude the relevance and necessity of modelling Internet marketing processes using information technologies and specialized computer programs.

Considering computer methods, approaches, and tools for modelling marketing tasks, in particular, in the implementation of Internet marketing, it should be noted that there are few literary sources on this topic (Delen et al., 2020; Dorokhova & Dorokhov, 2017; Kőrösi & Vinkó, 2021). Without pretending to be a complete overview of the publications, we will briefly dwell on the most recent and topical of them. Thus, the study (Choudur & Mingzhang, 2020) is devoted to using the Internet as a tool for marketing interaction with customers in the market when conducting e-commerce. It describes the application of Markov (Hui & Junhai, 2018) and also considers the model of differential Internet advertising, the conditions for the existence and stability of periodic solutions.

The paper (Kaczorowska, 2019) examines the role of digital technologies, the Internet of Things (IoT) and artificial intelligence (AI) in marketing interactions between brands and consumers. Chatbots and their impact on marketing are considered one of the tools. A closely related publication (Hsin et al., 2019) focuses on the technology of Internet memes for conducting marketing activities with its modelling by structural equations to test research hypotheses. Articles (Batyrbekova, Petrova & Ussova, 2020; Exenberger & Bucko, 2020; Dyachenko et al, 2018; Petrova, Buzko, Dyachenko, 2018; Geldiev et al., 2018) confirm the relevance of artificial intelligence, data mining, and machine learning methods for online marketing. A model of the CRISP-DM process is proposed for analyzing the behaviour of online customers using clustering, decision trees, and search for association rules. In (Limba et al., 2018), the model for assessing the effectiveness of Internet marketing is considered based on qualitative criteria, theoretical descriptive, comparative, and analytical methods, and expert interviews. In the study (Halunko, Kurkova & Oksin, 2018), methods for assessing the effectiveness of marketing communications on the Internet are systematized. Interactive video gaming technologies for creating advertising and communication materials allow advertising goods or services and behaviour in various purchase and consumption situations.

In particular, it describes techniques for optimizing Internet marketing using Google Analytics, CoMagic, and cookies. This enables targeting advertisements, identifying the target audience, tracking interests, and counting impressions and banner views. Several studies have used various mathematical methods. So, in the extensive work (Chaolin, 2020), Internet marketing in social networks based on modern information technologies is considered in detail. The need to control marketing expenses and consider the factors of the scale of information dissemination, user preferences, and advertising budget are emphasized.

Maximizing returns from Internet marketing is considered a multi-criteria optimization problem, and a model for maximizing impact is proposed. To solve this NP-hard problem, Monte Carlo sampling is used. An
NSGA-II-based initial choice algorithm is proposed to optimize objective functions and solutions. The work (Palos, Martin & Ramon, 2018) analyzes the behaviour of users of search engines on the Internet. The Extended Technology Acceptance Model is used with trust as an additional external variable. FIMIX-PLS and PLS-SEM modelling tools are also used. The publication (Satinder & Kamaljeet, 2020) is also devoted to using the PLS-SEM methodology for modelling social commerce, which uses social Internet technologies and tools to form an environment for social transactions.

In (Hon & Ho, 2018), a computer learning algorithm is proposed for data on Internet marketing results and also applied two-level clustering using a self-organizing map and the K-means algorithm. Finally, research (Pi & Yi, 2020) suggests a model for using YouTube for online advertising campaigns. A modified Delphi method is suggested to determine the criteria for evaluating YouTube users. Next, the analytical hierarchy method AHP was applied to determine the relative weights of assessment criteria, ranking alternatives, and choosing the optimal online advertising strategy.

After analyzing the sources listed and others in our work, we settled on choosing simulation as a tool for creating models. As known, simulation modelling uses three approaches (methods): discrete-event modelling, agent modelling and system dynamics. Discrete-event modelling simulates the operation of the system as a chronological sequence of events. Each event occurs at a particular time and is reflected in a change in the system's state. Agent-based modelling reflects the actions and interactions of autonomous agents as individual and collective entities and their impact on the system as a whole. System dynamics examines the behaviour of complex systems in time, considering the dependences on the structure of system elements and the interaction between them. In particular, causal relationships, feedback loops, response delays, environmental influences, and others are modelled.

**METHODOLOGY**

Firstly, let us consider *AnyLogic* software as a modelling tool. To build a simulation model of an advertising campaign for pharmaceutical products using a combination of social media marketing methods, the widely used and currently known computer modelling tool *AnyLogic (Personal Learning Edition 8.6.0)* was chosen. It should be noted that this program is entirely free, with no functional restrictions. It is crucial when using the models built into it for educational, scientific, and practical purposes (Fric, Stres & Blatnik, 2022).

This software product does not limit the user to one modelling paradigm, making it possible to choose any of the three main modelling directions: discrete-event, system dynamics, and agent-based. The key distinguishing feature of *AnyLogic* is its object-oriented modelling approach. This makes it possible to simplify the modelling of complex multicomponent and multifunctional systems significantly. Making the process of representing the composition of a complex system more natural and well-structured ultimately makes it possible to simplify and speed up the creation of models.

Another vital feature of *AnyLogic* is combining different modelling directions within the same model, such as agent-based modelling and system dynamics. An essential conceptual feature of *AnyLogic* is the ability to
represent the model as a set of parallel functioning activities consisting of one instance of active objects and several independently interacting with the environment. The program allows using Java language to develop or improve its model elements. The valuable component of the package is a convenient, clear, and modern graphical interface with all kinds of support for the developer and user. These tools allow new users to quickly adapt to the use of this product, which significantly simplifies the process of creating models, and reduces the labour and time costs of their development, testing, adaptation, and final use for simulation experiments.

The AnyLogic graphical modelling environment includes the following essential elements: Stock & Flow Diagrams used to develop models by methods of system dynamics; Statecharts, used in agent models to determine the behaviour of agents and in discrete-event modelling, for example, to simulate machine failures; Action Charts, used to build algorithms in discrete-event and agent modelling; Process Flowcharts, the essential elements for describing and representing processes in discrete-event modelling.

The modelling environment also includes low-level modelling constructions (variables, equations, parameters, events, etc.), forms of representation (lines, squares, ovals, etc.), various elements of analysis (databases, histograms, graphs), standard images, and forms of representation of experiments.

The study’s objective was to examine the impact and profitability of various elements of social media marketing aimed at consumers of pharmaceutical products. Advertising and sale of food additives in pharmacies were considered as an example. For this, we have developed an appropriate computer simulation model containing the main elements of the relevant Internet marketing processes. Next, we will consider and explain its main elements and their interconnections.

RESULTS

The model we are developing will reflect some of the components of online marketing of pharmacy products. The essential elements of the model are four storage devices shown in Figure 1, namely: UnknownUsers (visitors who know nothing about food additives); KnowledgeableUsers (visitors who know about the presence of food additives in the pharmacy); Buyers (buyers who have purchased food additives); RegularBuyers (pharmacy customers who have become regular customers of food additives).

At the beginning of the simulation, all visitors are referred to as those who do not know about the product (they are located in the UnknownUsers storage). At the same time, their input model number is established (specified, determined from practical conditions, and fixed). Filling the subsequent storages depends on the advertising campaign’s parameters, tools, and results and is characterized by the respective streams: Notification, Sales, Resales, and Costs.
In order for visitors to become knowledgeable (that is, they go to the KnowledgeableUsers storage), the pharmacy uses various methods of Internet marketing, such as SMM, SEO, Direct Marketing (EMAIL), Contextual Advertising (Kont), which is displayed in the model. For each of the marketing methods used, there are several indicators: UsagePrice (the price of one unit of an advertising method), Expenses (the total amount of funds for advertising), and Conv (an indicator of the effectiveness of advertising). The representation of methods and their indicators in the model’s graphical interface is shown in Figure 2.

The formula for calculating the efficiency of Conv is as follows: \( Conv = \frac{UsagePrice}{Expenses} \).

The transition of potential buyers from UnknownUsers storage to KnowledgeableUsers storage is due to the Notification stream. This stream informs users about the proposed food additives through Internet marketing methods. The stream changes due to the multiplication of unknowing users (UnknownUsers) by the sum of advertising performance indicators (ConvSum).
The formula for ConvSum is as follows: \[ \text{ConvSum} = \text{ConvSEO} + \text{ConvSMM} + \text{ConvEMAIL} + \text{ConvKont}. \]

Where there are such efficiency indicators: \(\text{ConvSEO}\) - for search engine optimization; \(\text{ConvSMM}\) - for promotion on social networks; \(\text{ConvEMAIL}\) - for direct marketing; \(\text{ConvKont}\) - for contextual advertising.

The formula for calculating the Notification stream is as follows: \[ \text{Notification} = \text{UnknownUsers} \times \text{ConvSum}. \]

The transition to KnowledgeableUsers storage is shown in Figure 3.

![Figure 3. Transition to KnowledgeableUsers storage](source: developed by the authors)

Next, consider the transition of visitors from the KnowledgeableUsers storage to Buyers storage. This is due to the Sales stream, which in the model is responsible for converting knowledgeable visitors into visitors who become customers. The stream changes due to the multiplication of ReturnAds and VirtMarketing parameters. Let us see how they are calculated. The ReturnAds parameter characterizes the number of buyers who appeared due to advertising. It is calculated by multiplying KoefPoyvlPokup (buyers’ arrival rate) and KnowledgeableUsers.

The formula for calculating ReturnAds is as follows: \[ \text{ReturnAds} = \text{KoefPoyvlPokup} \times \text{KnowledgeableUsers}. \]

The VirtMarketing setting reflects the appearance of buyers who have appeared through viral marketing.

It is calculated by multiplying the UnknownUsers by the KnowledgeableUsers and the ConvVirtMarketing conversion rate and dividing the result by the total number of Users. The transition to Buyer’s storage is shown in Figure 4.

The formula for calculating the parameter VirtMarketing is as follows: \[ \text{VirtMarketing} = \text{UnknownUsers} \times \text{KnowledgeableUsers} \times \text{ConvVirtMarketing} / \text{Users}. \]

Thus, finally, the formula for calculating the Sales stream is as follows: \[ \text{Sales} = \text{ReturnAds} \times \text{VirtMarketing}. \]

The next step in the model is the users’ transition from the Buyers storage to the RegularBuyers storage through the Resales stream. This stream is responsible for transforming buyers into regular buyers.

The stream changes due to the multiplication of the number of visitors; buyers (Buyers) are already by the buyers’ return rate (KofVoz). Consider the calculations for this transition.
The formula for calculating parameter $Resales$ is as follows: $Resales = Buyers \times KofVoz$. The transition to RegularBuyers storage is shown in Figure 5.

Finally, the model has a reverse Costs stream, responsible for returning buyers and regular buyers to knowledgeable users. This situation corresponds to cases where a buyer purchased a product several times and then stopped such purchases.

In this way, he returned to the state of an informed visitor (KnowledgeableUsers). The stream is changed by using the delay (...) function. It reflects the return of regular buyers to knowledgeable users with some delay (Parameter). The work of the Costs stream is shown in Figure 6.

The model created in this way makes it possible to analyze the costs of each type of Internet advertising separately and with a combination of several or all of its methods when they work together in terms of attracting and retaining the maximum number of buyers during the entire planned time of selling the product.
**DISCUSSION**

The final model, consisting of the components described above, is shown in Figure 7. It can be used to conduct simulations to determine the best cost ratios for various types of online advertising and their combinations. At the same time, the task to be solved is to inform potential buyers about the product as much as possible and to increase and maintain the number of buyers, especially repeat (regular) ones.

Simulation shows what kind of advertising or a combination of them gives the best results and at what cost. You can compare the combination of "price - result" and choose the most acceptable option for advertising.
Table 1 are presented numerical values of some input parameters and results for the illustrative experiment. The model in the interface with the initial data for the mentioned example is shown in Figure 8.

<table>
<thead>
<tr>
<th>Variables</th>
<th>Meaning of variable</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>UsagePriceSEO</td>
<td>price of one unit of an advertising method</td>
<td>1375 $</td>
</tr>
<tr>
<td>UsagePriceSMM</td>
<td></td>
<td>1025 $</td>
</tr>
<tr>
<td>UsagePriceEMAIL</td>
<td></td>
<td>350 $</td>
</tr>
<tr>
<td>UsagePriceKont</td>
<td></td>
<td>925 $</td>
</tr>
<tr>
<td>ExpensesSEO</td>
<td>total funds for this method of advertising</td>
<td>5500 $</td>
</tr>
<tr>
<td>ExpensesSMM</td>
<td></td>
<td>4100 $</td>
</tr>
<tr>
<td>ExpensesEMAIL</td>
<td></td>
<td>1400 $</td>
</tr>
<tr>
<td>ExpensesKont</td>
<td></td>
<td>3700 $</td>
</tr>
<tr>
<td>UnknownUsers</td>
<td>visitors who know nothing about food additives</td>
<td>1 week – 20000 to 25 week – 1000</td>
</tr>
<tr>
<td>KnowledgeableUsers</td>
<td>who know about the presence of food additives in pharmacy</td>
<td>1 week - 0, 25 week - 19000</td>
</tr>
<tr>
<td>Buyers</td>
<td>buyers who have purchased food additives after advertising</td>
<td>1 week - 0, 25 week - 5000</td>
</tr>
<tr>
<td>RegularBuyers</td>
<td>customers who have become regular buyers</td>
<td>1 week - 0, 25 week - 3000</td>
</tr>
</tbody>
</table>

Source: Own author's calculations based on the poll

Figure 8. The view of the model with data in the interface

Source: developed by the authors

The corresponding simulation results, namely, the dynamics of customer behaviour for this illustrative experiment, are graphically presented in Figure 9.

It should be noted that the duration of the simulation time period is determined based on the gradual depletion of the total amount of the initially allocated advertising budget. In this illustrative example, it was 25 weeks. All types of Internet advertising were used simultaneously.
As mentioned, food additives sold in pharmacies have been advertised. Analysis of the curves' nature shows an expected gradual coverage with advertising information of almost the entire array of potential buyers (red curve), as well as an initial sharp increase in new buyers (blue curve). Regular buyers also appear somewhat later (green curve).

![Figure 9. The results of the illustrative experiment](source: developed by the authors)

Over time, the number of original and regular buyers naturally decreases and reaches some constant minimum level. This behaviour of the curves correctly reflects the behaviour of consumers, as fading buyers, in the temporary continuation and completion of the advertising campaign, taking into account the life cycle of the offered product.

The proposed model allows you to consider and calculate different options for the time duration and intensity of an advertising campaign, the ratio of costs for different types of advertising, their combination, the size of the advertising budget, the influence of additional model parameters on the number of buyers and their retention.

**CONCLUSION**

Thus, we have proposed an approach and developed a computer simulation model for analyzing advertising costs for various types of Internet marketing and determining their best possible ratio.

This approach can be applied to the Internet promotion of all types of goods and services in organizations and business structures of various levels and sizes. The model is built using free software, intuitive structural blocks, and visualization tools, which makes it accessible and suitable for use and further development.


All authors have read and agreed to the published version of the manuscript.

**Informed Consent Statement:** not applicable
**Data Availability Statement:** The data presented in this study are available on request from the corresponding author.

**Institutional Review Board Statement:** The study was conducted according to the guidelines of the Declaration of Helsinki and approved by the ethics committee of the Simon Kuznets Kharkiv National University of Economics, approval number: 10/09-3, 10/02/2022.

**Conflict of interests**
The authors declare no conflict of interest.

**References**


About the authors

Liudmyla DOROKHOVA

Doctor of Philosophy in Pharmacy, Associate Professor, National University of Pharmacy, Kharkiv, Ukraine; Visiting Professor, University of Tartu, Estonia

Research interests: marketing, consumer behaviour, service quality

ORCID ID: https://orcid.org/0000-0002-3859-628X

Andres KUUSIK

Doctor of Philosophy in Economics, Professor, University of Tartu, Estonia

Research interests: marketing, consumer behaviour, customer loyalty

ORCID ID: https://orcid.org/0000-0003-4336-1319

Radi DIMITROV

PhD of economics, Associate Professor, Financial Management, University of Telecommunications and Post, Sofia, Bulgaria

Research interests: financial management, financial technologies, digital transformation of financial processes, accounting and auditing

ORCID ID: https://orcid.org/0000-0002-6655-5733

259
Kristian PENTUS,
Master in Economics, Junior Lecturer, University of Tartu, Estonia
Research interests: marketing, consumer behaviour, eye tracking
ORCID ID: https://orcid.org/0000-0001-5395-9424

Oleksandr DOROKHOV
Doctor of Philosophy in Technical Sciences, Visiting Professor, University of Tartu, Estonia
Research interests: fuzzy logic, decision-making, computer modelling in economic
ORCID ID: https://orcid.org/0000-0002-0737-8714

Mariana PETROVA
PhD in Physics and Mathematics, Professor, University of Telecommunications and Post; assoc.prof. St. Cyril and St. Methodius University of Veliko Tarnovo, Bulgaria
Research interests: management of IT processes, project and services, business administration, modern information systems and innovations, sustainable development.
ORCID ID: https://orcid.org/0000-0003-1531-4312

This work is licensed under the Creative Commons Attribution International License (CC BY)