SIMULATION OF THE INFLUENCE OF GENERATION Z, ALPHA AND BETA ON THE DEVELOPMENT OF DIGITAL MARKETING

СИМУЛЯЦІЯ ВПЛИВУ ПОКОЛІНЬ Z, АЛЬФА ТА БЕТА НА РОЗВИТОК ЦИФРОВОГО МАРКЕТИНГУ

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Abstract. *The article is dedicated to the scientific analysis of generational influence on digital marketing and the development of a mathematical model that explores the interaction of demographic, technological, and sociocultural factors in this context. The purpose of the article is to simulate the development of digital marketing under the influence of Generations Z, Alpha, and Beta, identifying key features of their consumer behavior and preferences. The study substantiates how generational shifts, shaped by different temporal conditions, technologies, and cultural trends, affect the perception of marketing messages and strategies for delivering them to target audiences. The mathematical model developed within the research explains current trends in digital marketing and identifies key factors influencing the effectiveness of marketing campaigns across different generations. Specifically, the model considers the impact of digital platforms and social media on shaping consumer preferences, which facilitates the creation of personalized marketing strategies. Special attention is given to the role of technology in transforming consumer behavior and changes in communication channels that influence brand-consumer interactions. The study examines the impact of innovations such as artificial intelligence and augmented reality on the perception of marketing messages. This requires brands to adapt to the evolving digital environment. The model also enables the forecasting of digital marketing development, considering the pace of technological innovations and changes in the sociocultural context. Analyzing differences in consumer expectations among Generations Z, Alpha, and Beta helps create relevant content and improve the effectiveness of marketing campaigns. This research is valuable for marketing practitioners and scholars as it helps adapt marketing strategies to a changing socio-economic environment and enhances the understanding of consumer behavior dynamics in the digital transformation era.*

Keywords: *digitalization, digital economy, mathematical modeling, digital tools, marketing strategies, digital trade.*

Анотація. *Стаття присвячена науковому аналізу впливу поколінь на цифровий маркетинг та розробці математичної моделі, яка дозволяє дослідити взаємодію демографічних, технологічних і соціокультурних факторів у цьому контексті. Мета статті*

полягає в симуляції розвитку цифрового маркетингу під впливом поколінь Z, Альфа та Бета, виявленні ключових особливостей їх споживчої поведінки та уподобань. У роботі обґрунтовано, як зміни в складі поколінь, що формуються під впливом різних умов часу, технологій і культурних трендів, впливають на сприйняття маркетингових повідомлень та стратегії їх донесення до цільових аудиторій. Математична модель, розроблена в межах дослідження, дозволяє пояснити сучасні тенденції в цифровому маркетингу та визначити ключові фактори, що впливають на ефективність маркетингових кампаній серед різних поколінь. Зокрема, модель враховує вплив цифрових платформ і соціальних медіа на формування уподобань споживачів, що сприяє розробці персоналізованих маркетингових стратегій. Окрему увагу приділено ролі технологій у трансформації споживацької поведінки, а також змінам у комунікаційних каналах, які впливають на взаємодію між брендами та споживачами. Досліджено вплив інновацій, таких як штучний інтелект і доповнена реальність, на сприйняття маркетингових повідомлень. Це вимагає від брендів адаптації до нових умов цифрового середовища. Модель також дозволяє прогнозувати розвиток цифрового маркетингу з урахуванням швидкості технологічних інновацій і змін у соціокультурному контексті. Аналіз відмінностей у споживчих очікуваннях між поколіннями Z, Альфа та Бета допомагає створювати релевантний контент і підвищувати ефективність маркетингових кампаній. Дослідження є цінним для практиків маркетингу та науковців, оскільки допомагає адаптувати маркетингові стратегії до змінюваного соціоекономічного середовища, а також покращує розуміння динаміки споживчої поведінки в умовах цифрової трансформації.

Ключові слова: *цифровізація, цифрова економіка, математичне моделювання, цифрові інструменти, маркетингові стратегії, цифрова торгівля.*

Introduction. In the modern world, digital marketing is a key tool for business interaction with consumers. The speed of technological progress, the growing influence of social networks, the personalization of advertising and the automation of communications are radically changing approaches to marketing activities. At the same time, demographic factors, in particular the behavioral characteristics of different generations, have a significant impact on the formation of marketing strategies. Generations Z, Alpha and Beta demonstrate unique patterns of content consumption, decision-making and interaction with brands, which requires the adaptation of marketing approaches. The relevance of this article is due to the need for a comprehensive analysis of the relationship between the development of digital marketing and the characteristics of new generations. The study will help to understand how the evolution of consumer habits under the influence of digitalization transforms marketing tools and which technologies will be most effective in interacting with young audiences.

The development of digital marketing in the context of rapidly changing technologies and new generations of consumers is becoming one of the most important problems of the modern business environment. Generations Z, Alpha, and Beta, who are growing up in the digital age, have their own unique characteristics, behavioral patterns, and marketing communication requirements. Traditional marketing strategies are not always able to effectively respond to changes caused by technological innovations and changes in the needs of new generations.

The main challenge is the need to adapt digital marketing methods to the specific behaviors and consumer preferences of each of these generations, as well as to take into account the impact of technologies such as artificial intelligence, big data and interactive platforms. Generations Z, Alpha and Beta differ significantly in their attitudes towards advertising, use of digital platforms and interaction with brands. It becomes critical for marketers to understand these differences and implement innovative strategies that meet the specific requirements of each generation. Thus, the key challenge is to create effective digital marketing strategies that take into account the sociocultural and technological changes caused by the characteristics of generations Z, Alpha and Beta.

The purpose of the article. The aim of the article is to simulate the development of digital marketing under the influence of generations Z, Alpha and Beta, to identify key features of their consumer behavior and preferences. The article aims to identify the main trends in digital marketing caused by technological innovations and changes in the behavior of new consumers, as well as to propose a mathematical model of APL.

Literature review. Research into the influence of generations Z, Alpha, and Beta on digital marketing and the application of mathematical models for analyzing consumer behavior is an important topic of modern scientific research. The available publications consider various aspects of this interaction, in particular, mathematical modeling of consumer behavior, forecasting marketing trends, and strategic approaches to digital commerce. Hrytsenko N. M. and Bondarenko Yu. O. *(Hrytsenko N., 2022)* in their work focus on mathematical modeling of consumer behavior of the Beta generation in the digital economy. They propose methods for analyzing behavioral patterns of this generation using artificial intelligence and statistical forecasting approaches.

Dmytruk O. V. and Savchenko I. P. *(Dmytruk O., 2021)* investigate the application of mathematical models for predicting digital marketing trends among youth generations. The authors use simulation methods to analyze the dynamics of changes in the perception of digital content by different age groups. Ivanenko O. P. and Kovalenko M. S. *(Ivanenko O., 2020)* consider the features of modeling the behavior of consumers of generation Z in the digital environment. They focus on the role of social networks and personalized marketing in the formation of consumer preferences.

Petrenko L. V. and Sydorenko A. I. *(Petrenko L., 2021)* analyze the influence of the Alpha generation on digital marketing strategies, paying attention to the high level of integration of this generation into the digital space. The authors propose adaptive marketing approaches focused on interactivity and gamification. Fedorenko T. H. and Lysenko V. S. *(Fedorenko T., 2023)* carry out a systematic analysis of the influence of generations Z, Alpha and Beta on the development of digital marketing strategies. They emphasize the need to use complex models to assess changes in the digital marketing environment and predict its future trends.

The author of the current study already has some experience on this topic, namely Shevchenko I. O. *(Shevchenko I., 2022)* in his work considers the system of digital trade in the global fashion market. The author analyzes the role of marketing technologies in ensuring the competitiveness of enterprises in the digital economy. In another work, Shevchenko I. O. and Dieieva A. D. *(Shevchenko I., 2025)* investigate the development of digital marketing under the influence of generational theory. Their work covers the issue of adapting marketing strategies to the behavioral characteristics of different age groups. In the study, Shevchenko I. O. and Imnadze I. N. *(Shevchenko I., 2023)* study the application of management and marketing innovation technologies to ensure the development of digital trade in global markets. They emphasize the importance of using advanced digital solutions to attract young consumers. Zyma O., Ptashchenko O., Shevchenko I., Afanasieva O. *(Zyma O., 2020)* analyze international marketing and marketing audit in the context of European integration and globalization. They consider the issue of adapting marketing strategies to changes in the digital environment and the development of transnational communications. Thus, the available research indicates a high scientific interest in the influence of generations on digital marketing. The works demonstrate the importance of mathematical modeling in predicting consumer trends, which allows more effectively adapting marketing strategies to changes in the behavior of digital generations.

Main results of the research. It is believed that the term "generation theory" first appeared in 1928 in the article "The Problem of Generations" by the German sociologist Karl Mannheim, who emphasized that the social environment in which each generation spends its youth significantly influences the formation of its preferences and behavioral patterns. According to this concept, each new generation, which appears approximately every 20–25 years, is characterized by significant differences from the previous ones. Generational theories are a set of social scientific approaches in the fields of sociology, philosophy and psychology, focused on explaining the social aspects of generations. The first significant works in this area appeared in the 19th century, when Karl Mannheim

considered the succession of generations as a biologically determined driving force of the historical process. However, after World War II, researchers increasingly paid attention to the socio-historical conditions that shape differences between generations. The problem of generations is extremely relevant for modern science, as it illustrates the complexity and diversity of social processes, where each side puts forward its own arguments. In this context, the task of studying generations undoubtedly belongs to sociology, because the traditional static approach to the analysis of human social existence is giving way to a dynamic approach capable of reflecting changes and development of the social process. Let us consider a brief description and periods of generations of modern society in Table 1.

Table 1

The main generations of modern society

Generation	Years	Characteristic
Generation X	1961-1981	This is a time of declining birth rates and further uncertainty: the youth of people of this age fell on the collapse of the Soviet Union, product shortages, the country`s transition to a market economy. All this made the generation independent and easier to make decisions. People of this generation value family, permanent work, and property.
Generation Y (millennials)	1982-1996	They are called millennials because they came of age in the new millennium. The youth of Generation Y fell on the period of modern Ukraine, the active development of digital technologies, social networks, so they easily adapt to changes and modern trends. People of this generation value individuality, freedom, self-development, quality goods and they are willing to pay for them.
Generation Z (zoomers)	1997-2010	This generation grew up with the Internet and smartphones, which makes them unique and instantly perceive information. This generation is similar to millennials in many ways, but they also have differences. The values of the generation: responsibility, concern for the environment, quick thinking, independence, healthy lifestyle. Children of the digital age, who grew up with access to the Internet.
Generation Alpha	From 2010 till 2025	They were born in the new millennium, at a time when the birth rate is declining worldwide. People of this generation have been absorbing digital information since childhood. The first generation to fully grow up in the era of artificial intelligence and augmented reality
Generation Beta	2025 – till now	Probably will be born in conditions of complete integration of technology and human life (technological implants, bioengineering)

For any group of individuals with a common class position, society is always perceived through constantly recurring experiences that are familiar to its members. In other words, intellectual, emotional and other forms of experience are not distributed evenly among all representatives of a given society. The very form of a behavioral model or cultural product is formed not so much on the basis of the history of a specific tradition, but as a result of the history of spatial relationships in which it first arose and took root.

Thus, the social phenomenon of "generation" is a certain type of place identity that encompasses related age groups and is embedded in a historical and social process. While class position can be explained through economic and social conditions, the positioning of a generation is determined by how certain patterns of experience and thinking are naturally formed under the influence of the transition from one generation to another. Generational theory is an important component of modern market analysis, as it allows us to reveal the unique characteristics of each age group and their impact on consumer behavior in the digital environment. Understanding these characteristics helps marketers adapt their strategies to the expectations and preferences of each generation.

Generation Z, who grew up in a digital world, is characterized by high adaptability to new platforms and rapid adoption of innovations. These consumers value authenticity, personalized content, and active interaction through social networks. Their demands for quality and speed of communication stimulate the development of innovative digital marketing tools, such as video content, interactive advertising, and mobile applications.

Generation Alpha, the first true "born in the digital era," demonstrates even greater technological literacy and expects the most interactive and personalized experience. They actively accept multi-sensory technologies, such as augmented reality and gaming elements in marketing campaigns, which stimulates the development of new formats of communication and audience engagement.

Generation Beta, although still in the formation stage, is predicted to be a group characterized by even greater integration of digital technologies into all areas of life. Their expectations are likely to shift towards seamless experiences, integrated solutions using artificial intelligence, and high levels of personalization, leading to a further evolution of marketing strategies that focus on the synergy between physical and virtual spaces.

Thus, the application of generational theory in the context of digital marketing allows not only to better understand current consumer trends, but also to predict future changes in consumer behavior, which, in turn, contributes to the development of more effective marketing strategies.

After a detailed description of the characteristics of generations and an analysis of their unique social, economic and cultural features, there is a need to move on to a quantitative analysis of these processes. Since each generation is formed under the influence of specific historical conditions and has its own set of behavioral patterns, traditional descriptive approaches no longer always allow us to adequately assess their interaction in modern society. That is why, for a deeper understanding of the dynamics of generations and their impact on various social processes, including digital marketing, it is advisable to apply the mathematical model of APL. This model integrates demographic, cultural and technological factors that determine the development of generations, and allows us to predict their trends, thereby providing a scientifically sound toolkit for analysis and decision-making in the relevant industries.

Simulating the impact of Generations Z, Alpha, and Beta on the development of digital marketing involves creating a model that allows you to simulate behavioral, social, and technological changes that occur as a result of the interaction of these generations with digital platforms and marketing strategies.

Generation Z is the most technologically literate generation that grew up on mobile devices and social networks. They are distinguished by their rapid adoption of new technologies, active use of online shopping platforms, and the great influence of social networks on their decisions. These features require the adaptation of digital marketing strategies, which should be focused on content personalization, interactivity, and the use of the latest technologies (e.g., video, influencer marketing, memes).

Generation Alpha is the first digital native, which significantly increases the importance of technology in their lives. They actively use voice assistants, augmented reality, and other interactive tools that change the approach to marketing. The challenge for marketers is to create experiences that

meet these expectations, using multi-sensory technologies and innovative advertising formats such as interactive videos and gamification.

Generation Beta is predicted to be even more digitally connected. They may be more receptive to artificial intelligence, personalized recommendations, and innovative technologies such as virtual reality (VR) and augmented reality (AR). This generation will create new challenges for digital marketing, requiring brands to be even more intuitive and adaptive.

Simulating this impact allows us to model not only changes in the technological environment, but also sociocultural trends that will shape marketing strategies for each generation. This makes it possible to predict consumer needs, determine the most effective communication channels, and adapt marketing tools to the rapidly changing preferences of young audiences.

Generational analysis (Z, Alpha, Beta) can be described by a mathematical model in the context of **the human support apparatus (HSA)** as a social system that evolves under the influence of demographic, technological and cultural changes.

Here is a mathematical model for the analysis of generations (Z, Alpha, Beta) in the context of the human support apparatus (HSA) as a social system.

$$P(t) = \begin{bmatrix} P_Z(t) \\ P_A(t) \\ P_B(t) \end{bmatrix}$$

Let:

$P(t)$ — the population distribution by generations at a point in time, i.e. the vector:

where, $P_Z(t)$, $P_A(t)$, $P_B(t)$ are the number of generations Z, Alpha and Beta, respectively.

$T(t)$ — the level of technological development (for example, the digitalization index).

$C(t)$ — the cultural level of society (can be taken into account through the level of education, availability of information, etc.).

$D(t)$ — demographic factors (birth rate, mortality, migration).

The model includes the following differential equations: **1. Dynamics of the number of generations**

$$\frac{dP_Z}{dt} = \lambda_Z P_Z + \mu_A P_A$$

$$\frac{dP_A}{dt} = -\lambda_A P_A + \mu_B P_B + \beta_Z P_Z$$

$$\frac{dP_B}{dt} = -\lambda_B P_B + \beta_A P_A$$

Where:
- λ_i — the rate of aging and the exit of a generation from active influence on society.
- μ_i — the coefficient of transfer of knowledge and experience from one generation to the next.
- β_i — the coefficient of adaptation of generations to technological changes.

2. Technological development

$$\frac{dT}{dt} = \alpha_T (P_A + P_B) - \delta_T T$$

Where:
- α_T — the influence of younger generations on technological development.
- δ_T — the rate of moral obsolescence of technologies.

3. Cultural evolution

$$\frac{dC}{}$$

$$\underline{\quad} dt = \gamma c P_A - \delta c C$$

Where:
- γ_c— the contribution of the Alpha generation to cultural development.
- δ_c— the decrease in the cultural level due to the change of generations.

4. Demographic factors

$$D(t) = B(t) - M(t) + M_i(t) \text{ Where:}$$

- $B(t)$— the fertility rate.
- $M(t)$— the mortality rate.
- $M_i(t)$— the migration rate.

Thus, the interaction of generations with technological, cultural and demographic development forms a complex system of dynamic equations that describes the evolution of the APL. The proposed mathematical model substantiates the relationship between generations Z, Alpha and Beta in the context of a socio-economic system that develops under the influence of technological, cultural and demographic changes. It makes it possible to analyze how the number of generations is changing, how they affect the development of society and what trends will be decisive in the future. The model allows you to assess the speed of implementation of new technologies, the level of their perception by different generations and their contribution to digital transformation. It also helps to predict changes in the labor market, the adaptation of society to the digital economy and the formation of educational and social strategies. The calculation of the model is necessary for a comprehensive analysis of the development of society, which allows you to make informed decisions in the field of economics, education and social policy.

Conclusions. To scientifically substantiate the impact of generations on digital marketing, the article proposes a mathematical model that describes the interaction of demographic, technological and socio-cultural factors. The model allows us to analyze how the role of each generation in the digital environment is changing, what factors affect the perception of marketing messages and how marketing strategies can adapt to these changes. The use of mathematical approaches allows us not only to explain current trends, but also to predict the future development of digital marketing in the context of generational evolution.

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