Hierarchical modeling of factors influencing the quality of interactive editions design*

Alona Kudriashova[1,*,†], Iryna Pikh[1,†], Vsevolod Senkivskyy[1,†], Irina Kalinina[2,†] and Yurii Slipetskyi[1,†]

[1] *Lviv Polytechnic National University, Stepan Bandera Str., 12, Lviv, 79013, Ukraine*
[2] *Petro Mohyla Black Sea National University, Desantnykiv Str., 68, Mykolaiv, 54000, Ukraine*

Abstract

Reader demands for book products are constantly increasing. There is a growing popularity of interactive editions. Therefore, building a model that prioritizes the influence of factors on the quality of interactive edition design, based on their weighted coefficients, is a relevant scientific task, and the goal of this research. A set of factors influencing the quality of the studied process has been formed, which is of great importance for predicting the optimal algorithm for its progression and achieving the expected result. A semantic network has been constructed, illustrating the relationships between factors, and serving as the basis for determining their weighted values. A formalized representation of the relationships between factors has been carried out using elements of predicate logic. The ranks and priority levels of the factors have been determined by constructing hierarchical trees of direct and indirect influences and dependencies using the ranking method. A multi-level structured model has been built, which reflects the place of each factor in the overall hierarchy and illustrates the connections between them, as defined in the semantic network. The weighting of the factors has been refined using the hierarchy analysis method, and an optimized model for the priority influence of factors on the quality of interactive edition design has been developed. The results, obtained through experimental research and mathematical modeling, can be used for managerial decision-making regarding interactive edition design, allowing for improved printing production efficiency and the quality of the finished book.

Keywords

interactive edition, design, factor, semantic network, ranking, priority, model, quality

1. Introduction

In recent years, book production technologies have undergone significant changes [1–3]. Innovative products — interactive books — have appeared on the market [4–6]. An interactive book is an edition that integrates traditional textual content with multimedia and digital elements, providing active interaction between the reader and the material. Such an edition may include audio, video, animations, hyperlinks, and other interactive components that enhance the perception of information. An interactive book can be produced in both digital and printed formats, where printed editions are supplemented by technological means such as QR codes or augmented reality applications that activate supplementary content. This book format allows for deeper user immersion into the content, enabling the creation of multi-layered narratives and interaction tailored to the audience's needs.

The total computerization has not only increased the variability of publication and design formation but has also fundamentally changed the methodology of these processes. An increasing

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* Corresponding author.
† These authors contributed equally.
alona.v.kudriashova@lpnu.ua (A. Kudriashova); iryna.v.pikh@lpnu.ua (I. Pikh); vsevolod.m.senkivskyi@lpnu.ua (V. Senkivskyy); irina.kalinina@chmnu.edu.ua (I. Kalinina); yurii.b.slipetskyi@lpnu.ua (Yu. Slipetskyi)
0000-0002-0496-1381 (A. Kudriashova); 0000-0002-9909-8444 (I. Pikh); 0000-0002-4510-540X (V. Senkivskyy); 0000-0001-8359-2045 (I. Kalinina); 0009-0003-6931-6767 (Yu. Slipetskyi)

number of key issues in preparing publications for print are being solved through the automation of prepress processes, the primary means of which are computer publishing systems [7].

The activities aimed at producing print products have a systematic nature. The primary signs of systematicity in any activity are goal orientation and algorithmicity [8]. The primary goal of printing enterprises is to produce high-quality printed products. In addition to the main goal, a hierarchy of goals may be created, where intermediate and higher-level goals exist. In the editorial and publishing process, intermediate goals may include the successful selection of the author's original work, the correct determination of the type of edition, the choice of the design option for the edition, quality editing, illustration, and font design, layout, and others, while higher-level goals may include the formation and design of the edition, the production of a sample copy, successful distribution of the edition, building a customer base, and more. The algorithmicity of activity lies in the sequential execution of operations necessary to achieve these goals.

The systematic approach allows for rational and comprehensive solutions to the tasks at hand. However, it should be noted that the execution of any tasks in the editorial and publishing process is impossible without the intellectual, creative, and reproductive work of the professional publishing team. In fact, a computer publishing system is a set of tools designed to meet the production needs of editors, proofreaders, designers, and other specialists.

In contrast to the positive trends of automation and computerization of prepress processes, there is also a trend of declining editorial and publishing culture in book design. This negative phenomenon is associated with two main factors. The first is the increase in the number of titles of printed editions and the reduction in the time allocated for their production. The fast pace of societal activity demands more efficiency in the development and production of printed products. As a result, the workload on publishing industry workers has increased. Due to the lack of an a priori quality assurance algorithm, design elements of the edition often do not receive adequate attention.

Additionally, this problem has arisen due to a careless attitude toward prepress preparation. Often, people who are proficient with the necessary software and hardware tools but do not understand the basics of publishing and printing processes are allowed to participate in the book creation process. This is the second factor that negatively affects editorial and publishing culture, effectively destroying it. The formation and design of a publication have shifted from a creative, intellectual process to an unsystematized execution of operations without adhering to necessary standards and requirements. As a result, there is a high probability of producing book products that fail to meet consumers' aesthetic and practical needs. Therefore, simply knowing how to use a computer should not be a qualification for working on book creation. Below is the ontology [9–11] of interactive edition design, which reflects the core concept of key factors and provides insight into the multitasking and variability of the studied process (Fig. 1).

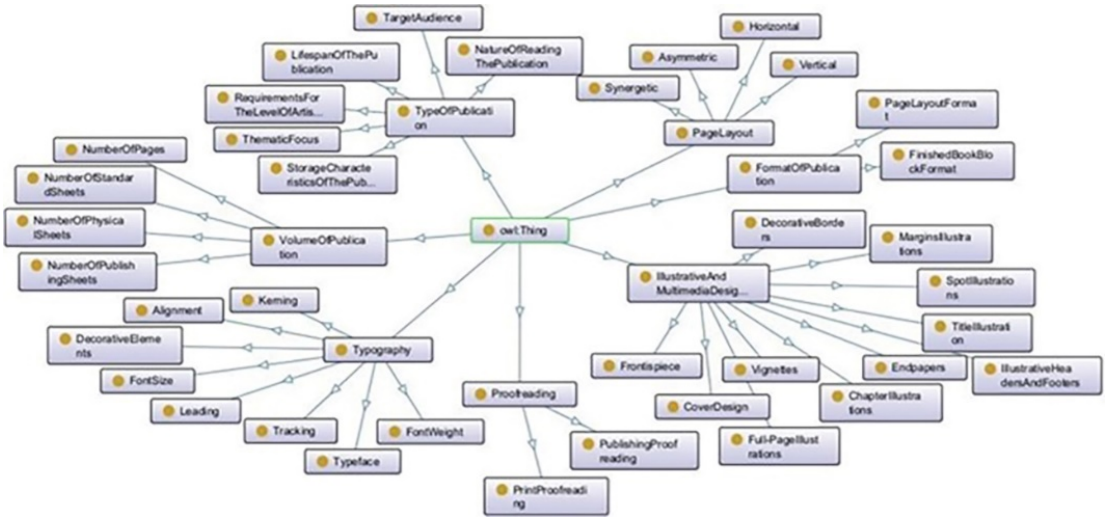

Figure 1: Ontology Graph of Interactive Book Edition Design.

To optimize publishing processes, maximum integration and harmonious functioning of the three levels of computer publishing systems are required: hardware, software, and user. Inconsistent, chaotic execution of operations and a lack of understanding of the connections between them result in an inability to predict the final outcome, which undoubtedly negatively affects the quality of the finished publication.

To ensure a high level of book quality and improve the efficiency of the publishing house as an organizational system, it is necessary to ensure thoughtful, consistent, and orderly execution of production procedures. This is possible by understanding the prioritization of key factors influencing the quality of interactive book editions, particularly one of the key stages — design. Therefore, determining the weighted values of the factors and constructing a model for the priority influence on the quality of interactive edition design is a relevant scientific task, and its resolution will be the goal of this research. Achieving this goal will promote the development of rational managerial decisions during the design of the edition and provide direct executors with a solid theoretical and practical foundation, serving as a guide not only for technical operations but also for the creative component.

2. Literature review

An analysis of literary sources on this topic shows that the issue of forming the quality of interactive editions is relevant and widely discussed. According to [12], the development and research of interactive books fully align with the challenges of today, due to the continuous penetration of advanced technologies into all spheres of human life. Attention is focused on comparing the level of knowledge acquisition by students through working with traditional versus interactive editions. For instance, when using a specific test sample of an interactive book, learning effectiveness reached 90,7%, product practicality was 91,8%, and attractiveness reached 94,2%. Based on the study [13], it can also be concluded that student motivation increases due to the use of interactive books — 96,37%.

From the perspective of evaluating the quality of book products, an interesting study [14] analyzed reader behavior at various stages of book consumption using the expectation confirmation theory. It is stated that readers can send feedback not necessarily after full consumption but at any point along this trajectory, even before consumption begins. The results show that a significant number of consumers leave positive or negative feedback before they start reading or after progressing to an early chapter of the book. The data confirm the correctness of the research vector chosen for our study, demonstrating that the initial impression of a book's quality is formed based on design: the correct format selection, the suitability of font and illustration design to the type of publication, professional layout, etc.

It is important to identify the factors that have a key influence on the quality of interactive editions. In [15], a set of certain quality characteristics related to books and their usage is described. It compares the relationship between mobility, formats, and the weight of books, which are determined by their volume, and readers' bodily practices from the early print period to today. It is noted that the format and volume of the edition significantly influence the reader's interaction experience with the book, as they determine the convenience of holding the book, the degree of book opening, and the comfort of carrying it, for example, for reading on the way to work or study. In [16], the high competition among designers to attract readers' attention is rightly noted. It is mentioned that, for successful design at the initial project stage, the correct choice of edition type, which determines its further physical representation, is crucial. Typography is highlighted as a separate factor, being a simple and effective means of visual communication, through which each letter can convey a specific message. The selection of font design elements directly depends on the type of publication being designed. Attention is focused on the importance of layout as the process of organizing content that ensures readability and forms the hierarchy of the reader's attention to the elements of the book. Accordingly, proofreading the laid-out pages, i.e., copyediting, plays an important role. [17] also highlights the importance of layout as one of the key processes in book design, serving to create harmony, coherence among the elements of the publication, and

maintaining overall coordination between them. In [18, 19], research conducted in various fields of visual communication is discussed. Visual communication creates the same feelings and emotions among people, regardless of the language they speak. It is, therefore, a universal means of communication since vision is the most important human sense. Information obtained through vision is remembered more clearly than information received through other senses. Thus, many studies are dedicated to improving the quality of image reproduction, such as [20–22].

This work expands on the authors' previous research concerning the identification of the best alternative website design options based on linear aggregation of criteria and fuzzy preference relations [23], the study of reader demand for books [24], and the development of quality models for encyclopedias and reference books [25].

At the same time, the analysis of literary sources revealed a lack of studies focused on identifying sets of factors to determine the weight of their influence on the design process of interactive editions. Therefore, developing a model of prioritized factor influence on the quality of interactive book design, based on methods of systems analysis, ranking, hierarchy analysis, graph theory, and semantic networks, is a relevant scientific task.

3. Material and methods

3.1. Determining the priority of factors

The creation of any interactive edition begins with conducting a thorough market analysis and studying global trends to determine the relevance, expected demand, competitiveness of the product, and the purchasing power of potential reader-buyers. In addition, as with any other stage, during the design phase, it is crucial to meticulously follow all technological and aesthetic standards to avoid releasing low-quality products. Therefore, there is a need to identify and analyze the factors affecting the quality of the edition's design and to determine their priority.

The formalized representation of the relationships between the factors of interactive edition design will involve the application of semantic networks and their description based on elements of predicate logic. Structurally, a semantic network is a directed graph, where the set of nodes corresponds to a set of factors, and the arcs represent the functional relationships between them. The semantic network model creates a foundation for the further constructive description of the subject area; it is visually clear and intuitive, as it is analogous to modern concepts of human memory's physiological mechanisms [23].

Predicate logic is a part of mathematical logic, and its formal language is represented by terms (any variables, constants, or functions) and the relationships between them—predicates (a logical function that can take the value “true” or “false”). Here, we will provide some constructions of predicate logic language that are used for the formal description of relationships between terms through predicate formulas. The latter consist of simple (atomic) predicates and logical connections: $\wedge$ — Logical “and”; $\leftarrow$ — “if”; $\forall$ — Universal quantifier (for all); $\exists$ — Existential quantifier (there exists at least one). In the context of the editorial and publishing process, we will refer to the terms as factors, and the relationships between them will be illustrated by predicates. Thus, the use of predicate logic in this work involves deriving all relationships between factors, taking into account the structure of the semantic network.

In further research, it is advisable to consider the following definitions and statements [24].

Definition 1. Any technological process in printing production includes a set of factors that have a decisive influence on the quality of its implementation, and, accordingly, on the quality of the printed product.

Let $R = \{r_1, r_2, \ldots, r_m\}$ — an arbitrary set of technological processes; $D = \{D_{1_m}, D_{2_m}, \ldots, D_{n_m}\}$ — a set of factors influencing the quality of interactive edition design, where n_m — the number of factors m - the process. We will also consider that

$$A(D_k) = \bigcup_{j=1}^{n} w(D_{jk}), \quad (k = 1,2,...,m), \tag{1}$$

where: $A(D_k)$ — numerical indicator of the quality function ^{m}-the process; $w(D_{jk})$ — numerical weighted indicator of the contribution ^{j}- th technological process. Then the definition can be presented as follows:

$$(\exists p)(\forall D)\, A(D_k); \quad r \in R; \quad d \in D. \tag{2}$$

Definition 2. The rank and priority of a factor are determined by its weight coefficient. Among any set of factors, at least one priority factor can be identified.

Thus, for the set of $W = \{w_{1_m}, w_{2_m}, \ldots, w_{n_m}\}$ the weights of the factors in the design of interactive editions, provided that $B(w) = max\{w_{1_m}, w_{2_m}, \ldots, w_{n_m}\}$, we will have:

$$(\exists p)(\forall w)B(w); \quad r \in R; \quad w \in W. \tag{3}$$

Statement 1. The existence of connections between factors is a prerequisite for their formal representation in the form of a graph.

Statement 2. Taking into account and analyzing the influences and dependencies between factors in the initial graphical model, constructed based on expert judgments, allows for determining the initial ranks of the factors.

Statement 3. When comparing factors within the initial graph, the synthesized multi-level model only shows the advantages among them.

Statement 4. The identification of final weight values, which determine the rank and degree of influence of factors on the design of interactive editions, is possible through the creation and processing of a pairwise comparison matrix and the calculation of the normalized components of the principal eigenvector of the matrix.

Definition 3. The set of factors, ordered by descending their normalized weight values, does not contain factors that are absolutely identical in their degree of influence on the quality of interactive edition design.

Provided that $C(w) = w_j > w_{j+1}$ for $(j = 1,2,\ldots n-1)$ It would be fair to note:

$$(\forall w)C(w); \quad w \in W. \tag{4}$$

According to Statements 1–4, the synthesis of a multi-level model of the influence of factors on the quality of interactive edition design is carried out by identifying the factors characteristic of the analyzed process, creating, analyzing, and processing the initial graphical model, in which connections between factors have been established based on expert judgments.

The basis of the ranking method is numerical indicators related to the quantities of influences and dependencies between factors and their corresponding weight coefficients. In this context, we distinguish between direct actions, referred to as first-order influences, and indirect actions, referred to as second-order influences. Dependencies will also be distinguished, establishing similar first and second orders of importance for them.

To calculate the total weight values of direct and indirect influences of factors and their integral dependence on other factors, we will introduce corresponding notations. Let q_{ij} — the number of influences or dependencies for j -th factor $(j = 1,\ldots,n)$; w_i — weight i -th type. We will distinguish certain types of connections between factors, which will depend on the type of connection identified by a numerical index value, namely: $i = 1$ — first-order influences; $^{i=2}$ — second-order influences; $i = 3$ — first-order dependencies; $i = 4$ — second-order dependencies.

For calculations, we will establish certain conditional numerical values for the weight coefficients concerning the types of interconnections. We will consider that for both types of influences, the weights will be positive, i. e. $w_1 > 0$, $w_2 = \frac{w_1}{2}$, while for dependencies, they will be negative, namely: $w_3 < 0$, $w_4 = \frac{w_3}{2}$. The integral weight values of the factors based on the sums of the weights of all types of connections will be denoted as D_{ij}.

Ultimately, we will obtain the following formula for calculations:

$$D_{ij} = \sum_{i=1}^{4} \sum_{j=1}^{n} q_{ij} w_i , \tag{5}$$

where n — is the conditional number of the factor in the technological process or its stage.

Since, according to the specified initial conditions, $w_3 < 0$ and $w_4 < 0$, thus, respectively, $D_{3j} < 0$ and $D_{4j} < 0$. To bring the weight values of the factors "to the beginning of the coordinates", meaning to obtain positive values, it is necessary to shift the histogram of the integral graphical representation of all types of connections upward based on the relationship:

$$\Delta_j = max\left|D_{3j}\right| + max\left|D_{4j}\right|, \left(j = 1,2,...,n\right). \tag{6}$$

Taking into account (5) and (6), the final formula for obtaining the total weight values of the factors will be as follows:

$$D_{Fj} = \sum_{i=1}^{4} \sum_{j=1}^{7} \left(q_{ij} w_i + \Delta_j\right). \tag{7}$$

The values D_{Fj} serve as the basis for ranking weights, i.e., establishing the levels of factors influencing the quality of interactive edition design. Based on the results of the ranking, we synthesize a graphical model according to the obtained weight values, reflecting the priority influence of the factors on the process.

3.2. Optimization of the Multi-Level Model of Factors

The primary significance of optimization lies in improving the input data through the application of an appropriate and reasonable set of measures. The optimization of the interactive edition design model is carried out using the hierarchy analysis method, which involves solving a series of tasks [24]:

- Construction of a pairwise comparison matrix of factors using a scale of relative importance of the objects.

In this case, the order of the matrix is determined by the number of analyzed factors, with the established weights of the factors $\left(d_n, d_m\right)$ being compared pairwise based on expert evaluations for each row and column of the matrix A. We accept that $A = \left(a_{ij}\right)$. The matrix is constructed in the form of a table and is inversely symmetric, meaning $a_{ij} = 1/a_{ij}$, and the elements of the main diagonal are equal to one. To facilitate the expert's work, the scale of relative importance of objects according to Saaty is used (Tab. 1).

Table 1
Scale of Relative Importance of Objects

Importance Rating	Comparison Criteria	Explanation for Choosing the Criterion
1	Objects are equivalent	No advantage d_n on d_m
3	One object slightly dominates the other	There is a basis for a weak advantage over d_n on d_m
5	One object dominates the other	There is a basis for a significant advantage over d_n on d_m
7	One object significantly dominates the other	There is a basis for a clear advantage over d_n on d_m

9	One object absolutely dominates the other	Absolute advantage d_n on d_m Is undisputable
2,4,6,8	Intermediate values	Auxiliary comparative assessments

- Calculation of the components of the principal eigenvector of the pairwise comparison matrix. The principal eigenvector $D(d_1, d_2, \dots, d_n)$ is defined as the geometric mean of the elements of each row of the matrix:

$$D_i = \sqrt[n]{a_{i1} \cdot a_{i2} \cdot a_{in}} \quad i = \overline{1,n}, \tag{9}$$

where n — the number of factors.

- Normalization of the values of the components of the principal eigenvector of the pairwise comparison matrix, which form the set of optimal weight values for the factors influencing the quality of the process.

The normalized components of the vector D_n define the optimized numerical priorities of the factors and establish the preliminary result of solving the task.

$$D_{in} = \frac{\sqrt[n]{a_{i1} \cdot a_{i2} \cdot a_{in}} \quad i = \overline{1,n}}{\sum_{i=1}^{n} \sqrt[n]{a_{i1} \cdot a_{i2} \cdot a_{in}}} \tag{10}$$

To facilitate the presentation of the weight values of the factors, we multiply the optimized components of the vector D_n by an arbitrary coefficient k. The consistency of the weight values of the factors is evaluated by multiplying the pairwise comparison matrix on the right by the vector D_n. As a result of the calculation, we obtain the normalized vector D_{n1}. The components of the eigenvector D_{n2} of the pairwise comparison matrix are obtained by dividing the components of the vector D_{n1} by the corresponding components of the vector D_n.

- Verification of the optimization results based on the criterion of the maximum value of the principal eigenvalue of the pairwise comparison matrix, normative values of the consistency index, and the consistency ratio.

The maximum eigenvalue $\lambda_{\max}$ of a positive, inversely symmetric matrix A is determined as the arithmetic mean of the components of the vector D_{n2}. The evaluation of the obtained solution is determined by the consistency index IU, which is calculated using the formula:

$$IU = \frac{\lambda_{\max} - n}{n - 1} \tag{11}$$

The obtained values are compared with the reference values of the consistency index—the random index DI. The results can be considered satisfactory if the calculated consistency index IU does not exceed 10% of the reference value of the random index DI, chosen based on the number of factors being analyzed.

Thus, to confirm the adequacy of the solution to the given task, the inequality $IU < 0{,}1 \times DI$ must hold. Below is a table of random index values for matrices of different orders, where the order of the matrix corresponds to the number of analyzed objects (factors) and is indicated in the first row, while the reference consistency index value for each order is indicated in the second row.

Table 2
Random Index Values for Matrices of Different Orders

Number of objects	3	4	5	6	7	8	9	10	11	12	13	14
Reference value of the index	0,58	0,90	1,12	1,24	1,32	1,41	1,45	1,49	1,51	1,54	1,56	1,57

Additionally, the results are evaluated using the consistency ratio, which is calculated by the formula: $DU = IU/DI$. The results of pairwise comparisons can be considered satisfactory if $DU \le 0{,}1$. This will indicate a sufficient level of process convergence and adequate consistency in expert judgments regarding the pairwise comparisons of the factors, as reflected in the corresponding matrix.

- Synthesis of the optimized model for the prioritized influence of factors on the quality of interactive edition design.

To obtain the weight values of the factors based on the multi-level model of factors, we assign them a grading of conditional numerical values according to the level of factor dominance, starting from the lowest. Let the weight of the lowest level be equal to 20 conditional units, and the weight of each subsequent level increase by 20 conditional units relative to the previous factor. The obtained numerical values of the factors are presented as components of the initial vector D_0, according to their order in the matrix. Based on the obtained weight values represented by the vectors D_n and D_0 we construct a histogram and a comparative graph. After a detailed analysis and comparison of the initial and normalized vectors, we synthesize the optimized model for the prioritized influence of factors on the process. This model serves as the basis for designing alternative and calculating optimal options for implementing the technological process, its stages, or individual operations, where the factors are ranked by weight coefficients of importance, which is a logical and promising continuation of the presented research.

4. Experiment, results and discussion

To ensure proper execution of the publication's design, where the quality of the result directly influences the quality of the final product, it is necessary to identify and examine a set of interrelated factors in this process, where the priority of each depends on the number of direct and indirect influences and dependencies.

The initial formalized representation of the relationships between the factors forming the design of an interactive edition, as mentioned above, will involve the application of semantic networks and their description based on elements of predicate logic.

We will assume that $D = \{D_1, D_2, D_3, D_4, D_5, D_6, D_7\}$ — the set of factors forming the design of an interactive edition, where D_1 — the type of edition; D_2 — the volume of the edition; D_3 — the format of the edition; D_4 — the layout of the pages; D_5 — proofreading; D_6 — font design of the edition; D_7 — illustrative and multimedia design of the edition.

We will form a semantic network of connections between the identified factors influencing the quality of interactive edition design (Fig. 2).

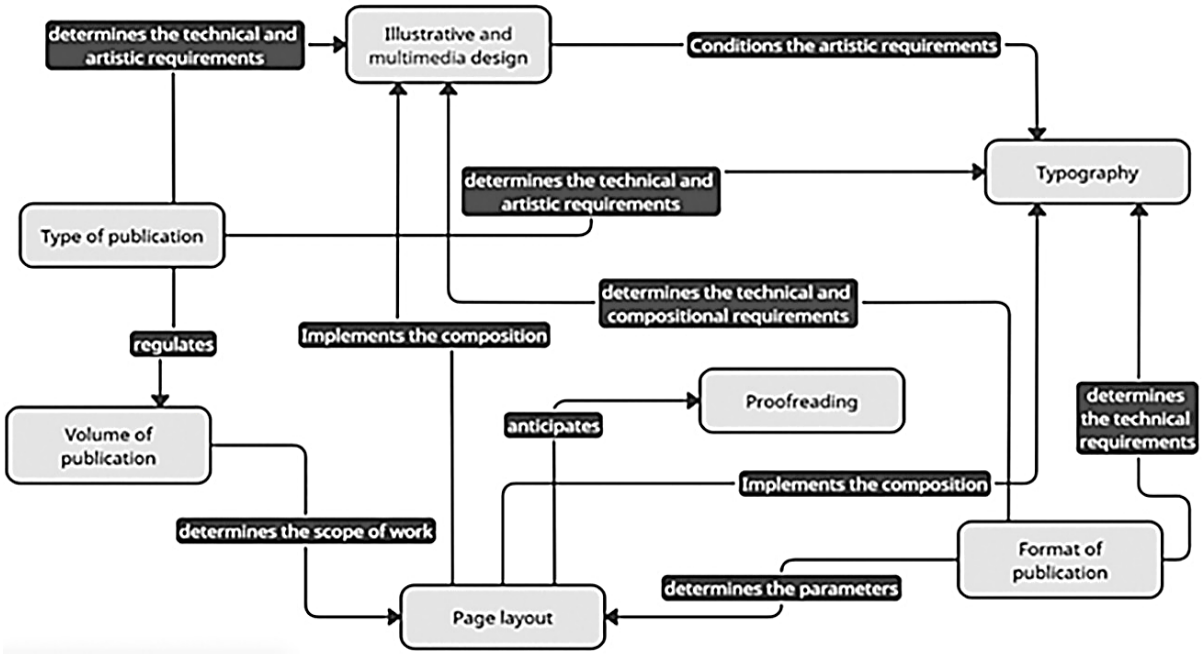

Figure 2: Semantic Network of Factors Structuring the Edition.

Using predicate language constructions, the functional relationships between the factors of interactive edition design will be presented as follows:

$(\forall D_i)$ [$\exists$ (D_1, type of edition) $\leftarrow$ regulates (D_1, D_2) $\wedge$ defines technical and artistic requirements (D_1, D_6) $\wedge$ defines technical and artistic requirements (D_1, D_7)];

$(\forall D_i)$ [$\exists$ (D_2, volume of the edition) $\leftarrow$ determines the scope of work (D_2, D_4) $\wedge$ is regulated (D_2, D_1)]; $(\forall D_i)$ [$\exists$ (D_3, format of the edition) $\leftarrow$ defines the parameters (D_3, D_4) $\wedge$ defines technical requirements (D_3, D_6) $\wedge$ defines technical and compositional requirements (D_3, D_7)];

$(\forall D_i)$ [$\exists$ (D_4, layout of the pages) $\leftarrow$ foresees (D_4, D_5) $\wedge$ implements the composition (D_4, D_6) $\wedge$ implements the composition (D_4, D_7) $\wedge$ is determined by the scope of work (D_4, D_2) $\wedge$ parameters are established (D_4, D_3)]; $(\forall D_i)$ [$\exists$ (D_5, proofreading) $\leftarrow$ is anticipated (D_5, D_4)];

$(\forall D_i)$ [$\exists$ (D_6, font design of the edition) $\leftarrow$ technical and artistic requirements are taken into account (D_6, D_1) $\wedge$ technical requirements are taken into account (D_6, D_3) $\wedge$ the composition is realized (D_6, D_4) $\wedge$ artistic requirements are stipulated (D_6, D_7)];

$(\forall D_i)$ [$\exists$ (D_7, illustrative design of the edition) $\leftarrow$ stipulates artistic requirements (D_7, D_6) $\wedge$ technical and artistic requirements are taken into account (D_7, D_1) $\wedge$ technical and compositional requirements are taken into account (D_7, D_3) $\wedge$ the composition is implemented (D_7, D_4)].

To establish the ranks of the factors in the design of interactive editions, we will use the factor ranking method.

For the implementation of this method, we will construct hierarchical trees of connections with other factors for each factor based on the developed semantic network (Fig. 2), taking into account direct and indirect influences (Fig. 3) as well as direct and indirect dependencies (Fig. 4).

Based on the formulated statements and the introduced indicators, we will determine the total weight values of the direct and indirect influences of the factors, as well as their integral dependence on other factors. For calculations, we will accept the following conditional values for the weight coefficients in conditional units: $w_1 = 10$, $w_2 = 5$, $w_3 = -10$, $w_4 = -5$. We will inpu0t the calculated data using the formulas 2.1–2.8 into Table 3.

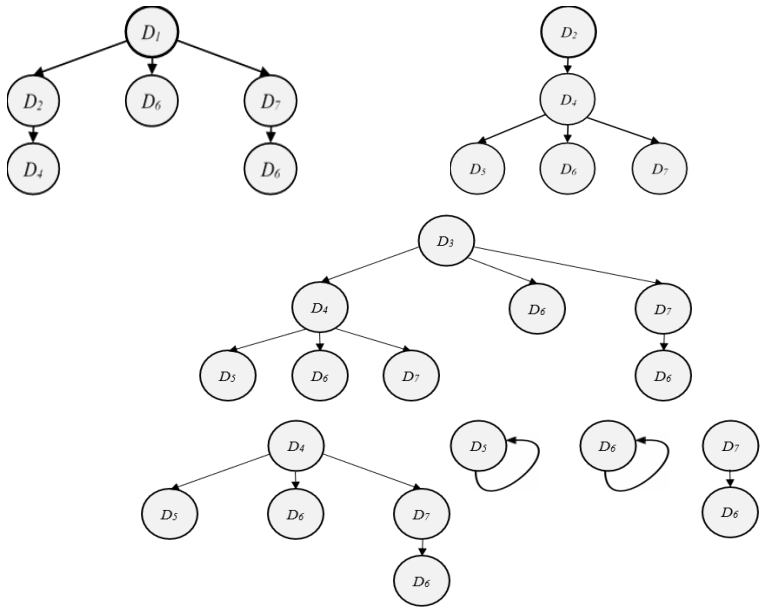

Figure 3: Graphs of Hierarchical Direct and Indirect Influences Between Factors of Interactive Edition Design.

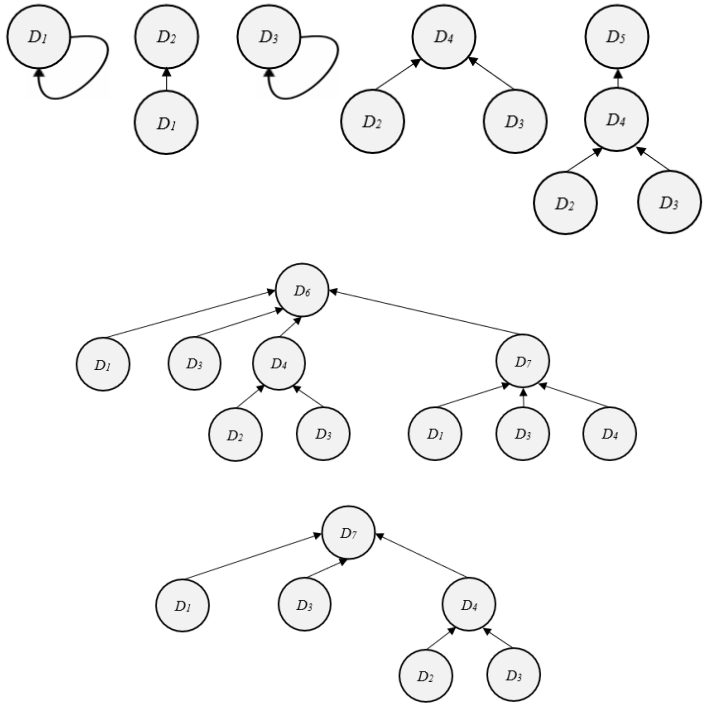

Figure 4: Graphs of Hierarchical Direct and Indirect Dependencies Between Factors of Interactive Edition Design.

Table 3
Calculated Data and Ranking of Factors in Interactive Edition Design

Factor Number j	q_{1j}	q_{2j}	q_{3j}	q_{4j}	D_{1j}	D_{2j}	D_{3j}	D_{4j}	D_{Fj}	Rank of the Factor r_i	Level of Priority
1	0	0	1	2	0	0	-10	-10	45	3	4
2	3	2	0	0	30	10	0	0	105	5	2

3	1	3	1	0	10	15	-10	0	80	4	3
4	3	4	0	0	30	20	0	0	115	6	1
5	3	1	2	0	30	5	-20	0	80	4	3
6	0	0	4	5	0	0	-40	-25	0	1	6
7	1	0	3	2	10	0	-30	-10	35	2	5

Using the ranking data, we will construct a multi-level structured model (Fig. 5) that reflects the position of each factor in the overall hierarchy and illustrates the connections between them as defined in the semantic network (Fig. 2).

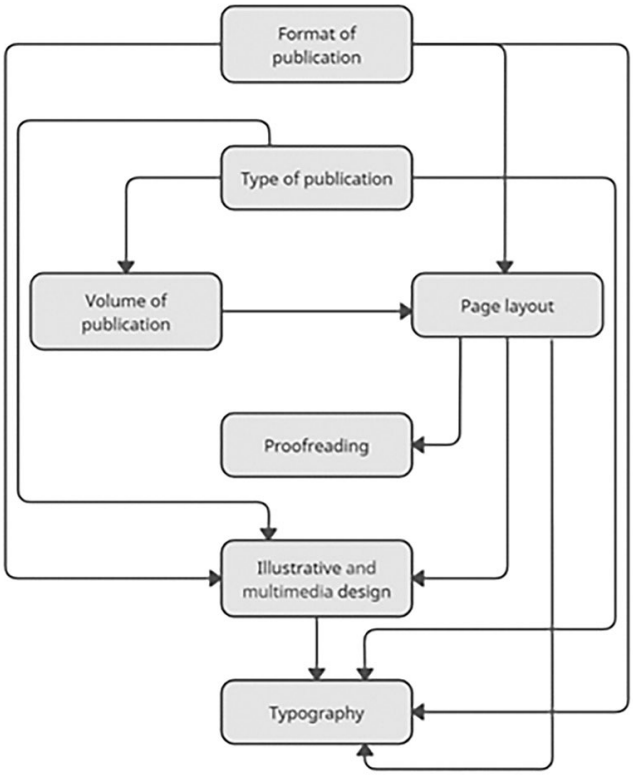

Figure 5: Multi-Level Model of Factors Influencing the Quality of Interactive Edition Design.

Thus, the highest level of priority belongs to the factor “format of the edition”, which is logical, as the subsequent choice of the technological process for producing the edition and the necessary equipment, under ideal conditions, depends on the chosen format. It should also be noted that as a result of the ranking, the factors “volume of the edition” and “layout” received the same level of priority. Therefore, the information regarding the weight values of the factors influencing the quality of interactive edition design should be clarified. To do this, we will use the method of multi-criteria optimization.

We will construct a pairwise comparison matrix of the design factors of the edition using the scale of relative importance of the objects (Tab. 1). For convenience, we will present the matrix in tabular form (Tab. 4):

Table 4
Pairwise Comparison Matrix of the Factors Structuring the Edition

	D_1	D_2	D_3	D_4	D_5	D_6	D_7
D_1	1	4	1/3	3	5	7	6
D_2	1/4	1	1/5	1/2	3	5	4

D_3	3	5	1	4	6	8	7
D_4	1/3	2	1/4	1	3	5	4
D_5	1/5	1/3	1/6	1/3	1	4	3
D_6	1/7	1/5	1/8	1/5	1/4	1	1/3
D_7	1/6	1/4	1/7	1/4	1/3	3	1

By calculating the pairwise comparison matrix of the factors, we obtain the principal eigenvector of the pairwise comparison matrix (2.9) D, the normalized vector (2.10) D_n, the normalized vector for evaluating the consistency of the weight values of the factors D_{n1} and the components of the eigenvector of the pairwise comparison matrix D_{n2}:

$$D = (0,641; 2,613; 1,06; 4,12; 1,388; 0,248; 0,394);$$

$$D_n = (0,061; 0,25; 0,101; 0,394; 0,133; 0,024; 0,038);$$

$$D_{n1} = (0,46; 1,886; 0,762; 2,973; 1,003; 0,181; 0,287);$$

$$D_{n2} = (7,540; 7,544; 7,545; 7,546; 7,541; 7,542; 7,553).$$

For the convenience of further comparison between the initial and normalized vectors, we will multiply the latter by an arbitrary coefficient, let's say $k = 500$. Then the adapted normalized vector will take the form:

$$D_n \times k = (30,5; 125; 50,5; 197; 66,5; 12; 19).$$

We will check the optimization results according to the criterion of the maximum value of the principal eigenvector of the pairwise comparison matrix, normative values of the consistency index, and the consistency ratio. After performing the calculations, we obtain: $\lambda_{\max} = 7,544$; $IU = 0,091$. The inequality $0,091 < 0,1 \times 1,32$ is valid, confirming the adequacy of the solution to the task. Since $DU = 0,069$, also holds, the execution of the inequalit $0,069 \le 0,1$ further confirms a sufficient level of convergence in the process and the adequate consistency of the expert judgments.

We will assign weight values to the factors based on the multi-level model of factors influencing the quality of interactive edition design (Fig. 5). We will obtain the following series of values: $D_6 - 20$, $D_7 - 40$, $D_5 - 60$, $D_4 - 80$, $D_2 - 80$, $D_1 - 100$, $D_3 - 120$. The obtained numerical values will be presented as components of the initial vector, according to their order in the matrix (Tab. 4): $D_1 - 100$, $D_2 - 80$, $D_3 - 120$, $D_4 - 80$, $D_5 - 60$, $D_6 - 20$, $D_7 - 40$.

We will obtain the initial vector: $D_0 = (100; 80; 120; 80; 60; 20; 40)$. The values of the factors D_n and D_0, as well as the adapted values $D_n \times k$ will be entered into comparative Table 5.

Table 5
Options for Weight Values of Factors in Interactive Edition Design

i	1	2	3	4	5	6	7
D_0	100	80	120	80	60	20	40
D_n	0,25	0,101	0,394	0,133	0,061	0,024	0,038
$D_n \times k$	125	50,5	197	66,5	30,5	12	19

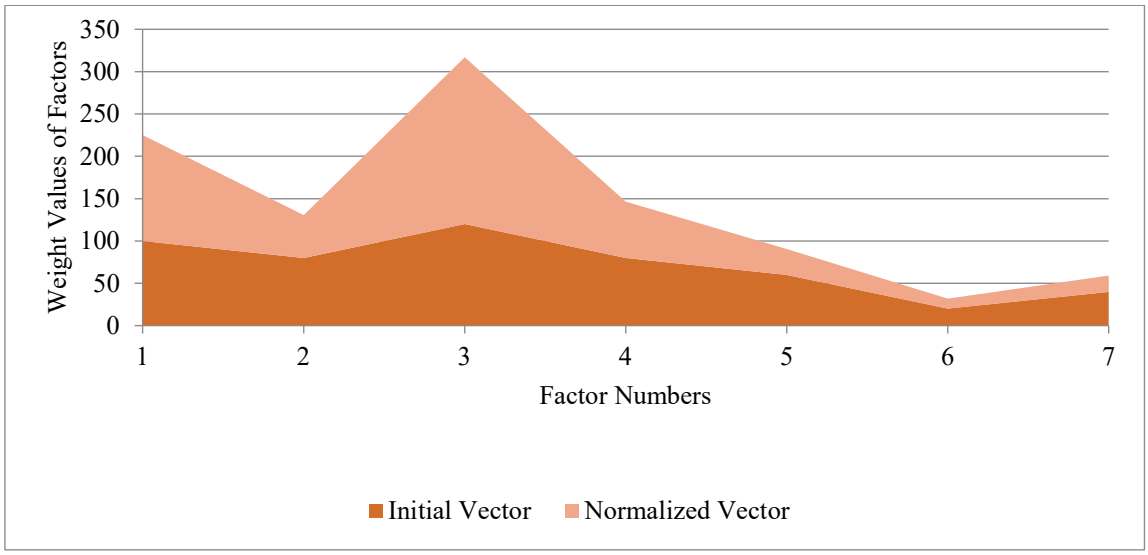

Figure 6: Comparative diagram of the weight values of the output vector components (D_0) and normalized (D_n) vectors.

After analyzing Fig. 6, we see that in order to synthesize the optimized model of the priority influence of factors on the process of forming the design of an interactive publication, it is necessary to use the components of the normalized vector. As a result of normalization, different weight values were established for factors D_2 and D_4.

When constructing the optimized model (Fig. 7), it will be possible to avoid the equal priority of factors D_2 and D_4, which was observed in the model obtained through the ranking of factors (Fig. 5).

Thus, the constructed model of factor priority influence reflects the importance of each factor for the design of an interactive publication. This was made possible through the formation of a set of factors using methods of expert evaluation, analysis, and synthesis. It was essential not only to highlight the influencing factors but also to demonstrate the direct and indirect influences and dependencies between them.

The visualization of the relationships between the analyzed factors was implemented using graph theory and semantic networks. The semantic network model (Fig. 2) became the foundation for the further constructive description of the subject area.

The formalized representation of the relationships between the factors influencing the quality of interactive publication design was achieved using elements of predicate logic.

Thus, the use of predicate logic in this work involved the formalized presentation of all relationships between factors, taking into account the structure of the semantic network.

Moreover, to establish the degree of influence of each factor on the quality of the analyzed process, it was decided to use the method of factor ranking. To implement the method in the process of publication design formation, based on the developed semantic network, hierarchical models of relationships between factors were built (Fig. 3, 4). Based on the determined priority levels (factor ranks) (Tab. 3), a multi-level model of factors influencing the quality of interactive publication design was synthesized. According to expert judgments and calculations, the factor with the highest weight is the “publication format”, while the lowest is “typographic design of the publication”.

In the course of the study, this model was optimized due to the presence of two factors with the same priority level (Fig. 6). The optimization of the model was driven by the need to improve input data and was carried out using the method of hierarchy analysis, which involves solving several tasks: constructing a pairwise comparison matrix (Tab. 4); calculating the components and normalizing the values of the main eigenvector (Expressions 9, 10); verifying optimization results based on the criteria of the maximum value of the main eigenvector, normative values of the

consistency index, and the consistency ratio; synthesizing the optimized model of factor priority influence on the quality of the analyzed process (Fig. 7).

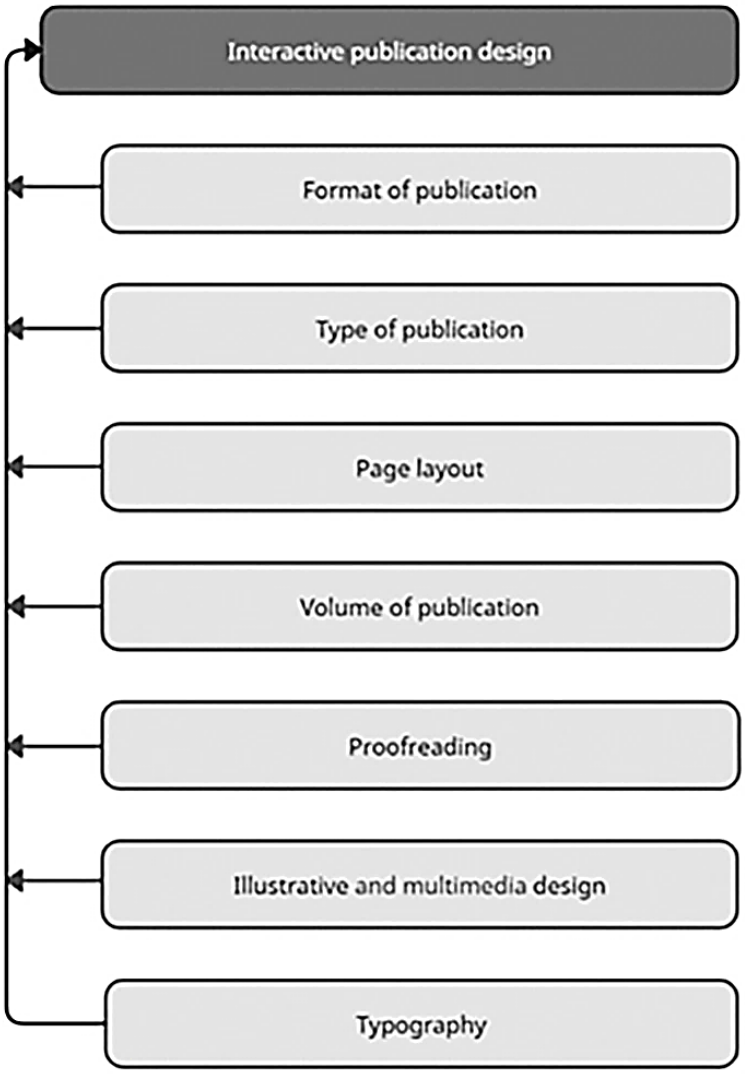

Figure 7: Optimized Model of Factor Priority Influence on the Quality of Interactive Publication Design.

The results of the study can be used in the planning and organization of work related to book design. The obtained information serves as the basis for forming a strategy for creating interactive book publications, which involves choosing optimal alternative options and provides an understanding of the necessary labor costs and the importance of factors. The prospect of further scientific research is associated with predictive evaluation of the quality of interactive publication design based on fuzzy logic methods and tools.

5. Conclusions

1. Based on expert evaluation, the following factors influencing the quality of interactive book design were identified: D_1 — type of publication; D_2 — volume of the publication; D_3 — format of the publication; D_4 — page layout; D_5 — proofreading; D_6 — typography; D_7 — Illustration and multimedia design of the publication.
2. A semantic network has been constructed that reproduces the connections between the factors influencing the quality of interactive book design. Using predicate logic, a formal representation of the relationships between these factors has been created.

3. The ranks of factors have been established for the process of designing interactive publications. Based on the developed semantic network, hierarchical trees of connections have been constructed for each of the factors involved in this process, taking into account both direct and indirect influences as well as direct and mediated dependencies.

4. Based on the ranking results, a synthesis of a graphical multi-level model of the factors influencing the quality of interactive publication design has been carried out. It has been determined that the factor D_3 "publication format" holds the highest priority level, while the factor D_6 "typographic design".

5. Using the hierarchical analysis method, the optimization of the multi-level model of factors influencing the quality of interactive publication design was carried out, due to the equal priority obtained for the factors D_2 "publication volume" and D_4 "page layout" in the previous research stage. As a result of the optimization, it was determined that the factor D_4 "page layout" has a higher priority than D_2 "publication volume" and the weight values of other factors were clarified. The optimization criteria include: the eigenvalues of the matrices $\lambda_{\max} = 7{,}544$, the consistency index $IU = 0{,}091$, and the consistency ratio $DU = 0{,}069$. These criteria fall within acceptable limits, indicating the adequacy of the problem solution.

6. A model of priority influence of factors on the quality of interactive publication design has been developed, which will serve as a theoretical and practical basis for making informed decisions regarding the technological operations related to the formation of the design of interactive books.

Declaration on Generative AI

The authors have not employed any Generative AI tools.

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