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MODELLING SEMANTIC RELATIONSHIPS BETWEEN THE FACTORS OF TYPOGRAPHIC AND COMPOSITIONAL ORGANISATION OF THE TYPESET PAGE

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The article investigates the problem of modeling semantic relationships among the factors of typographic and compositional organization of the typeset page as a complex multilevel system that determines the quality of book design and the effectiveness of printed information perception. The relevance of the study is the increasing complexity of design processes in publishing and printing production, where the parameters of page format, typeset area format, column structure, page component proportions, implementation of typographic and illustrative design, rules of text composition and layout, as well as overall page layout design exist in a state of multidirectional interdependence. The necessity of a systemic approach to structuring the factor space, taking into account both direct and indirect cause-and-effect relationships, is emphasized.

A formalized description of interactions based on the construction of a semantic network using predicate logic is proposed, ensuring a rigorous, consistent, and formally coherent representation of knowledge about the domain structure. The limitations of the predicate model in determining the relative significance of factors are demonstrated, which led to the transition to a directed graph representation of the factor system. A weighted model for the quantitative evaluation of structural interactions has been developed, providing differentiation of relationships by direction and depth of influence, the introduction of weighting coefficients, and the calculation of an integral index of structural participation for each factor, followed by normalization and ranking. Based on the obtained results, a hierarchical model of priority influence of factors has been formed, reflecting their structural role in the process of designing the initial parameters of a publication. The proposed approach creates prerequisites for integrating formalized models into decision-support systems in the publishing and printing industry. The practical significance of the study lies in establishing a methodological foundation for substantiated design decision-making and improving the quality of typographic and compositional solutions of the typeset page within publishing and printing production systems.

Keywords: *typographic and compositional organization; typeset page; semantic network; predicate logic; graph model; priority influence; integral index; multicriteria analysis; hierarchical model; publication quality; structural interaction of factors.*

Problem Statement. The quality of the typographic and compositional organization of the typeset page is formed under the influence of a set of interrelated technical, compositional, and semantic factors that determine page parameters, layout structure, typographic and illustrative design, and layout rules. Under contemporary conditions characterized by the multicriteria nature of design decision-making, these factors operate not in isolation but as elements of an integrated system with both direct and indirect cause-and-effect relationships. Existing studies predominantly address isolated aspects of typographic readability or layout automation, which does not provide a holistic understanding of the structure of their interaction.

The formalization of semantic relationships among factors based on predicate logic makes it possible to describe the system of interdependencies; however, it does not allow for determining the relative significance of each factor. The absence of a quantitatively substantiated model of priority influence complicates the adoption of optimal design decisions regarding the formation of a publication's initial parameters. This necessitates the development of a graph-hierarchical model that integrates qualitative description of interactions with their quantitative evaluation and ranking of factors within a unified system.

Analysis of Recent Research and Publications. **Analysis of Recent Research and Publications**

Contemporary scholarly discourse in the field of typographic and compositional organization of the typeset page has developed along three principal directions.

The first direction encompasses empirical studies of typographic readability. In the works of Charles Bigelow, the results of numerous experiments demonstrating a stable correlation between typographic characteristics and text perception metrics are systematized. B. D. Sawyer and colleagues identified statistically significant differences in the recognition speed of various typeface styles within comparative experimental frameworks, which is critical for typeface selection. In addition, Y. Matsuura and co-authors emphasize that font parameters directly influence character recognition accuracy during prolonged reading.

The second direction is associated with algorithmic analysis of document structure (Document Layout Analysis). A substantial contribution to this area was made by X. Zhong and collaborators through the development of the large-scale dataset PubLayNet, which enabled the standardization of layout accuracy metrics. B. Pfitzmann extended these approaches to heterogeneous document types within the DocLayNet project. The issue of segmentation error evaluation using the DLER metric is examined in detail in the works of A. Vesalainen. At the intersection of semantic and graph-based modeling, the developments of J. Wang should be noted; he proposed the GLAM model, in which the page is represented as a graph of interacting elements. A comprehensive review of graph neural network (GNN) architectures was provided by J. Zhou and colleagues. An overview of contemporary methods for annotation and taxonomy of scientific article layouts is presented in the work of A. Gemelli.

The third direction focuses on layout automation and multicriteria decision-making. S. M. Rebelo and co-authors demonstrated an automated layout composition system based on parameterized rules. In parallel, Z. Meng and collaborators proposed a graph-based decision-making model that enables balancing conflicting objectives, including aesthetic indicators, readability, and the economic cost efficiency of publication production.

Purpose of the Article. The purpose of this study is to develop and substantiate a model of the priority influence of factors in the typographic and compositional organization of the typeset page based on a formalized representation of their semantic interrelationships and graph-hierarchical structuring. The proposed approach provides quantitative evaluation of the structural significance of factors, determination of their rank distribution, and the formation of an ordered system for design decision-making aimed at optimizing the initial parameters of a publication.

Presentation of the main research material. The typographic and compositional organization of the typeset page emerges as the result of the interaction of numerous interdependent factors, the analysis of which constitutes a prerequisite for ensuring its qualitative characteristics.

Contemporary research in the field of visual communication demonstrates that the effectiveness of printed information perception is determined not only by textual content but also by the parameters of its visual representation. Empirical findings indicate that contrast, color combinations, typographic characteristics, and the structural organization of the layout directly affect reading speed, character recognition accuracy, and the level of cognitive load. It has been established that optimization of the spatial arrangement of elements and adherence to the principles of visual hierarchy contribute to improved readability in both print and digital media environments [1].

To achieve a high level of quality in the typographic and compositional organization of the typeset page—which directly affects the overall quality of printed production—it is necessary to identify and examine the complex of interdependent factors involved in this process, taking into account the priority of each factor depending on the number of its direct and indirect influences [2].

The initial formalized representation of relationships among the factors of typographic and compositional organization of the typeset page involves the application of semantic networks and their description using the formal apparatus of predicate logic [3].

Let us consider the set of factors $L = \{ L_1, L_2, L_3, L_4, L_5, L_6, L_7, L_8, L_9, L_{10}, L_{11}, L_{12}, \}$, де L_1 — publication page format, L_2 — typeset area format, L_3 — column structure, L_4 — implementation of typographic design of the publication, L_5 — development of illustrative design of the publication, L_6 — proportion of the components of the book page, L_7 — text complexity group, L_8 — illustration complexity group, L_9 — rules of text composition, L_{10} — rules of text layout, L_{11} — rules of illustration layout, L_{12} — page layout design.

The interaction among the key factors that shape the quality of the typographic and compositional solution of the typeset page can be appropriately represented in the form of a semantic network. [2].

The developed semantic network serves as an instrument for systematizing the factors that influence the formation of a publication's initial parameters.

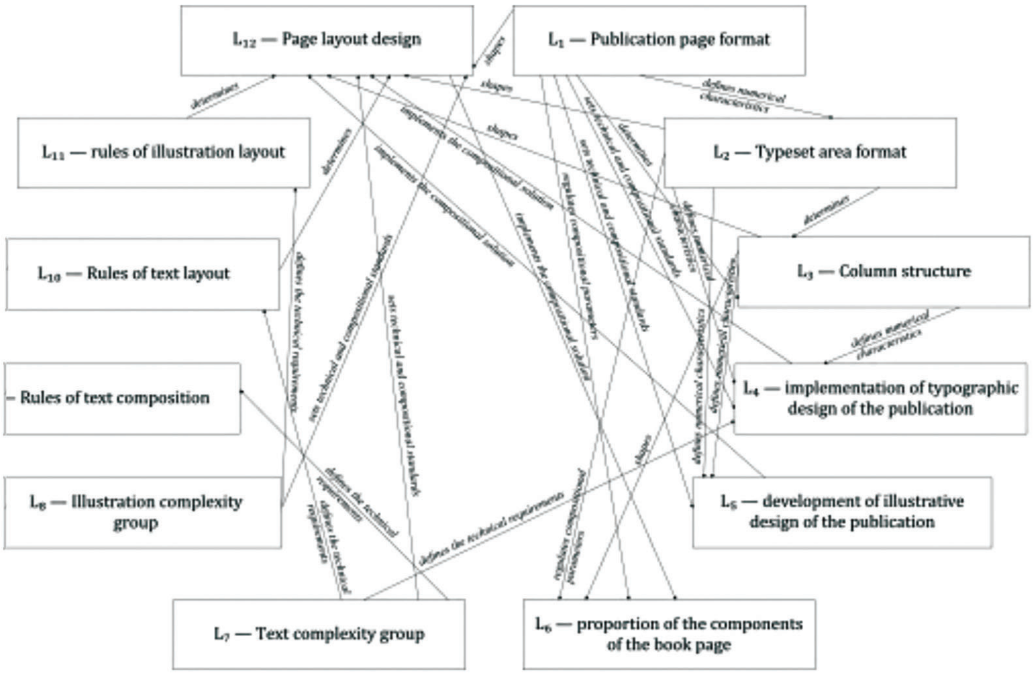

Fig. 1. Modeling of Semantic Relationships Among the Factors of Typographic and Compositional Organization of the Typeset Page

In the process of constructing semantic networks, relationships among factors are formalized using the language of predicate logic, within which semantic dependencies are described by predicate expressions. Such expressions are formed from elementary logical units combined through logical operators—conjunction (∧), interpreted as logical "and"; implication (←); and disjunction (∨), corresponding to logical «or»—as well as the universal (∀) and existential (∃) quantifiers. This framework ensures a rigorous, formally consistent, and non-contradictory description of relationships within the model.

The formalized description of functional relationships among the factors involved in designing a publication's initial parameters is carried out using predicate constructions of the following form:

$(\forall L_i)$ [∃ (L_1, Publication page format) ← defines numerical characteristics (L_1, L_2) ∧ determines (L_1, L_3) ∧ sets technical and compositional standards (L_1, L_4) ∧ sets technical and compositional standards (L_1, L_5) ∧ sets technical and compositional standards (L_1, L_6) ∧ shapes (L_1, L_{12})];

$(\forall L_i)$ [∃ (L_2, Typeset area format) ← determines (L_2, L_3) ∧ defines numerical characteristics (L_2, L_5) ∧ implements the compositional solution (L_2, L_6) ∧ shapes (L_2, L_{12})];

$(\forall L)$ [∃ (L_3, Column structure) ← defines numerical characteristics (L_3, L_4) ∧ defines numerical characteristics (L_3, L_5) ∧ shapes (L_3, L_6) ∧ shapes (L_3, L_{12})];

$(\forall L_i)$ [∃ (L_4, Implementation of typographic design of the publication) ← implements the compositional solution (L_4, P_{12})];

$(\forall L_i)$ [$\exists$ (L_5, Development of illustrative design of the publication) $\leftarrow$ implements the compositional solution (L_5, L_{12})];

$(\forall L_i)$ [$\exists$ (L_7, Text complexity group) $\leftarrow$ defines the technical requirements (L_7, L_4) $\wedge$ defines the technical requirements (L_7, L_9) $\wedge$ defines the technical requirements (L_7, L_{10}) $\wedge$ sets technical and compositional standards (L_7, L_{12})];

$(\forall L_i)$ [$\exists$ (L_8, Illustration complexity group) $\leftarrow$ defines the technical requirements (L_8, L_{11}) $\wedge$ sets technical and compositional standards (L_8, L_{12})];

$(\forall L_i)$ [$\exists$ (L_{10}, Rules of text composition) $\leftarrow$ determines (L_{10}, L_{12})];

$(\forall L_i)$ [$\exists$ (L_{11}, Rules of text layout) $\leftarrow$ determines (L_{10}, L_{12})];

$(\forall L_i)$ [$\exists$ (L_{12}, Page layout design) $\leftarrow$ implements the compositional solution (L_{12}, L_6)].

The formalized description of semantic relationships among factors, constructed using the apparatus of predicate logic, ensures a rigorous and non-contradictory representation of knowledge about the structure of the domain and makes it possible to capture substantive and causal relationships among the elements of the system [4].

At the same time, the predicate model is predominantly qualitative in nature and does not provide a direct assessment of the relative significance of factors, since it records only the existence of relationships among them. This necessitates a transition to a graph-based representation.

In the study of complex technological processes, particularly in the field of publishing and printing production, the task of determining the relative significance of factors belongs to the class of decision-making problems. The formation of such decisions is conditioned by the combined action of numerous factors and is characterized by the presence of multiple heterogeneous and interrelated criteria capable of influencing the outcome both directly and indirectly. This substantiates the expediency of applying a hierarchical approach to structuring the factor space, based on the integration of qualitative expert analysis with quantitative evaluation methods, in accordance with the general principles of factor-driven decision analysis [5].

The initial premise of the method is the assumption that any technological process is characterized by a finite set of factors

$$F = \{f_1, f_2, \ldots, f_n\}$$

each of which makes a certain contribution to the formation of the integral quality indicator. At the same time, the factors are not isolated: causal relationships exist among them, which may take the form of either influence or dependence. The presence of such relationships provides the basis for a formalized representation of the factor system in the form of a directed graph constructed on the basis of expert judgments, making it possible to identify initial assumptions regarding factor priority already at the stage of qualitative analysis [6].

To enhance the consistency of the model, it is proposed to differentiate types of relationships among factors according to two attributes: by semantic content (influence or dependence) and by depth of manifestation (direct or indirect). The number of direct interactions of the x-th factor is defined as follows:

$$N_x^{(1)} = \sum_{j=1}^{n} \delta_{xj}^{(1)},$$

where $\delta_{xj}^{(1)}$ — indicator function of a direct linkage between factors f_x and f_j. Second-level indirect interactions, realized through intermediate factors, are described by the following expression:

$$N_x^{(2)} = \sum_{j=1}^{n} \sum_{m=1}^{n} \delta_{xm}^{(1)} \times \delta_{xj}^{(1)}$$

This approach is consistent with contemporary conceptions of complex systems, in which substantial effects may arise from indirect, multistep interactions that are not captured in simplified models [7].

The quantitative interpretation of the identified relationships is carried out through the introduction of weighting coefficients α_1 and α_2, that reflect the relative significance of direct and indirect interactions, respectively $(\alpha_1 > \alpha_2 > 0)$. On this basis, an integral indicator of a factor's structural participation is formed

$$S_k = \alpha_1 N_x^{(1)} + \alpha_2 N_x^{(2)}$$

which aggregates the contribution of all types of its interactions with other factors. To ensure the validity of subsequent comparison and ranking, the indicators are normalized according to the following formula

$$\hat{S}_x = \frac{S_x}{\max\limits_{i=1,\dots,n} S_i}$$

The obtained normalized values are used to arrange the factors in descending order of priority, with each factor assigned a unique rank

$$R_x = rank(\hat{S}_x)$$

As a result, a hierarchically ordered set of factors is formed, reflecting their relative significance within the system. This approach correlates with the fundamental principles of the Analytic Hierarchy Process (AHP), in which element priorities are determined by aggregating local evaluations into a global scale of significance [8].

At the same time, in contrast to the classical AHP framework, the proposed methodology emphasizes internal interdependencies among factors, allowing them to be interpreted not as independent criteria but as elements of a unified, interconnected system. Based on the constructed interaction graph, a hierarchical tree of relationships with other factors is developed for each factor, representing both direct and indirect influences realized through other system elements. This form of representation enhances the transparency of the interaction structure and creates preconditions for the subsequent synthesis of priority influence models in predictive quality assessment of technological processes [4].

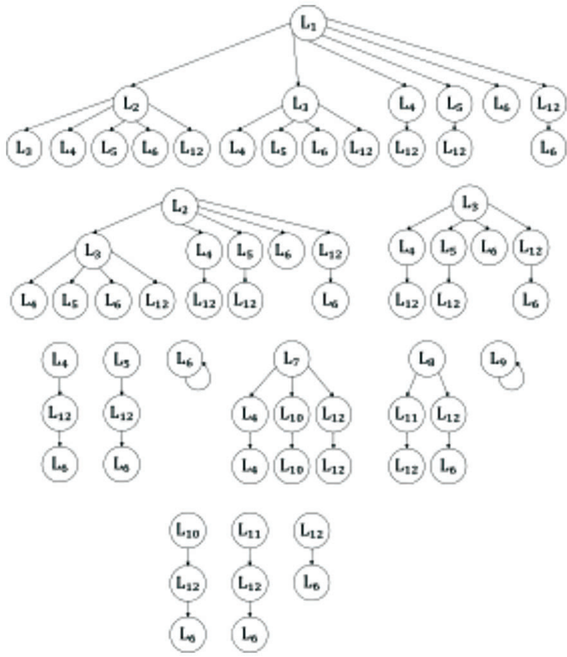

Fig. 2. Hierarchical graphs of interactions among factors of typographic and compositional organization of the typeset page with Identification of Direct and Indirect Relationships

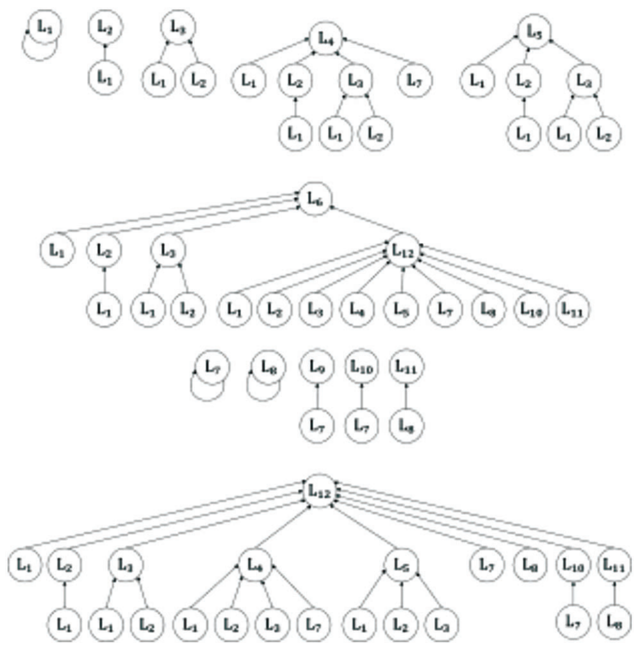

Fig. 3. Hierarchical Graphs of Interactions Among Factors of Typographic and Compositional Organization of the Typeset Page with Identification of Direct and Indirect Relationships

To formalize the nature of interaction among the examined factors, it is advisable to employ a conventional system of graphical indicators. In particular, a directed arrow of the form $fi \rightarrow fj$ is interpreted as the presence of a direct influence of one factor on another, whereas the notation $fi \Rightarrow fj$ is used to denote an indirect, mediated influence realized through intermediate system elements. A dependency relationship is represented by the opposite direction of the arrow, $fi \leftarrow fj$, while its indirect character is indicated by the symbol $fi \Leftarrow fj$. To denote the simultaneous fulfillment of several conditions, the logical conjunction operator ($\wedge$), is applied. The absence of an established relationship between factors is indicated by a special neutrality symbol $fi \parallel fj$, signifying the absence of both influence and dependence [9].

$L_1 \rightarrow L_2 \wedge L_1 \Rightarrow L_3, L_4, L_5, L_6, L_{12} \wedge L_1 \rightarrow L_3 \wedge L_1 \Rightarrow L_4, L_5, L_6, L_{12} \wedge L_1 \rightarrow L_4 \wedge L_1 \Rightarrow L_{12} \wedge L_1 \rightarrow L_5 \wedge L_1 \Rightarrow L_{12} \wedge L_1 \rightarrow L_6 \wedge L_1 \rightarrow L_{12} \wedge L_1 \Rightarrow L_{12}$;

$L_2 \rightarrow L_3 \wedge L_2 \Rightarrow L_4, L_5, L_6, L_{12} \wedge L_2 \rightarrow L_4 \wedge L_2 \Rightarrow L_{12} \wedge L_2 \rightarrow L_5 \wedge L_2 \Rightarrow L_{12} \wedge L_2 \rightarrow L_6 \wedge L_2 \rightarrow L_{12} \wedge L_2 \Rightarrow L_6$;

$L_3 \rightarrow L_4 \wedge L_3 \Rightarrow L_{12} \wedge L_2 \rightarrow L_5 \wedge L_3 \Rightarrow L_{12} \wedge L_3 \rightarrow L_6 \wedge L_3 \rightarrow L_{12} \wedge L_3 \Rightarrow L_6$;

$L_4 \rightarrow L_{12} \wedge L_4 \Rightarrow L_6$;

$L_5 \rightarrow L_{12} \wedge L_5 \rightarrow L_6$;

$L_6 \leftrightarrow L_6$;

$L_7 \rightarrow L_4 \wedge L_7 \Rightarrow L_{12} \wedge L_7 \rightarrow L_{10} \wedge L_7 \Rightarrow L_{12} \wedge L_7 \rightarrow L_{12} \wedge L_7 \Rightarrow L_6 \wedge L_2 \rightarrow L_6$;

$L_8 \rightarrow L_{11} \wedge L_8 \Rightarrow L_{12} \wedge L_8 \rightarrow L_{12} \wedge L_8 \Rightarrow L_6$;

$L_9 \parallel L_9$;

$L_{10} \rightarrow L_{12} \wedge L_{10} \Rightarrow L_6$;

$L_{11} \rightarrow L_{12} \wedge L_{11} \Rightarrow L_6$;

$L_{12} \rightarrow L_6 \wedge L_{12}$;

In the same manner, the direct and indirect dependencies among the factors are represented

$L_1 \parallel L_1$;

$L_2 \leftarrow L_1 \wedge L_2$;

$L_3 \leftarrow L_1 \wedge L_3 \leftarrow L_2 \wedge L_3$;

$L_4 \leftarrow L_1 \wedge L_4 \leftarrow L_2 \wedge L_4 \Leftarrow L_1 \wedge L_4 \leftarrow L_3 \wedge L_4 \Leftarrow L_1, L_2 \wedge L_4 \leftarrow L_7 \wedge L_4$;

$L_5 \leftarrow L_1 \wedge L_5 \leftarrow L_2 \wedge L_5 \Leftarrow L_1 \wedge L_5 \leftarrow L_3 \wedge L_5$

$L_6 \leftarrow L_1 \wedge L_6 \leftarrow L_2 \wedge L_6 \Leftarrow L_1 \wedge L_6 \leftarrow L_3 \wedge L_6 \Leftarrow L_1, L_2 \wedge L_6 \leftarrow L_{12} \wedge L_6 \Leftarrow L_1, L_2, L_3, L_4, L_5, L_6, L_7, L_8, L_{10}, L_{11}$;

$L_7 \parallel L_7$;

$L_8 \parallel L_8$;

$L_9 \leftarrow L_7 \wedge L_9$;

$L_{10} \leftarrow L_7 \wedge L_{10}$;

$L_{11} \leftarrow L_8 \wedge L_{11}$;

$L_{12} \leftarrow L_1 \wedge L_{12} \leftarrow L_2 \wedge L_{12} \Leftarrow L_1 \wedge L_{12} \leftarrow L_3 \wedge L_{12} \Leftarrow L_1, L_2 \wedge L_{12} \leftarrow L_4 \wedge L_{12} \Leftarrow L_1, L_2, L_3, L_7 \wedge L_{12} \leftarrow L_5 \wedge L_{12} \Leftarrow L_1, L_2, L_3 \wedge L_{12} \leftarrow L_7 \wedge L_{12} \leftarrow L_8 \wedge L_{12} \leftarrow L_{10} \wedge L_{12} \Leftarrow L_7 \wedge L_{12} \leftarrow L_{11} \wedge L_{12} \Leftarrow L_8$.

For the quantitative evaluation of structural interactions among factors, a weighted approach has been applied, involving the assignment of a specific numerical characteristic to each type of relationship. This approach is consistent with the general principles of indicator aggregation in decision-making models and structural analysis theory [10].

Taking into account the nature of interactions, four types of weighting coefficients expressed in relative units have been introduced:

- $\alpha_1 = 10$ (direct influence)
- $\alpha_2 = 5$ (indirect influence)
- $\alpha_3 = -10$ (direct dependence)
- $\alpha_4 = -5$ (indirect dependence)

Positive values reflect the strengthening of a factor's role within the system, whereas negative values characterize its structural dependence on other elements. Such differentiation of weights corresponds to the concept of directed influence and structural autonomy as discussed in studies on complex systems analysis. [11, 12].

The aggregate score for each factor is determined as an integral indicator.

$$S_x = \sum_{i=1}^{4} q_{xi} \times \alpha_i$$

where q_{xi} — the number of links of the i-th type for the x-th factor.

The obtained values of the integral indicators are used for the subsequent ordering of factors according to their level of structural significance.

The calculation results are presented in Table 1.1, which shows the number of links of each type, the intermediate weighted values, and the final integral indicator for each factor. On the basis of these data, a rank distribution is formed and the order of priority of the system elements is determined.

This procedure ensures the transition from a qualitative description of interactions to a quantitatively substantiated model of priority influence, consistent with classical approaches to multicriteria evaluation and structural modeling [11, 13].

Table 1.1

Calculation results and rank distribution of factors in designing the initial parameters of a publication

№ factor x	α_{1j}	α_{2j}	α_{3j}	α_{4j}	T_{1x}	T_{2x}	T_{3x}	T_{4x}	T_x	Factor Rank R_x	Order of Priority
1	4	6	0	0	40	30	0	0	155	5	1
2	1	0	2	2	10	0	-20	-10	95	2	4
3	3	2	2	2	30	10	-20	-10	125	4	2
4	2	2	1	2	20	10	-10	-10	115	3	3
5	2	2	2	1	20	10	-20	-5	115	3	3
6	0	0	5	7	0	0	-50	-35	0	1	5

Taking into account the identified priority structure, a model is formed that reflects the hierarchy of factor influence on the quality of the typographic and compositional organization of the typeset page.

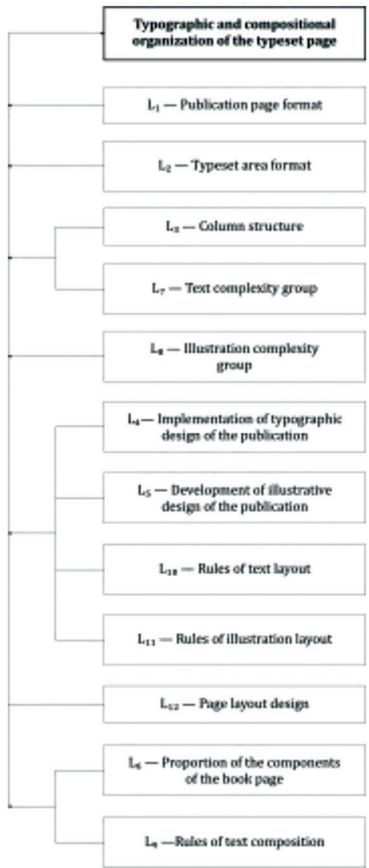

Fig. 4. Hierarchical Model of the Priority Influence of Factors in the Typographic and Compositional Organization of the Typeset Page

Conclusions. As a result of the study, a formalized model of the priority influence of factors in the typographic and compositional organization of the typeset page has been developed. The model is based on the integration of a semantic description of interrelationships with graph-hierarchical structuring of the factor space. The application of the apparatus of predicate logic made it possible to capture substantive and causal dependencies among factors, while the transition to a directed graph representation enabled consideration of both direct and indirect interactions within a unified system.

The proposed weighted approach to the quantitative evaluation of relationships ensured the determination of integral indicators of the structural participation of each factor and the formation of their rank distribution. The resulting hierarchical model reflects the relative significance of factors in the process of designing the initial parameters of a publication and establishes methodological preconditions for substantiated decision-making aimed at optimizing the typographic and compositional solution of the typeset page, as well as for the further development of predictive models for assessing the quality of publishing and printing processes.

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МОДЕЛЮВАННЯ СЕМАНТИЧНИХ ЗВ’ЯЗКІВ МІЖ ФАКТОРАМИ ТИПОГРАФІЧНО-КОМПОЗИЦІЙНОЇ ОРГАНІЗАЦІЇ ПОЛОСИ СКЛАДАННЯ

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У статті досліджено проблему моделювання семантичних зв'язків між факторами типографічно-композиційної організації полоси складання як складної багаторівневої системи, що визначає якість художньо-технічного оформлення книжкового видання та ефективність сприйняття друкованої інформації. Актуальність роботи зумовлена зростанням складності процесів проєктування у видавничо-поліграфічному виробництві, де параметри формату сторінки, формату полоси складання, колонковості, пропорцій складових сторінки, реалізації типографічного й ілюстраційного оформлення, правил складання та заверстування тексту й ілюстрацій, а також макетування перебувають у стані багатосторонньої взаємозалежності. Наголошено на необхідності системного підходу до структурування факторного простору з урахуванням прямих і опосередкованих причинно-наслідкових зв'язків.

Запропоновано формалізований опис взаємодій на основі побудови семантичної мережі із застосуванням апарату логіки предикатів, що забезпечує строгий, несуперечливий і формально узгоджений запис знань про структуру предметної області. Показано обмеженість предикатної моделі в аспекті визначення відносної значущості чинників, що зумовило перехід до орієнтованого графового подання системи факторів. Розроблено зважену модель кількісного оцінювання структурних взаємодій, яка передбачає диференціацію зв'язків за напрямом і глибиною впливу, введення вагових коефіцієнтів та розрахунок інтегрального показника структурної участі кожного фактора з подальшою нормалізацією і ранжуванням. На основі отриманих результатів сформовано ієрархічну модель пріоритетного впливу чинників, що відображає їх структурну роль у процесі проєктування вихідних параметрів видання. Запропонований підхід створює передумови для інтеграції формалізованих моделей у системи підтримки прийняття рішень у видавничо-поліграфічній галузі. Практичне значення роботи полягає у створенні методичної основи для обґрунтованого прийняття проєктних рішень та підвищення якості типографічно-композиційного вирішення полоси складання в системі видавничо-поліграфічного виробництва

Ключові слова: *типографічно-композиційна організація, полоса складання, семантична мережа, логіка предикатів, графова модель, пріоритетний вплив, інтегральний показник, багатокритеріальний аналіз, ієрархічна модель, якість видання, структурна взаємодія факторів.*

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