Design and Optimization of Multi-Page Publications for High-Quality Rendering

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Abstract

The purpose of this article is to improve the prepress processes, namely, to prepare the polygraphic edition for high-quality reproduction. After professional editing, the digital version of the publication must be processed and decomposed according to a certain algorithm in specialized software. This study will allow for high-quality design and error-free execution of the descent decomposition of multi-page publications, which will ensure error-free execution of this process and its optimization. In the study of the descent decomposition of multi-page publications, the formation of a universal term-set of values and corresponding linguistic terms in relation to linguistic variables reflecting the qualitative (fuzzy) characteristics of the selected factors was carried out. A model of logical derivation was built, which reflects the hierarchical dependence of the quality of the implementation of editing descents on the value of the linguistic terms of the factors. The value of the membership functions of linguistic variables is also calculated by constructing and developing matrices of pairwise comparisons for a set of linguistic terms with respect to the quanta of separation of intervals of values of the universal term set. Dependencies are constructed, interpreted as graphical models of visual representation of the values of membership functions in relation to linguistic terms, which is the completion of the first stage, which is called phasification.

Keywords [1]

Prepress, decomposition, publications, factors, linguistic terms, fuzzy logic.

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1 Introduction

A set of requirements and rules concerning indicators of quality completion of procedures related to different stages of preparation of published books cannot be specified only by numerical parameters. So, for example, a fairly significant volume of them in technological instructions for assembly processes is verbally descriptive in nature. A set of such linguistic characteristics of processes, phenomena or procedures is usually called linguistic variables, which are the basis of the theory of fuzzy sets [1, 2].

Linguistic variables in the tasks of the publishing and printing direction can be factors and parameters that influence the structure of the book publication, the features of the layout, the quality of printing, and the specifics of post-printing processes. The permissible values of linguistic variables form a term plural number, or a vague plural number that obeys certain restrictions [2, 3].

The transition from the descriptive meanings of the term to their formalized representation is carried out with the help of a mapping identified by membership functions [1, 2, 3]. With their help, linguistic information turns into numerical data, which, in turn, provide computer processing of

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models related to the design of publications, their compositional design at the stage of pre-printing, printing and post-printing design of circulation, solving problems of predicting the quality of books. - a tribute.

Linguistic variables in the tasks we are investigating are identified with factors affecting the quality of a book publication and can be used to predict this indicator both at individual stages of the publication of printed products and to establish its integral expression in relation to the publication as a whole. This principle is more universal, as it ensures the application of a single methodology not only to factors that can be specified in the form of numerical values, but also to cover weakly formalized requirements described in natural language.

The methodology of fuzzy sets and linguistic variables is applicable to study the process of descent of multi-page publications and some factors that affect its quality.

2 Related Works

In prepress processes, it takes a long time to achieve accurate alignment and correct placement of the pages and elements of the printed sheet but does not prevent common errors on the descent.

The main purpose of forming an assembly descent of multipage publications is the conscientiousness of its implementation, finally leads the quality of the publication. The speed of the order fulfillment and satisfaction of the consumer's needs largely depends on the parameters of this indicator. Since the qualitative formation of the layouts of publications is a topical issue of modern printing, the research carried out will have practical application for printing enterprises.

To properly execute the descent of pages in a prepared form, you must adhere to the following rules for designing and monitoring the specified process, namely:

- 1 - next to the first page, the last page should be placed along the spine;
- 2 - with two adjacent pages on the spine or head, one should be a pair, the other - an odd one;
- 3 - each pair of adjacent pages should contain: on the right - a pair, on the left - a pair;
- 4 - the sum of the columns of two adjacent pages is equal to the sum of the first and last page, for example, 1 + 4 = 5 and 2 + 3 = 5;
- 5 - if the first four pages are set clockwise, then the next four are counterclockwise.

The correctness of the descent can be checked on the print of the printed form. To do this, a sheet printed on both sides is folded into the correct part and the sequence of column numbers in the notebook is checked. Also known is the method of checking according to the table, depending on the fraction of the sheet [4, 5].

Since many publications nowadays are published both in print and electronically, many refer to the prepress processes as premedia services instead.

The prepress processes may take place at one single location, such as a large publishing and printing company, or at a variety of places. Usually, some tasks happen at a publisher while others take place at a printer or a dedicated prepress company (which are sometimes referred to as service bureaus or trade shops).

- Design: Since the advent of desktop publishing, many people in the printing industry no longer consider design to be a prepress task. The design process includes:
- Preparing data, which includes copyediting and product photography, such as for a mail-order catalog.
- Creating the layout is done using one of the leading design applications such as Adobe InDesign or QuarkXPress. People outside the graphic arts community may use tools like Microsoft Office or Publisher. There is also a wide range of specialized applications for tasks like database publishing.
- The correction cycle includes processes such as proofreading and image retouching, for which Adobe Photoshop is the leading application.
- Preflighting: Before finished pages go through the remaining processes, a validation is done to check if all the data meet the necessary production requirements.
- Proofing: During the design phase there are already page proofs being created. Proofs are usually also made by the company that is responsible for the printing. This can be done for internal checks of the impositioning (imposition proofs) as well as for their customer who needs to sign off the

proofs for approval. More and more such proofs are softproofs that are evaluated on a monitor. Hardcopy proofing remains popular when there is sufficient time for it and for color-critical or expensive jobs.

- Imposition: Depending on the final output device a number of pages will be combined into signatures.
- Output to the final output device such as a digital press, filmsetter, or CtP device [6].

Since high-quality reproduction of multi-page publications remains relevant in prepress processes, this study will improve it mathematically.

3 Basics of Fuzzy Logic in Ensuring the Quality of the Publication Production Process

The production of book products involves a large number of printing operations. After completing the mandatory processes, such as the design and layout of the pages of the book, the final operation of the prepress preparation of the publication is the implementation of the imposition, which must take into account the features of all subsequent stages of the technological process. The accuracy of the page imposition depends on the degree of complexity of the post-printing operations, since the mistakes made are reflected in the further technological stages of book publishing.

The book is usually a multi-page publication, the quality of the descent of the pages of which determines the final result - the sequence of all pages of the book block, the accuracy of the reduction, the readability of the printed edition. That is why this stage of prepress processing of book products is considered the most responsible in the creation of a printed publication.

Researches use methods and means of fuzzy logic to assess the process quality of implementation of mounting descents. A significant advantage of unclear logic is the possibility of fuzzification, that is, the replacement of the components of a crisp set by the concepts of an illegible set. An important element is the base (matrix) of fuzzy knowledge. It connects input and output variables. On the basis of the knowledge matrix, a system of fuzzy logical equations is constructed that provides the numerical values of the membership functions and the predicted quality of the technological process.

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At the same time, there still is a problem of the predictable establishment of the numerical values of the parameters of the descent implementation process, which would ensure the proper quality of the print run. A reasoned answer to this problem can be obtained by using fuzzy logic tools [1-3] and operations research [7-9] for solving. In a general interpretation, fuzzy logic is equivalent to the theory of illegible sets, the characteristic feature of which is a certain fuzziness (considering generally accepted norms in traditional mathematics) and blurring of the boundaries of setting the range of parameter values [8,10].

The basic concepts of fuzzy logic are illegible sets and linguistic variables, the defining component of which is MF, constructed using a set of meaning terms and linguistic factor terms. In the works of the founder of fuzzy logic [10], the concept of a universal set is introduced, as relating to the entire problem area. Then the fuzzy subset of the plural is defined through the universal set or scale and the membership function, i.e.

$$M = \left\{ \left(\mu_M \left(d \right), d \right), \, d \in D \right\}, \tag{1}$$

where $\left(0 \le \mu_M \left(d \right) \le 1 \right)$.

The membership function sets the degree of membership of each element of the fuzzy set to the universal set: $M \in D$.

With discreteness and finiteness of the base scale (i.e. divided into quanta or parts or gaps), the fuzzy set M can be submitted as:

$$M = \left(\mu_M\left(d_1\right)/d_1, \mu_M\left(d_2\right)/d_2, ..., \mu_M\left(d_n\right)/d_n\right) = \sum_{i=1}^{n} \mu_M\left(d_i\right)/d_i \,, \quad (2)$$

or in simplified form: $M = \sum_{i=1}^{n} \mu_i \,/\, d_i$. Symbol «/» in expression (2) does not mean a division sign, only conditionally «attaching» MF $\mu_M\left(d_i\right)$ to element d_i. Sign $\sum$ symbolically means a set of pairs $\mu_M\left(d_i\right)$ and d_i.

Finally MF act as an identifier for the input values of linguistic variables in a fuzzy format, i.e. d are assigned to the membership functions $\mu\left(d\right)$.

A linguistic variable is a variable whose meaning is expressed by means of ordinary speech — words or phrases. In this case, the set of possible values of a linguistic variable (LV) is usually called a term-multiplier, and its arbitrary element is called a term. So, for the linguistic variable "volume of publication", the terms will be the linguistic estimates "small", "medium", "large", which will form a term-set of values.

According to expression (1), the technological process of forming mounting slopes is represented as a procedure with one output — a variable P and many input variables. If these variables have a quantitative expression, then we can assume the presence of a gap in their setting, which in the general case is expressed through the lower and upper values of the variables [8]:

$$\left|\underline{s_i}, \overline{s_i}\right|, \; i = \overline{1,n}; \quad \left|\underline{P}, \overline{P}\right|. \quad (3)$$

Since the input set, in essence, the study contains qualitative variables, that is, factors in the process of implementing descents, it is necessary to establish (possibly in an expert way) the set and the boundaries for setting values

$$D = \left\{d^{(1)}, d^{(2)}, ..., d^{(j)}\right\}, \quad (4)$$

where $d^{(k)}$, $k = \overline{1,j}$ – a set of quantitative (if any) or qualitative conventional units, the power of which is determined by the index j.

Similarly, the original variable P with task limits from (3) can be expressed in conventional units by some set

$$P = \left\{p^{(1)}, p^{(2)}, ..., p^{(g)}\right\}. \quad (5)$$

Universal sets (3) – (5) determine the areas of assignment of input and output LV (analogues of the factors influencing the implementation quality of mounting descents) and ensure the implementation of dependence (1). At the same time, linguistic variables are evaluated in parallel with the help of qualitative linguistic terms such as "low", "medium", "high", "small", "large", etc., that is, by means of ordinary speech.

An important element of fuzzy logic is the indistinct knowledge base, which can be formed as a knowledge matrix [10]. It connects input variables or factors influencing the process with the result of its implementation — the initial variable. The knowledge matrix is designed using a set of fuzzy logical statements according to the rules "if-otherwise", "if-otherwise", "if-and-then". A system of fuzzy logical equations is constructed based on the knowledge matrix (logical statements) that provide numerical values of the membership functions and an integral forecast of the technological process quality.

In fuzzy logical equations, the operation $\vee$ means getting and operation $\wedge$ respectively $\min$. This means that for two values of membership functions μ_1 and μ_2 we get the following result combinations:

$$\mu_1 \vee \mu_2 = \max\left(\mu_1, \mu_2\right) = \begin{cases} \mu_1, if\ \mu_1 \geq \mu_2, \\ \mu_2, if\ \mu_1 < \mu_2, \end{cases} \quad (6)$$

$$\mu_1 \wedge \mu_2 = \min(\mu_1, \mu_2) = \begin{cases} \mu_1, if\ \mu_1 \le \mu_2, \\ \mu_2, if\ \mu_1 > \mu_2. \end{cases} \quad (7)$$

Finally, the modeling of the predictive quality assurance of the MIBP implementation is based on fuzzy logic is reduced to solving the following problems:

- establishment of a universal term-set of values and the corresponding linguistic terms of selected factors (linguistic variables);

– construction of a multilevel inference model, the structure of which reproduces the hierarchy of factors and linguistic terms that affect the quality of the process implementation. The component of the highest level determines the initial predicted indicator of the quality of MIBP implementation in the form of a fuzzy set;

- construction and processing of matrices of pairwise comparisons for a set of linguistic terms with respect to quanta of dividing the intervals of values of a universal set and obtaining membership functions for each of the linguistic variables;

- normalization of MF values and their correlation to the quanta of universal set separation;

- construction of combined graphs by normalized values MF for LV and their corresponding linguistic term.

We will consider the procedure for the implementation of mounting descents to be a certain function, the arguments of which will be identified earlier factors — linguistic variables. The value of this function will detect the predicted integral indicator of the quality of the implementation of MIBP, expressed through private indicators of the quality of the LV, grouped by functional purpose.

$$P = F_P(X, Y, Z). \quad (8)$$

In (8), the argument identifies the total indicator — a function that determines the quality of the publication structuring and takes into consideration the factors (in our case, arguments) corresponding to the initial data that affect the book structure and the quality of the implementation of the impositions:

$$X = F_X(x_1, x_2, x_3, x_4), \quad (9)$$

where: x_1 – LV «edition volume»; x_2 – LV «publication format»; x_3 – LV « notebook type »; x_4 – LV « block fastening type ».

Similarly, the quality of technological procedures will be determined by an indicator whose function looks as follows:

$$Y = F_Y(y_1, y_2, y_3), \quad (10)$$

where: y_1 – LV «picking method»; y_2 – LV «folding»; y_3 – LV « turnover decomposition ».

Finally, the variable identifies a partial indicator that reproduces the quality of the equipment.

$$Z = F_Z(z), \quad (11)$$

where z – LV «type of printing machine». For the identified linguistic variables, we will create a table that links the designation and name of the variable, the recommended limits for setting the values of the universal term-set, and the established linguistic terms [5-10].

Table 1

Term-sets of values of linguistic variables

Variable	Linguistic essence of the variable	Universal set of values setovalues (D)	Linguistic Terms (T)
x_1	Edition volume	(2-24) physical sheets	Small, medium, large
x_2	Publication format	(150x210-210x270) (315-567) cm^2	Small, medium, large big
x_3	Type of notebook	(1-5) c. u.	complex, incomplete, complete

x_4	Block fastening type	(2x32-24x32) (64-768) c. u.	Adhesive, combined, threads
y_1	Picking method	(4-768) c.	stacking, selection
y_2	Folding (accuracy, quality)	(1,5-3) mm	Low, medium, high
y_3	Turnover decomposition (accuracy of combination, quality)	(0-2) mm	Low, medium, high
z	Type of printing machine	(1-5) c. u.	Sheet, roll

The format value in the table. 1 is obtained from [8]. At the same time, the standard formats (before cropping) according to the second version of the design of book publications for part of the sheet 1/16 are translated into conditional areas of typesetting strips.

Table 2
Converting the formats of the strips of the edition set to the area

Format set	150×210	150×225	175×225	185×225	175×250	175×270	210×270
Square stripes (cm^2)	315	338	394	416	438	473	567

Considering the above reasoning, we build a model of logical inference, which reflects the hierarchical dependence of the implementation quality of mounting descents on the value of the linguistic terms of factors (Fig. 1).

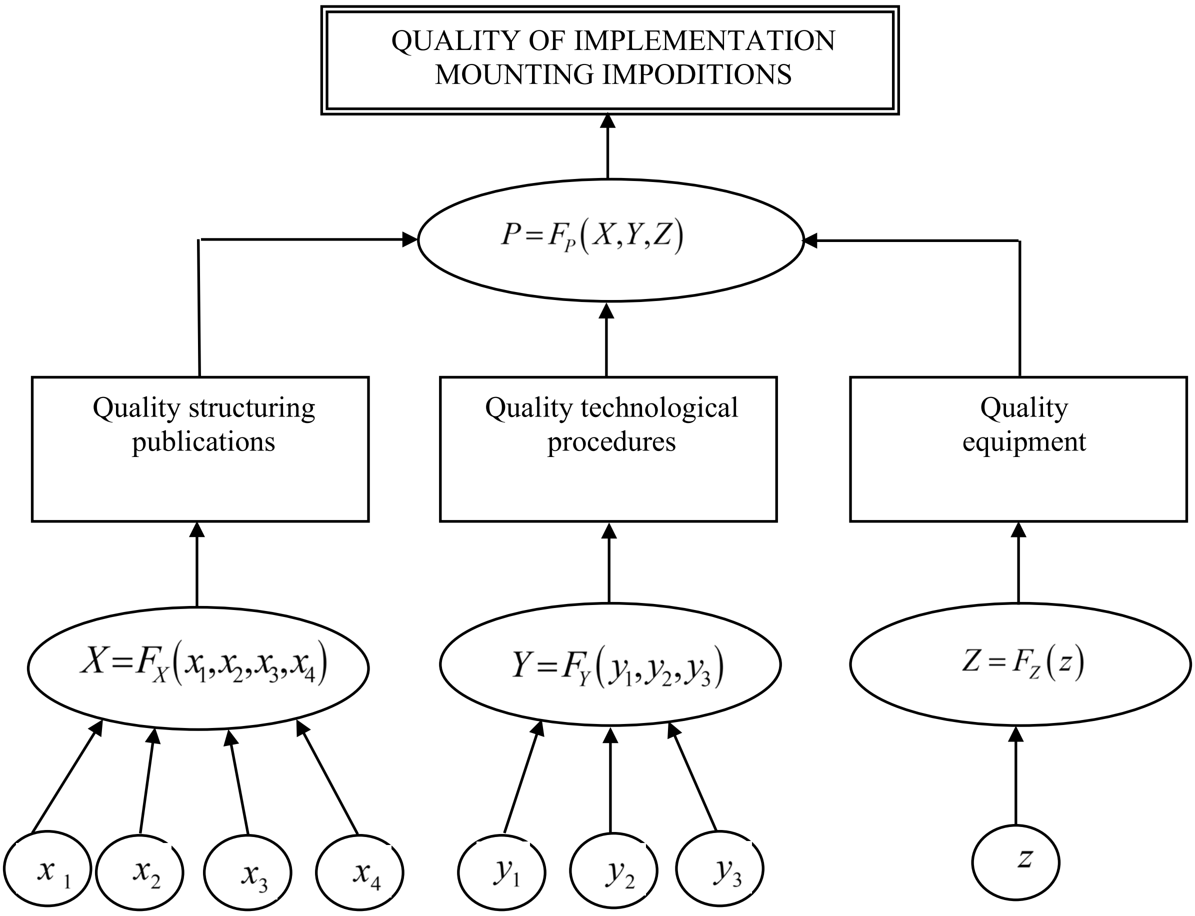

Figure 1: Model of inference: formation integral indicator of the quality of the mounting descents implementation

The multi-level fuzzy inference model works on the "bottom-up" principle, providing a sequence of establishing the forecast of the quality of the implementation of the mounting impositions due to its accumulation from the lowest to the highest levels. Structurally, it contains: a quality model for structuring the publication; quality model of technological procedures; equipment quality model. For subordinate models, MF is determined in relation to the corresponding factors (linguistic variables) — the basis to calculate the integral indicator of the quality of the technological process of implementing descents.

4 Construction and calculation of membership functions of linguistic variables

We formulate the task in general form as follows. We will consider the quality of the implementation of the editing descent as a linguistic term (see expression 8). For its formalized representation, we use the universal fuzzy set $D=\{d_1,d_2,...d_n\}$, on which the above LV and ranks $r_p(d_i)$, determining the priority of linguistic terms (LT) on quanta (parts) of the division of the universal set of values in the established ranges d_i $(i=1,...,n)$. As a result, the formalized representation of the LT "the quality of the mounting descent" can be represented by a fuzzy set, the elements of which include sets of pairs [3, 11]:

$$P_F=\left\{\frac{\mu_p(d_1)}{d_1},\frac{\mu_p(d_2)}{d_2},...,\frac{\mu_p(d_n)}{d_n}\right\}, \quad (12)$$

where : $P_F\subset D$; $\mu_p(d_i)$ — measure of belonging to a set P_F element $d_i\in D$.

Set of values $\mu_p(d_i)$, interconnected logical operations $\wedge$ and $\vee$, will provide a numerical expression of the desired MF linguistic term of the quality of the mounting imposition.

The distribution of membership measures looks like this:

$$\frac{\mu_1}{r_1}=\frac{\mu_2}{r_2}=...\frac{\mu_n}{r_n}, \quad (13)$$

where: $\mu_i=\mu_p(d_i)$; $r_i=r_p(d_i)$ for all $i=1,...,n$.

This takes into account the additional condition: $\mu_1+\mu_2+...+\mu_n=1$.

It is known that for the established ranks of factors, the numerical values of the membership functions are obtained from the relation [8, 12]:

$$\left.\begin{aligned}
\mu_1&=\left(1+\frac{r_2}{r_1}+\frac{r_3}{r_1}+...+\frac{r_n}{r_1}\right)^{-1};\\
\mu_2&=\left(\frac{r_1}{r_2}+1+\frac{r_3}{r_2}+...+\frac{r_n}{r_2}\right)^{-1};\\
&\cdots\cdots\cdots\cdots\cdots\cdots\\
\mu_n&=\left(\frac{r_1}{r_n}+\frac{r_2}{r_n}+\frac{r_3}{r_n}+...+1\right)^{-1}.
\end{aligned}\right\} \quad (14)$$

Range of possible values LV (table 1), identifying the selected factors, we conditionally divide into four parts, the number of which is sufficient for graphic reproduction of high-quality LT five split points. Thus, the relative estimates of the ranks of linguistic terms form a square inversely symmetric matrix. $A=a_{ij}$, де $a_{ij}=r_i/r_j$ for $i,j=1,...,5$.

Based on the stated and expressed conditions and caveats, we will formulate the research task as follows:

$$\left.\begin{aligned} &P_F = F\left(x_j, y_k, z\right) \to \max,\ \ j=\overline{1,4};\ k=\overline{1,3}; \\ &x_j > 0,\ \ y_k > 0,\ \ z > 0; \\ &\mu_p\left(d_i\right) \to \max,\ d_i \in D,\ P_F \subset D,\ i=\overline{1,5}. \end{aligned}\right\} \tag{15}$$

According to (15), it is necessary to achieve the maximum value of the function that determines the quality of the mounting descent, with positive values of the linguistic terms given by the universal term set, and the maximum values of the membership functions of the evaluation terms LV.

Final numeric values MF with the established ranks of linguistic terms at five division points of the universal set, we obtain as a result of processing the matrix [5, 11]:

$$A = \begin{bmatrix} 1 & \frac{r_2}{r_1} & \frac{r_3}{r_1} & \frac{r_4}{r_1} & \frac{r_5}{r_1} \\ \frac{r_1}{r_2} & 1 & \frac{r_3}{r_2} & \frac{r_4}{r_2} & \frac{r_5}{r_2} \\ \ldots & \ldots & \ldots & \ldots & \ldots \\ \frac{r_1}{r_5} & \frac{r_2}{r_5} & \frac{r_3}{r_5} & \frac{r_4}{r_5} & 1 \end{bmatrix}. \tag{16}$$

If the ranks are unknown, it is advisable to use a matrix of pairwise comparisons for each of linguistic terms given in Table. 1. The elements of such a matrix are obtained based on a scale of the relative importance of objects, containing nine comparative ratings, which reproduce the degree of advantage between the objects under consideration.

However, for two objects (for example, k_1 and k_2) depending on their importance and measure of impact, we will have the recommended values of the corresponding element of the matrix of pairwise comparisons in the position (k_1, k_2).The matrix is square, inversely symmetric, transitive.

Processing the matrix using the program “Simulation in System Analysis by Binary Comparisons” [15] provides getting the eigenvector of the matrix of pairwise comparisons, the components of which reproduce the ranks LV factors. In parallel, using relations (14), the values of the membership functions are calculated μ_i for each of the terms given in Table.1.

Let us set the conditional places for dividing the interval of possible values of LV in the universal set by points $\left(d_1, d_2, d_3, d_4, d_5\right)$. or the task formulated by us, we will assume that the ranks of the LT are obtained on the basis of expert judgments of polygraphic specialists.

1. Factor «edition volume»

Considering the comments made, we build matrices for the linguistic variable x_1 «edition volume». Universal set of values $D\left(x_1\right) = \left[2; 24\right]$ physical sheets. Term set of values $T\left(x_1\right) =$ < small, medium, large >. It should be noted that for a term the "small" rank of a variable on a given interval will decrease.

Universal set according to Table. 1 and expert judgments will consist of such split points: $D = \left\{2, 8, 14, 18, 24\right\}$.

$$A_{\text{small}}\left(x_1\right) = \begin{bmatrix} 1 & 5/9 & 3/9 & 2/9 & 1/9 \\ 9/5 & 1 & 3/5 & 2/5 & 1/5 \\ 9/3 & 5/3 & 1 & 2/3 & 1/3 \\ 9/2 & 5/2 & 3/2 & 1 & 1/2 \\ 9 & 5 & 3 & 2 & 1 \end{bmatrix}. \tag{17}$$

After calculating the matrix (16) according, we obtain the numerical values MF for the linguistic term «small» relative to the declared split points:

$$\mu_{\text{small}}(d_1)=0.45;\ \mu_{\text{small}}(d_2)=0.25;\ \mu_{\text{small}}(d_3)=0.15;\ \mu_{\text{small}}(d_4)=0.1;\ \mu_{\text{small}}(d_5)=0.05.$$

With respect to the term «average», we will get a matrix:

$$A_{\text{average}}(x_1)=\begin{bmatrix} 1 & 8 & 9 & 3 & 1 \\ 1/8 & 1 & 9/8 & 3/8 & 1/8 \\ 1/9 & 8/9 & 1 & 3/9 & 1/9 \\ 1/3 & 8/3 & 9/3 & 1 & 1/3 \\ 1 & 8 & 9 & 3 & 1 \end{bmatrix}. \quad (18)$$

For the term «average» from (18) we obtain the value MF.

$$\mu_{\text{average}}(d_1)=0.045;\ \mu_{\text{average}}(d_2)=0.363;\ \mu_{\text{average}}(d_3)=0.409;\ \mu_{\text{average}}(d_4)=0.136;$$

$$\mu_{\text{average}}(d_5)=0.045.$$

The term «large» gives rise to a matrix.

$$A_{\text{large}}(x_1)=\begin{bmatrix} 1 & 2 & 4 & 7 & 9 \\ 1/2 & 1 & 4/2 & 7/2 & 9/2 \\ 1/4 & 2/4 & 1 & 7/4 & 9/4 \\ 1/7 & 2/7 & 4/7 & 1 & 9/7 \\ 1/9 & 2/9 & 4/9 & 7/9 & 1 \end{bmatrix}. \quad (19)$$

Similarly to the previous one, from (19) for MF we obtain:

$$\mu_{\text{large}}(d_1)=0.043;\ \mu_{\text{large}}(d_2)=0.086;\ \mu_{\text{large}}(d_3)=0.173;\ \mu_{\text{large}}(d_4)=0.304;$$

$$\mu_{\text{large}}(d_5)=0.391.$$

Let us normalize the membership functions with respect to unity by calculating the normalization coefficients for LT.

$$k_l = 1/\max \mu_l(d_i),\quad (i=1,\dots,5),$$

where: $l=$ «small», «average», «large»; $\mu_{l_n}(d_i)=k_l\times\mu_l(d_i)$.

As a result, we obtain the following normalized values of FN for all linguistic terms of the variable «volume of publication»:

$$\mu_{\text{small}_n}(d_1)=1;\ \mu_{\text{small}_n}(d_2)=0.55;\ \mu_{\text{small}_n}(d_3)=0.33;\ \mu_{\text{small}_n}(d_4)=0.22;\ \mu_{\text{small}_n}(d_5)=0.11;$$

$$\mu_{\text{average}_n}(d_1)=0.11;\ \mu_{\text{average}_n}(d_2)=0.89;\ \mu_{\text{average}_n}(d_3)=1;\ \mu_{\text{average}_n}(d_4)=0.33;\ \mu_{\text{average}_n}(d_5)=0.11;$$

$$\mu_{\text{large}_n}(d_1)=0.11;\ \mu_{\text{large}_n}(d_2)=0.22;\ \mu_{\text{large}_n}(d_3)=0.44;\ \mu_{\text{large}_n}(d_4)=0.78;\ \mu_{\text{large}_n}(d_5)=1.$$

We use the normalized values of the membership functions of the LV «volume of publication» for the formalized representation of the linguistic terms «small», «average», «large» by fuzzy sets, the general form of which is given by the formula (12).

$$\text{volume is small} = \left\{\frac{1}{2};\frac{0,55}{8};\frac{0,33}{14};\frac{0,22}{18};\frac{0,11}{24}\right\} \text{ physical sheets;}$$

$$\text{volume average} = \left\{\frac{0,11}{2};\frac{0,89}{8};\frac{1}{14};\frac{0,33}{18};\frac{0,11}{24}\right\} \text{ physical sheets;}$$

$$\text{large volume} = \left\{\frac{0,11}{2};\frac{0,22}{8};\frac{0,44}{14};\frac{0,78}{18};\frac{1}{24}\right\} \text{ physical sheets.}$$

Based on the results obtained, that is, taking into account the elements of the fuzzy sets obtained above, we build combined graphs for the linguistic variable "publication volume" of membership functions in relation to the linguistic terms "small", "medium", "large".

At the same time, along the abscissa axis, we set the value of the volume of the publication in physical sheets from the universal term-set, the ordinate axis reflects the value of the membership functions of the corresponding linguistic terms (Fig. 2).

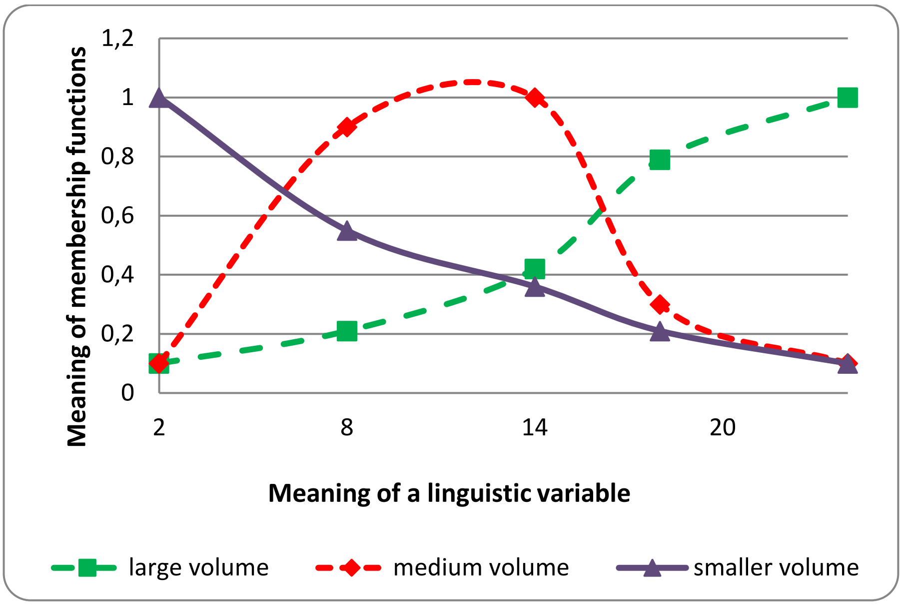

Figure 2: Membership functions of the linguistic variable «volume of publication»

Calculation of membership functions for other factors identified by LV from Table. 1, we perform similarly to the above algorithm according to the reduced scheme. For the variable "publication format", we will construct matrices for all terms and reflect the final results, i.e. normalized values of MF of linguistic variables in the form of a formalized representation of LT by fuzzy sets and graphics of MF.

We perform further calculations in the same way as above.

2. Factor «format of publication»

Linguistic variable x_2 «format of publication» put by the set formats according to the second design option for book publications related to fiction, popular science, educational, socio-political literature [5] on the universal set $D(x_2) = \left[(150\times 210);(210\times 270)\right]$. After transferring the boundaries of the task to adequate and convenient for further processing values according to Table. 2 we have: $D(x_2) = [315;567]$ см^2 with five division points into four quanta, the set of which will look like this: $D = \{315, 338, 390, 472, 567\}$. The corresponding set of LT values for LV «format of publication» $T(x_2) = $ < small, average, large>.

Building a matrix for a term «small».

$$A_{\text{small}}(x_2)=\begin{bmatrix} 1 & 7/9 & 3/9 & 2/9 & 1/9 \\ 9/7 & 1 & 3/7 & 2/7 & 1/7 \\ 9/3 & 7/3 & 1 & 2/3 & 1/3 \\ 9/2 & 7/2 & 3/2 & 1 & 1/2 \\ 9 & 7 & 3 & 2 & 1 \end{bmatrix}. \qquad (20)$$

Omitting the calculation of matrix (20), we construct the following matrix for the term «average».

$$A_{\text{average}}(x_2)=\begin{bmatrix} 1 & 4 & 9 & 7 & 2 \\ 1/4 & 1 & 9/4 & 7/4 & 2/4 \\ 1/9 & 4/9 & 1 & 7/9 & 2/9 \\ 1/7 & 4/7 & 9/7 & 1 & 2/7 \\ 1 & 4 & 9 & 7 & 2 \end{bmatrix}. \qquad (21)$$

A «large» matrix will look like this (22).

$$A_{\text{large}}(x_2)=\begin{bmatrix} 1 & 2 & 4 & 6 & 9 \\ 1/2 & 1 & 4/2 & 6/2 & 9/2 \\ 1/4 & 2/4 & 1 & 6/4 & 9/4 \\ 1/6 & 2/6 & 4/6 & 1 & 9/6 \\ 1/9 & 2/9 & 4/9 & 6/9 & 1 \end{bmatrix}. \qquad (22)$$

We use the reduced matrices for the values of the membership functions.

Completely normalized values and graphs (Fig. 3) of the obtained LV membership functions «format of publication» give below.

$$\text{Format small}=\left\{\frac{1}{315};\frac{0,78}{338};\frac{0,33}{390};\frac{0,22}{472};\frac{0,11}{567}\right\}\ \text{cm}^2;$$

$$\text{Format average}=\left\{\frac{0,11}{315};\frac{0,44}{338};\frac{1}{390};\frac{0,78}{472};\frac{0,22}{567}\right\}\ \text{cm}^2;$$

$$\text{Format large}=\left\{\frac{0,11}{315};\frac{0,22}{338};\frac{0,44}{390};\frac{0,66}{472};\frac{1}{567}\right\}\ \text{cm}^2.$$

Based on a survey of experts, we accept the following options for harmonizing the formats of book publications according to LT Table. 1: to term «small» refer formats (315-338) cm^2; term «average» refer formats (390-472) cm^2; term «large» – 567 cm^2.

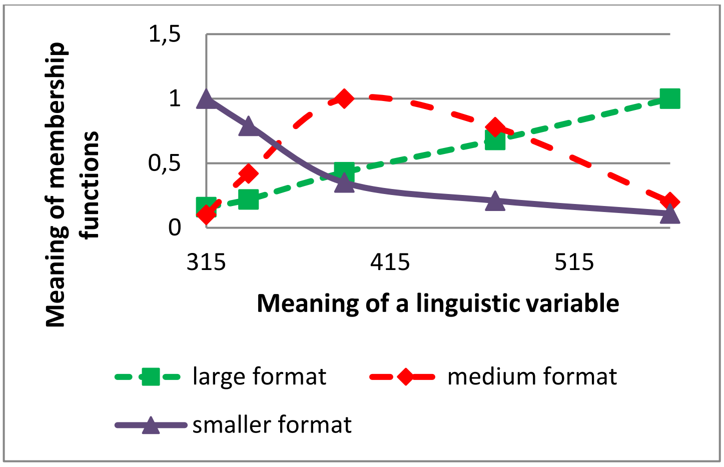

Figure 3: Membership functions of a linguistic variable

As can be seen from the graph, the membership function LV «format of publication» for terma «format average» reaches its maximum value at the extreme points of the term-set and inside the segment.

We perform the subsequent calculations by omitting the rank matrices LT.

3. Factor «type of notebook»

LV x_3 «type of notebook» identified by the universal set $D\left(x_3\right)=\left[1;2;3;4;5\right]$, which determines the volume and type of notebook. Many linguistic terms $T\left(x_3\right)=<$ complex, incomplete, complete $>$. At the same time, the full notebook provides the highest quality. Matrix processing results - a fuzzy set of membership functions are given below.

$$\text{complex notebook}=\left\{\frac{1}{1};\frac{0,45}{2};\frac{0,30}{3};\frac{0,11}{4};\frac{0,05}{5}\right\}\text{ c. u.;}$$

$$\text{notebook incomplete}=\left\{\frac{0,35}{1};\frac{0,80}{2};\frac{1}{3};\frac{0,33}{4};\frac{0,15}{5}\right\}\text{ c. u.;}$$

$$\text{notebook full}=\left\{\frac{0,11}{1};\frac{0,35}{2};\frac{0,50}{3};\frac{0,80}{4};\frac{1}{5}\right\}\text{ c. u.}$$

Graphs of membership functions LV «type of notebook» taking into account the above fuzzy sets will look like this.

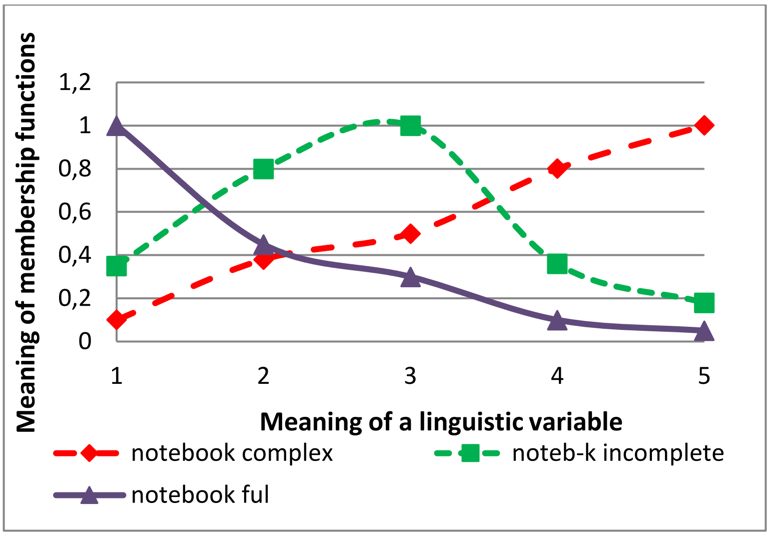

Figure 4: Membership functions of a linguistic variable «type of notebook»

4. Factor «block bonding type»

LV x_4 «block bonding type» identified by the universal set $D(x_4)=[64;256;416;576;768]$ conventional units formed by multiplying the number of physical sheets by the reciprocal of the share of a paper sheet. Many linguistic terms $T(x_4)=$ < adhesive, combined, sewing with threads >. The following membership functions are obtained

$$\text{adhesive}=\left\{\frac{1}{64};\frac{0,33}{256};\frac{0,22}{416};\frac{0,11}{576};\frac{0,06}{768}\right\}\text{ c. u.;}$$

$$\text{combined}=\left\{\frac{0,22}{64};\frac{1}{256};\frac{0,44}{416};\frac{0,33}{576};\frac{0,22}{768}\right\}\text{ c. u.;}$$

$$\text{threads}=\left\{\frac{0,11}{64};\frac{0,44}{256};\frac{0,66}{416};\frac{0,89}{576};\frac{1}{768}\right\}\text{ c. u.}$$

Graphs of membership functions LV « block bonding type» on the Fig.5.

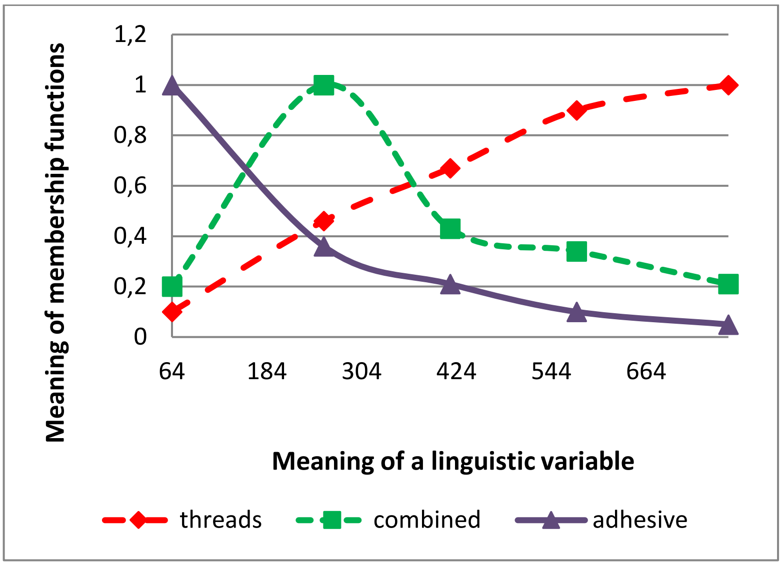

Figure 5: Membership functions of a linguistic variable «block bonding type»

5. Factor «method of picking»

LV y_1 «method of picking» rented on a universal set $D(y_1)=[4;192;384;570;768]$, which sets the number of pages of a notebook corresponding to different methods of acquisition. Lots of $T(y_1)=$ < setting, selection > with split points of the universal set will look like this.

$$\text{setting}=\left\{\frac{1}{4};\frac{0,33}{192};\frac{0,20}{384};\frac{0,11}{570};\frac{0,06}{768}\right\}\text{ pages;}$$

$$\text{selection}=\left\{\frac{0,04}{4};\frac{0,45}{192};\frac{0,70}{384};\frac{0,89}{570};\frac{1}{768}\right\}\text{ pages.}$$

Below are the combined graphs for the analyzed types of acquisition — nesting and selection, built as before based on the fuzzy set of membership functions obtained above LV y_1.

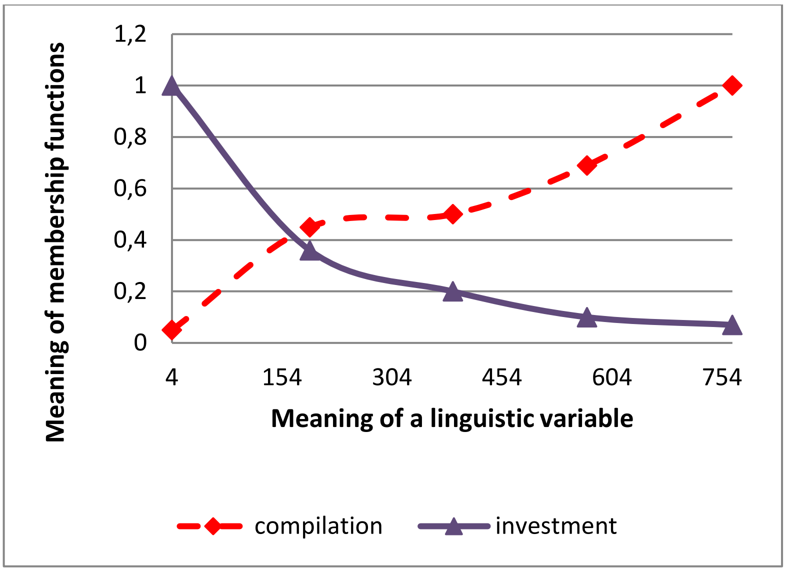

Figure 6: Membership functions of a linguistic variable «method of picking»

Collection of publications «setting» are produced with small volumes of pages in a notebook (4-96 pages) with volumes of more than 96 pages, it is advisable to complete notebooks using the method «selection».

6. The «folding» factor.

LV y_2 «folding», as the previous linguistic variable, concerns the quality of technological procedures. The universal set sets the allowable folding accuracy values within (1.5-3) mm and is set by such separation points of the specified interval. $:D(y_2)=[1.5;1.9;2.3;2.7;3]$. The corresponding set of linguistic terms $T(y_2) = <$ low, average, high $>$.

Fuzzy set of values of membership functions is:

$$\text{accuracy is low} = \left\{ \frac{0,11}{1,5}; \frac{0,22}{1,9}; \frac{0,6}{2,3}; \frac{0,92}{2,7}; \frac{1}{3} \right\} \text{ mm;}$$

$$\text{average accuracy } = \left\{ \frac{0,44}{1,5}; \frac{0,9}{1,9}; \frac{1}{2,3}; \frac{0,44}{2,7}; \frac{0,22}{3} \right\} \text{ mm;}$$

$$\text{high precision } = \left\{ \frac{1}{1,5}; \frac{0,44}{1,9}; \frac{0,16}{2,3}; \frac{0,11}{2,7}; \frac{0,06}{3} \right\} \text{ mm.}$$

Graphs of membership functions are shown in fig. 7.

Low folding accuracy, as can be seen from the graph in Fig. 7 corresponds to the minimum value at the point of 1.5 mm, at which the term "accuracy high" reaches the maximum value for this function. With average accuracy, the maximum membership function is reached in the middle of the interval of the universal thermoset of values of the linguistic variable «folding».

In the process of designing and implementing mounting impositions of book pages, when performing the folding procedure, it is necessary to take into account tolerances, which in this case are not calculated by the computer program for electronic mounting.

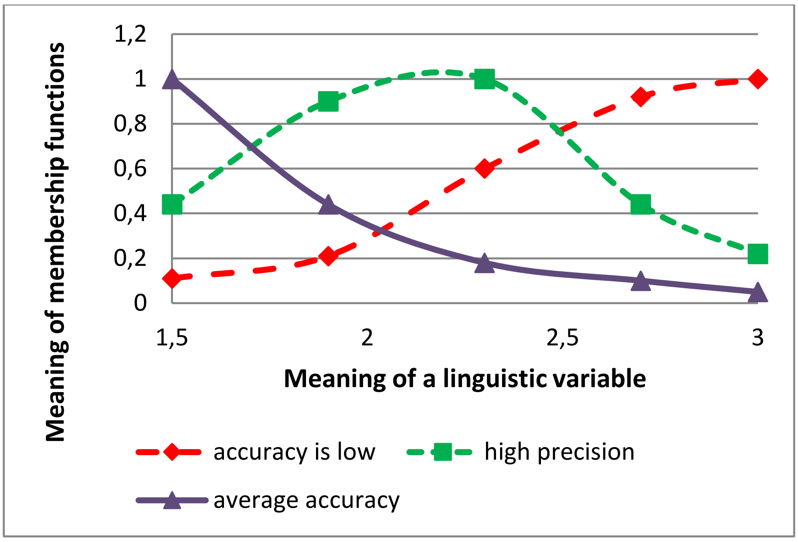

Figure 7: Membership functions of a linguistic variable «folding»

7. Factor «decomposition turnover»

The accuracy of text alignment on both sides of a sheet of paper is an important indicator when printing a turnover. LV y_3 «decomposition turnover» determines the quality of technological procedures, is set within (0-2) mm by the separation points of the specified interval: $D(y_3) = [0; 0.5; 1; 1.5; 2]$. The corresponding set of linguistic terms $T(y_3) = <$ low, average, high $>$.

The fuzzy set of MF values associated with the split points of the universal set is given below:

$$\text{accuracy is low} = \left\{ \frac{0,11}{0}; \frac{0,20}{0,5}; \frac{0,28}{1}; \frac{0,44}{1,5}; \frac{1}{2} \right\} \text{ mm;}$$

$$\text{average accuracy} = \left\{ \frac{0,22}{0}; \frac{0,44}{0,5}; \frac{0,96}{1}; \frac{1}{1,5}; \frac{0,22}{2} \right\} \text{ mm;}$$

$$\text{high precision} = \left\{ \frac{1}{0}; \frac{0,88}{0,5}; \frac{0,16}{1}; \frac{0,10}{1,5}; \frac{0,06}{2} \right\} \text{ mm.}$$

Graphs of membership functions for the resulting fuzzy set of values of membership functions are placed on Fig. 8.

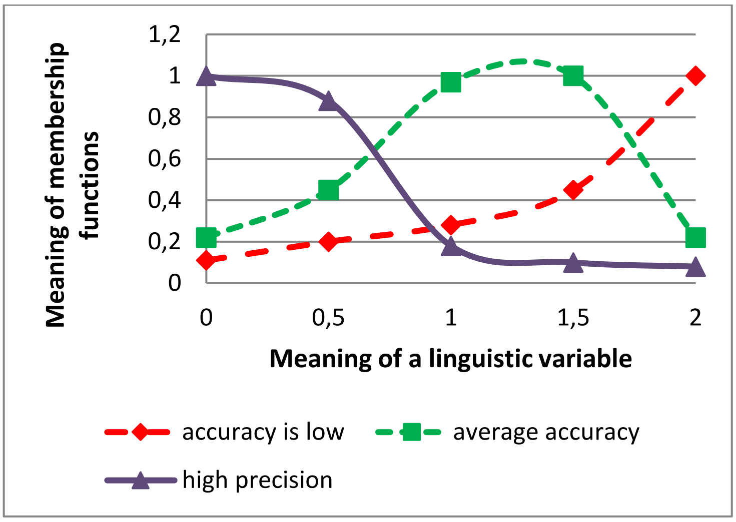

Figure 8: Membership functions of a linguistic variable «turnover decomposition»

8. Factor «type of printing machine»

The type of printing machine is identified LV «type of printing machine» on the universal set $D(z)=[1;2;3;4;5]$ conventional units by linguistic terms $T(z)=<$ roll, sheet $>$. A fuzzy set with normalized values of membership functions will look like this.

$$\text{sheet}=\left\{\frac{1}{1};\frac{0,85}{2};\frac{0,60}{3};\frac{0,22}{4};\frac{0,10}{5}\right\} \text{ c. u.;}$$

$$\text{roll}=\left\{\frac{0,06}{1};\frac{0,20}{2};\frac{0,78}{3};\frac{0,90}{4};\frac{1}{5}\right\} \text{ c. u.}$$

Graphs of membership functions LV «type of printing machine» taking into account the above fuzzy sets are shown in Fig.9.

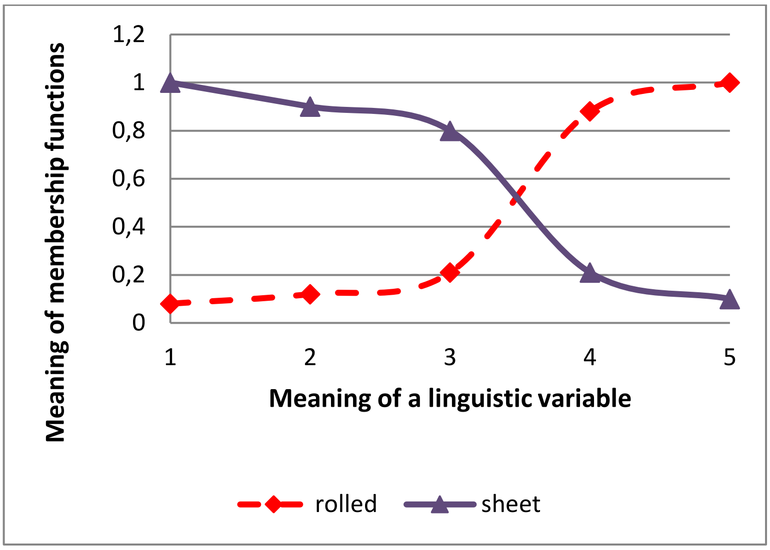

Figure 9: Membership functions of a linguistic variable «type of printing machine»

The resulting graphs are interpreted as graphical models of visual display of the values of membership functions in relation to linguistic terms.

5 Results/Discussions

In the study, the formation of a universal term-set of values and corresponding linguistic terms in relation to linguistic variables, which reflect the qualitative (fuzzy) characteristics of the isolated factors, was carried out.

A model of logical derivation has been built, which reflects the hierarchical dependence of the quality of multi-page publications for high-quality rendering implementation on the meaning of the linguistic terms of the factors. As a result, the formalized presentation of LT "quality of assembly descent" is represented by a fuzzy set, the elements of which contain sets of pairs (12).

The task of the study was to achieve the maximum value of the process quality function with positive values of linguistic terms given by the universal term-set, and the maximum values of the membership functions of the evaluation terms of linguistic variables (15).

The range of possible values of linguistic variables that identify the selected factors was conventionally divided into four parts, the number of which is sufficient for graphical reproduction of qualitative linguistic terms T by five separation points. Thus, relative estimates of the ranks of linguistic terms form square inversely symmetric matrices , where for . The processing of the matrices ensures obtaining an eigenvector, the components of which reproduce the ranks of the RT factors. In addition, the values of the membership functions are calculated for each of the terms specified in the table. 1.

The indicated actions are performed for all linguistic variables. According to normal values, combined graphs of membership functions with respect to the linguistic terms of Table 1 are constructed, the general form of which is given by formula (14).

6 Conclusion

The article calculates the value of the membership functions of linguistic variables by constructing and processing matrices of pairwise comparisons for a set of linguistic terms relative to the quanta of division of intervals of values of the universal set of terms. On the basis of the conducted research, a multi-level hierarchical model of logical derivation was built, in which the higher-level component determines the initial predicted indicator of the quality of the implementation of multi-page publications in the form of a fuzzy set. Graphs have been constructed that visually display the relationships between the LV parameters from the universal term set and the values of the membership functions of the corresponding linguistic terms.

The obtained results complete the first stage, which is called design and optimization. Further modeling of the process of producing multi-page publications will consist in the implementation of the defuzzification process, the essence of which is the construction of fuzzy logical equations and a fuzzy knowledge base based on established linguistic terms and their corresponding membership functions.

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