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Models of Postpress Processes Designing

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Abstract. The study has highlighted a set of factors influencing the quality of postpress processes designing. A fuzzy preference relations on a given set of alternatives has been formed. The matrices of relations of alternatives by Pareto-oriented factors have been constructed and the non-dominant subset has been defined. Based on a fuzzy preference relation, the corresponding sets of non-dominated alternatives have been distinguished. The optimal variant of the analysed process has been selected according to the maximum value of the utility function. Modelling of key operations and functions of postpress processes designing has been implemented through the development of a context diagram and a decomposition diagram of IDEF0 models, one of the elements of which are alternatives for this process implementation.

Keywords: postpress process, factor, alternative, fuzzy preference relation, utility function, optimization, model, IDEF0 modelling.

1 Introduction

The final stage of the book production technology which includes finishing and binding processes is often mistakenly identified with a set of mechanical, cyclically repetitive actions, depriving them of a highly intellectual information component. This approach increases the likelihood of partial or total rejection of the print run. A typical mistake is also the mismatch of manufactured products to their functional and operational characteristics. Thus, for example, for an edition that should serve for decades, one can use an adhesive binding of organic origin that is not suitable to meet the requirements and choose the wrong finishing material.

Computer-aided automation does not presents the expected results, since the procedures used are not integrated into a single, indivisible system. Under such conditions, post-operational information support is appropriate and necessary, which will result in a predictive assessment of the future products quality. Such an approach in the presence of uncertainty conditions requires the formation, calculation and multi-criteria assessment of alternative options for the implementation of postpress processes on the basis of fuzzy preference relations and determining the optimal one, which will result in obtaining the proper quality products. The specified procedure

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becomes an important component of IDEF0 models of the implementation of post-press processes designing.

2 Formal problem statement

An important point in the study of postpress processes is considered the presence of technological characteristics or parameters, on which the effectiveness of the publication in the general cycle of its production depends. Generalizing such factors, we introduce the concepts of factors that become the main elements of models for determining the priority of the factors influence on the course of implementation and predictive assessment of the quality of postpress processes.

Eventually, a set of the designing factors of the postpress processes will be presented in the form $R=\{R_1, R_2, R_3, R_4, R_5, R_6, R_7, R_8\}$, where R_1 are the edition parameters; R_2 are structural features; R_3 are operating conditions; R_4 is a type of production; R_5 are materials; R_6 is a type of equipment; R_7 are technological and economic calculations; R_8 is a technological process diagram [12]. The initial step to prioritizing the influence of these factors on the process is to design a semantic network, the essence of which is to capture the existing relations between the factors. It becomes the basis for the construction of a matrix of pairwise comparisons, processing of which leads to obtaining conditional weight values that determine the numerical priorities of factors — their importance value for the technological process. Next is the calculation and the determination of the optimal (among alternative) options for the implementation of post-press processes designing.

A multicriteria optimization of functions $r(x)=(r_1(x), ..., r_n(x))$ on the set *B* is to distinguish the maximum value of the utility functions $r_i(x) \to \max\limits_{x \in D},\ i=1, n.$ Accordingly, by the method of linear minimization of the criteria, combining partial target functionals $r_1, ..., r_n$ is carried out according to the formula [13-16]:

$$R(v,x)=\sum_{i=1}^{n} v_i r_i(x) \to \max_{x \in D};\ v \in V, \tag{1}$$

$$V=\left\{v=(v_1, ..., v_n)^Q;\ v_i>0;\ \sum_{i=1}^{n} v_i=1\right\},$$

where v_i are weights of the factors of Pareto set.

For the factors independent in utility and preference, the following utility function exists [17, 18]:

$$U(x)=\sum_{i=1}^{n} v_i u_i(y_i), \tag{2}$$

where: $U(x)$ is a multicriteria utility function; $(0 \le U(x) \le 1)$ are alternatives x; v_i is the weight of the i-th criterion, moreover $0 < v_i < 1$, $\sum_{i=1}^{n} v_i = 1$; $u_i(y_i)$; is the utility function of the i-th criterion $(0 \le u_i(y_i) \le 1)$; y_i is the value of the alternative x by the i-th criterion.

3 Literature review

The analysis of literary sources shows the necessity of a reasonable selection of factors influencing the quality of printed products [1-7]. In recent years, the simulation of postpress processes with the help of computer equipment and specific software has been used [8-11]. As risk and uncertainty are peculiar to complex processes, quantitative parameters for making a sound decision about the implementation of the studied process can be obtained on the basis of the methods of the operations research [12-16]. The design of the studied processes is performed through the calculation of alternative options for their implementation [17, 18]. It is important to take into account the fact that the equipment for performing separate operations of finishing and binding processes and the materials used for different types of products are individual [19-23]. The principle of vertical design is actively applied, which distinguishes between the procedures of analysis and synthesis. The synthesis creates the descriptions of objects that reflect their structure and parameters [25]. The selection of technology and postpress equipment depends on the type of printed matter, its purpose, production volumes, economic and financial indicators of the printing company activities [26, 27]. A significant problem is the adherence to standards for the edition production, metrological characteristics related to the quality in printing, modelling of business processes, which are important factors of planning and effective functioning of printing companies. The performed analysis indicates that there is no information approach to the problem of forming the book quality, the final stage of which is the postpress process. The essence of the new methodology is the use of methods and means of theory of operations research, modelling theory, expert assessment of publishing and printing processes, which will ensure the proper quality of printed products.

4 Objectives of the work (problem setting)

The formation and multicriteria assessment of alternative options for the implementtation of postpress processes based on fuzzy preference relationships. The determination of Pareto-optimal alternative on the basis of the results analysis of the non-dominant sets intersection of the relation convolutions and the maximum value of the membership function of a common set. Modelling of designing procedures of postpress process by means of context diagrams for the corresponding decomposition levels of IDEF0 models. Obtaining a model-basis for further predictive assessment of the quality of the postpress process.

5 Materials and methods

Making management decisions regarding the alternative implementation of technological processes can be complicated by the lack of information about their priority and the inability to quantify the benefits. Instead, it is possible to pair the alternatives in the segment [0; 1] and to represent the data in numerical form. The assessment is carried out on the basis of multicriteria optimization, where the factors of the technological process are the criteria. According to Pareto principle [17, 18], it is sufficient to select only the dominant factors with the highest weight parameters, which form Pareto set $P(D)$, where $D \subset R_i$ is a set of valid values. Accordingly, with a fuzzy preference relation, decision-making will be exercised by Pareto-optimal alternatives for a set of alternatives.

Introducing a clear relation of non-strict preference R_i for a set of alternatives $X = \{x_1, ..., x_n\}$ allows making one of the following statements for any pair of alternatives (x, y): x is not worse than y, that is $x \geq y$, $(x, y) \in R$; y is not worse than x being written as $y \geq x$, $(y, x) \in R$, x and y are not comparable, $(x, y) \notin R$, $(y, x) \notin R$. This approach makes it possible to narrow down the rational selection class.

If there is a strict preference $(x, y) \in R_z$ the alternative x prevails y, that is $x > y$. With clear utility functions r_j of the set X, the alternative x with a higher assessment $r_j(x)$ by the factor j is better than the alternative y whose assessment is $r_j(y)$. The above statement is described by a clear relation of the advantage R_j of the set X:

$$R_j = \{(x, y) : r_j(x) \geq r_j(y), x, y \in X\} \quad (1)$$

To single out Pareto-optimal alternative, it is necessary to select the alternative $x_0 \in X$ with the highest utility ranking on the set of all factors:

$$r_j(x_0) \geq r_j(y), \forall j = \overline{1, m}; \ \forall y \in X \quad (2)$$

The convolution of all the criteria of formed Pareto set into a single scalar is carried out by the intersection method [17].

We denote $Q_1 = \bigcap_{j=1}^{m} R_j$. Thus, the set of alternatives $X = \{x_1, ..., x_n\}$ with preference relation Q_1 corresponds to the set of alternatives with utility functions $r_j(x)$. Identifying non-dominant alternatives by a fuzzy preference relation Q_1 is to replace several relations $R_j\ (j = \overline{1, m})$ by the intersection between them. We will assume that $\mu_j(x, y)$ is a membership function of a clear preference relation r_j. We form the condition:

$$\mu_j(x,y)=\begin{cases}1, if\ r_j(x)\geq r_j(y), then\ (x,y)\in R_j\\ 0, if\ (x,y)\notin R\end{cases} \quad (3)$$

Accordingly, the membership function of the convolution Q_1 is written as follows:

$$\mu_{Q_1}(x,y)=\min\{\mu_1(x,y),\mu_2(x,y),...,\mu_n(x,y)\} \quad (4)$$

The convolution of the criteria, taking into account the weight values of the process factors v_j and the corresponding utility functions, will be:

$$Q(x)=\min_j v_j r_j(x) \quad (5)$$

The convolution of the initial relations Q_2 is also formed by the weight values of the analysed factors v_j and the corresponding utility functions:

$$Q_2=\sum_{j=1}^{m} v_j r_j(x),\ where \sum_{j=1}^{m} v_j=1,\ v_j\geq 0 \quad (6)$$

It corresponds to the following membership function: [15-18]

$$\mu_{Q_2}(x,y)=\sum_{j=1}^{m} v_j\mu_j(x,y) \quad (7)$$

The methodology of IDEF0 modelling has been used to model the studied process, which involves the construction of context diagrams of a tree structure, created on the principle of decomposition. Next, we denote the context diagram A-0, and the decomposition diagram of the first level — A-1. The arrows of the input type (what is being processed) will be the set of values $I=\{I_1,...,I_n\}$, the arrows of the control type (procedures and management strategies) will be the set $C=\{C_1,...,C_n\}$, the arrows of the output type (result) will be the set $O=\{O_1,...,O_n\}$, and the arrows of the mechanism type (required resources) will be the set $M=\{M_1,...,M_n\}$.

6 Experiment

We determine the quality of postpress processes designing by assessing fuzzy preference relations R_i on the set of alternatives $X=\{x_1,x_2,x_3\}$: R_1 (the edition parameters) — $x_1=x_2$, $x_2<x_3$; R_2 (operating conditions) — $x_1<x_3$, $x_2>x_3$; R_3 (structural features) — $x_1>x_2$, $x_2=x_3$; R_4 (a type of production) — $x_1>x_2$, $x_2=x_3$.

We form the matrices of relations for the factors R_1, R_2, R_3 and R_4. We use two types of numeric visualizers: 0 and 1, where 0 is the absence of preference.

$$\mu_{R_1}\left(x_i, x_j\right) = \begin{array}{c|ccc} & x_1 & x_2 & x_3 \\ \hline x_1 & 1 & 1 & 0 \\ x_2 & 1 & 1 & 0 \\ x_3 & 1 & 1 & 1 \end{array} \qquad \mu_{R_2}\left(x_i, x_j\right) = \begin{array}{c|ccc} & x_1 & x_2 & x_3 \\ \hline x_1 & 1 & 0 & 0 \\ x_2 & 1 & 1 & 1 \\ x_3 & 1 & 0 & 1 \end{array}$$

$$\mu_{R_3}\left(x_i, x_j\right) = \begin{array}{c|ccc} & x_1 & x_2 & x_3 \\ \hline x_1 & 1 & 1 & 1 \\ x_2 & 0 & 1 & 1 \\ x_3 & 0 & 1 & 1 \end{array} \qquad \mu_{R_2}\left(x_i, x_j\right) = \begin{array}{c|ccc} & x_1 & x_2 & x_3 \\ \hline x_1 & 1 & 1 & 1 \\ x_2 & 0 & 1 & 1 \\ x_3 & 0 & 1 & 1 \end{array}$$

We construct the convolution of relations $Q_1 = R_1 \cap R_2 \cap R_3 \cap R_4$. The absence of preference of the x_i -th alternative is considered to be zero by the factor analysed.

$$\mu_{Q_1}\left(x_i, x_j\right) = \begin{array}{c|ccc} & x_1 & x_2 & x_3 \\ \hline x_1 & 1 & 0 & 0 \\ x_2 & 0 & 1 & 0 \\ x_3 & 0 & 0 & 1 \end{array}$$

According to the convolution of relations Q_1, a subset of non-dominant alternatives will look like this [14-17]:

$$\mu_{Q_1}^{\text{нд}}\left(x\right) = 1 - \sup_{y \in X}\left\{\sum_{j=1}^{4}\mu_{Q_1}\left(y, x\right) - \mu_{Q_1}\left(x, y\right)\right\} \tag{8}$$

Having used these matrices of relations and (8), we get:

$$\mu_{Q_1}^{\text{нд}}\left(x_1\right) = 1 - \sup_{y \in X}\left\{x_2 x_1 - x_1 x_2; x_3 x_1 - x_1 x_3\right\};$$
$$\mu_{Q_1}^{\text{нд}}\left(x_2\right) = 1 - \sup_{y \in X}\left\{x_1 x_2 - x_2 x_1; x_3 x_2 - x_2 x_3\right\};$$
$$\mu_{Q_1}^{\text{нд}}\left(x_3\right) = 1 - \sup_{y \in X}\left\{x_1 x_3 - x_3 x_1; x_2 x_3 - x_3 x_2\right\}.$$

Now we set the fuzzy preference relation Q_2, $j = 1,4$:

$$Q_2 = \sum_{j=1}^{4} v_j r_j\left(x\right) \tag{9}$$

We form the membership functions for the convolution of relations Q_2 and the corresponding sets of non-dominant alternatives:

$$\mu_{Q_2}\left(x, y\right) = \sum_{j=1}^{4} w_j \mu_j\left(x, y\right), \ \sum_{j=1}^{4} w_j = 1, \ w_j \geq 0 \tag{10}$$

$$\mu_{Q_2}(x_1,x_2) = v_1\mu_{R_1}(x_1,x_2) + v_2\mu_{R_2}(x_1,x_2) + v_3\mu_{R_3}(x_1,x_2) + v_4\mu_{R_4}(x_1,x_2)$$
$$\mu_{Q_2}(x_1,x_3) = v_1\mu_{R_1}(x_1,x_3) + v_2\mu_{R_2}(x_1,x_3) + v_3\mu_{R_3}(x_1,x_3) + v_4\mu_{R_4}(x_1,x_3)$$
$$\mu_{Q_2}(x_2,x_1) = v_1\mu_{R_1}(x_2,x_1) + v_2\mu_{R_2}(x_2,x_1) + v_3\mu_{R_3}(x_2,x_1) + v_4\mu_{R_4}(x_2,x_1)$$
$$\mu_{Q_2}(x_2,x_3) = v_1\mu_{R_1}(x_2,x_3) + v_2\mu_{R_2}(x_2,x_3) + v_3\mu_{R_3}(x_2,x_3) + v_4\mu_{R_4}(x_2,x_3)$$
$$\mu_{Q_2}(x_3,x_1) = v_1\mu_{R_1}(x_3,x_1) + v_2\mu_{R_2}(x_3,x_1) + v_3\mu_{R_3}(x_3,x_1) + v_4\mu_{R_4}(x_3,x_1)$$
$$\mu_{Q_2}(x_3,x_2) = v_1\mu_{R_1}(x_3,x_2) + v_2\mu_{R_2}(x_3,x_2) + v_3\mu_{R_3}(x_3,x_2) + v_4\mu_{R_4}(x_3,x_2)$$

$$\mu_{Q_2}^{нд}(x) = 1 - \sup_{y\in X}\left\{\sum_{j=1}^{4}\mu_{Q_2}(y,x) - \mu_{Q_2}(x,y)\right\} \quad (11)$$

$$\mu_{Q_2}^{нд}(x_1) = 1 - \sup\left\{\left(\mu_{Q_2}(x_2,x_1) - \mu_{Q_2}(x_1,x_2)\right);\left(\mu_{Q_2}(x_3,x_1) - \mu_{Q_2}(x_1,x_3)\right)\right\}$$
$$\mu_{Q_2}^{нд}(x_2) = 1 - \sup\left\{\left(\mu_{Q_2}(x_1,x_2) - \mu_{Q_2}(x_2,x_1)\right);\left(\mu_{Q_2}(x_3,x_2) - \mu_{Q_2}(x_2,x_3)\right)\right\}$$
$$\mu_{Q_2}^{нд}(x_3) = 1 - \sup\left\{\left(\mu_{Q_2}(x_1,x_3) - \mu_{Q_2}(x_3,x_1)\right);\left(\mu_{Q_2}(x_2,x_3) - \mu_{Q_2}(x_3,x_2)\right)\right\}$$

To determine Pareto-optimal alternative, we perform the intersection of sets $Q_1^{нд}$ and $Q_2^{нд}$ and define the membership function of a common set:

$$Q_{нд} = Q_1^{нд} \cap Q_2^{нд} \quad (12)$$

$$\mu_{нд}(x) = \min\left\{\mu_{Q_1}^{нд}(x), \mu_{Q_2}^{нд}(x)\right\} \quad (13)$$

The selection of the most efficient alternative is made by the maximum numeric value of the membership function $\mu_Q^{нд}(x_i)$. Since the alternatives for postpress processes designing are of the control type (procedures and management strategies), we obtain the following context diagram of IDEF0 model (Fig. 1).

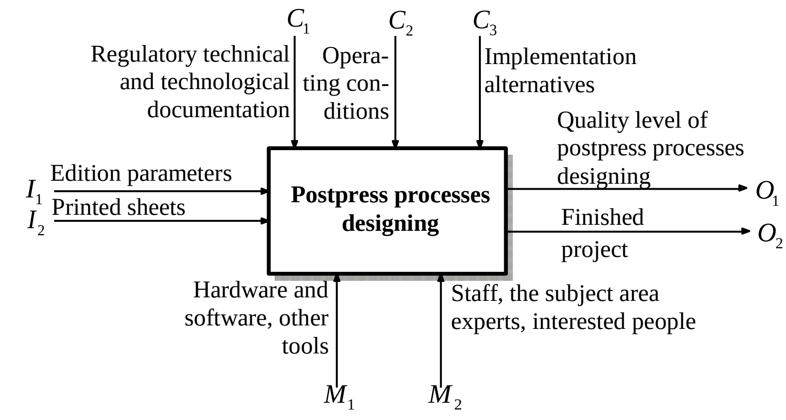

Fig. 1. Context diagram of IDEF0 model of the postpress processes implementation

7 Results

As a result of the corresponding calculations, we get a subset of non-dominant alternatives of the following form:

$$\mu_{Q_1}^{нд}(x_1) = 1 - \sup_{y \in X}\{0-0; 0-0\} = 1;$$
$$\mu_{Q_1}^{нд}(x_2) = 1 - \sup_{y \in X}\{0-0; 0-0\} = 1;$$
$$\mu_{Q_1}^{нд}(x_3) = 1 - \sup_{y \in X}\{0-0; 0-0\} = 1.$$
$$\mu_{Q_1}^{нд}(x) = [1;1;1]$$

The membership functions of the additive convolution of relations Q_2 for each planned alternative, when the values of the factors weights are set $v_1 = 0,53;$ $v_2 = 0,27;$ $v_3 = 0,13;$ $v_4 = 0,07$ have such values: $\mu_{Q_2}(x_1, x_2) = 0,73$; $\mu_{Q_2}(x_1, x_3) = = 0,2$; $\mu_{Q_2}(x_2, x_1) = 0,8$; $\mu_{Q_2}(x_2, x_3) = 0,47$; $\mu_{Q_2}(x_3, x_1) = 0,8$; $\mu_{Q_2}(x_3, x_2) = 0,73$.

We present the values of the membership functions with the help of the matrix of relations:

$\mu_{Q_2}(x_i, x_j) =$

	x_1	x_2	x_3
x_1	1	0,73	0,2
x_2	0,8	1	0,47
x_3	0,8	0,73	1

We find the elements of the subset of non-dominant alternatives for the relation Q_2:

$$\mu_{Q_2}^{нд}(x_1) = 1 - \sup\{(0,8-0,73); (0,8-0,2)\} = 0,4$$
$$\mu_{Q_2}^{нд}(x_2) = 1 - \sup\{(0,73-0,8); (0,73-0,47)\} = 0,74$$
$$\mu_{Q_2}^{нд}(x_3) = 1 - \sup\{(0,2-0,8); (0,47-0,73)\} = 1,26$$

After calculations, we get:

$$\mu_{Q_2}^{нд}(x_i) = [0,4;\ 0,74;\ 1,26].$$

According to the intersection of sets $Q_1^{нд}$ and $Q_2^{нд}$ the maximum value will have the membership function $\mu_Q^{нд}(x_3) = [0,4;\ 0,74;\ 1,26]$, i.e. the third option is considered the optimal one.

The process of functional decomposition of the context diagram shown in Fig. 1 consists in its division into lower order functions and setting of the direction of the boundary arrows, which contributes to the detailing of activities within the studied process. Based on the above statements, we construct the resulting decomposition diagram of the context diagram (Fig. 2).

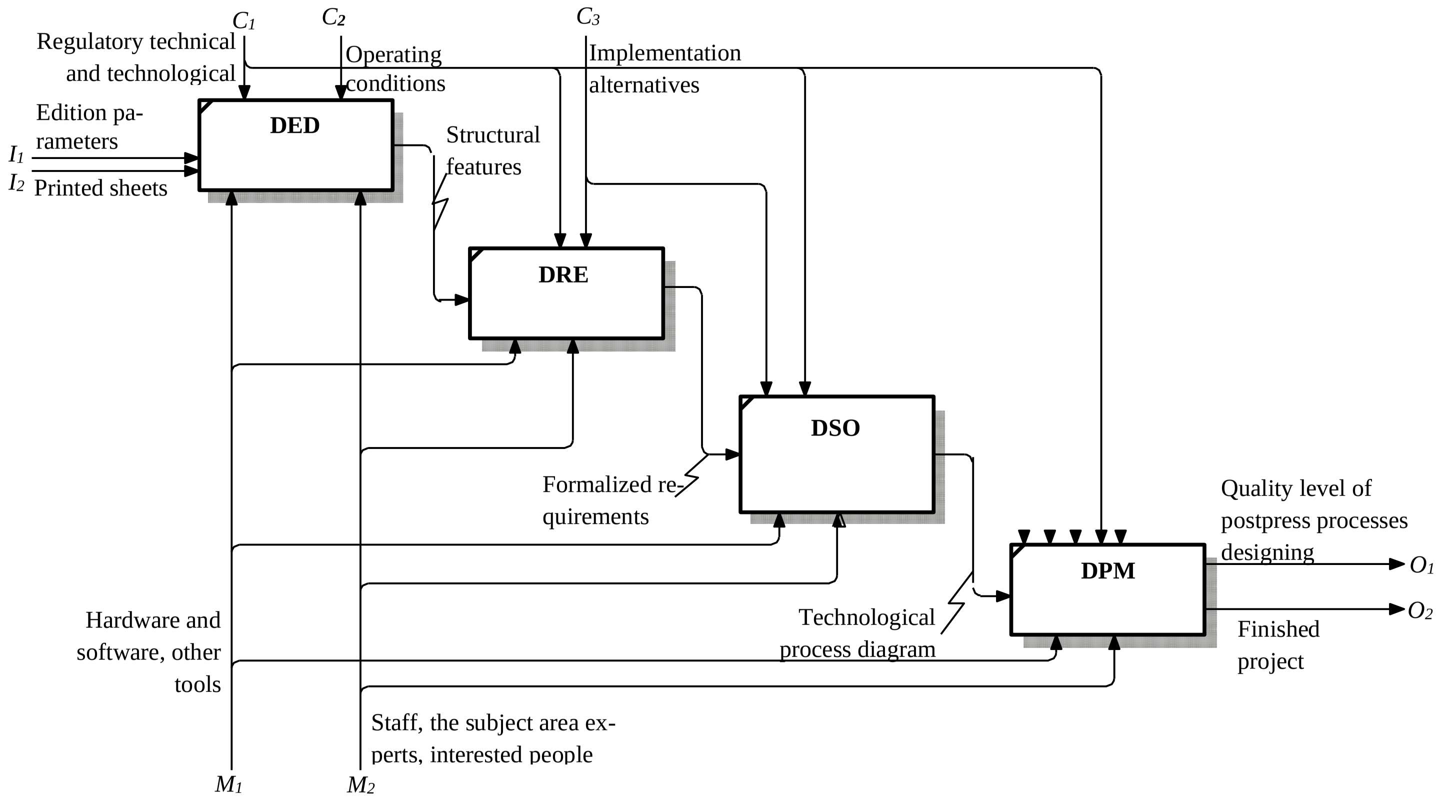

Fig. 2. Diagram of the first decomposition of IDEF0 model of the postpress processes designing

The diagram of the first decomposition of IDEF0 model of the postpress processes designing contains the following functional blocks: DED — the determination of the edition design, DRE — the determination of the requirements for the finished edition, DSO — the determination of the sequence of technological operations, DPM — the determination of the processing modes [12, 19].

We will analyse the components information load of the sets of boundary arrows in IDEF0 model of the postpress processes designing:

– I_1 *(the edition parameters).* The key parameters of the book editions are a kind, type, format and volume. Editions are divided into kinds according to a number of typological features: production method, periodicity, material structure, composition of the main text, language feature, purpose, frequency of issue, structure, etc. The format determines the size of the print sheets and the finished book block. The volume indicates the number of paper sheets or pages within a single copy [19].

– I_2 *(printed sheets).* The result of prepress processing of the originals and printing of the print run is the printed paper sheets that arrive at the postpress section.

– C_1 (*regulatory technical and technological documentation*). Regulatory technical documents include technical requirements and legal regulations, in particular: laws, standards, specifications, codes of established practice, etc.

– C_2 *(operating conditions). Operating* conditions include the lifespan and operating intensity of the finished edition [19].

– C_3 *(implementation alternatives*). Pareto-optimal alternatives, determined by the assessment of fuzzy relations on a given set of alternatives [18].

– O_1 *(quality level of postpress processes designing).* The result of the post-press processes designing is an appropriate level of the project quality.

– O_2 *(finished project).* The project determines the progress of all technological actions aimed at the implementation of postpress processes.

– M_1 *(hardware and software, other tools)*. The postpress processes designing is done using the computer technology and specific, narrow-profile software.

– M_2 *(staff, the subject area experts, interested people).* The participation of production workers in the design. If necessary, the authors and customers of the book edition are involved [19, 20].

8 Conclusions

Matrices of relations for certain factors influencing the quality of postpress processes designing have been formed. Membership functions for the convolution of relations and corresponding sets of non-dominant alternatives have been received. The selection of the most efficient alternative according to the maximum value of the membership function of the convolutions has been implemented.

Modelling of key operations and functions provides the basis for predictive assessment of the quality of the studied process.

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