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Multi-criteria choosing the method to print a job

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Abstract

The choice of printing method for this or other print product depends on many factors and, in particular, on the type and characteristics of a publication such as its volume, and the urgency of an order. The optimal selection from the available methods variety strives to get the best "price–quality–time" ratio. The issues with finding the best solutions to achieve the set goals with limited resources have always been faced by people. The concept of decision-making considers a decision a conscious choice of one of many options. At present, in connection with the growing needs of practice, an interdisciplinary scientific direction is actively developing. One of its sectors is the mathematical theory of decision-making under many criteria. With the exemplary choice of a particular print job (publication), the multi-criteria task of printing technology choice and the effect of a job volume on the cost and time of its manufacture are considered in the light of Edgeworth–Pareto principle.

Keywords: print run, printing time, print sheet, cost, Edgeworth–Pareto set

1. Introduction and background

For various tasks, starting with the products advertising and ending with vendor image performance, almost all the companies widely use printing industry services. Unfortunately, customers are not always aware of the wide print production ways variety. The choice of printing method depends on many factors and, in particular, on the type and technical characteristics of the publication, its volume, and the urgency of the order.

The most commonly used technologies are offset lithography, flexography, screen printing, inkjet printing, and electrophotography as well as some others. With the right choice of method, one can get the optimal "price–quality" ratio. It can also significantly affect both the cost and time of the order fulfilment.

Such factors as cost, time of manufacture, print run volume, print substrate, number of inks used, and of course, the quality requirements are taken into account for making the decision when choosing the printing method for a particular publication. Quality requirements are in general understood as a set of properties that reflect the level of novelty, reliability and durability, economic, ergonomic, aesthetic, environmental, and other consumer demands to the product, reflecting its ability to meet the conditioned or intended needs in the producer–customer relations (Shishkina and Khvalenya, 2021; Put, 2010; Pedersen, 2011).

Besides assessing the quality of printed products and practical advices for both printing professionals and customers, Khvalenya (2020) considers not only theoretical issues but also gives recommendations for the measurement accuracy, use of standards, quality assessment of consumables and finished products, use of the measuring instruments and objective measurement methods. There is underlined that the scientific approach to the introduction of a quality assessment system in the printing industry should be based on the recommendations of ISO standards.

The need for a systematic approach to determining the quality of print products was considered by Ivashko and Piguz (2018) with the accent on its estimation by taking into account the psychophysiological issues of hardcopy data visual perception, as well as the technology specifics directly affecting a certain feature of product quality. There were also attempts to reveal the print quality dependence on the job size for various technologies such as electrophotography, inkjet, screen printing, and offset lithography (SOOPAK, 2021).

When applying to a printing company, almost any customer has a logical question: is it possible to reduce the cost of an order without losing quality? Along with the other issues, this greatly depends on the choice of equipment. Analysis of the cost of manufacturing orders in various print houses shows that digital printing fits in general the urgent small jobs, while the traditional offset lithographic processes is preferable for large print runs and both kinds of technology complement each other very effectively (cgsadmin, 2019; Kingsley, 2022).

On the contrary, the cost of each copy greatly depends on the volume of the prepress work in traditional, for example, offset lithographic printing and the run increase leads to a reduction of each copy cost. Graphically these dependencies comprise a direct horizontal line for digital and hyperbole for offset lithographic processes. Their intersection point separates the areas of application of the two technologies. In this light, the comparison of purposeful production speeds for two particular presses: the Canon copier and Heidelberg QM 46 DI, shows that the latter prints faster just starting from the volume of 300 copies (Bendyugovsky, 2001).

It follows from above that due to the number of various factors to be taken into account, an individual approach to the choice of manufacturing technology for each specific publication is necessary.

2. Search for the best solutions

The problems associated with the search for the best solution to achieve the goals set with limited opportunities (resources) have always been posed. The concept of decision-making as a primary element of activity considers the decision as a conscious choice of one of a number of options (alternatives, plans, strategies, etc.). This choice is made by the “decision maker” who strives to achieve certain goals, i.e., by a person or a group of people who have decision-making rights, the possibilities of implementation, and are responsible for the consequences, for example, the head of the organization, an individual customer – it all depends on the specific decision-making situation (Podinovski, 1999).

Problems of multi-criteria selection, which contains not one, but several criteria at once, are of both theoretical and practical interest since a large number of applied technological and economic problems are formalized in a multi-criteria form. Positive solution is of great interest to practice, since in specific applied problems, the choice, as a rule, should be limited to one or a relatively narrow number of selected options. According to the well-known Edgeworth–Pareto principle, each option chosen must be Pareto-optimal. The criterion of optimality of the Italian economist Pareto is used in solving problems with optimization means improving some indicators without worsening others (Pareto, 1919). The Pareto region is associated with the choice of a particular Pareto-optimal option as the “best”.

As an example, this paper discusses the task of choosing the method of printing a job in a particular print house. To make a decision, goals are formulated, which are technical and economic indicators of production. Particular attention is paid to identifying and describing the “decision maker” preferences. His goals are most often strived by the desire to increase or decrease special functions called criteria (indicators of efficiency or quality, target functions…). In relatively simple cases, it is possible to deal with one criterion. And then the best or optimal option is the one that maximizes or minimizes it.

Edgeworth–Pareto principle allows to solve multi-criteria problems. In this case, the problem of choosing the optimal solution is solved according to three criteria (cost, production time, print quality), while the choice of printing method was earlier carried out only according to one criterion – the print product quality.

The principles set forth in the work of Pareto were used by many authors, primarily to assess social phenomena, in particular, the well-known rule “80 : 20” is a universal principle, according to the general assessment, of an event (Podinovski, 1999; Bogoyavlensky, 2014). The Pareto set can be defined as a set in which the value of any of the particular optimality criteria can be improved only by worsening other particular criteria – any of the solutions belonging to the Pareto set cannot be improved simultaneously according to all the particular criteria. In the works of Podinovski (1999), and Lotov, Bushenkov and Kamenev (2004) such problem solution is specified under conditions of uncertainty and risk. So, the analysis and construction of the histogram (Pareto diagrams) is not relevant, since the work considers the field of compromises and creates a space of variable criteria, and solutions belonging to the Pareto set are called effective (optimal).

The mathematical model of the decision-making situation consists in the choice of this optimal criterion. Denote through the vector X variable data on the cost of publication manufacture S_{cpm}, and the optimality criterion Z_i (i = 1, ..., m). Let Q be the set of valid values of the model variable.

In other words, for the set Q there is given an ordered set of Z_i (Z_1, Z_2, ..., Z_m), which consists of m functions Z_i, each of them corresponding to the vector X at the value of a certain criterion Z_i (X), in this case the time to print T_{time}.

Formulation of the multi-criteria Pareto optimality looks like

$$\forall X \in Q,\ 0 \leq x \leq x_i = 1,\ i = 1, n$$

$$X_{xx}\ (S_{cpm}) = X_{min}\ (S_{cpm}) \text{ at } X_{xx} = 0 \qquad [1]$$

if for valid solutions $X_1, ..., X_i$ the conditions of the task are met

$$Z_i(X_1) \geq Z_i(X_2).\ i = 1, 2, 3, \cdots, m \qquad [2]$$

and there is such a criterion Z_j ($1 \leq j \leq m$) that the strict inequality is satisfied

$$Z_j(X_1) > Z_j(X_2), \qquad [3]$$

then solution $X_1 \in Q$ is said to dominate solution $X_2 \in Q$.

In accordance with the introduced definition the solution X_i of a set of permissible ones within the multi-criteria optimization problem [1] will be optimal according to Pareto.

To assess the impact of various parameters at some standard quality level on a process of printing, the calculations were carried out with building the graphs for conditional print sheet cost and printing time dependence on the print run size.

To choose the best method, there is taken a standard edition possible to be printed both digitally and by offset lithography: a brochure printed on a sheet of 60 cm × 84 cm / 16 format, with a volume of 2 physical print sheets and inking schemes 1+1 and 4+4, respectively. A coefficient that indicates the inking of the face and turnover K_{lo} = 2. Since different paper formats are used for different presses, a brief description of the publication parameters as applied for printing on each of the selected machines is given in Table 1.

To compare the digital and offset lithographic processes printing methods (as alternatives), including the comparison of 1+1 and 4+4 inking schemes, the printing presses listed in Table 2 were selected.

To determine the optimal version of printing for this publication, it is necessary to solve a multi-criteria task by building a matrix of initial parameters for finding a solution as the optimal way to perform a job.

In order to objectively assess the quality of print products, materials of the same price class were selected for

Table 1: Publication parameters

Model	**Paper sheet size** $H \times W / P$	K_{br}	O_{pps}	$K_{sh\text{-}run}$	d
Printing scheme 1+1					
Xerox Nuvera 314 EA	21 × 29.7 / 2	1	32	1	1
Konica Minolta bizhub PRO 1250	21 × 29.7 / 2	0	32	2	1
KBA Rapida 66-2	42 × 60 / 8	1	8	1	1
KBA Rapida 105-2	60 × 84 / 16	1	4	1	1
Heidelberg QM 46-2 DI	31 × 42 / 4	1	32	1	1
Printing scheme 4+4					
Xerox Colour C75	21 × 29.7 / 2	0			1
ComColor 9150 Rice	21 × 29.7 / 2	0			1
Konica Minolta C1100	21 × 29.7 / 2	0			1
KBA Performa 66-4	42 × 60 / 8	2			1
Heidelberg SM 74-8	42 × 60 / 8	4			1

Where H and W are height and width in and P denotes the number of pages taht fit the format of the printed sheet (forming a signature); if 4 pages fit on a printed sheet, the edition is 4 share (1/4 of the full printed sheet).
K_{br} is a coefficient of bringing the paper sheet format to 60 cm × 90 cm;
O_{pps} is a volume of publication in physical print sheets (pps);
$K_{sh\text{-}run}$ is a coefficient that takes into account the number of sheet-runs per 1 physical printed sheet;
d is a number of duplicates on the printed sheet, pieces.

Table 2: Machines used in comparison

Model	Inking Face	Inking Turnover	Printing method
Printing scheme 1+1			
Xerox Nuvera 314 EA	1	1	Digital
Konica Minolta bizhub PRO 1250	1	0	Digital
KBA Rapida 66-2	1	1	Offset lithography
KBA Rapida 105-2	1	1	Offset lithography
Heidelberg QM 46-2 DI	1	1	Offset lithography
Printing scheme 4+4			
Xerox Colour C75	4	0	Digital
ComColor 9150 Rice	4	0	Digital
Konica Minolta C1100	4	0	Digital
KBA Performa 66-4	2	2	Offset lithography
Heidelberg SM 74-8	4	4	Offset lithography

calculations. The required amount of consumables and the labor needed to manufacture the products were calculated.

Based on these calculations, the cost of printing one conditional printed sheet at 1+1 and 4+4 inking, as well as the time of printing were obtained. It seemed expedient to take as a basis the interval of job volumes from 200 to 500 copies and compare the technical and economic efficiency of their production with various printing methods.

3. Results of calculations

The results of calculating the cost of one conditional print sheet and the duration of production are presented in Table 3.

To select the preferred way of printing there is used the model which consists of two parts. The first one describes the cost per copy (S_{cpm}) dependence on job volume while the other shows how the latter affects the duration (T_{time}) of manufacture. Both parts objectively reflect the printing process, as they are built on the basis of actual data. Alternative values and criteria are shown in Table 3 for 200 and 500 copies. Currently, the considered job volume is most often encountered in practice when deciding on the choice of digital or offset lithography technologies. The practice of choosing one of them shows that for runs of less than 200 copies at 4+4 inking scheme the digital one is more cost-effective while for the runs of more than 1 000 copies at the same inking scheme the traditional offset lithography is more preferable. However, for 1+1 inking scheme runs from 500 to 2 000 copies the worldwide practice tends to more widely use digital printing.

Table 3: Results for alternative printing technologies

No.	Alternative	Cost S_{cpm} (rub.)		Duration T_{time} (hour)	
	Printing scheme 1+1				
	Job volume (copies)	**200**	**500**	**200**	**500**
1	Xerox Nuvera 314 EA	17.17	11.58	1.04	1.81
2	Konica Minolta bizhub PRO 1250	27.54	23.03	3.28	6.60
3	KBA Rapida 66-2	26.87	13.84	2.92	3.31
4	KBA Rapida 105-2	39.72	18.73	2.10	2.24
5	Heidelberg QM 46-2 DI	51.27	26.90	8.90	10.26
	Printing scheme 4+4				
	Job volume (copies)	**200**	**500**	**200**	**500**
1	Xerox Colour C75	44.27	37.88	2.09	3.62
2	ComColor 9150 Rice	33.67	29.50	3.28	6.60
3	Konica Minolta C1100	34.46	27.51	3.12	6.20
4	KBA Performa 66-4	110.66	41.72	8.39	8.97
5	Heidelberg SM 74-8	126.79	47.12	5.56	5.90

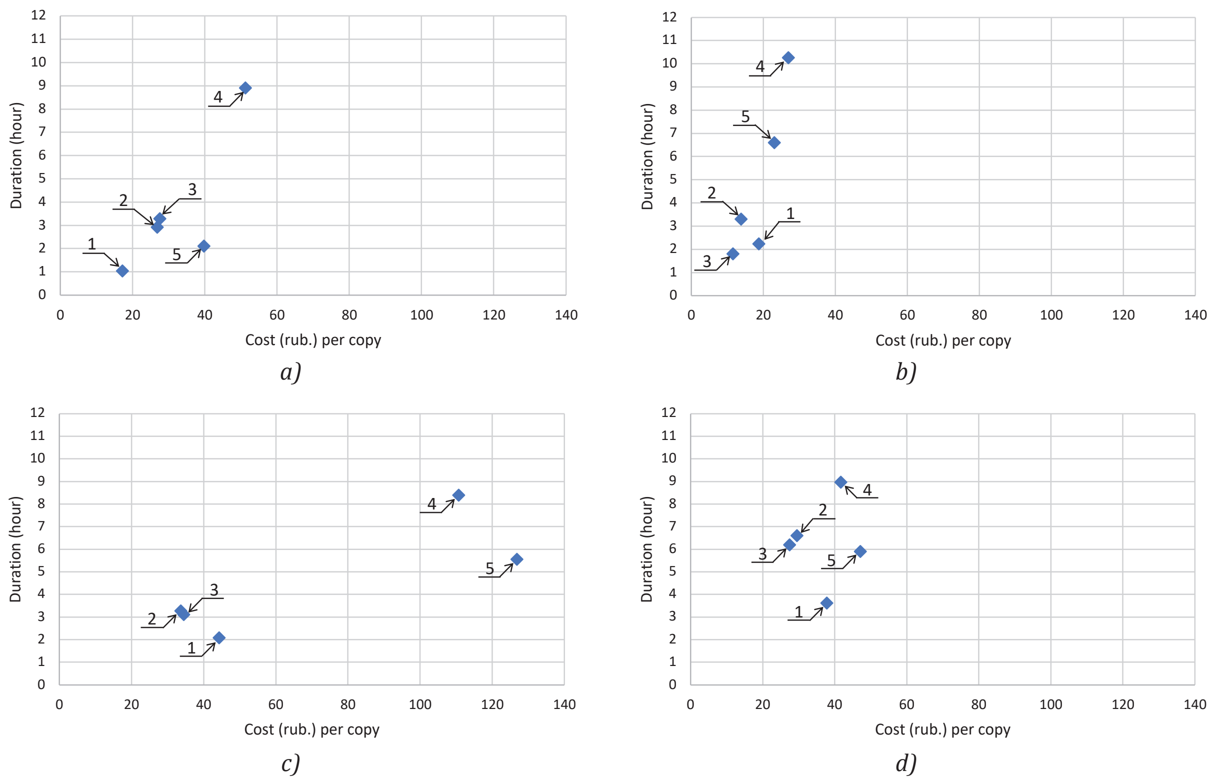

Figure 1: Two-dimensional criteria space and a Pareto set for 1+1 inking for 200 copies (a), and 500 copies (b); and for 4+4 inking for 200 copies (c), and 500 copies (d), respectively

So, the research and calculations to compare the economic feasibility of the printing technologies under consideration for larger print runs with 1+1 inking scheme are carried here using the proposed method as an example of exploring the existing scientific principles for solving complex problems where multiple parameters need to be considered. The proposed method can be also used for the effectiveness comparing of the other printing technologies, for example, flexography vs. gravure printing.

Evaluation of alternative printing methods (alternatives in general) is carried out according to the so-called “risk matrix”. To consider the choice of the best alternative on the base of Savage’s criterion (Nogin, 2005) we build a table of values (Table 3) and find acceptable solutions, as well as determine the values that are optimal according to Pareto (Lotov, Bushenkov and Kamenev, 2004). Two-dimensional criteria space in size according to the number of criteria and individual alternatives is presented in Figure 1.

4. Discussion

Let’s choose the Pareto set by a pairwise comparison of alternatives according to all criteria.

According to criteria of “cost” and “time” the alternative 1 is optimal from alternatives 1 and 2 (Figure 1a, Figure 1b) at 1+1 inking scheme. Then alternative 2 is excluded from consideration due to the higher costs and time. Comparison of alternatives 2 and 3 shows, in turn, that the latter one is more preferable according to the same set of criteria, which excludes the alternative 2 from consideration.

Further comparison of alternatives 3 and 4 reveals that the first of them is more preferable according to the “cost” criterion, while the other (4) prevails in relation of spent “time”.

Therefore, none of these alternatives is excluded from consideration. At the same time, the preference of alternative 4 over 5 is vivid according to the both criteria.

So, only the options 1, 3, and 4 comprise the Pareto set for the “decision maker” choice.

The Pareto set of alternatives shown in Figures 1a, 1b, and in Figures 1c, 1d includes the most optimal alternatives for choosing the way of printing among the concerned typical nomenclature of “digital / offset lithographic processes” presses.

As a result, the following options are included in the Pareto set:

- the alternatives 1, 2, 3 for 200 copies and 1, 3, 4 for 500 copies at 1+1 inking scheme;

- the alternatives 1, 2, 3 for the both job volumes of 200 and 500 copies at 4+4 inking scheme.

The choice of the best option from the proposed ones remains with the "decision maker".

5. Conclusions

Task of choosing the optimal way to print a publication according to the "cost – time" criteria at a standard quality level is solved with taking into account the results of comparative calculations based on parameters of 10 digital and offset lithographic processes presses.

Diagrams characterizing the two-dimensional criteria spaces and the Pareto set for printing at 1+1 and 4+4 inking of 200 copies and 500 copies have been built on the basis of calculated data. Among all possible options, the one that was optimal according to Pareto was chosen. The best alternatives were chosen, also guided by Savage's criterion.

The proposed solution of the multi-criteria optimization problem can be used by print house managers to develop the optimal version for the way of production with taking into account the customer demands.

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