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PROBLEMS OF FUNCTIONING OF PRINTING ENTERPRISES IN CONDITIONS OF UNCERTAINTY*

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Abstract. The article deals with the problems of development of printing enterprises in Ukraine in the conditions of uncertainty connected with military operations (destruction of enterprises, problems with supply of imported raw materials, logistic obstacles, risks of shelling, power cuts, etc.). The study points out the dependence of the printing industry on the import of raw materials and the dependence on customer enterprises, many of which ceased to operate after the start of a full-scale invasion of Ukraine. It is proved that the producers of printing products are forced to adapt to modern realities in conditions of uncertainty. A list of necessary factors that will create an additional impetus for the development of enterprises is presented. The relationship between such components as new sales markets, availability of resources, efficiency of material and technical support, enterprise development is described in detail. It is proposed to examine the possibility of using the theory of strategic games as a direction for optimizing the configuration of printing enterprises with material reserves. It is established that the development of the printing market is determined by the development of the industries consuming printing services. This proves the intensification of the struggle for sales markets. Since printing is a material-intensive industry, it is relevant to take into account modern challenges. To solve the problem of enterprise development it is proposed to use the theory of strategic games. On the basis of the calculation of possible strategic options it is determined which strategy should be chosen for the printing enterprise. The possibilities of the development of conditions for the optimization of the equipment of printing houses with material reserves using the theory of strategic games are shown.

Key words: game theory, efficiency, strategy, development, inventories.

JEL Classification: C02, C79, D29, D81, E66, L10, L20, L52, L60, M20

1. Introduction

Against the background of armed aggression against Ukraine, the urgency of preserving the economic development of the state is of particular importance. The activities of all business entities today are associated with many subjective and objective risks. The printing industry supports the activities of many other industries and at the state level becomes particularly important in the focus of national security.

Printing is the use of tons of paper that is constantly processed, it is expensive equipment and large production facilities that can become easy targets for the enemy. For example, in the city of Kharkiv, printing companies were partially destroyed by the invaders. Many businesses are still unable to resume operations due to constant shelling or power outages. The printing industry depends on paper imports, which have been a major problem during the war. The problem of effective operation of printing enterprises also depends on the customer enterprises, and since many production facilities in Ukraine were shut down, the production of printed products also decreased. This is not to say that all regions experienced the same decline in production, although it should be noted that all companies felt the negative impact (to varying degrees). It is also important to note that there is no time to talk about restoring 100% of pre-war production volumes.

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Managers of a large number of companies today talk about loading only 30-50% of the possible volume. Therefore, it can be said that most printers are working to keep customers and support equipment, as it is difficult to ensure the profitability of the printing business today.

It should be noted that not only Ukrainian enterprises, but also Western ones have experienced negative changes in their activities. For example, the printing associations of the EU reported that printing houses were forced to build up stocks of paper for production for three to four months in advance, and the process of buying paper is difficult, since there are long delays in its production and timely delivery. However, the accumulation of raw materials in warehouses is not effective for Ukrainian printing companies, since there is a constant threat of shelling. In addition, in some cases, the storage conditions for raw materials have changed; many companies have moved to other locations; logistics operations within the country itself have been further complicated by restrictions related to curfews, roadblocks, etc.; there has been a problem with delivery to certain areas due to additional risks. This difficult situation is forcing print providers to adapt to modern realities under conditions of uncertainty. In order to give an additional impetus to the development of the printing industry in today's conditions, it is necessary to: create favorable conditions for production in those areas where it is possible; find ways to support printing houses that should meet the needs of the market; develop ways to improve the efficiency of operations in conditions of uncertainty.

Purpose of the article: investigation of the possibility of using the theory of strategic games as a direction for optimizing the equipment of printing companies with material reserves in modern economic conditions with a high degree of uncertainty.

2. Literature review

Since the beginning of the full-scale war in Ukraine, the problems of the functioning of printing enterprises have been repeatedly raised by practitioners. The system of material and technical support (the problem of the raw material base, logistics, fuel, etc.) plays an important role in supporting the development of a printing enterprise in today's conditions. Managers of printing houses have to make key management decisions in conditions of uncertainty of the external environment to solve the problem of development, the authors proposed to use the theory of strategic games.

A large number of works are devoted to game theory. Cardano first described games in "Liber de ludo aleae" (around 1564), and game theory was widely developed in the 50s of the twentieth century. It is now recognized as an important tool in many fields (Chen, Nok., 2022; Fang, Liu, Basak, Zhu, Kiekintveld, Kamhoua, 2021). As of 2020, fifteen game theorists have won the Nobel Prize in Economics. Today, the International Journal of Game Theory is published, which proves its popularity among scientists. Game theory itself is defined as the study of mathematical models of strategic interaction between rational agents (Myerson, Rodger B., 1991). Game theory is widely used in the study of sales markets of industrial enterprises (Berninghaus, Güth, Levati, et al., 2011). The study of models of selection of sales markets for enterprises (Anisimov, V. & Anisimov, E. & Saurenko, T., 2020) proves the importance of logistics processes, and the introduction of anti-crisis measures related to the activities of enterprises is largely based on the adequate provision of necessary resources (Obydiennova, Antyptseva, Dudnieva, 2019). Thus, it is possible to trace an inextricable link between the following components: 1) new sales markets; 2) availability of resources; 3) efficiency of logistics; 4) development of the enterprise.

3. Development of the printing market under martial law

The printing industry is an industry that mainly employs small and medium-sized enterprises, and its development is determined by general economic factors, such as the growth of the industry as a whole or consumer demand. The development of the printing market is determined by the development of the industries that consume printing services, and the fact that printing is one of the high-tech industries further complicates its activities under military conditions. At the same time, both state-owned enterprises and private enterprises are currently in difficult conditions. It is also worth noting that printing is a material-intensive industry, which has certain characteristics in the composition of production assets: 1) a relatively large share of working capital; 2) a high percentage of premises, machinery and equipment (more than 90% of the total cost of fixed assets); 3) in the production process, enterprises use a large number of resources; 4) in the structure of the cost of printing products, the largest share is occupied by raw materials (materials), and so forth. For products that require significant post-printing work, the percentage is lower, but this is still a key position – 30-70% of the cost price.

With the beginning of a full-scale invasion, paper from abroad stopped coming to Ukraine, the exchange rate rose, and logistics became so expensive that it was extremely difficult to make any price calculations. The problem was aggravated by the fact that European countries also felt an imbalance. Paper producers attributed the price increase to problems with the

availability of raw materials (wood) and higher energy prices.

Last year was also difficult for the printing market due to problems with the supply of resources. Domestic manufacturing enterprises were partially closed, others were bought by competitors or became inaccessible to the Ukrainian market due to product prices that increased significantly due to logistical problems, etc. On the one hand, enterprises tried to find suppliers, but on the other hand, they did not have timely delivery of raw materials to warehouses. At the same time, the companies that ordered printing products did not always understand such circumstances in the printing market, as a result of which the profitability of the printing house decreased or the customer was lost. The issue of obtaining high quality raw materials in large quantities and at affordable prices for printing companies is still extremely important and sometimes decisive for the existence of the company as a whole. In other words, the issue of the probability of late delivery of necessary material resources to printing companies is updated.

The main task of any enterprise, publishing house or printing house is to develop even in the conditions of military operations. This statement is also true because the possibility of successful functioning of the state as a whole depends on economic stability. This problem can be solved in a comprehensive and joint manner only by reacting quickly to the changes that are taking place and by working out all possible ways of providing material resources to printing companies.

4. Effective material and technical support as a factor in the development of a printing enterprise

Taking into account all the obstacles connected with the activities of printing houses in Ukraine, it is necessary to note that the material and technical support (MTS) system of production plays an important role in improving the use of material resources. The main goal of MTS production is to meet its material needs in a timely manner with the highest possible economic efficiency, which fully coincides with the goal of supply logistics. In order to successfully achieve the company's management goal, it is necessary to: identify the critical nomenclature of material resources used in the production process; ensure the exact correspondence between the number of deliveries and their needs; maintain reasonable purchase terms; meet the quality requirements of materials; try to ensure the timely delivery of materials to production units and workplaces. The implementation of the MTS process in printing enterprises is divided into stages: 1) organization of material supply to the company's warehouses; 2) management of production stocks; 3) organization of MTS workshops, sites and workplaces. In this case, one can use two forms of delivery: direct (transit) and warehouse. The first option is not economically feasible, since it leads to a deterioration in the turnover of the enterprise's working capital. In the second case, the material resources are first transferred to the warehouses of intermediary companies. This form of delivery is widely used by printing enterprises as it allows rational use of working capital of the enterprise, not to create excess materials in the warehouses of the enterprise, thus contributing to increase of profitability of the enterprise. However, the appearance of an intermediary in the "producer-consumer" chain naturally leads to additional costs for covering the costs of intermediary organizations' activities. At the same time, this need is justified by the lack of possibility to establish direct links between the producer and the consumer of material resources. The effectiveness of the warehouse form of delivery depends largely on the optimal choice of the supplier (intermediary) and the frequency of purchases. This is characterized by a high degree of uncertainty associated with military operations on the territory of Ukraine.

The next stage of MTS production is carried out in the internal environment of the enterprise and is aimed at optimizing the level of production stocks. At this stage, specific types of work are performed: the need for each type of material resource for the planned period is determined, production stocks are optimized, their rational use is monitored, etc. As it is known, production stocks are a set of material resources that have arrived at the enterprise's warehouse but are not involved in the production process. They are among the objects that require large capital investments and therefore represent one of the factors that determine the efficiency of the organization of production in the enterprise. The number of material resources should be sufficient in quantity and quality to ensure the continuity of the production process in the printing enterprise. At the same time, unreasonably high value of production stocks leads to inefficient use of working capital of the enterprise, which creates the need to optimize the size of production stocks. In normal conditions of activity of enterprises, rationing of production stocks is used (the process of establishing for each type of material resources a reasonable minimum amount of them necessary to ensure the rhythmic operation of a printing enterprise). Standards are set in calendar days, in physical and monetary terms. Effective management of production stocks in printing enterprises includes, in addition to the traditional control method, the use of modern inventory

Table 1
The most widely used production inventory management systems

System	Characteristics
with a fixed delivery size	Replenishment takes place at the expense of a certain amount of a certain type of resource; the volume of purchases should be not only rational, but also optimal (as a criterion of optimality, a minimum of total costs (use of warehouses, storage costs and transportation costs) for storing a stock of materials and transportation costs are most often used); increasing the delivery time leads to savings in transportation costs; the probable risk of illiquid stocks.
with guaranteed delivery size	It includes the calculation of the guarantee (insurance), the maximum and the maximum desired stock level; it is aimed at ensuring the need for this type of resource for the time (maximum possible) of the expected delivery delay; the value of the maximum desired stock in this system corresponds to the optimal loading of the warehouse premises while ensuring a minimum of total costs.
with a fixed interval between deliveries	The system is based on determining the optimal delivery interval; in the practice of printing enterprises, a system with a fixed delivery interval can be used for material resources with a limited shelf life, for example, for the supply of glue to a printing enterprise. In the system under consideration, the delivery time is predetermined and does not change under any circumstances, and the delivery quantity is constantly recalculated. The calculation is based on the expected consumption before the material resource arrives at the company's warehouse.
"Just-in-Time" inventory management system	Its main difference is that the supply of material resources is carried out directly at the primary stage of production, and not to the warehouse; it is assumed that production facilities are ready to process materials and semi-finished products from the side almost "from the wheels", as a result of which the volume of production stocks is minimized; in order to assess the effectiveness of the organization of the production process, in addition to the level of costs, it is necessary to take into account the duration of the production cycle of products.

management systems: 1) optimization of the delivery value; 2) the size of the delivery interval. Other inventory management systems are based on the use of these two basic systems (Table 1) (Organization of Printing Production, 2002).

Despite the fact that the above-mentioned approaches to inventory management are designed to ensure a continuous production process, in today's conditions none of the systems can guarantee the efficiency of the enterprise, since the external conditions are characterized by a high degree of uncertainty, which does not allow the full implementation of the presented systems. That is, today printing enterprises are subject to the requirements of greater flexibility of production, which is achieved, in particular, through the use of modern inventory management systems.

5. Development of printing enterprises in conditions of uncertainty

The necessity to adapt the printing industry to modern realities leads to the necessity to study the effectiveness of various methods of material resources management in such conditions. The search for methods of inventory management in printing enterprises in conditions of uncertainty, taking into account modern challenges, becomes relevant.

In order to solve the problem of development of the enterprise in the presence of certain factors, the efficiency of the process is evaluated by the minimum value of the probability of completion of the task, which is possible with the worst values of uncertain factors. The optimality condition of the process (system) in this case has the following form:

$$W = \max(\min)\ [P(A/Z)], \quad (1)$$

where A is a random variable involved in reaching the goal; Z are undefined factors; $P\ (A/Z)$ is the probability of event A under conditions Z.

Such problems are solved using game theory, which allows one to apply a mathematical basis to problems that are usually solved empirically, without using quantitative estimates.

For further research, the theory of two-player games (A and B) is used. The outcome of a game, a win or a loss, is characterized by a number (the game price).

The principle (theorem) of Minimax, which can be formally written:

$$\max_a \left[\min_b V(a,b) \right] \le \min_b \left[\max_a V(a,b) \right], \quad (2)$$

where a and b are the characteristics of the actions of players A and B;

$V\ (a, b)$ – loss function (payment function).

When such an equation occurs, the corresponding value of the function $V(a, b)$ is called the saddle point of the game, which is the intersection of the optimal strategies of players A and B (Berninghaus, Güth, Levati, et al., 2011).

At this point, one player's minimum maximum loss coincides with another player's maximum minimum loss. In this case, consider a finite game, i.e., a game in which players A and B have only a finite number of strategies.

Player A has strategies $A_1, A_2,...,A_n$.

Player B has strategies $B_1, B_2, \ldots, B_m$. This is a m×n game.

The win of player A in strategies A and B is denoted by a_{ij} (Tishchenko, 1976).

This game can be interpreted as a battle between two enterprises for product sales markets. Let one

of the enterprises (player A) try to oust the other enterprise (player B), which has two sales markets, from one of them.

In a formal entry, the winning function of a given game is set by the ratio:

$$H(y,x)=\begin{cases}K_1(x-y), \ if \ x\geq y \ (k_1>0);\\ K_2 \ (y-x), \ if \ x\leq y \ (k_2<0),\end{cases} \quad (3)$$

where *x, y* – are the amounts of funds allocated by players A and B, respectively, to maintain the markets.

Player a's strategy is to distribute these funds between two markets. If the amount X is sent to the first market, then the amount 1-x is sent to the second market. At the same time, player B also has a single amount to save the markets, and his strategy will consist in allocating the amount B to the first market and 1-y to the second.

Suppose that player A, having gained an advantage in one of the markets, receives a profit (a production order) equal to the loss of his funds multiplied by the coefficient characterizing the importance of the market (k_1 for the primary market; k_2 for the secondary market). Dependency graph $H(x_0,y)$ from y is a pair of rectilinear segments if $x_0=0$ or $x_0=1$, one of these segments is drawn into points.

In the function graph max $\{k_1(1-y),k_2y\}$ the first term under the maximum sign decreases with increasing *y*, and the second term increases. Therefore, for small values of *y*, the maximum can be reached on the first term, and for large values of *y* – on the second term. Thus, for such a *y**, the minimum value of the maximum is taken for which:

$$k_1(1-y^*)=k_2y^*, \quad (4)$$

Hence, the following:

$$\max_x H(x,y)=\max_{x\geq y}\left\{\max k_1(x-y),\max_{x\leq y} k_2(x-y)\right\}=$$

$$=\max\{k_1(1-y),k_2y\} \quad (5)$$

Therefore,

$$V=\min_y\max_x H(x,y)=\min_y\max_x\{k_1(1-y),k_2y\}, \quad (6)$$

$$\text{In } y^*=\frac{k_1}{k_1+k_2} \quad (7)$$

Thus, what is found in *y** is the only optimal strategy of player B. It can be seen that the optimal strategy of player B is to distribute the available funds among the markets and at the same time in proportion to the importance of the markets. In general, the profit is a random variable and its value can be written in the payoff matrix or the efficiency matrix.

6. Research results

Using the methodology of operations research, the authors call the measure of profit a_{ij}, performance indicators W_{ij} strategy option A_i in the conditions of B_j. In the efficiency matrix, instead of the decision option, write the strategy option and replace W_{ij} by a_{ij}. To solve the game m×n means to know for each player such a strategy that its average profit for more games is the largest (Vorobyov, 1974).

Construct the efficiency matrix of a printing enterprise. Printing enterprise A plans to purchase paper products for the production of printed products, the need for which depends on the demand of enterprise B. The need for printing paper with reduced demand can be 5 tons; with normal demand – 8 tons; with increased demand – 10 tons. the price of paper for the production of printing products can be: 1) 85 thousand UAH/ton with reduced demand; 2) 93 thousand UAH/ton with normal demand; 3) 100 thousand UAH/ton with increased demand.

It also answers the question: What strategy should the company choose to purchase 5 tons, 8 tons, or 10 tons of paper? Therefore, the cost matrix is created and nine possible strategies for the company are calculated (Table 2). The table shows that the minimum term is -925 thousand; -880 thousand; -850 thousand, and the column maxima are -425 thousand; -680 thousand; -850 thousand, and the maximum minimum term (by columns) coincides with the minimum maximum of columns by terms. Thus, the best solution is to buy 10 tons of paper products at the price of 85 thousand UAH/ton.

7. Conclusions

The article proved that many enterprises of the printing industry are unable to resume their work due to the war on the territory of Ukraine. Many enterprises-consumers of printing products were forced to partially or completely stop work. In addition, the printing industry is dependent on paper imports, which caused additional problems during the war. As a result, most printing houses are working

Table 2

Player expense Matrix

Paper stock for the production of printed products	Demand		
	B_1 (low)	B_2 (normal)	B_3 (high)
A_1=5	a_{11}=-425 thousand	a_{12}=-704 thousand	a_{13}=- 925 thousand
A_2=8	a_{21}=- 680 thousand	a_{22}=-680 thousand	a_{23}=- 880 thousand
A_3=10	a_{31}=- 850 thousand	a_{32}=-850 thousand	a_{33}=- 850 thousand

to keep customers and maintain equipment, and it will take several years to restore production to pre-war levels. Ukrainian printers cannot store raw materials in warehouses because of the constant threat of shelling. The storage conditions for raw materials have also changed (many companies have moved to other locations; logistics within the country have also become more complicated due to restrictions related to curfews, roadblocks, etc.). Therefore, the issue of obtaining high quality raw materials in large quantities and at an acceptable price is extremely important for printing enterprises, and sometimes crucial to the existence of the company as a whole.

Thus, in the article the question of making key management decisions in conditions of uncertainty was examined, namely the study of the feasibility of using the theory of strategic games as a direction for optimizing the equipment of printing houses with material stocks. The article presents approaches to the management of material and technical support and notes that in today's conditions none of the systems can guarantee the efficiency of the enterprise. The necessity to adapt the printing industry to modern realities leads to the importance of researching the effectiveness of various methods of material resources management. The theory of two-player game was used in the work. The conducted research allows to draw a conclusion about the effectiveness of the application of the theory of strategic games in the management of the material and technical support of the enterprises of the printing industry in the conditions of uncertainty and, if necessary, in making quick managerial decisions. At the same time, the example shows the wide range of possibilities for the development of conditions for the optimization of the equipment of printing enterprises with material reserves with the help of economic and mathematical modeling methods.

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