Modeling of complex diversification for centralized pharmacy network

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Abstract. The risk management of a centralized pharmacy network identifies the research object. The paper proposes a strategy of complex diversification for the pharmacy network. By constructing portfolio models for complex diversification and solving relevant multicriteria problems, multiple pareto-optimal portfolios have been found for successive risk management. Based on the fundamentals of Markowitz portfolio theory and multicriteria optimization, this paper builds four models of the optimal portfolios for centralized pharmacy network. In contrast to the classic two-criteria model (risk minimization while maximizing income), our models have been introduced to maximize entropy, which enhances the diversification effect. Matlab software has been developed for solving multicriteria problems. Model verification was performed on real data provided by one of the pharmacy networks. The modeling results will be useful for automating the business processes of any trading network, managing risk, analysing loyalty programs to improve the effectiveness of their operations.

1 Introduction

The modern pharmacy market of Ukraine is characterized by a fierce competition between its leaders. The consolidation of pharmacy networks is continuing actively. For 2017-2018, the share of TOP-100 pharmacy networks by sales increased by 8.4%. All this is against the background of market sales growth of 15% (up to UAH 40.6 billion in the first half of 2019) in UAH terms and a decrease of 3% in kind (up to 543.7 million packages) [1].

The decrease in demand is a reflection of the fact that the pharmacy market is subject to fluctuations, since it is almost entirely financed by the consumer and directly depends on the well-being of the population. This indicates the risks involved in managing the pharmacy network. And ignoring these risks will lead to a loss of profit, loss of financial revenues, and a decrease in the level of competitiveness of the network. For sustainable development and dynamic growth, pharmacy networks need to diversify their operations by optimally allocating their own resources across outlets. This will avoid the large group of risks associated with the likely occurrence of losses in the sale of products or services. Risk tracking allows the network to respond to internal and external changes in a timely manner, reducing financial, material, moral, human and other losses.

A pharmacy network is an amalgamation of pharmacies whose consolidation is based on certain principles. There are pharmacy networks of three types: holding; centralized; mixed [2].

Holding type pharmacy network is a collection of pharmacies and subdivisions, each of which has its own

Code of the Unified State Register of Enterprises and Organizations of Ukraine. They can have their own bank accounts, act independently, but have one owner, that is, they are only formally linked.

A centralized pharmacy network is characterized by the fact that all pharmacies and units have a single Code of the Unified State Register of Enterprises and Organizations of Ukraine, and a license is generally allowed under the same license; pharmacy banks do not have their own accounts.

A mixed-type pharmacy network is a structure in which the characteristics of holding networks are combined with those of centralized ones.

The conducted studies are based on the basic principles of the classical portfolio theory of Markowitz [3], of Contemporary Applications of Markowitz Technique of J. B. Guerard [4], the modern digital portfolio theory K. Kenneth Jones [5], The works of the Ukrainian scientist B. Yu. Kishakevich [6] are known in the field of multicriteria modeling of optimal loan portfolios. However, despite numerous results, the problem of modeling the comprehensive diversification of the pharmacy network has not been previously investigated.

The attempt of the state to directly influence the pharmacy market resulted in the Draft Law "On Amendments to the Law of Ukraine" On Medicines "on Ensuring Economic Competition and Protecting Patients' Rights in Retailing of Medicines" No. 8591 of 12.07.2018.

The bill establishes significant restrictions on opening pharmacies by establishing a distance between pharmacies of at least 500 meters; the number of

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pharmacies in legal entities – no more than 8 pharmacies within one area, and individuals – entrepreneurs – no more than 1 pharmacy; introduction of unequal conditions of activity of municipal, state and private pharmacies. However, it should be noted that the pharmacy network – the market leader occupies just over 11% of its volume among legal entities, the top 3 hold 23.6%, the top 5–30% of the market. The top 100 drugstore networks accumulate 73% of the pharmacy market. Single pharmacies and pharmacy networks, which have up to 10 pharmacies, own 46% of the outlets. Megamans (more than 50 outlets) generally own 36%. All this indicates that the pharmacy market is not monopolized with a large number of players on it, and therefore there are risks to the network in a competitive environment.

The object of the study in this paper is to manage risks in the functioning of a centralized pharmacy network by diversifying the portfolios of its structural elements and the network itself as a whole.

The purpose of the work is to build a complex of models of diversified portfolios and to study them under different operating conditions, which in particular are caused by changes in the legislation and the rapid development of the information society. The emergence of such processes in Ukraine is the emergence of a National Electronic Health System in Ukraine "eHealth" [7].

2 Optimal portfolio models of pharmacy network

Research on the functioning of the pharmacy network as a whole based on a systematic approach raises the question of determining the overall structure of the system that would provide optimal modes of functioning and adaptation. A pharmacy network is considered to be an open system consisting of several interconnected subsystems; combines goals, resources and processes that occur within and around the network.

For the pharmaceutical supply system, the characteristic features are the hierarchy of control systems, the presence of elements of different origin and functional orientation, a considerable number of subsystems.

Diversification represents a strategic decision on the possibilities of enterprise development by managing the portfolio of different types of activities of the units or taking advantage of the competitive advantages of joining efforts to achieve a single goal; expansion of directions of activity of the enterprise. Diversification is a tool for adapting the pharmacy network to achieve the strategic goals of the company, such as reducing risk, enhancing the financial stability of the network, stabilizing financial revenues, building the potential for competitiveness and insensitivity to market changes. Increasing the financial stability of the network is due to the increase in the value of working capital by obtaining the maximum financial result from the purchased goods in the least period of time [4].

The diversification process is complicated by the fact that the pharmacy network is a structure that does not have its own production base, resells the available goods and does not have the ability to influence their price and quality characteristics, but can optimally select the assortment according to the specific needs of each outlet. In addition, the pharmacy network operates in a highly competitive market, which limits its agility in the process of forming the final price of the product.

A qualitative approach to managing the pharmacy network outlets in a highly competitive marketplace minimizes the risks of the actual or potential decline in the profitability of pharmacies.

Applying a portfolio approach in this paper, we examine the complex process of pharmacy network diversification, taking into account the activities of suppliers, the network itself and customers over a single period of time.

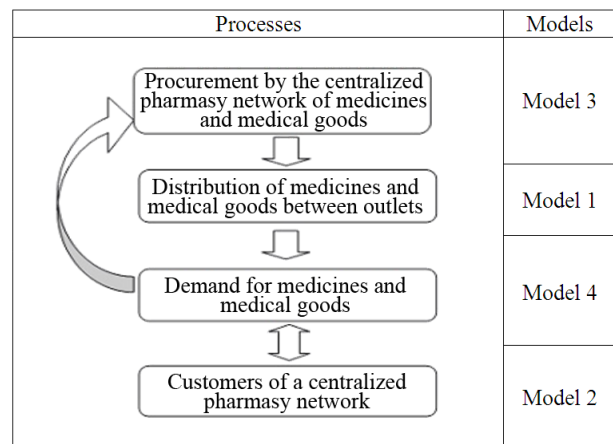Flowchart of a complex diversification program is presented in Figure 1.

Fig. 1. Flowchart of a comprehensive diversification program.

All models have the same composition of the vector objective function, which consists of three criteria: Risk, which is reduced; Sum is the portfolio yield that is desirable to increase; Entropy as a value that characterizes the level of diversification of the relevant portfolio (diversity assessment) that the pharmacy network is trying to increase in its activities. In addition, each model has its own specific system of constraints, which is determined by the business process of the pharmacy network in the structure of its activities.

2.1 Portfolio model of optimizing the distribution of finances

Let's build a formalized portfolio model of optimizing the distribution of finances between outlets of a centralized pharmacy network – Model 1. By distributing goods optimally across outlets, the network earns maximum profits by responding promptly to the circulation of drugs over a period of time, since demand for drugs in a particular pharmacy is not constant and goods that are not sold in one outlet can be timely sold in another and generate profits without increasing the length of the composition. Trade turnover of a pharmacy network is the

sum of trade turnover of its pharmacy establishments. The turnover of an individual pharmacy is estimated to be sufficient at the level of UAH 2 million, which defines additional limitations in Model 1.

Let x_i is the share of the i-th pharmacy in the turnover of the pharmacy network, which is equal to the share of allocated financial resources in the i-th pharmacy; a_i – expected turnover of this pharmacy (UAH); n is the number of pharmacies in the network.

In this model, the Risk criterion – structural risk – is the risk of irrational distribution of financial resources of a centralized pharmacy network between outlets. Structural risk is defined as the covariance of turnover of i-th and j-th pharmacies.

So, we have a multicriteria quadratic programming problem.

$$\begin{cases} Risk = \sum_{i=1}^{n}(a_i - \bar{a}) \cdot (a_j - \bar{a}) \cdot x_i \cdot x_j \to min, \\ Sum = \sum_{i=1}^{n} a_i \cdot x_i \to max, \\ Entropy = -\sum_{i=1}^{n\Sigma} x_i \ln(x_i) \to max, \\ \sum_{i=1}^{n} a_i \cdot x_i \geq 2 \cdot 10^6 \cdot n, \\ \sum_{i=1}^{n} x_i = 1, x \in [0..1]. \end{cases} \quad (1)$$

The solution to problem (1) is the vector $\overline{X^*} = (x_1, x_2, \dots, x_n)$ – the optimal plan for the distribution of financial resources of the central pharmacy network between outlets.

2.2 Portfolio model of optimal combination customers

Any medicinal product or medical device has certain properties that are attractive to a particular segment of consumers. The more pharmacy consumers are, the lower the risk of loss of income. We will divide pharmacy customers into three groups: loyal (regular), casual and online clients. We believe that all three customer groups do not intersect. Loyal customers include pharmacy turnover and discount cards. Casual – all other visitors, with low purchase frequency.

The pharmacy network's goal is to increase the average check and purchase frequency for each customer group. To formalize Model 2, we introduce the following notation:

y_1 – share of loyal customers in the pharmacy customer portfolio,

y_2 – share of casual pharmacy network customers,

y_3 – share of online pharmacy customers,

b_i – average check for the i-th group of pharmacy network clients (UAH),

$\bar{b}_i$ – expected average check for the i-th group of pharmacy network clients (UAH),

q_i – the average frequency of visits to the i-th pharmacy customer group,

$\bar{q}_i$ – expected average frequency of visits to the i-th pharmacy customer group.

The risks in this situation are the failure to obtain an average check from loyal Risk1 customers and a decrease in the frequency of visits to casual Risk2 clients. This model also provides two criteria that meet the goal of maximizing profitability: Sum1 – the total average

frequency of visits to pharmacy customers and Sum2 – the total average check across the network as a whole.

$$\begin{cases} Risk1 = \sum_{i=1}^{3}\sum_{j=1}^{3} y_i \cdot y_j \cdot (q_i - \bar{q}_i) \cdot (q_j - \bar{q}_j) \to min, \\ Risk2 = \sum_{i=1}^{3}\sum_{j=1}^{3} y_i \cdot y_j \cdot (b_i - \bar{b}_i) \cdot (b_j - \bar{b}_j) \to min, \\ Sum1 = \sum_{i=1}^{3\Sigma} y_i \cdot q_i \to max, \\ Sum2 = \sum_{i=1}^{3\Sigma} y_i \cdot b_i \to max, \\ Entropy = -\sum_{i=1}^{3\Sigma} y_i \cdot ln(y_i) \to max \\ \sum_{i=1}^{3} y_i = 1, y_i \in [0;1]. \end{cases} \quad (2)$$

For problem (2), modifications generated by different combinations of Risk1, Risk2, and Sum1, Sum2 criteria are possible to investigate the effectiveness or development of new loyalty programs. Another modification of the model is to deepen the study of clients' portfolio to the level of each individual outlet. Then the sum of the optimal customer portfolios of a particular outlet forms the optimal portfolio of pharmacy network clients as a whole.

The solution to problem (2) is the vector $\overline{Y^*} = (y_1, y_2, \dots, y_n)$ – the optimal combination of distribution of groups of loyal, casual and Internet clients.

For the task, possible modifications are generated by various combinations of the Risk1, Risk2 and Sum1, Sum2 criteria in order to study the effectiveness or develop new loyalty programs.

Entropy Maximization Criteria provides a strategy to diversify a customer portfolio.

The second direction of modification of model (2) is to deepen the study of the customer portfolio to the level of each individual outlet. Then the sum of the optimal customer portfolios of a particular outlet forms the optimal portfolio of customers of the pharmacy network as a whole. Let's introduce the following notation:

y_{k1} – the share of loyal customers in the portfolio of clients of the k-th outlet;

y_{k2} – the proportion of random customers of the k-th outlet;

y_{k3} – the share of Internet customers of the k-th outlet;

b_{ki} – the average check for the i-th group of customers of the k-th outlet;

$\bar{b}_{ki}$ – the expected average check for the i-th group of customers of the k-th outlet;

q_{ki} – the average frequency of visits in the i-th group of customers of the k-th outlet;

$\bar{q}_{ki}$ – the expected average frequency of visits in the i-th customer group of the k-th outlet;

n – the number of pharmacies in the network.

$$\begin{cases} Risk1 = \sum_{k=1}^{n\Sigma}\sum_{i=1}^{3}\sum_{j=1}^{3} y_i y_j (q_i - \bar{q}_i)(q_j - \bar{q}_j) \to min \\ Risk2 = \sum_{k=1}^{n}\sum_{i=1}^{3}\sum_{j=1}^{3} y_i y_j (b_i - \bar{b}_i)(b_j - \bar{b}_j) \to min, \\ Sum1 = \sum_{k=1}^{n\Sigma}\sum_{i=1}^{3\Sigma} y_i \cdot q_i \to max, \\ Sum2 = \sum_{k=1}^{n\Sigma}\sum_{i=1}^{3\Sigma} y_i \cdot b_i \to max, \\ Entropy = -\sum_{k=1}^{n\Sigma}\sum_{i=1}^{3\Sigma} y_i \cdot ln(y_i) \to max, \\ \sum_{k=1}^{n}\sum_{i=1}^{3} y_i = 1, y_i \in [0;1]. \end{cases} \quad (3)$$

2.3 Portfolio model of optimizing supplies

We build a model of a portfolio of suppliers, for which the purchase prices for goods are taken – Model 3. In the process of purchasing medicines and medical supplies from suppliers, the pharmacy network seeks to minimize costs and select the right amount at the lowest possible cost. Each pharmacy must have a compulsory set of vital and social medicines in its range. At the same time, each pharmacy network seeks to maximize the difference between the retail price and the purchase price (margin). In addition, the Decree, 2019 [8] establishes four groups of medicines on the National List of Essential Medicines, for which regressive retail margins are formed based on the purchase price, including taxes, and do not exceed the following amounts: group of medicines l_1 – purchase price up to 100 UAH – 25% purchase price supplement, group l_2 – purchase price from 100 to 500 UAH – 20% purchase price supplement, group l_3 – the purchase price from 500 to 1 000 UAH – a supplement to the purchase price of 15%, group l_4 – the purchase price is more than 1 000 UAH – the purchase price supplement is 10% [9].

All this imposes certain restrictions on the formation of an optimal portfolio of goods orders for the pharmacy network. Other products in the pharmacy network that are not on the National List of Essential Medicines and are not covered by the purchase price premium are denoted as group l_5.

Let, g_{klf} – purchase volume of the k-th type of goods from the l-th group from the f-th manufacturer (pieces), K – number of types of goods, F – number of manufacturers, p_{klf} – purchase price of the k-th type of goods from the l-th group from the f-th producer (UAH), w_{klf} – the share of the f-th manufacturer of the k-th commodity from the l-th group in the pharmacy network purchasing portfolio, s_{klf} – the price of sale in the network of the k-th type of goods from the l-th group from the f-th manufacturer (UAH).

$$\begin{cases} Risk = \sum_{k=1}^{K}\sum_{l=1}^{5}\sum_{f_i}^{F}\sum_{f_j}^{F}\left(p_{klf_i}-\overline{p}_{klf_i}\right)\cdot\left(s_{klf_i}-\overline{s}_{klf_i}\right)\cdot w_{klf_i}\cdot w_{klf_j} \to min, \\ Sum1 = \sum_{f=1}^{F}\sum_{l=1}^{5}\sum_{k=1}^{K}p_{klf}\cdot w_{klf} \to min, \\ Sum2 = \sum_{f=1}^{F}\sum_{l=1}^{5}\sum_{k=1}^{K}s_{klf}\cdot w_{klf} \to max, \\ Entropy = -\sum_{f=1}^{F}\sum_{l=1}^{5}\sum_{k=1}^{K}w_{klf}\cdot\ln\left(w_{klf}\right) \to max, \\ \dfrac{s_{k1f}-p_{k1f}}{p_{k1f}} \le 0.25,\, p_{k1f}\le 100, \\ \dfrac{s_{k2f}-p_{k2f}}{p_{k2f}} \le 0.2,\, 100<p_{k1f}\le 500, \\ \dfrac{s_{k3f}-p_{k3f}}{p_{k3f}} \le 0.15,\, 500<p_{k1f}\le 1000, \\ \dfrac{s_{k4f}-p_{k4f}}{p_{k4f}} \le 0.1,\, p_{k1f}\ge 1000, \\ \sum_{f=1}^{F}\sum_{l=1}^{5}\sum_{k=1}^{K}w_{klf}=1,\quad \sum_{f=1}^{F}\sum_{l=1}^{4}\sum_{k=1}^{K}g_{klf}>0. \end{cases} \quad (4)$$

In this case, the risks are caused by fluctuations in the purchase and sale prices of medicines and medical supplies by different suppliers. Two criteria that meet the goal of maximizing profitability are Sum1 – the total purchase price that is minimized and Sum2 – the total cost of sales across the network that is maximized.

The solution to problem (3) will be the matrix $G^*=\|g_{klf}\|$, which is the optimum plan for purchasing the k-th product from the l-th group at the f-th manufacturer for a centralized pharmacy network.

2.4 Portfolio model for optimizing the set of goods for each individual outlet

Model 4. The formation of the product portfolio of each individual outlet takes into account the peculiarities of its geographical location (traffic, proximity to medical facilities, etc.) and the expected demand for goods.

Thus, for each pharmacy will be created a separate assortment portfolio, which is aimed at maximizing the satisfaction of demand for goods at each specific outlet. The risks diversified by such a portfolio are caused by fluctuations in demand for different commodities.

z_{ki} – the share of demand for the k-th type of goods in the total demand for the product portfolio of the i-th point of sale,

d_{ki} – demand for the k-th type of goods in the i-th outlet (UAH.) (Or another option is possible D_{ki} – the demand for the k-th type of goods in the i-th outlet (packages)),

$$\begin{cases} Risk = \sum_{i}^{n\Sigma}\sum_{k,m}^{K}z_{ki}z_{mi}\left(d_{ki}-\bar{d}\right)\left(d_{mi}-\bar{d}\right) \to min, \\ Sum = \sum_{i}^{n\Sigma}\sum_{k}^{K}z_{ki}\cdot d_{ki} \to max, \\ Entropy = -\sum_{i}^{n\Sigma}\sum_{k}^{K}z_{ki}\cdot\ln(z_{ki}) \to max, \\ \sum_{i=1}^{n}\sum_{k}^{K}z_{ki}=1,\, z_{ki}\in[0;1].\, \{ \end{cases}$$

$$(5)$$

The solution to problem (5) will be the matrix $Z^*=\|z_{ki}\|$, which is the optimal plan for the distribution of demand shares for the k-th type of goods by the i-th outlets in a centralized pharmacy network (product portfolio).

Modifications to model (4) are also possible with the inclusion in its composition of the demand for goods expressed in the number of packages D_{kl}, as well as its deepening to the level of inclusion of the goods of the k-type in the l-th group, as shown in model (4).

The break-even condition is a balance between purchase costs and sales revenues, ie the volume of goods ordered must correspond to the volume of goods sold at all outlets of the network.

From models (3) and (4) we obtain the relation between the portfolio of orders from suppliers and the assortment portfolio of retail outlets of the network (in monetary units):

$$\sum_{k=1}^{K}\sum_{l=1}^{5}\sum_{f=1}^{F}g_{klf}\cdot w_{klf}=\sum_{i=1}^{n}\sum_{k=1}^{K}z_{ki}\cdot D_{ki}. \quad (6)$$

3 Solution of multicriteria problem of complex diversification by the method of successive procedures

We will consider in more detail the solution of multicriteria problems of complex diversification on the example of the first of complex models by the method of successive procedures [10].

3.1 Solution of optimizing the distribution of finances

The sequential assignment method for multi-criteria problems is applied when partial criteria can be ordered in decrease of their importance. To choose a diversification strategy, we choose the following ratio of order: Entropy – Sum – Risk.

In the first step, let us determine the optimal value of the first *Entropy* criterion in the valid solution area.

$$Entropy: -\sum_{i=1}^{n\Sigma} x_i \, ln(x_i) \rightarrow max$$
$$\begin{cases} \sum_i^n \bar{a}_i \cdot x_i \geq 2 \cdot 10^6 \cdot n, \\ \sum_i^n x_i = 1, 0,001 \leq x \leq 0,9. \end{cases} \quad (7)$$

The optimal solution for the first partial criterion is *Entropy*[*]. In the second step, we solve the conditional optimization problem on the next most important *Risk* criterion, adding to the conditions that determine the admissible solutions, the conditions for deviation of the first *Entropy* criterion from the found optimal value of *Entropy*[*] by no more than the value of the admissible assignment $\delta_1 > 0$. So we have the formalization of the second stage:

$$Sum: \sum_i^n \bar{a}_i \cdot x_i \rightarrow max,$$
$$\begin{cases} \sum_{i=1}^n x_i \cdot ln(x_i) + \delta_1 \cdot Entropy^* \leq 0, \\ \sum_i^n \bar{a}_i \cdot x_i \geq 2 \cdot 10^6 \cdot n, \\ \sum_i^n x_i = 1, 0,001 \leq x \leq 0,9. \end{cases} \quad (8)$$

The optimal solution according to the second criterion *Sum*[*] is obtained. Repeat the procedure for the next criterion *Sum*, adding to the conditions that determine the admissible solutions, the conditions for deviation of the first *Entropy* criterion and the second *Sum* criterion from the found optimal values *Entropy*[*], *Sum*[*] not more than the values of allowable concessions $\delta_1 > 0$ and $\delta_2 > 0$.

$$Risk = \frac{2}{n} \sum_{i=1}^{n\Sigma} \sum_{j=i+1}^n (a_i - \bar{a}_i) \cdot (a_j - \bar{a}_j) \cdot x_i \cdot x_j \rightarrow min$$
$$\begin{cases} \sum_{i=1}^n x_i \, ln(x_i) + \delta_1 \cdot Entropy^* \leq 0, \\ \sum_i^n \bar{a}_i \cdot x_i \geq 2 \cdot 10^6 \cdot n, \\ (1 - \delta_2) Sum \leq Sum^*, \\ \sum_i^n x_i = 1, 0,001 \leq x \leq 0,9. \end{cases} \quad (9)$$

The solution obtained in the third stage is the solution of the three-criteria conditional optimization problem (1). The experiments with the models were conducted on the real data of one of the pharmacy networks operating in the city of Zaporizhzhia. All calculations were performed in the Matlab package [11].

Figure 2 shows the optimal solutions obtained in the third step of the sequential assignment method for different pharmacy size networks: small $n = 5$, medium $n = 33$, and meganetworks $n = 65$.
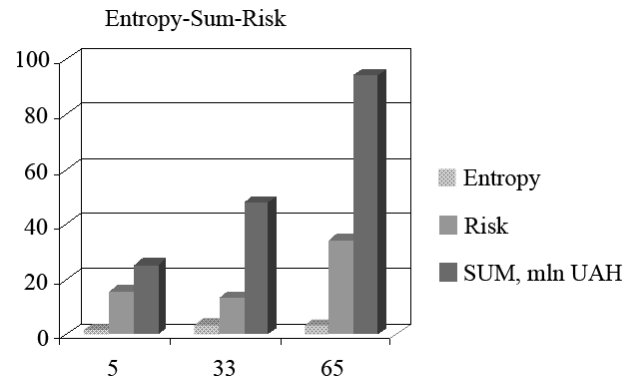

Fig. 2. Optimal solutions for different in size pharmacy networks.

Were built pareto-optimal portfolios. Figure 3 presents the two-criterion projections of the set of Pareto-optimal portfolios obtained for model 1 on real data on the turnover of retail outlets in the pharmacy network.

The black points "○" correspond to experiments that take into account the pharmacy's overall risk, which is the sum of its own and systemic risks.

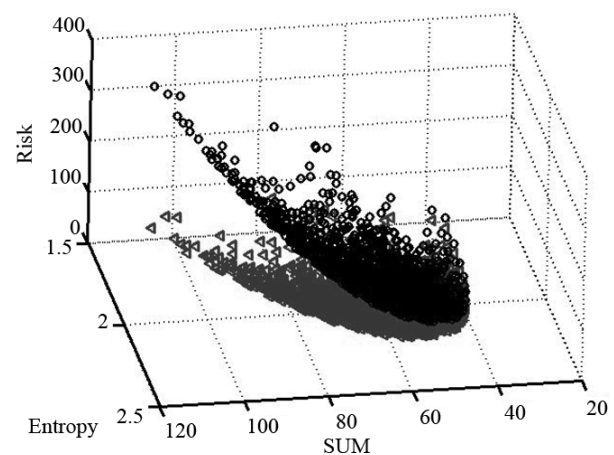The gray points "Δ" indicate a set of portfolios in which only systemic risk was taken into account.

Fig. 3. Solutions to model (1) in the Entropy – Sum – Risk space built in Matlab.

Figures 4-6 presents two-criteria projections that can be followed by relevant Pareto boundaries, with pareto-optimal risk management portfolios.

The experiments in Matlab [11] with models for solving the corresponding multicriteria problems by the method of successive concessions showed that the order of criteria is important for choosing a diversification

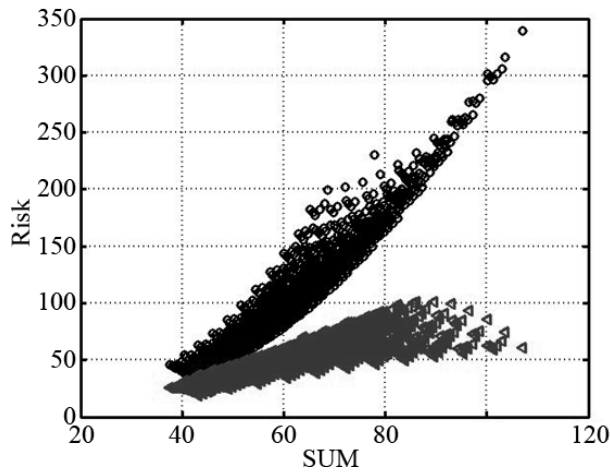strategy. The best results were obtained for this order: Entropy – Sum – Risk.
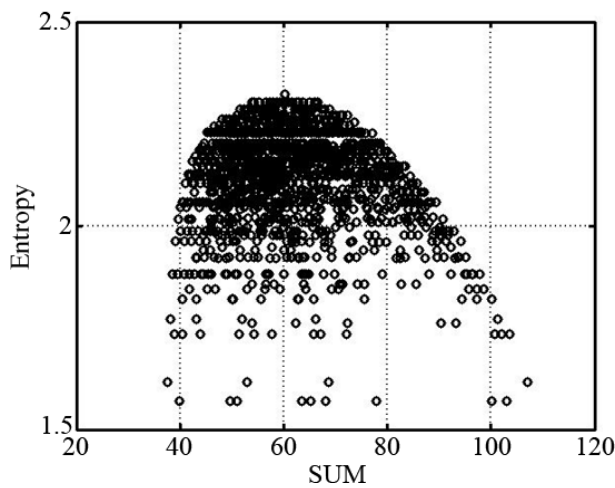

Fig. 4. Projection in Sum – Risk space.

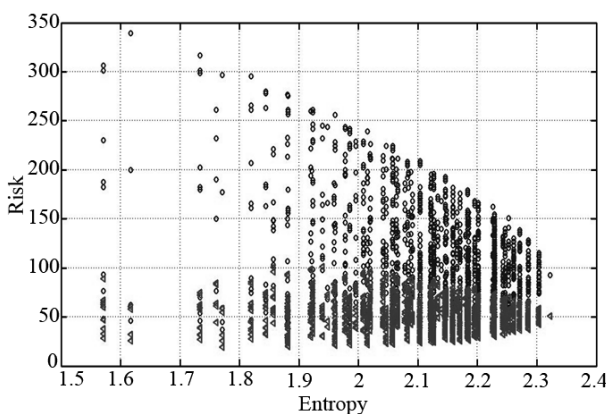**Fig. 5.** Projection in Sum – Entropy space.

Fig. 6. Projection in Entropy-Risk space.

3.2 Solution of optimizing optimal combination customers

Experiments with models (model verification) were carried out on the data of one of the pharmacy networks operating in the city of Zaporizhzhia (Ukraine). Since there was no monitoring of the frequency of visits to

customer groups by pharmacies, the study was carried out using a simplified model of the form:

$$\begin{cases} Risk = \sum_{i=1}^{3} \sum_{j=1}^{3} y_i\, y_j (b_i - \bar{b}_i)(b_j - \bar{b}_j) \to min, \\ Sum = \sum_{i=1}^{3\Sigma} y_i \cdot b_i \to max, \\ Entropy = -\sum_{i=1}^{3\Sigma} y_i \cdot ln(y_i) \to max \\ \sum_{i=1}^{3} y_i = 1, y_i \in [0;1]. \end{cases} \quad (10)$$

The case is considered when instead of a diversified portfolio of clients, preference is given to loyal customers. Let's replace entropy maximization with a criterion of the form: $1Loyal = y_1/y_2/y_3 \to max$

$$\begin{cases} Risk2 = \sum_{i=1}^{3} \sum_{j=1}^{3} y_i\, y_j (b_i - \bar{b}_i)(b_j - \bar{b}_j) \to min, \\ Sum2 = \sum_{i=1}^{3\Sigma} y_i \cdot b_i \to max, \\ 1Loyal = y_1/y_2/y_3 \to max \\ \sum_{i=1}^{3} y_i = 1, y_i \in [0;1]. \end{cases}$$

$$(11)$$

For a portfolio in which preference is given to random visitors, the criterion is used:

$2Loyal = y_2/y_1/y_3 \to max$.

For a marketing policy aimed at maximizing the number of Internet clients, let's use the criterion: $3Loyal = y_3/y_1/y_2 \to max$.

Similar studies are conducted for individual pharmacies belonging to the same network, but have different composition of the initial customer portfolio.

For ease of comparison, the results of experiments are summarized in Table 1.

Table 1. The results of the experiment for centralized pharmacy network and individual pharmacies.

Initial conditions	Strategy	Sum	Risk	Recommendations
The network portfolio is dominated by on-line clients	Transition of the network to a diversification strategy	Increase	Increase	Recommended
	Change the composition of the portfolio in favor of the loyal, that is, develop loyalty programs	Increase	Increase	Recommended
Especially for pharmacies that have a large proportion of casual visitors in their portfolio	Separating the pharmacy from the network	Slight increase	Significant increase	Undesirable
Especially for pharmacies that have a large proportion of casual visitors in their portfolio	Pharmacy's transition to a diversification strategy	Slight decrease	Significant reduction in risk	Recommended

In more detail the modeling of optimal portfolio of clients of Pharmacy network and the results of the experiment are described in the paper [12].

4 Conclusion

Managing a pharmacy network in terms of digital transformation of the healthcare system involves the effective management of their own risks, minimizing them by diversifying their own activities, leading to new challenges and enhancing the relevance of research in this area.

The scientific novelty of this work is the formalization on the basis of portfolio theory and methods of multicriteria optimization of complex diversification models, taking into account the current conditions of functioning of pharmacy networks in a competitive market environment and changes in the legislation.

The practical value of the mathematical modeling performed in this work is confirmed by series of experiments conducted on real data, which demonstrated the possibility of using the developed tool for automatic distribution of resources of centralized pharmacy networks in the form of pareto-optimal portfolios in order to minimize risks. Among the areas of further research are conducting a number of experiments with different ways of formalizing risk in portfolio models and finding relevant analytical dependencies.

The developed models are universal, focused on accessible data, which are monitored by the internal audit of any pharmacy network.

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