

UDC 615.12:658.310

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## THE USE OF KOKHONEN'S NEURONETS FOR JUSTIFYING THE CHOICE OF SUPPLIERS FOR A PHARMACEUTICAL ENTERPRISE

*The quality and safety of manufactured pharmaceuticals can only be guaranteed on condition that high-quality raw materials and packaging are used in their production. This explains the necessity to evaluate the compliance of potential pharmaceutical suppliers with certain requirements in terms of quality of raw materials and reliability of supply. The present article describes the use of Kokhonen's neuronets as the main instrument for selecting the best supplier.*

*Key words:* supplier, due quality of raw materials, Kokhonen's neuronet, rating of suppliers.

### PROBLEM STATEMENT

The need to ensure the production of high quality pharmaceuticals entails the necessity to find suppliers of quality raw materials.

World practice proves that it is advisable to use one supplier who would guarantee timely supply of each consignment of raw materials of due quality. This approach is ideal for the pharmaceutical industry as well, since the use of substances from one particular supplier guarantees the quality of pharmaceuticals produced at the industrial enterprise. However, this practice is not always reasonable in terms of ensuring business stability. At the same time, changing manufacturers of raw materials might have an adverse effect on pharmacological and therapeutic properties of medicines, and consequently affect people's health.

### ANALYSIS OF RECENT RESEARCH WORKS AND PAPERS

The quality of raw materials, equipment, energy supply, as well as other resources and services that are purchased by the enterprise are extremely important for ensuring the quality of manufactured products. Therefore, both international standards ISO 9000 and requirements set by Good Manufacturing Practice (GMP) describe the procedure of selecting the suppliers of raw materials and supervising their activity taking into consideration the following aspects: establishing criteria

for selection and evaluation; auditing the quality management system adopted by the raw material supplier, as well as the manufacturing environment where this raw material is processed; further supervision of the selected suppliers and their recurring assessment [3, 7].

European GMP Commission establishes a number of requirements referring to suppliers of raw materials and packaging materials, such as: [7]:

- Manufacturers of pharmaceuticals are ultimately responsible for selecting their suppliers;
- Availability of detailed and precise specifications;
- Dealing only with those suppliers that are included in the registration file;
- Specifications form an integral part of the contract with a supplier;
- Manufacturers are advised to work mainly with reliable and trusted suppliers;
- Purchase of raw materials should be executed by personnel who have thorough and precise knowledge of suppliers;
- Manufacturers can only change the supplier of raw materials provided that their products are absolutely identical to those declared in the registration file;
- Suppliers evaluation results should be included in the Annual Product Quality Review;
- If there is no auditing of the supplier, manufacturers should organize on-receipt inspection of each packaging unit of raw materials that are delivered;

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- The on-receipt inspection can be simplified or even cancelled basing on the results of the auditing of the supplier.

All these requirements explain the reason why before contracting a new supplier manufacturers of pharmaceuticals have to make sure that the supplier has an efficient system of quality management, complies with specifications and can guarantee invariable quality of dispatched materials [3]. Efficient economical and mathematical tools can help to organize and carry out this assessment.

#### ASPECTS OF THE GENERAL PROBLEM THAT REQUIRE FURTHER RESEARCH

The problem of selecting the best supplier is usually solved with the help of the following tools: electronic trading platforms, tenders in the form of continuous reverse (Dutch) auctions; expert evaluation method; conducting individual analysis on the basis of standards adopted by the enterprise, etc.

The most popular method of choosing a supplier is the method of rating assessment based on the main criteria set by the pharmaceutical enterprise. Comparing the results of rating assessment for different suppliers, manufacturers can choose the best partner [1, 5]. However, it is important to consider the fact that it is difficult and sometimes practically impossible to make potential suppliers provide objective data for expert evaluation.

Besides, manufactures can resort to cost-based coefficient method, also called “a method of missions”, where the best option (mission) is chosen out of the number of options according to the criteria of total profit. This method is interesting from the point of view of cost estimate, since it helps to determine “the cost” of a supplier [1]. The drawback of the method lies in the fact that it requires receiving, assessing and analyzing a large amount of information for each potential supplier.

In order to choose a supplier, manufacturers can also use a model based on dominant characteristics. This method focuses on one selected parameter (criterion) [6]. The advantage of this method is its simplicity, but it ignores all the other factors and selection criteria, which is a serious drawback.

If a manufacturer chooses a supplier selection model on the basis of its advantages, the final evaluation result and the choice of evaluation instruments depend on information provided by various subdivisions of the enterprise [1]. As a rule, this kind of supplier evaluation has informal character. If the ultimate consumer (manufacturing department) and the procurement department are immediately connected with each other, they can provide a quick feedback as to the supplier's

behavior, which makes this “informal” approach quite reasonable and valid.

#### OBJECTIVES OF THE PRESENT PAPER

All the shortcomings of the above mentioned supplier evaluation methods are eliminated by the use of neuronets, namely the models based on Kokhonen's neuronet as the main instrument of best supplier selection. The use of these models makes it possible to take into consideration only the values of input variables without including the corresponding initial values, which guarantees flexible adaptation of the whole system and possibility to solve tasks involving a large number of properties of the object.

Kokhonen's neuronets help to produce topologically continuous representation of input  $n$ -dimensional  $F$  space into output  $m$ -dimensional space  $F: R^n \rightarrow R^m$  as a result of “training” procedure.

Training is performed without supervision on the basis of samples that are fed into the system. Competitive training is used as a method of training. The structure of self-organizing neural network is a network with direct distribution of signal. In the process of training input samples are fed into the network, and the  $n$ -dimensional input space is divided into different regions of decision, each of them corresponding to a separate neuron. Boundaries of each region are perpendicular to the lines drawn between centrodes of the neighboring regions of decision.

#### THE MAJOR RESULTS OF THE RESEARCH

The article dwells upon the results of modeling supplier selection processes for one of the leading pharmaceutical enterprises in Kharkiv region. The first stage of the analysis involves the evaluation of each supplier on the basis of assessment criteria listed in table 1.

In this situation input vector of data will be:  $X = [1x, x2, \dots, xn]$ , which means that each element of the vector represents the corresponding result of supplier evaluation.

In order to ensure connected distribution of data space [4], it is necessary to normalize the input data  $X$ .

Sigmoid function is adopted as activation function in order to guarantee the necessary adaptation of the network. This is a continuous escalating function with a range of values  $\{0, 1\}$ . Sigmoid function is monotonic and differential everywhere. This is the reason why it is widely used in artificial neural networks [2].

Then the network is trained with the help of certain algorithm [2]. The initial value of the radius of the weight region is considered to be equal to 2.1.

The training process continues until weight coefficients are almost invariable (fig.).

Table 1

CRITERIA FOR SUPPLIER EVALUATION	
1-level criteria	2-level criteria
Quality assurance level (0-30 points)	Compliance with specifications Quality system status Availability of conformity certificates Access to the product file Product stability Quality index by product series
Manufacturing level (0-30 points)	Full manufacturing cycle Qualified and competent personnel Level of technology and potential for development
Logistics (0-20 points)	Packaging types and dimensions Level of service Frequency of supply Transportation facilities Geographic location Reliability of supply
Marketing (0-20)	Contractual price Terms of payment Real assortment of products Prospective assortment Public image and track record Focus on the consumer

Table 2 shows examples of rating of potential suppliers.

Table 2

RATING AND CHARACTERISTICS OF SUPPLIERS		
Rating of Supplier	Cate-gory	Characteristics
Approved	A	A reliable supplier (behaves in a transparent, reasonable and predictable way; tries not only to meet the requirements, but also to exceed the expectations; guarantees high quality of product and reliability of supply)
	B	A supplier with little experience (appropriate quality of product and sufficient evidence as to their ability to meet requirements)
Tempor-arily approved	C	Potential supplier (the manufacturer has certain doubts and complaints as to their ability to meet all the requirements)
Rejected	D	The supplier is in “quarantine” (although the supplier is rejected, “quarantine” means that the supplier’s products can undergo another quality test in 6-12 months).
	E	The supplier is in “black list” (the supplier is rejected, and recurrent quality test of his products can take place only in 3-5 years).

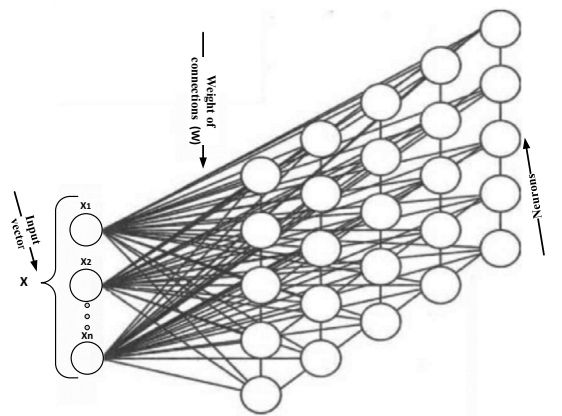


Fig. Neuronet Structure

The process of network training and the formation of corresponding clusters are followed by their classification. In order to describe the neuronet it is necessary to classify the suppliers depending on requirements that are put forward to them. The classification is then used to bring the derived clusters in correlation with the corresponding types of suppliers.

After that the model is ready for operation. The input vector of the model describes the supplier, and at the output we receive their corresponding rating.

CONCLUSIONS AND PROSPECTS OF FURTHER RESEARCH

1. Pharmaceutical industry requires timely supply of each consignment of raw materials of appropriate quality.
2. International standards ISO 9000 and the requirements of Good Manufacturing Practice describe the procedure of selecting the suppliers of raw materials and supervising their activity.
3. In order to meet the requirements of European GMP Commission, pharmaceutical manufacturing enterprises should test the reliability of potential suppliers of raw materials and packaging. This explains the necessity to use efficient evaluation tools according to the criteria of quality and reliability of supply.
4. The analysis of existing methods of potential supplier evaluation prove the practicability of Kokhonen’s neuronets as the main instrument for selecting the best supplier.
5. Kokhonen’s neuronet is trained without supervision on the basis of samples that are fed into the network. Competitive learning is used as a method of training. In this case the input vector describes the supplier, while at the output we receive the corresponding rating.

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## УДК 615.12:658.310

К. С. Світлична

### ВИКОРИСТАННЯ НЕЙРОМЕРЕЖ КОХОНЕНА ДЛЯ ОБҐРУНТУВАННЯ ВИБОРУ ПОСТАЧАЛЬНИКІВ ФАРМАЦЕВТИЧНОГО ПІДПРИЄМСТВА

Гарантувати якість вироблюваних лікарських засобів можливо тільки за умови використання якісної вихідної сировини та пакувальних матеріалів. Це обумовлює необхідність проведення оцінки відповідності потенційних постачальників фармацевтичного підприємства вимогам, що висуваються щодо належної якості сировини та надійності поставок. У статті обґрунтовано використання нейронних мереж Кохонена як основного інструменту для вибору найкращого постачальника.

**Ключові слова:** постачальник, належна якість сировини, нейронна мережа Кохонена, рейтинг постачальників

## УДК 615.12:658.310

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### ИСПОЛЬЗОВАНИЕ НЕЙРОСЕТЕЙ КОХОНЕНА ДЛЯ ОБОСНОВАНИЕ ВЫБОРА ПОСТАВЩИКОВ ФАРМАЦЕВТИЧЕСКОГО ПРЕДПРИЯТИЯ

Гарантировать качество производимых лекарственных средств возможно только при условии использования качественного исходного сырья и упаковочных материалов. Это обуславливает необходимость проведения оценки соответствия потенциальных поставщиков фармацевтического предприятия требованиям, которые предъявляются к надлежащему качеству сырья и надежности поставок. В статье обосновано использование нейронных сетей Кохонена как основного инструмента для выбора наилучшего поставщика.

**Ключевые слова:** поставщик, надлежащее качество сырья, нейронная сеть Кохонена, рейтинг поставщиков

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Надійшла до редакції:

15.04.2014