ISSN (Print) : 0974-6846
Indian Journal of Science and Technology, *Vol 9(16), DOI: 10.17485/ijst/2016/v9i16/89896, April 2016* ISSN (Online) : 0974-5645

The use of Multivariate Statistical Analysis Methods in the Process of Tangible Assets Assortment Optimization

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Abstract

Background/Objectives: Research objective - development of scientific, methodical provisions and practical recommendations about formation of rational system of stockpile management of enterprise with use of modern tools of multidimensional statistical analysis. **Methods/Statistical Analysis:** For the solution of this research problems was used the complex of multi-dimensional statistical methods: The cluster and dispersive analysis. Each of methods was applied adequately their functional opportunities that develop an author's methodology of group of material resources allowing to optimize costs of management of nomenclatures of resources. **Findings:** The article describes the approaches of choosing the multivariate statistical analysis methods allows to systematize the nomenclature and to optimize the enterprise physical resources assortment. The need to improve classification methods of reserves in an economic entity under the conditions of influence of great number of multidirectional internal and external environment factors is proved. This method of ranging of material stocks compared with traditional methods of optimization of the range of material stocks, are allows to construct more rational mechanism of management of economic re-sources at all stages of financial and economic activity. **Application/Improvements:** Results of research will be used in system of resource management in the sphere of supply, production and sale at various levels of flexible logistical systems.

Keywords: Assortment, Classification, Cluster Analysis, Economic Assessment, Management, Methods, Tangible Assets, Variance Analysis

1. Introduction

The foundations of market system are the business entities using the economic resources for carrying out commercial activity. All principal processes of their financing and operating activities (supply, production and sale) are directly connected with use of material, labor, financial, information and other types of resources.

The economical use of material resources is a major factor of cost reduction, reduction of production cost, earnings growth and enhancement of efficiency of enterprise performance. These expenses are justified if the incomes, exceeded incur charges, are the result of their implementation. The bringing of material assets to really necessary and sufficient level predetermines the release of current assets, the involvement of additional resources in production, creating the conditions for release of production additional volume. The material assets are the production and technical output at different stages of production and distribution, the products of national consumption and other goods expecting the involvement in process of production or personal consumption.

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Native and foreign scholars' transactions deals with formation of the theory and methodology of material flows management and structurizations, rationing and optimization of material assets. Such scholars as B. A. Anikin, G. L. Brodetskiy, A. G. Butrin, A. M. Gadzhinskiy, A. P. Dolgov, V. V. Dybskaya, E. I. Zaytsev, M. E. Zalmanova, K. V. Inyutina, Kulagovskaya T. A., V. S. Lukinskiy, L. B. Mirotin, Yu. M. Nerush, O. A. Novikov, A. V. Parfeno, O. D. Protsenko, A. I. Semenenko, V. I. Sergeev, I. I. Sidorov, Yu. I. Ryzhikov, S. A. Uvarov, A. D. Chudakov, V. V. Shcherbakov etc. made a significant contribution to development of these questions.

It is possible to note foreign scholars' transactions such as Ballou Ronald H., Betsy Farber, Bowersox Donald J, Brownlee K. A., Daniel Wardlow, Donald F. Wood, Foster D., Firon H. E., Michael Gillingham, James C. Johnson, Closs David J., Martin Christopher, Kenneth Lysons, Douglas M. Lambert, Leenders M.R, Paul R. Murphy, Jr., Richard A. Johnson., T. Whitin, Jeremy Shapiro etc. However, in spite of significant number of researches in the field of material assets structurization, many theoretical, methodological and methodical issues of this important problem have not resolved yet. So, in particular, there is no consensus concerning classification, structurization and systematization of material assets; problems of material assets classification using of economic-statistical and economic-mathematical methods demand further researches.

The variety of the points of view and theoretical messages of foreign and Russian researchers on a problem of material assets management, debatability of specified questions formed the basis for a choice of this work subject, caused its purposes and objects.

The problem of materials management arises in case of creations the stockpile of separate type physical resource for purpose of demand satisfaction on certain interval of time. The solution of materials management problems is provided during the strategic and operational planning, the control and regulation of some parameters set connected with stocks. The creation and storage of stocks is interfaced to considerable expenses, as a result it is important to provide the efficiency of the materials management mechanism with due regard to the optimum investments size.

As the expenses associated with stockpile management have rather contradictory character, underway of management decision development it is important to consider an optimum between insufficient and excess volume of stocks proceeding from cost minimization for their formation. So, the inventory shortage can further the stoppage in production, the volumes reduction of realization or taking possession of raw materials and supplies at an over-inflated prices. Whereas the surplus of stocks leads to rising scale of expenditures on their storage, non-receipt of potential gain owing to tying-up of financial resources in stocks, to losses by reason of their physical spoilage or moral aging. The result is that it is equally bad for enterprise to suffer both shortage and surplus of material assets.

The developed control stocks system has to provide the rational product portfolio policy of business entity. The product portfolio is the component list of types and versions, types and grades of material assets differing in marketing indicators. The performance assurance of material assets assortment management is important to make the optimum classifier and assortment matrix. Thus the classifier is a division of all stocks according to common features or properties into classes, groups, categories. The larger the format of enterprise is than the larger the division levels. On the basis of classifier system by range structuring it is based the assortment matrix by way of the catalogue of all stocks line items (including temporarily missing) disclosing subcategories, brands and other accounting units. On the basis of assortment matrix it is formed the assortment minimum - the catalogue of stocks line items which have to be constantly at the enterprise during particular period of time.

It should be noted that during the classifier formation and assortment matrix it is necessary to use the optimal inventory model for specific economic entity in the current situation. However in scientific literature there isn't an agreement of opinion concerning the methods and models used for the purpose of stocks division into homogeneous groups[1–6].

In a general sense the model is the special object created by way of receiving and (or) storage of information (in form of mental picture, sign vehicles description or material system) disclosing properties, characteristics and the original object communications of rule-of-thumb nature essential to the task solved by the subject[7].

The most widespread in practice of economic agents business activity models of material resources division into groups by the AVS method are too simple and often do not consider to multiple-factority and constant circulation of financial resources. Moreover, in our opinion, the borders allocation of groups A, B and C is disputable and insufficiently reasonable. We consider that for these purposes it is necessary to use statistical

tools that are more powerful and based on application of multidimensional statistical methods of the analysis.

One of the perspective directions in course of material resources structuring is the use of the cluster analysis[8–12]. As we can suppose, the need for cluster analysis methods application to studying inventory movements and financial resources is proved by the help to construct scientifically based classifications, to reveal internal communications between units of population. In addition, the multidimensional statistical methods of the analysis can be used for the purpose of information compression and it is an important factor in the conditions of constant increase and complication of material and financial resources streams in deliveries chains[13–14].

2. Materials and Methods

The operations associated with the ordering, storage and delivery of necessary resource volume are carried out in the course of stock management. Stockpile management provides the development of the material assets range; forecasting of the most probable volume of the drain on separate reserves; current monitoring of the actual drain on reserves; analysis of actual expenses and time for replenishment of supplies, etc.

At the enterprise, it is important to produce the effective stock management system as rule and indicator sets that define a time point and volume of sales for supplies replenishment Figure 1.

The inventory control system worked for particular enterprise has to provide the decision of such problems as: 1) Sizing of required storage (standard inventory and its replenishment frequency); 2) Control way development of stock actual size and expediency of its replenishment according to established standard. Moreover, on the assumption of acceptable balance of return level and financial activity risk, it points out conservative, moderate and aggressive approaches to stocks formation. Conservative approach provides as total satisfaction of current demands of the main economic processes for all types of stocks and their reserves creation on cases of disruption with raw materials and supplies, modification of manufacturing environment, blocking collection of receivables, demand swing, etc. In this wise of stocks formation has an adverse effect on finance indicators of commercial entity operation (in particular, profitability and efficiency ratios), however minimizes adverse effect of risks on conditions and results of its functioning. The moderate approach to stocks formation provides creation of reserves intended to liquidate the most probable dislocations arising in the course of primary enterprise activity. The determination of stocks insurance necessary volume has to be carried out on the basis of forecasting of their use taking into account the objective and reliable data for the previous periods allowing allocating separate stock categories and their sizes additional requirements. As part of this strategy enterprise performance can be characterized by average data of profitability and risk. The aggressive approach to stocks formation shows the minimization of all forms of insurance reserves up to their total absence. If during operating business there are no production failures, at the enterprise the highest performance indicators of economy management will be reached. While any problems in realization of operating business normal course stipulate substantial casualties owing to unfavorable volume variance and product sales. The aggressive approach shows the maximum risk of business processes.

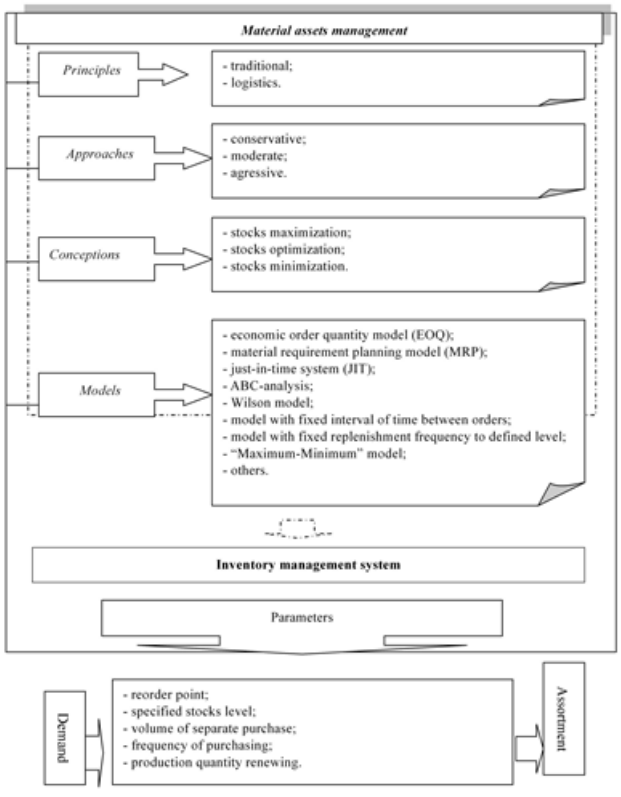

Figure 1. The general provisions of formation inventory control system.

The inventory control system of profit making organization has to be described in terms of parameter part which structure can include the following:

Order point should be understood to mean the minimum stocks test objective that need the replenishment at the time of achievement;

- Standard stocks level as the specified stocks rate reached after purchase;
- The volume of stock particular purchase;
- Procurement activities frequency - time between two possible stock purchases, i.e. replenishment frequency etc.

Performance effectiveness of inventory control system in many ways will be defined by the forecast accuracy of resources demand that is quite complex challenge. The successful solution of the potential demand definition problem for a concrete stock type depends on type which stock is characterized. So, as distinguished from probabilistic demand the determined demand is known precisely in advance. The intension usage rate at static demand is invariable in time and at dynamic demand - the intensity usage rate changes depending on time. The stationary demand type shows in time invariable probability density function, while non-stationary – the probability density function changing in time. Underway of stocks optimization models development it is important to pay special attention to assortment policy improvement of the enterprise based on formation of rational range structure. In turn, the range structure is a ratio of groups, subgroups, types and kinds of stocks. Thus the main range indicators are:

- Range width is a total quantity of various stocks categories entering into the range;
- Range depth is a quantity stocks types within the framework of certain type, grades on an article, products in one group, etc.;
- Range completeness, considered as actual availability compliance of separate types, versions and stocks identity to developed assortment list, the existing or potential requirements etc.;
- Range stability reflects completeness and width oscillations during a certain space of time and characterizes continuous stock availability of separate type;
- Range novelty is under consideration of ability to satisfy changing wants using of new stocks kinds.

During models development it uses various mathematical tools of object definition, especially theories of sets, probabilities, counts, mathematical logic, mathematical programming, the differential or integral equations etc. Thus the models share on the following types:

- The functional models is capable to describe object from the point of view of its functions and expressing direct dependences between endogenous and exogenous variables;
- The models expressed by means of equation systems against endogenous variables;
- Optimizing models, which main part - the equations systems toward endogenous variables constructing for optimum solving for some economic indicator;
- Simulation models provide precise imagery of economic phenomenon in the context of which the mathematical equations can contain difficult, nonlinear, stochastic dependences.

At the same time in the construction of optimization stocks models using the rational qualifiers of physical resources, it is expedient application of multidimensional statistical methods (the cluster and dispersive analysis).

The important stage of the cluster analysis is determination of specific combining objects method among which more widely known are the following: Linkage between groups: Communication between groups; communication in groups; nearby neighbor; distant neighbor; centroid clustering; median clustering; a method k-verages; Ward-Method etc. Cluster analysis various methods let to receive the clusters differing by the size and the form.

In our opinion, particular significant has to be an application to classification of physical resources several thousand nomenclatures of the cluster analysis by method of k-averages. Oftentimes it is called a reference method of the cluster analysis. Its essence is as follows: The number of clusters (K) is defined by the user. On the first step it defines the quantity K clusters – references. Further each object joins to immediate reference. As criterion can be use the minimum distance in a cluster concerning an average. In case of object entering in a cluster, an average recalculated. After reference recalculation, objects are again distributed on the next clusters, etc. The procedure comes to the end at stabilization, i.e. power center of gravity.

Table 1. The results of joint realization ABC and XYZ – analyses of JSC Stavropol-Lada material resources nomenclature

The part of details	The part name
1	2
AX	Piston pin
AY	Cylinders block, crank-shaft, cylinder head
AZ	Generator, steer link, valves, piston, gearshift mechanism
BX	Jet
BY	Steering shaft, bearing strip, steering shaft pulley, circuit, roller tension, pinion gear of centrifugal mud pump, guide bush, grease filter, water pump, electrolytic cell, plugs
BZ	Brake blocks, down-draft carburetor, conrod fill piece, regulator of temperature, clutch plate
CX	Screw nut, blind plug, flat, flathead, safety appliance, connection hose, piston seals, crankshaft oil seal, dribble pipe, splint pin, clevis
CY	Centrifugal mud pump, chain wheel, cogged belt, collar, limiting sleeve, pistons
CZ	Connecting rod, idler shaft, brake fluid line, main drive shaft, shock strut, pinion gear, fan belts, wiper relay, left actuator, right actuator

Table 2. averages of centers for each cluster at the price and coefficient of variation

Variables	Clusters medium								
Variation coefficient, %	14,64	84,49	73,97	30,20	17,38	61,62	39,28	37,34	7,97
Total price kRUR.	108,00	2457,18	80,03	34,89	23,62	22,76	173,67	11,80	2,72

3. Results and Discussion

In this research as an example we will carry out the cluster analysis of nomenclature part of JSC Stavropol Lada material resources and it is comparable the received results with the two-dimensional analysis, which is carried out on the ABC and XYZ method.

Submit findings without giving specifics of carried out calculations using graphic approach ABC.

9 details belong to group A, 19 details got to group B, the group C included 30 details making 6, 7% of total cost and 53% of the general nomenclature.

The division of nomenclature into XYZ groups was made with use of dynamic coefficient of variation.

The association of ABC and XYZ analyses results allowed making the matrix consisting of nine classes of material resources. Table 1.

The following stage will be the cluster analysis.

We recommend using STATISTICA 10,0 and SPSS 12.0 as the software of clustering process.

As the result of the cluster analysis, we defined the averages of centers for each cluster. Table 2.

It is possible to interpret the received clusters in the following. Table 3.

Table 3. Allocated clusters interpretation

Cluster number	Cost characteristic	Variation value
1	high	minimum
2	maximum	maximum
3	high	maximum
4	average	average
5	average	minimum
6	minimum	maximum
7	maximum	average
8	minimum	average
9	minimum	minimum

The structure of each cluster is in Table 4.

The results of cluster analysis have to be supplement by ones of variance analysis.

The variance analysis in our proposed methods is necessary for statistical hypothesis checking about correctness of physical resources distribution to nine clusters.

Let's consider the application mechanism of variance analysis[15,16].

Let us assume that observation data make l of independent classes received from l of right distributed normal collections which have different averages $m_1, m_2, \ldots, m_l$ and common variances D.

Table 4. The clusters structure

Cluster	Part name
№ 1 ($C_{Bbic}V_{min}$)	Flow head, piston pin, crankshaft
№ 2 ($C_{max}V_{max\_}$)	Gearshift mechanism
№ 3 ($C_{Bbic}V_{max}$)	Generator, steer link
№ 4 (CV)	Steering shaft pulley, clutch plate, electrolytic cell, grease filter, down-draft carburetor, guide bush, water pump, plugs, roller tension
№ 5 (CV_{min})	pump, steering shaft, circuit, orifice plug, bearing strip, pinion gear of centrifugal mud pump, safety appliance, race-ways 82, centrifugal mud pump
№ 6 ($C_{min}V_{max\_}$)	Brake blocks, conrod fill piece, regulator of temperature, connecting rod, wiper relay, brake fluid line, pinion gear, idler shaft
№ 7 ($C_{max}V$)	Valves, cylinders block, piston
№ 8 ($C_{min}V$)	Main drive shaft, rail, cogged belt, left actuator, shock strut, chain wheel, right actuator, fan belts, cartridge, pistons
№ 9 ($C_{min}V_{min}$)	Piston seals, clevis, blind plug, dribble pipe, flathead, collar, flat, screw nut, crankshaft oil seal, guide bush, splint pin, connection hose

Testing of averages congruence hypothesis. $m_1 = m_2 = ,..., = m_l$. For example, during inventory control with use of variance analysis, it is possible to prove the quantity and the structure of physical resources allocated groups.

The basic issues of variance analysis are as follows:
Let x_{ik} denotes unit i of sample k, unit i of sample k,
$i = 1,2,...,n_k$;$k = 1,2,...,l$;
$\overline{x_k}$ - Sample average of k.

$$\overline{x_k} = \frac{1}{n_k}\sum_{I=1}^{n_k} x_{ik},$$

$\overline{x_k}$ - Common sample average.

$$\overline{x} = \frac{1}{n}\sum_{k=1}^{l}\sum_{i=1}^{n_k} x_{ik},$$

n – Total amount of observations .

$$n = \sum_{k=1}^{l} n_k,$$

The sum of squared observations deviations x_{ik} of overall mean amount can be as follows:

$$\sum_{k=1}^{l}\sum_{i=1}^{n_k}(x_{ik}-\overline{x})^2 = \sum_{k=1}^{l} n_k(\overline{x_k}-\overline{x})^2 + \sum_{k=1}^{l}\sum_{i=1}^{n_k}(x_{ik}-\overline{x_k})^2.$$

Let's write the basic issue of variance analysis:
Q=Q1+Q2.

Q - The sum of squared deviations of overall mean amount,

$Q1$ - The sum of squared deviations of sample mean groups from overall mean,

$Q2$ - The sum of squared observations deviations of sample mean in groups.

If the hypothesis of averages equality is right, it is necessary to prove[17,18] that statistics Q1/D and Q2/D are independent and have distribution X^2 c l-1 and n-1 degrees of freedom. It follows that, statistics $s_1^2 = \frac{Q_1}{l-1}$ *and* $s_2^2 = \frac{Q_2}{l-1}$ - are unbiased estimators of unknown error variance observation D. The evaluation s_1^2 defines class means spreading and approximation s_2^2 - concentration among groups, which makes conditions by random variations of observational data. Non-negligible variate excess s_1^2 over value s_2^2 is attributable to distinction of averages among groups. Ratio of these valuations on condition that hypothesis $H_{0\,is}$ true, has Fisher distribution with l-1 and n-1 the degrees of freedom:

$$\frac{s_1^2}{s_2^2} = \frac{Q_1/(l-1)}{Q_2/(n-1)} = F(l-1, n-1)$$

Determining statistics is used for proof of hypothesis H_0 about averages equivalence. The hypothesis is compatible with observational data, if sample value F_B of statistics F is less than inverse Fisher distribution $F_{1-\alpha}(l-1, n-1)$. If F_B is more than $F_{1-\alpha}(l-1, n-1)$,the hypothesis H_0 is deflected and it should be that among averages $m_1 = m_2 = ,..., = m_l$ there are even two unequal one another.

Let's check on the verity of carried clustering with use of variance analysis main issues.

We use the application program - STATISTICA for the purpose of calculations simplification. The received results are in Table 5.

Table 5. Table of variance analysis results

Indicators	The result throughout consequences				
	SS	Degrees of freedom	MS	F	p
Total price kRUR.	863,664	45	19,193	38,932	0,0001
Variation coefficient, %	4556,067	52	87,617	177,732	0,00000001
Er.	488,040	990	0,493	-	-

Let's explain the received results. In the table there are: the sums of squared deviations of sample mean groups $\bar{x}$ from overall mean $\bar{x}_k$ between groups Q1 (SS Effect = 863.664 for indicator "total price" and 4556.067 for indicator "variation coefficient"), the mean of sum squares (MS = 19,193 "total price" and 87,617 for "variation coefficient"), degrees of freedom (df Effect = 45 for "total price" and 52 for "variation coefficient"), sample statistics value F, F_B = 38,932 for total price and 177,732 for variation coefficient and calculated confidence level p = 0,0001 for total price and 0,00000001 for variation coefficient.

As calculated confidence level p is less than defined confidence level α = 0,05 that averages congruence hypothesis inflects. This goes to prove that the averages in each of nine clusters significantly differ from each other and it points to the fact of the verity of carried clustering.

The STATISTICA program makes possible to choose separate main effects and to construct the plots of corresponding average values.

The main significant effects plots are in Figure 2 and Figure 3.

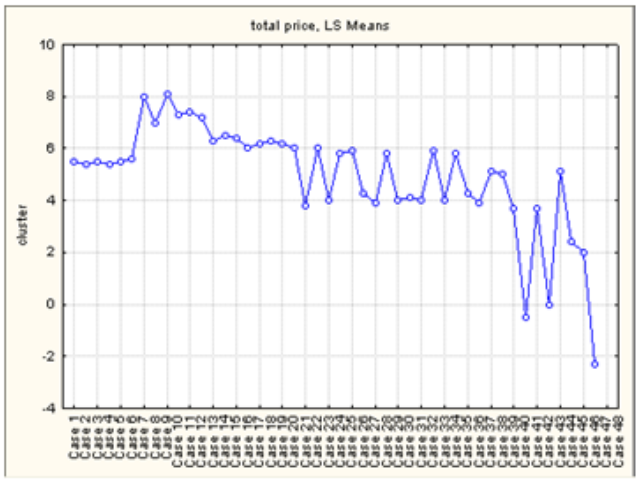

Figure 2. The plot of means (unweighted) by indicator "total price".

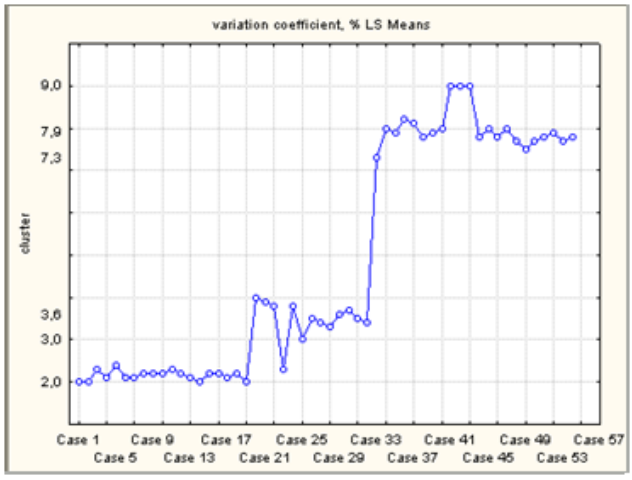

Figure 3. The plot of means (unweighted) by indicator "variation coefficient".

As the variance analysis rejected the averages congruence hypothesis, we will carry out the pairwise comparison of average values, using the linear contrasts method. Using Scheffe method (Scheffe test) let us attend the pairwise comparison of averages. In the pair wise comparison Table 4, there are confidence levels to check the averages congruence hypothesis for all allocated clusters pairs Table 6.

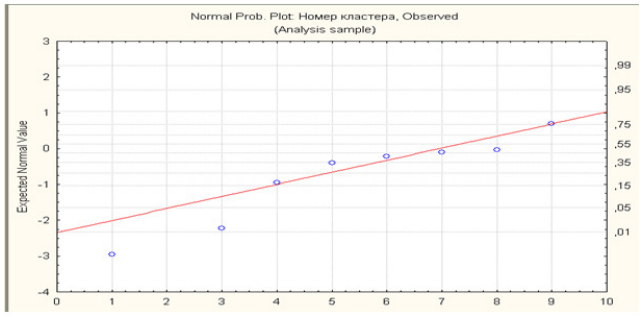

Figure 4. The basic data for check on of variance analysis on normal probability paper.

Table 6. Table of average values pair-wise comparison

Clusters number	1	2	3	4	5	6	7	8	9
1	-	0,00	0,67	0,00	0,12	0,00	0,52	0,00	0,00
2	0,00	-	0,00	1,00	0,00	0,41	0,00	1,00	1,00
3	0,67	0,00	-	0,00	0,61	0,00	0,00	0,00	0,00
4	0,00	1,00	0,00	-	0,00	0,38	0,00	1,00	1,00
5	0,12	0,00	0,61	0,00	-	0,00	0,00	0,00	0,00
6	0,00	0,40	0,00	0,38	0,00	-	0,00	0,90	0,60
7	0,52	0,00	0,00	0,00	0,00	0,00	-	0,00	0,00
8	0,00	1,00	0,00	1,00	0,00	0,91	0,00	-	1,00
9	0,00	1,00	0,00	1,00	0,00	0,60	0,00	1,00	-

The deduced analysis testify that the averages of first and second, first and fourth, first and eighth, first and ninth, first and sixth, second and third, second and seventh, second and fifth, third and fourth, third and seventh, third and sixth, third and eighth, third and ninth, fourth and fifth, fourth and seventh, fifth and seventh, fifth and sixth, fifth and eighth, fifth and ninth, sixth and seventh, seventh and eighth, seventh and ninth clusters are significantly various.

Let us make a check on of variance analysis assumptions.

In the course of variance analysis, it is supposed that basic data are the observations independent samples received from normally distributed main entities, which have the same dispersion. Let us check these hypotheses by means of the STATISTICA program. Construct for this purpose the normal categorized probability chart Figure 4.

As is clear from the chart, the points that correspond to normally distributed data fall on straight lines. The basic data are rather closely grouped towards straight lines. Therefore, the made assumption about dispersions congruence is confirmed.

4. Conclusion

Thus, the researches of classification methods and structuring of physical resources have to be continued in a number of directions that will allow to reduce the expenses connected with inventory control and to correct the inventory and orders policy. Our technics of use multidimensional statistical methods (cluster and variance analyses) in studying of financial resources movement allows to carry out the scientifically based group of physical resources, to allocate resources uniform groups on several indicators and that, as a result, will allow to lower costs of management of many thousands resources nomenclatures.

The received results testify to some distinction of two-dimensional and cluster analysis results. By cluster analysis results, the bigger quantity of physical resources is referred to group with high (and maximum) cost and the maximum coefficient of variation, in difference from the two-dimensional analysis. In our opinion, it is justified true as this physical resources group deserves the closest attention and control.

Correctly made and structured stocks classifier is the main source of information allowing to analyze the range and to come to decisions on its updating or rotation. The received results of material assets grouping based on the cluster analysis will allow increasing the effectiveness of assortment formation actions in the conditions of resource limitation. The developed stocks optimization system has to be formed proceeding from general and special principles of management characterizing it as actively functioning, aimed at achievement of the greatest possible economic and other results according to the resource opportunities. However the final management decision has to be made taking into account particular conditions of enterprise performance, features of its organizational culture, communication with suppliers and consumers, a development level of logistic infrastructure, etc. While the application of automated control stocks system, using the mathematic economic models, assurance of reliability and efficiency of information acquisition with state-of-the-art IT solutions, integration and automation of logistic operations and functions promotes the improvement of the inventory control system effectiveness.

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