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Fractals and Scaling in Logistic Processes, Flows and Management

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Abstract: Logistics is an integral management tool which enables reaching goals of business organization due to effective control of material and (or) service flows and concurrent flows of documents, information and financial resources. Up-to-date tendencies in logistics development imply the intensive mastering of new views and directions in exact sciences. In this work the authors propose a synergetic physical and mathematical approach which ultimately uses the fractal theory, scaling effects and fractional operators. The multiobjective synthesis of mathematical and physical directions (fractional dimension, strange attractors, scaling, distributed environments, non-Markovian processes (hereditarity), artificial intelligence, theory of games, neural network, cellular automation, phase transition topology and so on) with specificity of transport and warehouse logistics which was considered by the authors in this work allows turning to the new synergetic statement of the main business problem for the purpose of searching for new optimal strategies.
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1. Let us give some logistics definitions. *Logistics* is the science about planning, controlling and managing transportation, storing and other material and non-material operations which take place during the process of bringing raw materials to production, intraproductive processing of raw materials, half-stuff and materials. *Logistics* is also defined as a scientific area related to searching for new ways of increasing the efficiency of materials streams. *Logistics* is an integral management tool which helps reaching the goals of business organization by means of effective management of material and (or) service streams and also concomitant streams of documents, information and financial resources. Now one can note a wider approach to *logistics* which includes analysis of suppliers and consumers market, co-ordination of supply and demand in the market of goods and services and also harmonization of interests of members of goods movement process as well as the abovementioned points. One of the main functional areas of logistics is transportation of products. In other words, consumer needs a high-quality product in the proper quantity, proper place, proper time and delivered with minimal costs. In the market economy environment, the issues of rational and effective organization of processes of managing and controlling traffic of the material and financial streams in a company with the purpose of increasing the efficiency of material-

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and-technical supply of the business itself and sale of finished goods produced by the business become particularly vital.

All the aspects listed above point out to importance of the “just in time” logistics systems criterion. This criterion implies the optimal choice of the kind of transportation and composing a schedule of consumers service that allows to fulfill the supply tasks successfully and just in time. Organic parts of a transportation network are railways, river and sea navigable paths, motor roads and pipelines for oil and gas transportation, an air-line network. Each of these kinds represents a total of means and ways of communications, various engineering devices and constructions to provide the effective work.

Depending on the company tasks and strategies they choose a kind of transportation to deliver products. At that the production allocation, technical and economic features of different kinds of transportation, which define areas of their rational application, are considered. The problem of changing the transportation kind is solved by means of integration systems. One of them implies that the equipment which is used in one kind of transport during transportation is a continuation of the processing line of the cargo treatment in other kind of transport. It means, for example, that a container which is carried over by a truck can be used at a railway terminal for further cargo transportation. Containers itself have many advantages: they reduce handling costs, cargo spoiling and so on. But its main advantage is that they allow integrating the application of different kinds of transportation though its use increases the cost and weight of the unit of product and the problems with its redelivery or back load arise.

As it was noted, logistics is the united engineering, technology, economy and planning. Therefore providing technical and technological associativity of members of a transportation process, co-ordination of their economical interests and also using united systems of planning should be referred to as problems of the transport logistics. Technical associativity in a transport complex means the co-ordination of vehicles parameters both within separate types and in the interspecific context. Technological associativity implies application of the united technology of transportation, direct reloading and reloading-free communication. Economical associativity is a general methodology of investigations of the market condition and designing a tariffication system. Co-operative planning means development and application of united plans of schedules.

2. In Russia, with its huge territory, just transport unites, literally, every branch of the economy into one complex. Transport supplies normal vital activity of the state as well as its national safety and integrity [1].

The problem of choosing a kind of transportation is solved in interdependence with other logistics problems such as creating and supplying the optimal stock level, choosing a sort of packing and others. Information about typical features of different types of transport serves as a base for choosing a type of transport which is optimal for the particular transportation.

A significant part of operations in logistics on the path of motion of material stream from the primary origin of raw materials to the final consumption is carried out using different vehicles. The costs of these operations are up to 50% of the sum of the logistics general costs.

Transport represents an artificial complex open system which consists of two subsystems: the transport for general use and the transport not for general use. The transport for general use (arterial) serves the sphere of circulation and people. The conception of the transport for general use involves railway transport, water transport, motor transport, air transport and pipeline transport. The transport not for general use, or the intraproductive transport, and also vehicles of all kinds which belong to the non-vehicles businesses is usually a component part of some production systems.

Transport smoothly blends with production and trade processes. Therefore the transport component takes part in many logistics problems.

The transport logistics problems first of all include problems whose solution strengthens co-ordination of actions of transport process members themselves and also: creating transport systems including creation of transport corridors and transport chains; providing technological unity of storage/retrieval process; co-operative planning the transport process along with a storage one and a production one; choosing a kind of vehicle; choosing a type of vehicle; determining rational routes of delivery and others [2, 3]. Detachment of mathematical researches of transport streams into an independent section of the applied mathematics was carried out for the first time by F. Haight [2].

Logistics application in transport turns business rivals to partners who mutually supplements each other in the transport process as it is used to be in production or trade.

3. The transport process issues should underlie the logistics model and would include realistic assumptions into this model. An important research area is the analysis of vehicles routing, learning compromises between resources storages, its transportation and allocation. It shows that integration of the expert system with the transport-and-routing system on the basis of interconnected optimization may serve as a promising trend of researches.

Computerization of different parts of the logistics system and connecting them to a united high-speed information network is of great importance and that will allow tracing the cargo motion and controlling transport streams. All of these actions are intended to reduce the transport costs value and deliver a cargo just in time. It should be noted that "so far the scientists have more comprehension of the Universe origination processes than about reasons of formations of car traffic jams" [3].

4. Displacement of material streams in a logistics chain is impossible without concentration of necessary supply in certain locations what the corresponding warehouses are intended for. Hence, the main function of *a warehouse* is concentration of resources, its storing and providing the continuous and rhythmical supply of consumers orders. A logistics process in stock is quite complicated since it requires total co-ordination of functions of resources supply, cargo handling and physical orders distribution. Virtually, logistics in stock involves all the main functional areas which are considered at a micro-level. That is why the logistics process in stock is much wider than the technological process and it includes resources supply, deliveries control, cargos unload and acceptance, intra-depot cargo transportation and transshipment, cargos warehousing and storing, packaging customers orders and shipping, orders transportation and expedition, collection and delivery of empty cargo carriers, orders fulfillment control, stock informational maintenance, providing the customer service. Therefore, stock should not be considered independently but should be as an integrated component of *the logistics chain*.

5. The up-to-date trends in logistics development imply an intensive mastering of new views and trends in the exact sciences. The theory of traffic flow is based on researches of physicists, mathematicians, economists and transport workers [2, 3]. Here they apply methods of hydrodynamics, theory of magnetism, cybernetics, synergetics and so on. In the eighties - nineties of the last century in USA the transport systems problems (jams, road traffic accidents, environment pollution) were raised to the rank of national safety problems.

In this work, basing on [4-6], the authors propose a synergetic physical-and-mathematical approach which essentially uses the fractals theory, scaling effects and fractional operators. This approach is developed by the first author beginning from the eighties of the 20-th century and it has showed itself in a wide spectrum of radio physical problems. It is about time to apply the proposed and developed *fractal approach in logistics in the wide* sense. Exactly such *an author statement* of the considered problem pretends to the superiority in the world science and practice.

Fractal approaches use fractional topology dimension of the signals and images space, the mathematical apparatus of fractional integrals and derivatives (fractional operators) and the self-similarity or the scaling properties. In different fields of mathematics the sets which are negligibly small and indistinguishable in the Lebesgue measure sense arise. To distinguish such sets with a pathologically complex topological structure one should use unconventional smallness characteristics such as capacity, potential, measures and Hausdorf dimension and so on. It has been most profitable to use the Hausdorf fractional dimension which is closely related to conceptions of the entropy, fractals and strange attractors in the dynamic systems theory.

Conceptions which were introduced by Hausdorf are based on a Caratheodory construction. This fractional dimension is determined by a p-dimensional measure with a random real positive number p which was introduced by Hausdorf [7]. Generally, the measure conception is not related to neither metrics nor topology. However the Hausdorf measure can be built in an arbitrary metric space on the basis of its metric and the Hausdorf dimension itself is related to the topology dimension.

Sets whose Hausdorf-Besikovitch dimension is a non-integral are referred to as fractal sets or fractals. More strictly, a set is referred to as a fractal set or a fractal in a general sense if its topology dimension does not coincide with the Hausdorf-Besikovitch dimension. The Hausdorf-Besikovitch is a metric conception but there is its *fundamental association* with the topology dimension which was ascertained by L.S. Pontryagin and L.G. Shnirelman who introduced a metric order conception, namely: the lower bound of the Hausdorf-

Besikovitch dimension for all metrics of the compact is equal to its topology dimension [8]. As it was shown by A.S. Besikovitch for the first time [9], there are the wide differences between the Lebesgue fields and fractals. Frostman proposed one of commonly used methods for estimation of the sets Hausdorf dimension known as a masses allocation principle [10].

6. Thus, the multi-criteria synthesis of mathematical and physical trends which was *considered in this work by the authors for the first time* (fractional dimension, strange attractors, scaling, distributed media, non-Markovian processes (heredity), artificial intelligence, theory of games, neural networks, cellular automation, topology, phase transitions and so on) with specificity of the shipping logistics and the warehouse logistics will allow proceeding to the new synergetic formulation of the main problem of reduction of costs for storeholding and products transportation to its recipient when managing the flow of materials and products flow from the origin to the consumer and also to the discrete-continuous simulation with the purpose of searching for the optimal strategies.

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