Journal of KONES Powertrain and Transport, Vol. 21, No. 4 2014
ISSN: 1231-4005
e-ISSN: 2354-0133
ICID: 1130470
DOI: 10.5604/12314005.1130470

SOME ASPECTS OF RISK ASSESSMENT IN THE LOGISTICS CHAIN

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Abstract

The paper presents selected aspects of the evaluation of the effectiveness and risks of the logistics chain that supports the enterprise. It was assumed that the logistics chain includes all activities associated with the flow of materials from the sourcing of raw materials for sale to the ultimate purchaser of the product and the disposal of used products. It was found that the elements of the supply chain are usually unstable which generates difficulties in determining the appropriate level of the risk of the chain. The paper presents a formal record of risk and performance. There is proposed determination of the effectiveness of individual links of the logistics chain.

The task of the logistics chain is to provide goods from producers to the final customers, thereby making available these goods in a place and time suited to the needs and expectations of customers. The movement of goods in the logistics chains is determined by the sequence of interrelated actions. In the logistics chains, many entities are involved to different extents. This determines the spatial distribution of different configuration of individual users of the whole logistics chain. In particular, example of a logistics chain of production company, stages of the procedures for quantitative risk analysis, the problems in the logistics chains, assessment of the risk of the task in the logistics chain, the concept of risk, effectiveness and risk in logistics chains are presented in the paper.

Keywords*: chain logistics, risk, efficiency of the logistics chain*

1. Introduction

From a macroeconomic point of view characteristic of logistics systems is their service nature in relation to other sectors of the economy. In this aspect, often mentions the logistics chain, whose task is to provide products to users located in places other than the place of manufacture. The more that the specificity of the market causes that in many cases we are dealing with a situation where at some point the number of produced goods exceeds local demand and in others, there is a lack of these products.

The task of the logistics chain is to provide goods from producers to the final customers, thereby making available these goods in a place and time suited to the needs and expectations of

customers. The movement of goods in the logistics chains is determined by the sequence of interrelated actions, from the source, in which the product appears, to the mouth where the product is delivered to the recipient. In the logistics chains, there are many entities that are involved to different extents in the process of the movement of goods from the sphere of production to the sphere of consumption. This determines the spatial distribution of different configuration of individual users of the whole logistics chain.

An important aspect is efficiency often called the efficiency of the operation of logistics chains. The corresponding efficiency in individual cells, i.e. suppliers, manufacturers, intermediaries, customers, determines the success or failure of distribution processes.

Since the elements of the logistics chain are usually, unstable problem is to determine the appropriate level of the risk of the chain. On the logistics chain factors, interact dependent on both the organization of the chain itself and its cells – so called internal factors, and factors independent of the structure and organization of cells logistics – external factors. The impact of these factors is the risk of the operation of logistics chains.

Analysis and risk assessment enables the management of supply chains, which minimizes the risk. Risk management should begin at the stage of its design; and organization of the logistics should begin chain when there is taken into basic factors, criteria and determines the optimal operating principles of the links of the chain in variety of conditions. Risk management, continues of course, during the operation of the logistics chain. It is important then constant control of logistics processes taking place within the logistics chain in order to not to lead to excessively high level of risk to its functioning. [13].

Risk assessment in the field of logistics processes requires consideration of three aspects concerning: transport risk and safety requirements in the context of environmental protection and land development (including the identification and quantification of risk to people, property and the environment associated with the carriage of dangerous materials and its impact on the users of the area and ecosystems along the transport routes), the technical and technological conditions (resulting from the existing road network and storage as well as the traffic intensity) and economic conditions of transport and storage (including length and transport time and transport costs for alternative routes).

In transport and logistics, risk analysis been used to develop emergency plans, transport route selection in particular dangerous goods, the evaluation of potential suppliers and customers, etc.

2. The problems in the logistics chains

Defining the logistics chain can use the concept of the network, in general, defined as [5, 14]: logistics channel structure, which follows the flow of goods from producers to distribution facilities (logistics), and final customers or a group of independent companies competing and cooperating in order to improve the efficiency and effectiveness of the product flow and the accompanying information in accordance with the expectations of the customers [1, 5]. Can therefore be said that the logistics chain is connected to each other, and if mutually dependent activities with designated start and end points. Are set out in it interrelation between the elements of a specified process. For example, in functional terms these interrelations will apply depending on the subsequent links (companies and institutions) that are involved in the movements of goods. However, in terms of organizational and managerial it is an integrated sequence of processes to manage the flow of materials from suppliers to final customers.

It is important to integrate and coordinate the cooperation of companies to allow smooth delivery of goods to the consumer [14]. Given the above, the logistics chain can be defined as a set of interrelated storage facilities involved in the supply of material requirements for companies from suppliers (sphere of supply of the company) and shipping of products – finished goods from companies to the end users – customers (the sphere of distribution of the companies) (Fig. 1).

In summary, the logistics chain includes all activities related to the movement of goods from raw material sourcing to sale to the final purchaser of the product and the disposal of used good. In

every moment of the flow may appear returns, materials and products rejected by the next company in the chain or wastes that require disposal. The structure of the logistics chain is defined as a set of elements (entities): raw material suppliers, manufacturers, wholesalers and consumers associated with the corresponding relations on the flow of materials.

Depending on the number of intermediaries on the way of movement, the structure of the logistics chain can be single-level or multi-level (hierarchical). A characteristic feature of the hierarchical structure is the need to move materials from suppliers through the levels before they are delivered to customers [7, 8, 12].

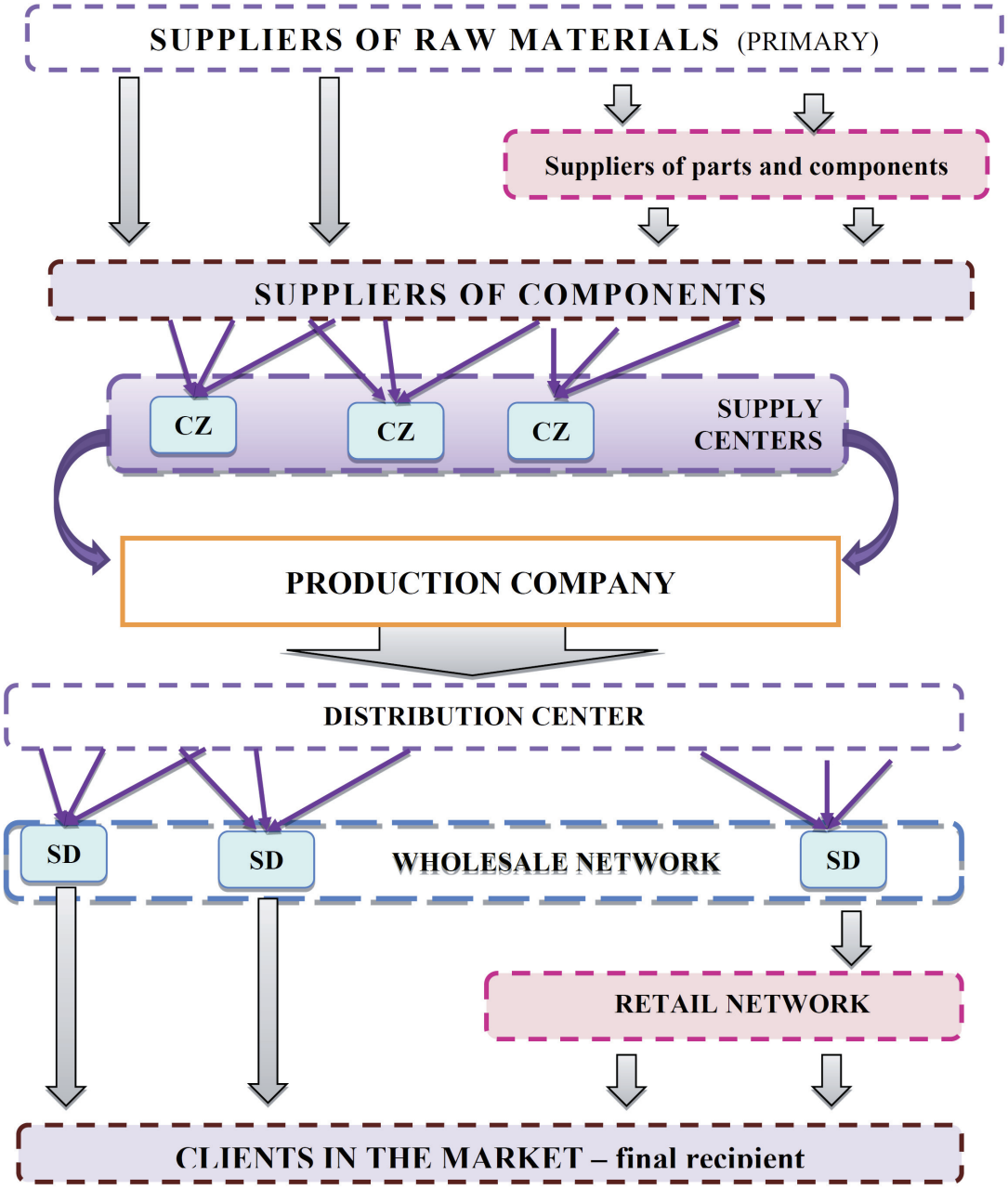

Fig. 1. Example of a logistics chain of production company

Problems in the supply chain can be divided into three groups. The first group concerns the production technology used, the second and the third to maintain inventory deliveries and shipments, and streamline operations taking place within the company.

The efficiency of functioning of the logistics chain to service the companies is affected by, among others, on:

- the choice of production technology,
- inventory levels of key materials for production, and thus economic EOQ inventory levels,
- features of information systems MRP and MRP II,
- the cost of maintaining inventory in the producer's own warehouse,
- the supply of raw materials just-in-time,
- the length of the transport cycles for external transport,
- the cost of maintaining inventory in external warehouses,
- response time of suppliers / external warehouses for demand for materials.

As can be seen, these problems affect the efficiency of the logistics chain, which in turn affects the efficiency of the logistics system, which is element of the chain. Wherein by the efficiency of the system understood is the ability to perform specific tasks, i.e. achieving the intended objectives of the action, functioning according to specifications and requirements in the existing conditions.

3. Assessment of the risk of the task in the logistics chain

3.1. The concept of risk

The concept of efficiency assumes different meanings according to the scope, purpose and area of research. In the theory of systems, efficiency is defined as the adaptation of the system to perform tasks [1]. In addition, an assessment of the operation of the particular complex systems, refers to the relationship between the action and the resources provided for the implementation of this action. An important aspect in assessing the effectiveness of the systems in the area of systems theory is the perception of the important role of the reliability of the system as a property significantly affecting the capacity to perform the tasks by the system [15]. This involves the risk of implementation of particular actions.

In the literature, you can find many definitions of risk, depending on the discipline of the publication. Most often risk refers to broadly defined issues of security, technology or economics. In technical issues is often used alternative to determining the risk of reliability..

Generally, it can be assumed that we are talking about the risk when clearly you can define existing threats and estimate the probability of its occurrence.. Otherwise, – when one or both of the above elements are unknown – we have to deal with uncertainty.

Any decision concerning the economic activity entails a risk relating to achievements the objective. The risk is defined in the literature in two different ways, depending on the achievement of the desired effect:

- as a threat – a possibility of not achieving the objective,
- as a threat and an opportunity – allows for the possibility of achieving the effect different from expectations.

In the activity of enterprises can be distinguished four types of risk:

1. business – for the operations,
2. market – on the financial market,
3. credit – relating to borrower breach a contract,
4. operating – on losses resulting from the lack of control over the quality of production, fraud, random events, etc.

From the point of view of reliability, risk can be expressed as the probability of damage. Usually assumed operation is combined with more than one effect (each with an appropriate probability). Thus, the risk for a given action can be represented as a vector of pairs of an event being the result of actions (effect) and the probability of its occurrence:

$$\forall \boldsymbol{e} \in \boldsymbol{E} \qquad \boldsymbol{R}(\boldsymbol{e}) = \left[\left(p_1^e, n_1^e \right), ..., \left(p_i^e, n_i^e \right), ... \left(p_{I(e)}^e, n_{I(e)}^e \right) \right], \tag{1}$$

where:
e – number of action,
$\boldsymbol{E}$ – number of set of actions $\boldsymbol{E}=\{1,\ldots,e,\ldots,E\}$,
i – number of the event (effect),
$\boldsymbol{I}(e)$ – set of numbers of events of e-this actions $I(e)=\{1,\ldots,i,\ldots,I(e)\}$,
p_1^e – probability of occurrence of the i-th event of the e-this action,

$$\forall e \in \boldsymbol{E}, \qquad \sum_{i=1}^{I} p_i^e = 1. \tag{2}$$

To assess the risk of not only a single event but also a number of sequences of events, which are not always independent, you should model the risk of the whole system and then evaluate them quantitatively. Thus, risk analysis requires the identification of possible occurrence of events and their consequences also estimation of the occurrence probability of the events and the impact assessment of occurring events. In the effect of modelling identifies the contents of sets events $\boldsymbol{E}$, the impact of events $\boldsymbol{I}(e)$ and the probability of occurrence of events.

The procedure for quantitative risk analysis consists of eight stages (Fig. 2).

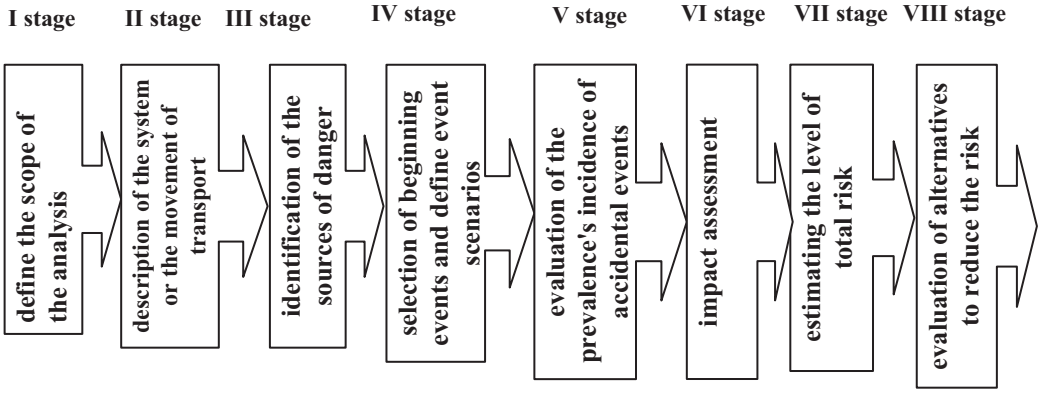

Fig. 2. Stages of the procedures for quantitative risk analysis

During the risk assessment assumed to be known previous experience with similar systems known risk assessment models and data sets collected during the operation of the analysed systems. The method of risk management of any technical system, including the logistics chain consists of five stages:

1. define the system and the objectives and criteria of analysis,
2. threat analysis, defining scenarios of unfavourable events,
3. collection of data,
4. qualitative and quantitative risk assessment,
5. minimization of risks occurrence and weakening of consequences of unfavourable events.

3.2. Effectiveness and risk in logistics chains

In the logistics chains risk is the possibility of adverse events resulting from the realizations of the orders, market sales or operations of the company itself [8]. Thus, risk analysis can be used to manage and control various types of risk associated with the flow of goods by defining the parameters that have the greatest impact for the movement and for the identification and evaluation of risk-mitigation strategy. These strategies may include changes in the ways of transport, shipment size, route, type of container, the choice of transfer or intermediate storage.

The main activities, which are burdened with risk in the case of the logistics chain, apply to the transport and storage. Among them can be distinguished:

1. risk to transport associated with:

- mode of transport,
- route,
- emission of harmful exhaust compounds,
- the presence and behaviour of other road users (not part of the logistics chain)
- loading and unloading,
- atmospheric conditions during transport,

2. risk regarding storage associated with:

- method of storage,
- loading and unloading.

Both the risk and the effectiveness of the logistics chain is a measure of the evaluation of its activities. In this aspect, it is often said of the so-called economic efficiency. Economic efficiency is determined as a result of economic activity, branches of production, the entire economy, determined by the ratio of the resulting effect to the effort, as well as a component of the concept of general social efficiency, which besides economic effects also includes non-economic effects.

Methods and indicators used in assessing the effectiveness of economic science can be successfully used to assess the technical systems. In particular, if they concern business in the functioning of transport companies performing transport services. Evaluation of the functioning of transport systems, taking into account economic criteria is in many cases justified and necessary. It allows you to perform a synthetic evaluation of the efficiency of logistics chain, which will be taken into account both indicators of technical efficiency and economic.

In terms of technical efficiency is seen as a measure of system performance, taking into account external conditions and manner of application of the system [1]. It can be presented in terms of both descriptive and normative. The effectiveness of the technical system in descriptive terms is the total feature of the system and its exploitation process, expressing the impact assessment of the system. The effectiveness of the technical system in terms of the normative is however, the degree of implementation of tasks assigned to the system, taking place in certain operating conditions and in a certain period of time.

In general, the study of systems includes the following types of efficiency[15]:

- potential efficiency of the system, expressing rated abilities of the system, allowing the achievement of the objectives of the operation,
- realized efficiency, expressing the degree of capacity utilization of the system in the process of implementing specific purposes and under certain conditions,
- obtained efficiency, expressing the value of the results obtained in the process of implementing a particular purpose, as a result of realization of a particular function of the system.

Exploitation efficiency of the logistics chain will provide therefore in descriptive terms a common feature of the chain and the process of its exploitation expressing the effects of the system. In terms of normative, however it will be a performance of the evaluation of the system, determined by the degree of implementation of tasks in the transport process under certain operating conditions in certain time.

Risk assessment of realization of tasks in the logistics chain is to determine the relationship between the predicted size for the chain tasks and its equipment and the cost fulfilment of tasks by this system and the probability of occurrence of adverse events. Models based on a mapping such models, which aim is to study the relationship between the size of the tasks of the logistics chain, its equipment and the cost of implementation of the tasks and the possibility of occurrence of adverse scenarios. Among the models of such applications, particularly the roles of process models, which made the distribution process into phases, based on the assumption that you can always divide the process of the movement and storage of cargo between sources and mouths stream loads on the phase corresponding to the various stages of the movement or storage of goods. The method of dividing the process into phases and the “content” of each phases of the objective and scope of the research, which is to serve the mapping of the logistics process.

Taking into account the presented approach to the modelling of logistics processes occurring in the logistics chain, for the purposes of the article was assumed that the state of the logistics chain would be a phase of the process, while the change of state (transition from the phase of the process to the next) will be an event. It was assumed that with respect to time the phase of the process is characterized by its duration, and the event the moment of its occurrence. With such assumptions, the relationship between the states of the system mapped as a network, which was called a network phase's process.

With such assumptions phases of the processes of the network maps the relationships between the phases of the process and the structure of the network of phases of the processes maps the structure of logistics process, wherein each phase is a structure node and the event its arc. In this context, a network node interface, depending on the approach, can map a part of the route of the system or a warehouse, through which the stream of goods or goods which are allocated to respective elements of the infrastructure. Phase of the process will map the element of both point (node) and linear (transport connection).

Logistics process can be broadly divided into transport and storage. Typically, transport processes occurring in the logistics chain are non-stationary. This means that volume of traffic on the road depends on the time of day. Especially volume of traffic in the city is different at different hours of the day (e.g. summit morning or afternoon). Similarly, the movement of trains are on the railway lines or the processing of passengers at airports. Non-stationary nature of the transport processes impedes research. Therefore, it is certain simplifications, which allow you to assume that the transport processes are stationary, i.e. intensity of the traffic is independent of time. This means that in each time interval the probability of the occurrence of a specified number of movement depends only on the length of the fixed period, and not the position of the interval on the timeline. It can therefore be assumed for suitably small segments that transport processes are stationary.

For this purpose, it is assumed that a day is divided into compartments $(t_j, t_{j+1}]$, of different but constant for each compartment, intensity of tasks, which can be written as follows:

$$\boldsymbol{Td} = \bigcup_{j=0}^{k-1} \left(t_j, \ t_{j+1} \right], \tag{3}$$

where:

$\boldsymbol{Td}$ – a set of time intervals constituting a day (24 hour),
j – number of time interval,
k – number of the last time interval.

It is understood that, for any time intervals the set of numbers of time intervals is strictly monotonic ordered set. The processes of storage were assumed that they are stationary..

Treating effectiveness as a cumulative quality characteristics of the logistics chain, will be expressed by the specific characteristics and express the efficiency of transformation of expenses for useful results. This means that the efficiency of logistics chain can be regarded as a feature of the system, measurable and useful when comparing logistics chains of given class, expressing different aspects of the different time intervals and expressed differently depending on the type of chain, its purpose and conditions of use.

Assuming that the individual element chain will be numbered with an index v, and $\overline{V}$ would be number of cells, set of elements V will be defined as $\boldsymbol{V} = \{1,...v,...,V\}$. It is assumed that there can be direct transport links between the different elements of the chain. Assuming that on the Cartesian ratio $\boldsymbol{V} \times \boldsymbol{V}$ is inflicted a mapping γ conducting elements of the Cartesian product in the set of {0, 1}, i.e.: $\gamma: \ \boldsymbol{V} \times \boldsymbol{V} \rightarrow \{0,1\}$, wherein if $\gamma(v,v')=1$, then between cells v and v' ($v' \neq v$) is a direct link, otherwise $\gamma(v,v')=0$. Pair for which $\gamma(v,v')=1$ form a set $\boldsymbol{L}$ of direct links, i.e.:

$\boldsymbol{L}=\{(v,v'): \quad \phi(v,v')=1, \ v \neq v' , \ v,v' \in \boldsymbol{V}\}$.

Taking into account the above, the effectiveness of the logistics chain can be written as the ratio of useful effects $\Psi(t,v)$ to the direct expenditure incurred $\Theta(t,v)$ referred to the time of operation of the system for each of the cells, 1, 11] i.e.:

$$\forall v \in V \quad \Xi(t,v) = \frac{\Psi(t,v)}{\Theta(t,v)}, \tag{4}$$

wherein:

- volumes $\Psi(t,v)$ and $\Theta(t,v)$ mean values of the effects obtained and wasted expenditure to the moment of time t for v – this cell from the onset of action of the logistics chain, i.e. from $t=0$.

Function $\Theta(t,v)$ in time interval $(0,t)$ is a non-decreasing function of time. Expenditures shall be construed as part of resource consumed for each v-th cell in the action and written as:

$$\forall v \in V \quad \pi(t,v) = \frac{d\Theta(t,v)}{dt}. \tag{5}$$

Hence, the value of the function $\Theta(t,v)$, at the moment τ, i.e. $\Theta(\tau,v)$ depending on whether the function $\pi(t,v)$ is continuous or discrete, for each v-th link in the chain, can be calculated from the formulas:

$$\Theta(\tau,v) = \int_0^{\tau} \pi(t,v)dt \quad \text{or} \qquad \Theta(\tau,v) = \sum_{i=0}^{k} \pi_i \Delta t_i(v). \tag{6}$$

Function $\Psi(t,v)$, in the concerned interval of time can take both positive and negative values**.** The value of the achieved results in the action can be written in the form:

$$\forall v \in \boldsymbol{V} \quad \mu(t,v) = \frac{d\Psi(t,v)}{dt}. \tag{7}$$

Due to the set of variables, determining the efficiency can be assumed that a set of basic characteristics of expressing the efficiency of the chain is built on the basis of the relationship between the variables and its links.

In the model of risk assessment of the logistics chain is mapped characteristics of elements of its structure (e.g. capacities, travel time, loading and unloading time), the demand for transport and the organization to which the description of the use of structural elements of the logistics chain for the tasks. It is also necessary mapping of the properties of the elements of the chain, which will allow the test run the risk of changes occurring in the chain, i.e. enables mapping running changes in status of the logistics chain for different decision situation.

4. Conclusions

Efficiency is the collective characteristics of the quality of the logistics chain, which can be expressed by the specific characteristics and thus express the transformation effectiveness of expenditure incurred for useful effects. This means that the efficiency of logistics chain can be regarded as a feature of the system, measurable and useful when comparing logistics chains of the class, expressing different aspects of the action in different time intervals and expressed differently depending on the type of chain, its purpose and conditions of use.

In contrast, the risk of logistics chains is the possibility of adverse events resulting from the implementation of the orders, the market sales or operations of the company itself. Thus, the risk analysis can be used to manage and control various types of irregularities relating to the flow of goods by defining the parameters that have the greatest impact for the task and for the identification and evaluation of risk limitation strategy.

The essence of risk assessment in the logistics chain is the study of the relationships between the tasks of the system, its equipment and organization of the activity of the logistics chain, come down to the choice of strategy implementation process.. An important aspect in this regard is the proper selection of equipment chain for time-varying tasks and changing environmental conditions.

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