

# A method for optimisation of enterprise logistic supply chain

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**Abstract.** The aim of the study was to develop an optimisation method for management of current assets of an industrial enterprise by the concept of logistics supply chains. The ways of acceleration of working capital turnover at the stages of supply, production and marketing of goods and services have been identified. The necessity of applying the concept of supply chain management to working capital management has been justified. This allowed defining the management principles in the supply chain of an industrial enterprise. As a result, a method for optimization of enterprise current assets of an industrial enterprise as a central element of a supply chain has been offered. It has been proved that the presented method makes it possible to determine the effect of working capital acceleration both in the material and financial subsystems. A tool for realisation of this effect is the structuring of working capital by title deeds.

## Introduction

An analysis of the management system that had been used in many industrial enterprises shows that there is no integrated approach for organization of the logistics chain. This situation is also caused by the lack of a method for managing of working capital in the concept of SCM (Supply Chain Management) [1], which most fully reflects the current integration processes in the production industries.

The aim of the work is to optimize the management of current assets of an industrial enterprise by the concept of a logistics supply chains.

Working capital acceleration can be done in the following ways:

1. Supply phase: optimization of stock, systematic warehouse stocks control; replacement of raw materials with cheaper substitutes; choosing of reliable suppliers; implementation of technologies of "lean" production and logistics.
2. Production stage: reduction of the production cycle; synchronization enterprise production processes; loss insurance and increase of labour discipline; reuse of waste materials; usage of technologies of "lean" production.
3. Marketing and sales of goods and services: reduction of the sale time, improvement of marketing effectiveness; improvement of sales channels effectiveness; optimization of

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commodity stocks, discount and loyalty systems and usage of factoring; securitization of capital funds.

In current business environment, one of the most topical problems is the organization of constant uninterrupted accounting with counterparties for shipped products under conditions of shortage of own funds. Thus, the way for continuity and high turnover of current assets is formation of a stable supply chain with the focus on the company and its counterparties at all the stages from supply to marketing and sales.

Scientific studies of working capital management can be structured in the following groups:

1) Simulation of money flows. The role of financial resources in modern logistics was previously defined [2], the possibility of applying a single methodological base for flow management was justified on the example of the "just in time" manufacturing model. Author has proved that the methodology of organization and management of material flows can be applied to financial flows, which once again confirms their unity. Moreover the similarity of models of optimization of a monetary stock and sizing of the order in supply chains in a micro logistic system has been revealed [3], a method of calculation of parameters for multi commodity deliveries with attraction of extra resources and accompanying financial flows in logistical system has been developed.

2) Modeling of non-monetary flows. Some authors propose the usage of bills of exchange in the payoffs between enterprises and counterparties; they had introduced a mechanism for optimization of financial flows as well as proved the necessity of creating business units [4]. In some works, the classical ABC and XUZ analyzes of material logistics are adapted to the analysis of account receivables and payables. In [5] authors suggest that the management of tangible and monetary assets must follow the same rules.

3) Inventory management. In work [6], a dynamic model of operation sequence has been proposed that specifies the volume of production resources, the demand of the market for final goods or services. In another work [7], a modification of a total logistics costs model (TLC), which is based on the system approach and the principles of logistics management, was proposed. The author developed an algorithm for the formation of an inventory management system in supply chains, justified the usage of regulatory methods using logistic concepts such as rapid response and "just-in-time".

4) Usage of principles of logistic management on working capital on the basis of the financial logistics apparatus. Leading specialists in logistics consider financial logistics as a part of the resource logistics and note that financial logistics is currently the least studied section of enterprise logistics.

Thus, the implementation of the supply chain management concept to the formation and management of current assets of industrial enterprises can be considered as topical problem as well as has scientific and practical interests.

## **Methodical bases of current assets optimization in a supply chain**

The idea is that the efficiency of using working capital of integrated enterprises can be achieved through the synchronization of their supply chains by the criterion of integrated costs for the formation and management of working capital in the cost chain (Table 1).

**Table 1.** Costs for the formation of working capital in the supply network.

<b>Integral costs in supply chain</b>			
<b>Expenses</b>		<b>Losses</b>	
In the basis chain	In the multiplied chain	In the basis chain	In the multiplied chain
In the inventories maintainance		Discounts	
Interest on a loan	In the inventories maintainance	Consumer leave	Consumer leave
		Warehouse certificates circulation	

Today many industrial enterprises have developed a tender supply system which primarily leads to fluctuations in the qualitative characteristics of raw materials, an increase of transaction costs [8] and transitory tie. In the world best practice of business processes management of manufacturing companies two strategies for managing supply chains are most known in which current assets are formed on the basis of the principle of "pushing out" or "pulling out" supplies [9, 10, 11, 12, 13].

In the "push" strategy, current assets undergo delivery push when the material flow is the primary one; the goods are delivered to the end consumer with the postponed payment. In the "pulling" strategy current assets undergo the principle of pulling out the supply when the material flow is secondary, the goods are delivered to the final consumer with the prepayment.

Comparison of the classical organization of working capital management and supply chain based one allowed formulating the following principles for the organization and management of working capital in the supply chain concept: transition from competition to cooperation with counterparties through the chain; cooperation with a smaller number of reliable buyers and suppliers of material resources; vertical integration with key customers and suppliers to reduce the risks and secure the supply chain; co-management of streaming processes; high order response rate and diversification of payment forms; an established system of mutual payoffs for the delivered resources; formation of a shared cost chain; maximization of profit due to acceleration of capital turnover.

In some works [14] the process of circulation of current capital in the supply network formed as a result of multiplying the basic ("horizontal") Supply Chain 1 (SC1, using the "pull out" strategy) and the "vertical" superstructure supply chain 2 (SC2, using the "push out" strategy):

- financial part of working capital in the form of a prepayment forms financial flows in the supply chain SC2;
- material part of working capital in the form of raw materials forms material flows in the supply chain SC2.

In the proposed supply network, current assets are accelerated simultaneously in two chains: within the "horizontal" chain as movement of the financial part of working capital; within the "vertical" chain as movement of material working capital what allows avoiding the "freezing" of capital and reducing costs. This acceleration provides the synergy effect which includes the sales increase with the same amount of invested capital and hence the profit increase.

Costs for synchronisation of flows which include information flow (products orders) and material flow (product supply) determine the costs of maintenance investments in inventories. To determine their functional dependence on the order execution delay the dynamical theory of J.Forrester can be used [15].

Finished products are shipped to the consumer from the warehouse. The delay in orders executed on the warehouse stocks is formed from the delay in processing orders at the enterprise and the delay in the shipment of products from the warehouse. Orders sent to production units undergo delay in the order book and as well as production lag:

$$x = x_1 + jx_2 + (1-j) * (x_3 + x_4) \quad (1)$$

where  $x$  is delay in the fulfillment of orders by the enterprise (days),

$x_1$  is delay in order registration at the factory;

$j$  is the demand covered with current stock of finished goods;

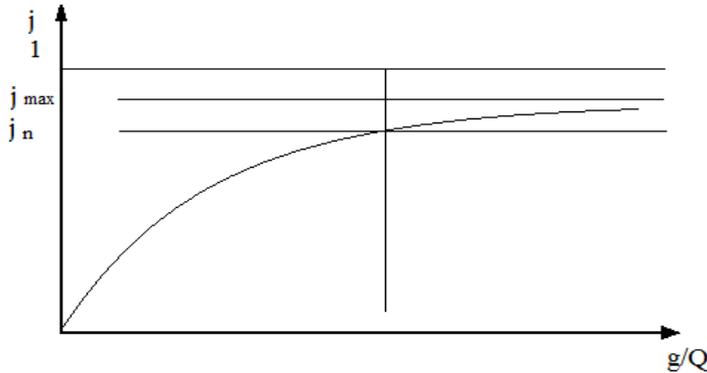
$x_2$  - delay in the shipment of goods from the warehouse (days);

$x_3$  - production lag (days);

$x_4$  - order production lag (days).

The value of  $j$  is variable associated with the aggregated order flow for all types of produced goods and services. It is obviously that with inventory decrease an increasing proportion of the order flow will be sent to production rather than being covered with inventory.

In work [15] one of the possible dependencies between the value of  $j$  and the amount of stock ( $g/Q$ ) is presented on Figure 1.



**Fig 1.** Demand covered with current stock of finished goods

The nature of this dependence is determined by the following: some types of products are so specific that they are not ever made into stock. Therefore, there should be an upper limit for the  $j_{max}$  of orders that are covered from current inventory stock.

The next characteristic is the part of orders  $j_n$  which under normal conditions can be satisfied at the expense of the normal stock size  $Q$ . The term "normal stock size" ("desirable stock") is derived from the average level of business activity which defines amount of stock enough for business operation. As a measure of stock its ratio to a stock that is sufficient is used. "Normal stock size"  $Q$  is defined as:

$$Q = v \cdot M_n, \quad (2)$$

where  $v$  is a coefficient of relative stock at an enterprise that links the level of the desired goods stock with an average year sales rate;

$M_n$  is the annual sales with prepayment (rubles per year).

With deemed  $j, j_{max}, c_1$  and  $Q$ , you can determine the actual stock of finished products:

$$g = -\frac{v \cdot M_n}{c_1} \cdot \ln \frac{j_{max} - j}{j_{max}}. \quad (3)$$

where  $c_l$  is minimum lag of shipment (days).

Then the cost of linking capital and the actual stock:

$$y_l = g \cdot H_p \quad (4)$$

where  $y_l$  is the cost of capital immobilization (RUR);

$H_p$  is the enterprise profitability rate;

$g$  is the value of the actual annual stock (RUR).

Taking into account formulas (3) and (4) the following one is derived:

$$y_1 = -C_1 \cdot M_n \cdot \ln\left(\frac{j_{\max} - j}{j_{\max}}\right) \quad (5)$$

## Development of a method for supply chain optimization

It was decided to improve presented method for the application to working capital. The following statement will be considered – with the increase in delivery delays expenses are reduced and losses are increased.

The optimization task was to find the optimal lag between the production order and its delivery. The objective function is the criterion for the functioning of circulating assets of a company in the supply chain.

It was shown in [16] that an increase of the time of production delay leads to a reduction in the expenses for forming a stock of finished products but also to an increase in the "losses" (enterprise's profit).

The main factors of "losses" are discounts to loyal customers and the effect of customers leave due to a significant delay in the products delivery and high pre-payment rates. The maximum amount of the discount is defined by the specific weight of costs.

Customer leave is caused by the following reasons. The first one is significant delay in the product delivery due to the need to purchase materials and then manufacture products at customer's request.

The second reason is the market policy of mutual payoffs that is inadequate and inflexible to market needs (for example when the enterprise insists on high pre-payment rates). The higher the first payment, the more customers leave this manufacturer for its competitors. The third reason for customers leave is the lack of the ability to completely redeem the finished products.

Thus, the optimization problem is to determine a lag point that provides the optimum of the objective function ( $y$  – integrated costs in the supply chain).

$$y = (y_1 + y_2) \quad (6)$$

To solve this problem it is necessary to allocate costs and losses in the basic ( $y_l$ ) and multiplexed ( $y_2$ ) supply chains. The condition of balance of these chains is the equality of deliveries delays in both chains. The flows of the basic chain are characterized by delivery delay in conditions of prepayment and include:  $y_{11}^{SC1}$  (cost of maintaining the actual stock),  $y_{12}^{SC2}$  (cost of maintaining the actual stock in the multiplied cycle),  $y_{12}^{SC1}$  (interest on the loan for resources or borrowed funds). Then cost of maintaining stocks in the basic chain  $SC_l$  can be represented by the following expression:

$$y_1 = y_{11}^{SC1} + y_{12}^{SC1} + y_{12}^{SC2} \quad (7)$$

The analysis of the flows of the basic supply chain of an industrial enterprise made it possible to determine the total costs of supply chains. Using the coefficient of relative stock

in the enterprise  $v$ , that links the level of the desired goods stock with an average year sales rate, after the mathematical transformations the total cost of maintaining the stocks in the basic chain can be represented in the following way:

$$y_1 = -H_p * \frac{v * M_{p1}}{c_1} * \ln\left(\frac{j_{max} - j_1}{j_{max1}}\right) + \frac{(i - i_c) * M_{p1} * L * X}{365} - H_p * \frac{v * M_{p2}}{c_1} * \ln\left(\frac{j_{max} - j_2}{j_{max3}}\right) \quad (8)$$

where  $X$  - delay in orders fulfillment (days);

$j_{max}$  - the maximum share of costs;

$j_1, j_2$  - the share of costs in the basic and multiplied chains respectively;

$H_p$  - return rate (RUR per year);

$L$  - interest rate on a loan for resources;

$i_c$  - specific weight of material costs;

$i$  - specific weight of prepayments;

$c_1$  - minimum shipment delay (days);

$M_{p1}$  - revenue from prepayment in the basic chain (RUR per year);

$M_2$  - revenue from immediate payments in the multiplied chain (RUR per year).

The feature of the proposed formula is that the revenue in the multiplied chain ( $M_2$ ) is a function of the revenue in the basic supply chain:

$$M_2 = i^* * M_{p1} \quad (9)$$

where  $i^*$  is the optimal multiplier which provides the synergy effect in the form of additional profit from accelerating the capital turnover.

The economic need to introduce into the cost accounting model (7) interest rate on the loan ( $y_{12}^{SC1}$ ) is caused by the following: in the proposed delay scheme when the prepayment for the order is received it starts a new chain of SC2 and the debt in the original chain SC1 is paid off by the transfer of the title deed document. Obviously, the higher the prepayment, the higher the intensity of the flows in the SC2 and lower the intensity of the flows in the chain SC1. Thus it is necessary to attract new funds to cover old obligations and pay off interest rates.

Losses in the multiplied chain include lost revenue due discounts to customers (RUR), lost profits (annual losses of the enterprise, RUR),  $y_2^{SC2}$  - losses from customer leave, losses from discount on warehouse certificates that arise due to a change in the market price of the goods. Total losses in the multiplied chain can be expressed in the following form:

$$y_2 = y_{21}^{SC1} + y_{22}^{SC1} + y_{23}^{SC1} + y_2^{SC2} \quad (10)$$

where  $y_{21}^{SC1}$  is profit lost due discounts to customers;  $y_{22}^{SC1}$  is annual losses;  $y_{23}^{SC1}$  is profit lost due to customer leave;  $y_2^{SC2}$  is profit lost due discounts on warehouse certificates.

The analysis of losses in the multiplied chain ( $y_2$ ) is carried out in [17] with the rate of losses from discounts in the basic chain ( $\epsilon_1$ ); loss rates, respectively, from a significant delay in delivery and high prepayment ( $\delta, \delta_i, k_i$ ), discount rates ( $d$ ), minimum shipment delay ( $s$ , days), delay in receiving full payment ( $x$ , days) which covers loan and a number of other factors.

Using the constants of model  $C_3, b, a_2$  after mathematical transformations the total losses in the multiplied chain can be represented in the following form:

$$y_2 = M_{p1} * H_p * (e^{\epsilon_1(x-c)} - 1) + C_3 * (e^{\delta(x-c)} + e^{\delta_1(i-a_2)} - 2 + b - k_i) + d * (1 - i) * v * M_{p1} + C_3 * e^{\delta_2(x-c)} \quad (11)$$

## Practical recommendations

The implementation of the optimization task for the functioning of working capital (6) is based on control of the balance between the delay in the resource supply and the labor productivity on the enterprise.

Thus the following optimization task is determined: to find the delay (days) that provides the optimum for the objective function - the criterion for the functioning of circulating assets in the supply network:

$$y = y_1 + y_2 \rightarrow \min \quad (12)$$

The solution of this problem will allow determining the parameters of the supply network of an industrial enterprise:

- period of working capital turnover in the basic and multiplied chains  $x^*$ . It corresponds with the optimal stock amount in each chain  $g^{SC1}$  and  $g^{SC2}$  as well as with the optimal ratio between assets in production and in warehouse in each cycle  $j^{1*}$  and  $j^{2*}$ .

- the optimal multiplier  $i^*$  which provides the synergy effect in the form of additional profit to the enterprise from accelerating the capital turnover.

The method of circulation funds optimization made it possible to determine the effect of current assets accelerating both in the material and financial subsystems. A tool for realization of this effect is the structuring of working capital by title deed documents. Practical application of the supply chains optimization method to an industrial enterprise has allowed reducing losses from the effect of customer leave and losses from discounting due to a balance between the supply lag of resources and labor productivity.

## Conclusion

As a result of this work the necessity of applying the concept of supply chain management to the formation and management of current assets has been proved as well as the usage management and organizational principles for supply chain of an industrial enterprise have been established.

The method of optimization of working capital of an industrial enterprise has been suggested. Unlike existing methods the proposed one is based on the intersystem approach and allows to determine the optimal parameters of working capital in the chain "supplier of level 1 - producer - consumer of level 1". Furthermore it takes into account the flowing nature of working capital and is based on identified classical and logistics costs.

It is shown that the method of circulation funds optimizing of an industrial enterprise makes it possible to define the effect of accelerating current assets both in the material and financial subsystems. A tool for realization of this effect is the structuring of working capital by title deed documents.

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