Contributions to Game Theory and Management, XV, 339–364

Stable Goal-Based Management Strategy for Supply Chain Finance

Nikolay Zenkevich, Anastasiia Ostashova and Anastasiia Ivakina

St. Petersburg State University,
Graduate School of Management,
7/9, Universitetskaya nab., St. Petersburg, 199034, Russia
E-mail: zenkevich@gsom.spbu.ru, Anastasiya.Ivakina@gmail.com, Anastasia.ostashova@yandex.ru

Abstract The article is devoted to improving the methodology for managing the total working capital of the supply chain to reduce costs for given ranges of liquidity. The paper analyzes the current state of research on working capital management in supply chain finance and substantiates the multi-objective nature of managing joint working capital in the supply chain. The possibilities of individual financial instruments to reduce the cost of total working capital for given ranges of liquidity have been explored. The necessity of using the technique of dynamic goal programming in the problem of working capital management is substantiated. A model and algorithm of goal management have been developed, which is implemented on cases of real supply chains and has shown its effectiveness.

Keywords: working capital management, supply chain finance solutions, inventory financing, reverse factoring, multi-objective optimization, dynamic goal programming.

1. Introduction

The need for financial supply chain management is highlighted by both practitioners and the academia. From a consultancy perspective, financial supply chains should be managed as closely as physical supply chains. The academia represented by Gupta and Dutta expresses the same importance of management of upstream flow as management of downstream flow of goods (Gupta and Dutta, 2011). As a result, many scholars have attempted to develop a conceptual framework of financial supply chain management and working capital management.

The supply-chain perspective of working capital management is becoming more and more popular (Wuttke et al., 2013; Blackman et al., 2017; Virolainen et al., 2019). First, practitioners and academics recognize that working capital management cannot be performed properly at the intra-organizational level since it involves liabilities at the inter-organizational level and requires collaboration at all stages of the supply chain (Protopappa-Sieke and Seifert, 2017). What is more, many studies devoted to working capital management in the supply chain emphasize that working capital management at the inter-organizational level is financially beneficial for all members of the supply chain and the supply chain (Hofmann and Kotzab, 2010; Talonpoika et al., 2016). For instance, the total financial costs of the supply chain on working capital can be reduced due to the implementation of such supply chain finance solutions as reverse factoring, inventory financing and others (Protopappa-Sieke and Seifert, 2017).

https://doi.org/10.21638/11701/spbu31.2022.25

The literature on working capital management hardly rises to the supply chain level. Although many researchers have already stressed the need to manage working capital at the inter-organizational level (Hutchison et al., 2007; Randall and Farris II, 2009), the discussion still lacks models, mechanisms, and tools for working capital management in the supply chain. To be more precise, models for working capital management in the supply chain are mainly presented at a conceptual level in most papers. In addition to this, only some of them consider the problem of working capital management as a multi-objective one. Along with this, many researchers admit that the multiple objectives and complex interrelationships inherent in the problem of working capital management make the use of models with unidimensional objective functions inappropriate (Masri et al., 2018).

Thus, this paper aims to address a *research gap* in practical tools for dynamic multi-objective collaborative working capital management based on the use of supply chain finance solutions in liquidity-profitability settings for real-life cases.

2. Working Capital Management from Supply Chain Perspective

In this paper we proceed with the view of working capital pointing out that working capital consists of inventory, accounts receivable and accounts payable originates from finance literature (Hill et al., 2010; Knauer and Wöhrmann, 2013). Consequently, it is suggested to calculate working capital as follows:

$$WorkingCapital = Inventory + AccountsReceivable - AccountsPayable.$$

It comes from the fact that through the normal course of business, organizations buy inventory to produce goods and services, oftentimes on credit; then these goods and services are sold, oftentimes on credit; and, as a result, accounts receivable and accounts payable, together known as trade credit, are generated. Thus, it turns out that the other items of current assets and current liabilities cannot concern the day-to-day activities of the organization as directly as inventory, accounts receivable and accounts payable. Based on this, the adherents of this view recognize working capital as an investment tied up into inventory and accounts receivable and released with accounts payable (Monto, 2013).

One of the ways to measure and control the effectiveness of working capital management of a single company is thought to be a time-based measure of *cash conversion cycle or cash-to-cash (C2C).* According to Richards and Laughlin (1980), "the cash conversion cycle, by reflecting the net time interval between actual cash expenditures on a firm's purchase of productive resources and the ultimate recovery of cash receipts from product sales, establishes the period required to convert a dollar of cash disbursements back into a dollar of cash inflow from a firm's regular course of operations". Since then, many scholars have agreed that the cash conversion cycle can be considered as a suitable proxy for working capital management (Hofmann and Kotzab, 2010; Viskari et al., 2012).

Cash conversion cycle can be recognized as the time interval (in days) during which the organization has funds tied up in working capital, starting from the payment of inventory to the supplier and ending when accounts receivable is collected from the customers (Viskari et al., 2012). Consequently, the cash conversion cycle will be characterized:

$$CCC = DIO + DRO - DPO.$$

A reasonably low cash conversion cycle implies that a company has low costs to finance its day-to-day business operations or, in other words, low financial (financing) costs on working capital. The *financial costs on working capital* are usually caused when working capital is tied up for a certain period before the payment is received from the customer (Viskari & Kärri, 2013). As a rule, they are determined by the amount of capital tied up in the organization (inventory – INV, accounts receivable – AR and accounts payable – AP), the cycle time, and the cost of capital (c) usually presented by the weighted average cost of capital:

$$FC = INV \times \left[(1+c)^{\frac{DIO}{365}} - 1\right] + AR \times \left[(1+c)^{\frac{DRO}{365}} - 1\right] - AP \times \left[(1+c)^{\frac{DPO}{365}} - 1\right].$$

The supply chain perspective of working capital management is becoming more and more popular today. First, practitioners and academics recognize that working capital management cannot be performed properly at the intra-organizational level since it involves liabilities at the inter-organizational level and requires collaboration at all stages of the supply chain (Seifert, 2010). What is more, many studies devoted to working capital management in the supply chain emphasize that working capital management at the inter-organizational level is financially beneficial for all members of the supply chain and the supply chain (Hoffman and Kotzab, 2010; Talonpoika et al., 2016; Protopappa-Sieke and Seifert, 2017).

In the fundamental research conducted by Hofmann and Kotzab (2010), the authors argued that shortening the cash conversion cycle for just one firm does not add value to other members in the supply chain. As a result, the need for collaborative working capital management was declared and, for the first time ever, the collaborative cash conversion cycle (CCCC) was introduced. According to Hofmann and Kotzab, the *collaborative cash conversion cycle* is calculated a sum of the individual cash conversion cycles and can be described as:

$$CCCC = \sum_{l=1}^{n} \sum_{k=1}^{m} CCC_l^k,$$

where l is the stage of the supply chain, k is the company at the particular stage of the supply chain.

Following Hofmann and Kotzab (2010), Viskari and Kärri (2012) developed a way to calculate the *total financial costs on working capital* (TFC). According to academics, the total financial costs on working capital can be calculated in the same way as the collaborative cash conversion cycle. Therefore, it is only necessary to sum up the financial costs on working capital for individual companies included in the supply chain:

$$TFC = \sum_{l=1}^{n} \sum_{k=1}^{m} FC_l^k,$$

where l is the stage of the supply chain, k is the company at the stage of the supply chain.

With increased competition between supply chains, looking for opportunities to reduce the total financial costs on working capital is currently one of the top priorities for every supply chain. One of the possible ways to decrease such costs may become the adoption of supply chain finance solutions which are now becoming

more and more widespread. Protopappa-Sieke and Seifert (2017) assure that the undeniable benefit of supply chain finance solutions is the possibility to lower the cost of financing for "weaker" members of the supply chain through stronger credit ratings of other members (van der Vliet et al., 2015; Gelsomino et al., 2016).

3. Supply Chain Finance Solutions

For the purposes of this paper, two supply chain finance solutions were selected for further analysis – inventory financing and reverse factoring. The fact is that these supply chain finance solutions give an opportunity to manage and improve all three components of the individual cash conversion cycle of each member of the supply chain (days inventory outstanding, days receivables outstanding and days payable outstanding). At the same time, Gelsomino et al. (2019) describes the selected supply chain finance solutions as the most popular among practitioners. Most of the retailers also confirm that inventory financing and reverse factoring are the most effective solutions in terms of improving working capital in the supply chain. Considering the above, the implementation of inventory financing and reverse factoring will be described below.

Inventory financing. Hofmann (2009) states that the innovative form of inventory financing aims to achieve different goals of the two participants in the supply chain. More specifically, the supplier usually tries to sell the goods to the buyer and get paid for them as soon as possible, while the buyer wants to get the ownership of the goods as close as possible to the moment when demand arises. In fact, both participants of the supply chain seek to shorten the period during which capital is tied up in inventory. And the innovative form of inventory financing allows them to do so. This results in shorter individual cash conversion cycles, as well as a shorter collaborative cash conversion cycle.

The scheme of inventory financing is shown in Figure 1. As can be seen, inventory financing usually involves three players: a supplier, a buyer, and a logistics service provider (LSP/3PL). Typically, the process of inventory financing begins with the supplier producing the goods and selling a certain portion of them to the logistics service provider. According to Gelsomino and Steeman (2017), the logistics service provider usually needs 2 days after production to take the goods and 10 days to pay for them. This means that the supplier must store the goods for 2 days on its own and transfer ownership to the logistics service provider only after this period.

When the buyer realizes the need for the goods produced by the supplier, it can immediately buy them from the logistics service provider. To do this, the buyer, first, needs to place a purchase order at its supplier. In other words, the buyer and supplier need to agree on the quantity of goods delivered through the logistics service provider and prices of the goods. Only after that, the logistics service provider will deliver the goods to the buyer. In general, the buyer has an obligation to pay for the goods purchased from the logistics service provider within 30 days. In addition to this payment, the buyer also must pay the premium (interest) to this intermediary for the process of inventory financing to be considered complete.

Reverse factoring. In terms of implementation of reverse factoring in the supply chain, it can be stated that reverse factoring is often applied in the supply chain pairs, where the buyer has a strong credit rating and the supplier — a need for cheaper short-term financing. The fact is that reverse factoring may benefit sup-

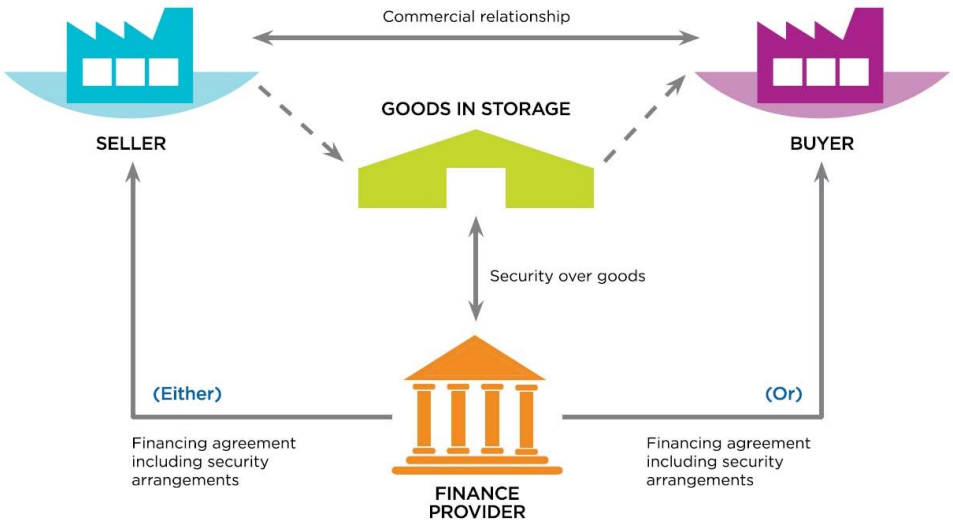

Fig. 1. Inventory financing scheme (de Boer et al., 2015)

pliers, especially the small ones, which often experience substantial difficulties with raising capital from banks. In this case, the supply chain finance solution will allow them to obtain money from banks at a lower interest rate due to a stronger credit rating of the buyer (de Boer et al., 2015).

The scheme of reverse factoring is demonstrated in Figure 2: it usually involves three players: a supplier, a buyer, and a financial institution (for example, a bank). The process of reverse factoring usually starts with the buyer placing a purchase order at its supplier. After that, the supplier generally delivers the goods with invoices to the buyer and the buyer provides the bank with these invoices. Then, the supplier has an opportunity to request an early payment from the bank. In practice, the early payment varies from 10% to 95% of the delivery, and it takes 3 days for the bank to pay it. For this payment, the supplier will have to cover the interest thereafter. However, both the buyer and the bank will also have their own obligations. In particular, the process of reverse factoring can only end when the buyer pays off the loan principle to the bank and the bank, in turn, covers the rest of the payment to the supplier.

4. Model for Multi-Objective Collaborative Working Capital Management with Supply Chain Finance Solutions

The basis for mathematical modeling will become a real-world three-stage supply chain distribution network. We will further use the concept of the collaborative cash conversion cycle, however, since the number of companies at the first and third stages will be larger, a new index k will be introduced. The values for this index will vary from 1 to K_l ($k = \overline{1, K_l}$), where K_l will be different for each stage. At the first stage ($l = 1$) K_l will be equal to N, at the second stage ($l = 1$) – to 1, while at the third stage ($l = 3$) – to M. The point is that there will be only one distributor in the supply chain distribution network, while the number of suppliers and retailers can be up to N and M, respectively. In relation to this, the collaborative cash

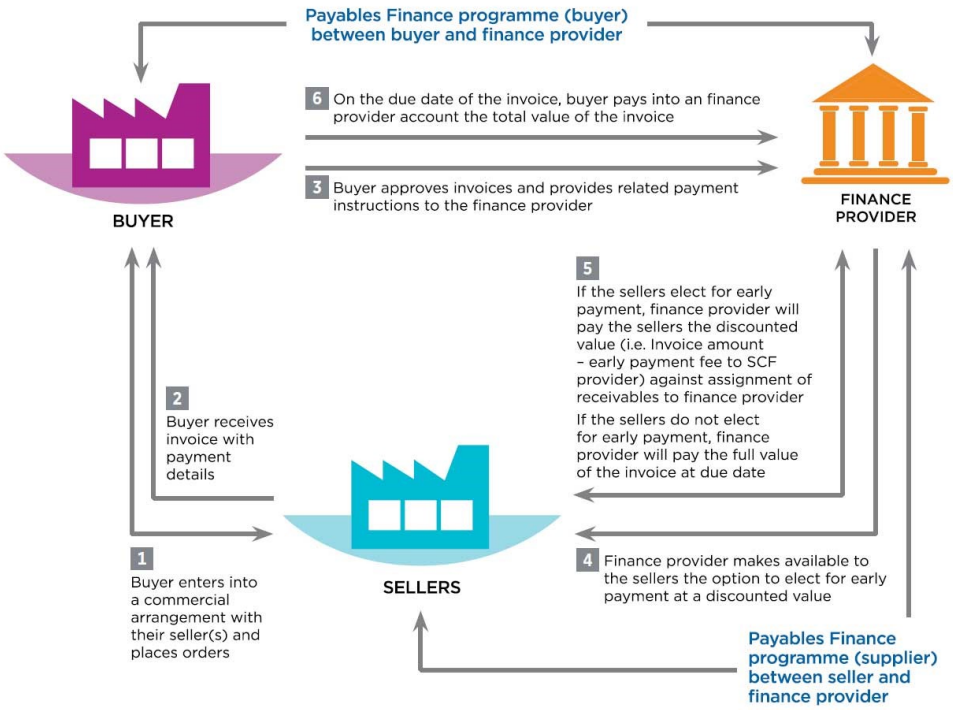

Fig. 2. Reverse factoring schemes (de Boer et al., 2015)

conversion cycle based on the individual cash conversion cycles of all members of the supply chain distribution network will be calculated in the following way:

$$CCCC = \sum_{l=1}^{3} \sum_{k=1}^{K_l} CCC_l^k,$$

$$CCC_l^k = DIO_l^k + DRO_l^k - DPO_l^k,$$

where $CCCC$ is the collaborative cash conversion cycle, CCC_l^k is the cash conversion cycle of company k at stage l, DIO_l^k is the days inventory outstanding for company k at stage l, DRO_l^k is the days receivables outstanding for company k at stage l, DPO_l^k is the days payable outstanding for company k at stage l.

The adoption of supply chain finance solutions – inventory financing and reverse factoring – will have significant impact on the components of the collaborative cash conversion cycle. Table 1 represents the impact of selected solutions on individual cash conversion cycles of each member of the chain.

Following the logic of *inventory financing* scheme described earlier, the buyer is obliged to buy the goods from the 3PL provider instead of the supplier (Hofmann, 2009). 3PL provider is buying only a part of the original amount, and he needs 2 days to collect it from the supplier. The distributor stores the goods from 3PL not less than 2 days to sell it further the supply chain (Gelsomino and Steeman, 2017). 3PL provider has 10 days to pay the supplier. The distributor pays to 3PL provider in 30 days.

At the same time *reverse factoring* scheme implies the following set of actions. The part of supplier's receivables will be payed earlier (in 3 days) by the factoring company, while the rest – by the distributor in accordance with the initial terms of payment.

Table 1. Supply chain finance solutions impact on cash conversion cycle

	Inventory financing	**Reverse factoring**
DIO_1^k	$DIO_1^k = x_1^k \times 2 + DIO_1^{0k} \times \left(1 - x_1^k\right)$	—
DRO_1^k	$DRO_1^k = x_1^k \times (x_1^k \times 10 + (1 - x_1^k) \times DRO_1^{0k}) + (1 - x_1^k) \times (y_1^k \times 3 + (1 - y_1^k) \times P_2^k)$	
DPO_1^k	—	$DPO_1^k = DPO_1^{0k}$
DIO_2	$DIO_2 = \sum\limits_{k=1}^{N} \left(x_1^k \times 2 + \left(1 - x_1^k\right) \times \left(DIO_2^0 \times \omega_1^k\right)\right)$	—
DRO_2	—	$DRO_2 = \sum\limits_{k=1}^{M} \left(z_3^k \times 3 + \left(1 - z_3^k\right) \times P_3^k\right)$
DPO_2	$DPO_2 = \sum_{k=1}^{N} \left(x_1^k \times \left(x_1^k \times 30 + \left(1 - x_1^k\right) \times DPO_1^{0k}\right) + \left(1 - x_1^k\right) \times P_2^k\right)$	
DIO_3^k	—	$DIO_3^k = DIO_3^{0k}$
DRO_3^k	—	$DRO_3^k = DRO_3^{0k}$,
DPO_3^k	—	$DPO_3^k = P_3^k$

The restraints on early payments confining to industry standards can be formulated as follows:

$$0 \le x_l^k \le 1,$$

$$0,1 \le y_l^k \le 0,95,$$

$$0,1 \le z_3^k \le 0,95.$$

Next step of the modeling is to evaluate the amount of costs for onboarding the finance solutions schemes. Because the logistics service provider and the bank mentioned above usually charge interest for their services, the financial costs on supply chain finance solutions should also be considered in the general model. First, it can be stated that, as in the base model, the financial costs on inventory financing will be borne by the distributor. However, due to the increase in the number of inventory financing contracts, the distributor will have to pay interest to the logistics service provider under the terms of several inventory financing contracts at once. In a similar form, the distributor will bury the financial costs on reverse factoring. The point is that the number of reverse factoring contracts will increase with the presence of more retailers in the supply chain. In relation to this, the formulas for calculating the financial costs on inventory financing and the financial costs on reverse factoring for the distributor will change significantly. The only formula that will not change will be the formula for calculating the financial costs on reverse factoring at the supplier's stage. The fact is that each supplier of the supply chain distribution network will have to pay interest to the bank on only one reverse factoring contract. Hence, the financial costs on inventory financing at the distributor stage, the financial costs on reverse factoring at the supplier's stage and the financial costs on reverse factoring at the distributor stage will be calculated in the following way:

$$FC\_IF_2 = \sum_{k=1}^{N} \left(INV_1^{0k} \times x_1^k \times \frac{t_1^k}{365} \times i_2^k \right), t_1^k = DIO_2^0 - DIO_2,$$

$$FC\_RF_1^k = AR_1^{0k} \times y_1^k \times \frac{P_2^k}{365} \times r_1^k, k = (1, N),$$

$$FC\_RF_2 = \sum_{k=1}^{M} \left(\left(AR_2^0 \times \frac{DPO_3^{0k}}{DRO_2^0} \right) \times z_3^k \times \frac{P_3^k}{365} \times r_2^k \right),$$

where FC_IF_2 is the financial costs on inventory financing at the distributor stage, INV_1^{0k} is the level of inventory at the suppliers stage before optimization, t_1^k is the number of days that the logistics service provider stores the goods purchased from supplier k before the delivery to the distributor (the duration of the inventory financing contract), i_2^k is the inventory financing rate for the distributor paired with supplier k, $FC\_RF_1^k$ is the financial costs on reverse factoring at the suppliers stage, AR_1^{0k} is the level of accounts receivable at the suppliers stage before optimization, r_1^k is the reverse factoring rate for supplier k paired with the distributor, FC_RF_2 is the financial costs on reverse factoring at the distributor stage, AR_2^0 is the level of accounts receivable at the distributor stage before optimization, DPO_3^{0k} is the days payable outstanding at the retailers stage before optimization, DRO_2^0 is the days receivables outstanding at the distributor stage before optimization, r_2^k is the reverse factoring rate for the distributor paired with retailer k.

As in the base model, in the general model, the financial costs on supply chain finance solutions will be only one of two components of the financial costs buried by each participant of the supply chain. Another component of the financial costs will be the financial costs on working capital (). Unlike the financial costs on supply chain finance solutions, this type of costs will be inherent for each company involved in the supply chain distribution network. In consequence, the financial costs at the supplier's stage, the financial costs at the distributor stage and the financial costs at the retailer's stage will be counted as follows:

$$FC\_WC_l^k = INV_l^k \times \left[\left(1 + c_l^k\right)^{\frac{DIO_l^k}{365}} - 1 \right] + AR_l^k \times \left[\left(1 + c_l^k\right)^{\frac{DRO_l^k}{365}} - 1 \right] -$$

$$-AP_l^k \times \left[\left(1 + c_l^k\right)^{\frac{DPO_l^k}{365}} - 1 \right], l = \overline{1,3}, k = \overline{1, K_l},$$

$$FC_1^k = FC\_WC_1^k + FC\_RF_1^k, k = (1, N),$$

$$FC_2 = FC\_WC_2 + FC\_IF_2 + FC\_RF_2,$$

$$FC_3^k = FC\_WC_3^k, k = (1, M),$$

where $FC\_WC_l^k$ is the financial costs on working capital for company k at stage l, INV_l^k is the level of inventory for company k at stage l, c_l^k is the cost of capital for company k at stage l, AR_l^k is the level of accounts receivable for company k at

stage l, AP_l^k is the level of accounts payable for company k at stage l, FC_1^k is the financial costs at the suppliers stage, $FC\_WC_1^k$ is the financial costs on working capital at the suppliers stage, FC_2 is the financial costs at the distributor stage, FC_WC_2 is the financial costs on working capital at the distributor stage, FC_3^k is the financial costs at the retailers stage, $FC\_WC_3^k$ is the financial costs on working capital at the retailers stage.

It will be also crucial to mention that the financial costs at each stage of the supply chain distribution network will be subject to "hard" constraints in the general model. The point is that members of the supply chain will be ready to engage in collaborative working capital management based on the use of supply chain finance solutions in only two cases. In the first case, the financial costs of the participants of the supply chain distribution network should be significantly improved due to collaborative working capital management based on the use of supply chain finance solutions. In the second case, the financial costs of the companies involved in the supply chain should at least be no worse than when these companies operated independently. As a result, the general model will assume that to engage members of the supply chain in collaborative working capital management based on the use of supply chain finance solutions, the values of their financial costs after optimization should not exceed the values of their financial costs before optimization:

$$FC_l^k \leq FC_l^{0k}, l = \overline{1,3}, k = \overline{1,K_l},$$

where FC_l^k is the financial costs for company l at stage l, FC_l^{0k} is the financial costs for company l at stage l before optimization.

Due to the increase in the number of participants of the supply chain in the general model, the number of goals to be achieved will also increase. However, the goals themselves will remain the same. About the individual goals of the participants of the supply chain distribution network, the general model will also imply that every member of the supply chain will seek to limit its cash conversion cycle to the recommended industry/company-specific stability interval. As for the common goal of the supply chain distribution network, the goal will be to reduce the total financial costs of the supply chain by $\beta\%$. As earlier, the total financial costs of the supply chain will be recognized as the sum of the individual financial costs of all members of the supply chain. Therefore, in the general model, they will be calculated as follows:

$$TFC = \sum_{l=1}^{3} \sum_{k=1}^{K_l} FC_l^k,$$

where TFC is the total financial costs of the supply chain.

To summarize all the above, the general model will include the following goals to be achieved:

Goal 1: To decrease the total financial costs of the supply chain by $\beta\%$.

Goal 2: To limit the cash conversion cycle of supplier 1 to the recommended industry/company-specific stability interval.

. . .

Goal N+1: To limit the cash conversion cycle of supplier N to the recommended industry/company-specific stability interval.

Goal N+2: To limit the cash conversion cycle of the distributor to the recommended industry/company-specific stability interval.

Goal N+3: To limit the cash conversion cycle of retailer 1 to the recommended industry/company-specific stability interval.

...

Goal N+M+2: To limit the cash conversion cycle of retailer M to the recommended industry/company-specific stability interval.

In the general model, all the goals listed above will be formulated in the form of "soft" constraints using two types of deviation variables – positive ones and negative ones. The achievement function, in turn, will consist of several unwanted deviation variable(s) which will be determined for each of the goals separately. The results of formulating the "soft" constraints of the general model and determining the unwanted deviation variable(s) to be minimized are shown in Table 2. As can be seen, the unwanted deviation variable for the first goal will be the positive one. The fact is that the initial goal type implies that the financial costs of the supply chain above the aspiration level are unacceptable. For each of the remaining three goals, there will be not one, but several unwanted deviation variables to be minimized. To be more concrete, the negative deviation variable will be recognized as the unwanted one in the "soft" constraint related to the lower limit of the cash conversion cycle, while the positive deviation variable – in the "soft" constraint related to the upper limit of the cash conversion cycle. All in all, the sum of the unwanted deviation variables will have to be minimized for each of the three goals to achieve them as close as possible.

TFC^0 is the total financial costs of the supply chain before optimization, β is the percentage by which the total financial costs to be decreased, d_1^- is the amount by which goal 1 is underachieved, d_1^+ is the amount by which goal 1 is overachieved, CCC_1^1 is the cash conversion cycle of supplier 1, $CCC_{1\_low}^1$ is the lower limit of the cash conversion cycle of supplier 1, $d_{2.1}^-$ is the amount by which goal 2.1 is underachieved, $d_{2.1}^+$ is the amount by which goal 2.1 is overachieved, $CCC_{1\_up}^1$ is the upper limit of the cash conversion cycle of supplier 1, $d_{2.2}^-$ is the amount by which goal 2.2 is underachieved, $d_{2.2}^+$ is the amount by which goal 2.2 is overachieved, CCC_1^N is the cash conversion cycle of supplier N, $CCC_{1\_low}^N$ is the lower limit of the cash conversion cycle of supplier N, $d_{N+1.1}^-$ is the amount by which goal N+1.1 is underachieved, $d_{N+1.1}^+$ is the amount by which goal N+1.1 is overachieved, $CCC_{1\_up}^N$ is the upper limit of the cash conversion cycle of supplier N, $d_{N+1.2}^-$ is the amount by which goal N+1.2 is underachieved, $d_{N+1.2}^+$ is the amount by which goal N+1.2 is overachieved, CCC_2 is the cash conversion cycle at the distributor stage, CCC_{2_low} is the lower limit of the cash conversion cycle at the distributor stage, $d_{N+2.1}^-$ is the amount by which goal N+2.1 is underachieved, $d_{N+2.1}^+$ is the amount by which goal N+2.1 is overachieved, CCC_{2_up} is the upper limit of the cash conversion cycle at the distributor stage, $d_{N+2.2}^-$ is the amount by which goal N+2.2 is underachieved, $d_{N+2.2}^+$ is the amount by which goal N+2.2 is overachieved, CCC_3^1 is the cash conversion cycle of retailer 1, $CCC_{3\_low}^1$ is the lower limit of the cash conversion cycle of retailer 1, $d_{N+3.1}^-$ is the amount by which goal N+3.1 is underachieved, $d_{N+3.1}^+$ is the amount by which goal N+3.1 is overachieved, $CCC_{3\_up}^1$ is the upper limit of the cash conversion cycle of retailer 1, $d_{N+3.2}^-$ is the

Table 2. "Soft" constraints of the general model and unwanted deviation variable(s) to be minimized

Goal №	Goal type	Goal programming form	Unwanted deviation variable(s) to be minimized
1	$TFC \leq TFC^0 \times (1-\beta)$	$TFC+d_1^- -d_1^+ = TFC^0 \times (1-\beta)$	d_1^+
2	$CCC_1^1 \geq CCC_{1\_low}^1$ $CCC_1^1 \leq CCC_{1\_up}^1$	$CCC_1^1+d_{2.1}^- - d_{2.1}^+ = CCC_{1\_low}^1$ $CCC_1^1 + d_{2.2}^- - d_{2.2}^+ = CCC_{1\_up}^1$	$d_{2.1}^- + d_{2.2}^+$
...	...	...	...
N+1	$CCC_1^N \geq CCC_{1\_low}^N$ $CCC_1^N \leq CCC_{1\_up}^N$	$CCC_1^N + d_{N+1.1}^- - d_{N+1.1}^+ = CCC_{1\_low}^N$ $CCC_1^N + d_{N+1.2}^- - d_{N+1.2}^+ = CCC_{1\_up}^N$	$d_{N+1.1}^- + d_{N+1.2}^+$
N+2	$CCC_2 \geq CCC_{2\_low}$ $CCC_2 \leq CCC_{2\_up}$	$CCC_2 + d_{N+2.1}^- - d_{N+2.1}^+ = CCC_{2\_low}$ $CCC_2 + d_{N+2.2}^- - d_{N+2.2}^+ = CCC_{2\_up}$	$d_{N+2.1}^- + d_{N+2.2}^+$
N+3	$CCC_3^1 \geq CCC_{3\_low}^1$ $CCC_3^1 \leq CCC_{3\_up}^1$	$CCC_3^1 + d_{N+3.1}^- - d_{N+3.1}^+ = CCC_{3\_low}^1$ $CCC_3^1 + d_{N+3.2}^- - d_{N+3.2}^+ = CCC_{3\_up}^1$	$d_{N+3.1}^- + d_{N+3.2}^+$
...	...	...	...
N+M+2	$CCC_3^M \geq CCC_{3\_low}^M$ $CCC_3^M \leq CCC_{3\_up}^M$	$CCC_3^M + d_{N+M+2.1}^- - d_{N+M+2.1}^+ = CCC_{3\_low}^M$ $CCC_3^M + d_{N+M+2.2}^- - d_{N+M+2.2}^+ = CCC_{3\_up}^M$	$d_{N+M+2.1}^- + d_{N+M+2.2}^+$

amount by which goal N+3.2 is underachieved, $d_{N+3.2}^+$ is the amount by which goal N+3.2 is overachieved, CCC_3^M is the cash conversion cycle of retailer M, $CCC_{3\_low}^M$ is the lower limit of the cash conversion cycle of retailer M, $d_{N+M+2.1}^-$ is the amount by which goal N+M+2.1 is underachieved, $d_{N+M+2.1}^+$ is the amount by which goal N+M+2.1 is overachieved, $CCC_{3\_up}^M$ is the upper limit of the cash conversion cycle of retailer M, $d_{N+M+2.2}^-$ is the amount by which goal N+M+2.2 is underachieved, $d_{N+M+2.2}^+$ is the amount by which goal N+M+2.2 is overachieved.

5. Dynamic Model for Multi-Objective Collaborative Working Capital Management with Supply Chain Finance Solutions

The first step to implement the methodology for multi-objective collaborative working capital management with supply chain finance solutions is to set the year goal with quarterly decomposition. The goals may be ranked differently based on the financial statement and decision maker priorities (or dilemmas) before optimization. To come with a solution is possible only after analyzing either all supply chain and its members. Consistent answers to the questions 1–3 in the table will serve as a good algorithm for prioritizing goals in the analysis of distributive supply chains.

Table 3. Decision maker dilemmas

Dilemma	**The basis of the dilemma**	**The basis of the decision**	**Decision**	**Goal(s) with higher priority**
1.Which goal will have higher priority? – The goal of decreasing the total final costs by X%? – The goal of getting the cash conversions cycles into industry specific liquidity intervals?	What goals the supply chain want to achieve: – To get short-term profit? – To provide long-term liquidity for the members of the supply chain?	Supply chain strategy	To get short-term profit	The goal of decreasing the total final costs by X%
			To provide long-term liquidity for the members of the supply chain	The goal of getting the cash conversions cycles into industry specific liquidity intervals
2.Which goal should have higher priority: – The goal of getting the cash conversion cycle of *distributor* into industry specific liquidity intervals? – The goal of getting the cash conversion cycle of *retailer* into industry specific liquidity intervals? – The goal of getting the cash conversion cycle of *supplier* into industry specific liquidity intervals?	Who is (are) the most powerful member(s) of the supply chain? – Supplier(s)? – Distributor? – Retailer(s)?	Supply chain network type	The distributor is the most powerful player in the supply chain, since only distribution network is considered	The goal of getting the cash conversion cycle of *distributor* into industry specific liquidity intervals
3. Which goal should have higher priority: – The goal of getting the cash conversion cycle of *retailer* into industry specific liquidity intervals? – The goal of getting the cash conversion cycle of *supplier* into industry specific liquidity intervals?	Who is (are) the most powerful member(s) of the supply chain? – Supplier(s)? – Retailer(s)?	Bargaining power of a supply chain member	Supplier is more powerful	The goal of getting the cash conversion cycle of *supplier* into industry specific liquidity intervals
			Retailer is more powerful	The goal of getting the cash conversion cycle of *retailer* into industry specific liquidity intervals

The process of goal-based management of working capital in supply chains during the year can be divided into 4 periods:

1) optimization of the first quarter;
2) joint optimization of the first and second quarters;
3) joint optimization of the first, second and third quarters;
4) joint optimization of the first, second, third and fourth quarters (year).

The "accumulative" effect of optimization is necessary to achieve the goal of reducing the total annual cost of working capital. Since the function of the total financial costs is a power function, it does not have the additivity property. It cannot be argued that the sum of the optimized total cost of working capital over the 4 periods will equal the optimized annual cost.

Consider the data required for targeted management of working capital in supply chains:

- average quarterly values of stocks, receivables, and payables of all participants in the supply chain;
- average cost and revenue;
- quarterly cost of capital (WACC);
- quarterly stock financing and reverse factoring rates.

The source of the above financial indicators of companies can be management reporting. Since the modeling uses the averages of past periods, they can be used as a guide for planning activities in the future.

Below is information on the details of the phased quarterly modeling.

First quarter simulation. The modeling of the first quarter occurs exactly according to the algorithm described previously.

As a result of optimization and application of financial instruments, the decision maker receives optimized values of balance sheet indicators: $\mathrm{Inv}_{l,1}, \mathrm{AR}_{l,1}, \mathrm{AP}_{l,1}$. $\mathrm{Inv}_{l,1}$ — the average value of the company's inventories of the functional area l after the optimization of the 1st quarter, $\mathrm{AR}_{l,1}$ – average receivables of a company in functional area l after optimization of the 1st quarter, $\mathrm{AP}_{l,1}$ – average value of accounts payable of a company in functional area l after optimization of the 1st quarter.

Modeling the first and second quarters. To simulate the first and second quarters, it is necessary to adjust the initial data. The input data for modeling the first and second quarters will be the average values of inventories, receivables, and payables of the first and second quarters, calculated by the formulas:

$$Inv^0_{l,12} = \frac{Inv_{l,1} + {Inv_{l,2}}^0}{2},$$

$$AR^0_{l,12} = \frac{AR_{l,1} + {AR_{l,2}}^0}{2},$$

$$AP^0_{l,12} = \frac{AP_{l,1} + {AP_{l,2}}^0}{2},$$

where $Inv^0_{l,12}$ – the average value of the company's inventory of the functional area l before optimization for the 1st and 2nd quarter, $AR^0_{l,12}$ – average receivables of a company in functional area l before optimization for the 1st and 2nd quarter, $AP^0_{l,12}$ – average amount of accounts payable of a company in functional area l

before optimization for the 1st and 2nd quarter, $Inv_{l,1}$ – the value of the company's reserves of the functional area l after optimization for the 1st quarter, $AR_{l,1}$ – the amount of receivables of the company of the functional area l after optimization for the 1st quarter, $AP_{l,1}$ – the amount of accounts payable of the company of the functional area l after optimization for the 1st quarter, ${Inv_{l,2}}^0$ – the value of the company's reserves of the functional area l before optimization for the 2nd quarter, ${AR_{l,2}}^0$ – the amount of receivables of the company of the functional area l before optimization for the 2nd quarter, ${AP_{l,2}}^0$ – the amount of accounts payable of the company of the functional area l before optimization for the 2nd quarter.

The values of revenue and net cost were found by adding the corresponding values for the 1st and 2nd quarters:

$$Revenue_l^{1,2} = Revenue_l^1 + Revenue_l^2,$$
$$NC_l^{1,2} = NC_l^1 + NC_l^2,$$

where $NC_l^{1,2}$ – cost for the first and second quarters, NC_l^1 – cost for the first quarter, NC_l^2 - cost for the second quarter, $Revenue_l^{1,2}$ – revenue for the first and second quarters, $Revenue_l^1$ – revenue for the first quarter, $Revenue_l^2$ – revenue for the second quarter.

Compared to the modeling described earlier, at this stage the formulas that use the indicator of the number of days of the period will be adjusted. In all formulas that use the number of days (turnover and cost calculation formulas), it is necessary to make an adjustment for the number of days in 2 quarters (182 days).

As a result of optimization and application of financial instruments, the decision maker receives optimized values of balance sheet indicators: $Inv_{l,12}, AR_{l,12}, AP_{l,12}$. $Inv_{l,12}$– average inventory value of a company in functional area l after joint optimization of the 1st and 2nd quarters, $AR_{l,12}$ – average receivables of a company in functional area l after joint optimization of the 1st and 2nd quarters, $AP_{l,1}$ – average value of accounts payable of a company in functional area l after joint optimization of the 1st and 2nd quarters.

Simulation of the first, second and third quarters. The joint modeling of the 1st, 2nd and 3rd quarters will be carried out similarly to the joint modeling of the 1st and 2nd quarters. As input data, the average values of inventories, receivables, and payables for 3 periods will be taken

$$Inv_{l,13}^0 = \frac{Inv_{l,12} + {Inv_{l,3}}^0}{2},$$
$$AR_{l,13}^0 = \frac{AR_{l,12} + {AR_{l,3}}^0}{2},$$
$$AP_{l,13}^0 = \frac{AP_{l,12} + {AP_{l,3}}^0}{2},$$

where $Inv_{l,13}^0$ – the average value of the company's inventory of the functional area l before optimization for 1, 2 and 3 quarters, $AR_{l,13}^0$ – average receivables of a company in functional area l before optimization for 1st, 2nd and 3rd quarters, $AP_{l,13}^0$ – average amount of accounts payable of a company in functional area l before optimization for 1st, 2nd and 3rd quarters, $Inv_{l,12}$ – the value of the company's reserves of the functional area l after the joint optimization of the 1st and 2nd

quarters, $AR_{l,12}$ – the amount of receivables of the company of the functional area l joint optimization of the 1st and 2nd quarters, $AP_{l,12}$ – the amount of accounts payable of the company of the functional area l joint optimization of the 1st and 2nd quarters, ${Inv_{l,3}}^0$ – the value of the company's reserves of the functional area l before optimization for the 3rd quarter, ${AR_{l,3}}^0$ – the amount of receivables of the company of the functional area l before optimization for the 3rd quarter, ${AP_{l,3}}^0$ – the amount of accounts payable of the company of the functional area l before optimization for the 3rd quarter.

The joint values of revenue and cost for the 1st, 2nd and 3rd quarters were found by simply adding the quarterly values for the 1st, 2nd and 3rd quarters.

At this stage, formulas that use the indicator of the number of days of the period will be adjusted. In all formulas that use the number of days (turnover and cost formulas), you need to make an adjustment for the number of days in 3 quarters (273 days).

As a result of optimization and application of financial instruments, the decision maker receives optimized values of balance sheet indicators: $Inv_{l,13}, AR_{l,13}, AP_{l,13}$. $Inv_{l,13}$– average inventory value of a company in functional area l after joint optimization of the 1st, 2nd and 3rd quarters, $AR_{l,13}$ – average receivables of a company in functional area l after joint optimization of the 1st, 2nd and 3rd quarters, $AP_{l,13}$ – the average value of accounts payable of a company in functional area l after joint optimization of the 1st, 2nd and 3rd quarters.

Modeling of the first, second, third and fourth quarters. As input data for modeling this stage, the average values of inventories, receivables, and payables for 3 periods were taken:

$$Inv^0_{l,14} = \frac{Inv_{l,13} + {Inv_{l,4}}^0}{2},$$

$$AR^0_{l,14} = \frac{AR_{l,13} + {AR_{l,4}}^0}{2},$$

$$AP^0_{l,14} = \frac{AP_{l,13} + {AP_{l,4}}^0}{2},$$

where $Inv^0_{l,14}$ – average inventory of a company in functional area l before optimization for the 1st, 2nd, 3rd and 4th quarters, $AR^0_{l,14}$ – average receivables of a company in functional area l before optimization for the 1st, 2nd, 3rd and 4th quarters, $AP^0_{l,14}$ – average value of accounts payable of a company in functional area l before optimization for the 1st, 2nd, 3rd and 4th quarters, $Inv_{l,13}$ – the value of the company's reserves of the functional area l after the joint optimization of the 1st, 2nd and 3rd quarters, $AR_{l,13}$ – the amount of receivables of the company of the functional area l joint optimization of the 1st, 2nd and 3rd quarters, $AP_{l,13}$ – the amount of accounts payable of the company of the functional area l joint optimization of the 1st, 2nd and 3rd quarters, ${Inv_{l,4}}^0$ – the value of the company's reserves of functional area l before optimization for the 4th quarter, ${AR_{l,4}}^0$ – the amount of receivables of the company of the functional area l before optimization for the 4th quarter, ${AP_{l,4}}^0$ – the amount of accounts payable of the company of the functional area l before optimization for the 4th quarter.

The joint values of revenue and cost for the 1st, 2nd, 3rd and 4th quarters were found by simply adding the quarterly values for the 1st, 2nd, 3rd and 4th quarters.

In the formulas for calculating turnover and costs, it is necessary to make an adjustment for the number of days in 4 quarters (365 days).

As a result of optimization and application of financial instruments, the decision maker receives optimized values of balance sheet indicators: $Inv_{l,14}, AR_{l,14}, AP_{l,14}$. $Inv_{l,14}$– the average inventory value of a company in functional area l after joint optimization of the 1st, 2nd, 3rd and 4th quarters, $AR_{l,14}$ – average receivables of a company in functional area l after joint optimization of the 1st, 2nd, 3rd and 4th quarters, $AP_{l,14}$ – the average value of accounts payable of a company in functional area l after joint optimization of the 1st, 2nd, 3rd and 4th quarters.

It is important that the optimization results of the 1st, 2nd, 3rd and 4th quarters are the results of the annual optimization. The amount of costs for the total working capital obtained at this optimization step is equal to the annual value of the costs.

An important point of the goal programming of each stage is the ranking of targets and minimizing deviations from them. At each stage of the modeling, the decision maker will plan on the ranking of goals based on the data before optimizing each period. The variance in minimization process is described earlier, this process will not be changed in the quarterly simulation.

6. Implementation of the Model for Multi-Objective Collaborative Working Capital

After developing the model for multi-objective collaborative working capital management based on the use of supply chain finance solutions, the next step will be to identify who will be a decision-maker or the end-user of the model. In this article, it will be assumed that the model will be used by either the logistics service provider or the financial service provider. In most cases, the logistics service provider, also known as the 3PL provider, is responsible for collaborative working capital management in the supply chain. Sometimes this role can be occupied by the financial service provider, for example, the bank or any other financial institution.

The decision maker will use use pre-emptive goal programming for practical implementation of the model. In this method it is essential to prioritize all the goals from the most to the least important for a particular case. Because of the controversial nature of goals of managing joint working capital the decision maker will encounter number of dilemmas to prioritize them adequately. To solve these dilemmas, the decision maker should analyse the state of a supply chain analysed (for example), powers of members. Only after analysis of all supply chain features it is possible to prioritise goals.

7. Real-Life Case

As an example of realization of the algorithm of joint working capital management a case of an information and communication technology supply chain is represented. Annual financial indicators were taken from company's public reports. Quarter indicators, information about cost of capital and finance solutions were received from interview with supply chain stakeholders.

Supply chain british description. Supply chain consists of 3 members (supplier, distributer, and retailer) that operate in a field of information and communication. Distributer is a Russian information and communication technology company providing services for the assembly and implementation of GPS towers on the territory of the Russian Federation, Europe, and Asia. The supplier is a domestic

company involved in the distributor's procurement process through supplying components for the assembly of GPS towers. The retailer in the considered supply chain is a Russian mobile phone company. It provides GPS services to both corporate and government subscribers across all regions of the Russian Federation, Europe, and Asia.

The supply chain is distributional as all its members do not produce anything but deliver products to the end users. Distributer is the most powerful member of this supply chain and supplier is the least powerful.

The supply chain is collaborative. It is assumed that at the beginning of the modelling, material supplies have been arranged between the members and all contracts have been signed. During the period under review (20XX), supply chain members do not use finance solutions to manage their joint working capital, moreover, they do not identify the problem of managing joint working capital as multi-objective. In the table below key balance sheet and financial indicators of companies before optimization represented. All balance sheet indicators as well as working capital and financial costs are represented in millions of rubles. Days inventory outstanding, days receivables outstanding and days payable outstanding are represented in days.

Table 4. Data before optimization

	Supplier	**Distributer**	**Retailer**
Inventories	1,342	11,593	972
Accounts receivable	1,374	458	119
Account payable	901	4,256	85
Working capital	1,815	7,795	1,006
Days inventory outstanding (DIO)	77	184	64
Days receivable outstanding (DRO)	68	6	7
Days payable outstanding (DPO)	52	68	6
Cash conversion cycle (CCC)	93	122	65
Collaborative cash conversion cycle (CCCC)	280		
Financial costs on working capital (FC)	33	236	6
Total financial costs (TFC)	274		

It is seen from the table above that collaborative cash conversion cycle as well as individual cash conversion cycles take high values (280 days and more than 65 days each). A similar conclusion can be drawn about the total financial costs (TFC) on working capital (274 million rubles).

Let's say that the decision maker decided to reduce the TFC by implementing finance solutions by 95%. That means that one of the quarter goals will be a reduction of total financial costs by 95% from total financial costs before optimization.

It is important to highlight that a reduction of total final costs by 95% can affect individual cash conversion cycles of each member of the supply chain. The values could go beyond the liquidity intervals. Lower value of the industry-specific stability interval defined by Garanina and Petrova is – 16.18 days, upper value is 61.5 days. If a company gets into the liquidity interval it can positively evaluate its liquidity (Garanina and Petrova, 2015). This means that in the process of optimizing each quarter, 3 goals of getting supply chain members into the liquidity intervals will appear.

The process of setting goals in managing the joint working capital of the supply chain can be divided into 2 stages:

1. Prioritizing of annual goals;
2. Decomposition of annual goals into periods.

In this case prioritizing of annual goals will be as following:

Priority 1 goal: To decrease the total financial costs of the supply chain by 95%.

Priority 2 goal: To limit the cash conversion cycle of the distributor to the recommended industry-specific stability interval, where the lower limit is 16.18 days and the upper limit is 61.5 days.

Priority 3 goal: To limit the cash conversion cycle of the retailer to the recommended industry-specific stability interval, where the lower limit is 16.18 days and the upper limit is 61.5 days.

Priority 4 goal: To limit the cash conversion cycle of the supplier to the recommended industry-specific stability interval, where the lower limit is 16.18 days and the upper limit is 61.5 days.

While decomposing the annual goals into periods their order in each period except the last one could vary from the annual order that is stated above. This change will be due to the fact that during the first three stages of optimization, the intentions of the decision maker may change depending on the situation before optimization. Fourth period should have the annual goals since it optimizes the annual values of the financial indicators of the supply chain.

Appendix 3 discusses possible options for prioritizing goals at the first three stages of optimization. Not all goal prioritizing combinations are presented in it. However, the information in the table illustrates the ranking principle. This principal could be formulated this way: if cash conversion cycle of a supply chain member doesn't get into the liquidity interval, the goal of ensuring it getting into the interval takes the first position, while the remaining goals retain the annual ranking order.

After discussion about the principles of goals-prioritising it is possible to proceed to optimization. The results of multi-criteria optimization with the analysis of influence of finance solutions on balance-sheet and financial indicators are represented below.

First optimisation period. To conduct first optimisation period, it is essential to analyse data before optimisation. The most important balance-sheet indicators and indicators from P&L statement are shown in the Table 5. All values in the table are given in millions of rubles.

Table 5. Balance sheet and P&L indicators before optimisation

	Inv	**AR**	**AP**	**WC**	**Cost of sales**	**Net Sales**
Supplier	1576	1756	754	2578	1521	1802
Distributer	9537	569	3521	6585	5765	7481
Retailer	1054	105	93	1066	1424	1696

Based on this data it is possible to calculate days inventory outstanding (DIO), days receivable outstanding (DRO) and days payable outstanding (DPO), individual and collaborative cash conversion cycles (CCC and CCCC) and individual and total financial costs (FC and TFC). DIO, DRO, DPO, CCC and CCCC are given in days. FC and TFC are given in millions of rubles.

Table 6. Financial indicators of the first period before optimisation

	DIO	**DRO**	**DPO**	**CCC**	**CCCC**	**FC**	**TFC**
Supplier	94.30	88.70	45.11	137.88	306.84	59.16	224.32
Distributer	150.55	6.92	55.58	101.89		158.61	
Retailer	67.38	5.63	5.95	67.07		6.55	

The values of cash conversion cycles of all members do not get into the industry liquidity interval $(-16.18; 61.5)$. One of the annual goals is to decrease the total financial costs of the supply chain by 95%. In the desired value of total final costs is 11.22 million of rubles. This value is an aspiration level of the decision maker.

Based on data before optimization the goals in the first quarter will be prioritised as following:

Priority 1 goal: To limit the cash conversion cycle of the distributor to the recommended industry-specific stability interval, where the lower limit is 16.18 days and the upper limit is 61.5 days.

Priority 2 goal: To limit the cash conversion cycle of the retailer to the recommended industry-specific stability interval, where the lower limit is 16.18 days and the upper limit is 61.5 days.

Priority 3 goal: To limit the cash conversion cycle of the supplier to the recommended industry-specific stability interval, where the lower limit is 16.18 days and the upper limit is 61.5 days.

Priority 4 goal: To decrease the total financial costs of the supply chain by 95%.

These goals could be written as soft constrains (Table 7).

Table 7. Goals order in the first quarter

Goal	**Goal type**	**Goal programming form**	**Unwanted deviation variable(s) to be minimized**
1.1	$CCC_2 \geq CCC_{2\_low}$	$CCC + d^-_{2.1} - d^+_{2.1} = CCC_{2\_low}$	$d^-_{2.1} + d^+_{2.2}$
1.2	$CCC_2 \leq CCC_{2\_up}$	$CCC_2 + d^-_{2.2} - d^+_{2.2} = CCC_{2\_up}$	
2.1	$CCC_3 \geq CCC_{3\_low}$	$CCC_3 + d^-_{3.1} - d^+_{3.1} = CCC_{3\_low}$	$d^-_{3.1} + d^+_{3.2}$
2.2	$CCC_3 \leq CCC_{3\_up}$	$CCC_3 + d^-_{3.2} - d^+_{3.2} = CCC_{3\_up}$	
3.1	$CCC_1 \geq CCC_{1\_low}$	$CCC_1 + d^-_{1.1} - d^+_{1.1} = CCC_{1\_low}$	$d^-_{1.1} + d^+_{1.2}$
3.2	$CCC_1 \leq CCC_{1\_up}$	$CCC_1 + d^-_{1.2} - d^+_{1.2} = CCC_{1\_up}$	
4	$TFC \leq TFC^0 \times (1-q)$	$TFC + d^-_4 - d^+_4 = TFC^0 \times (1-q)$	d^+_4

The next step of method is to apply finance solutions and minimize unwanted deviations.

As a result of optimization all the liquidity goals were achieved. Nevertheless, the fourth goal proved unattainable. The value of TFC after optimisation is 23.67 million of rubles while the aspiration level of the decision maker is 11.22 million of rubles.

Changes in DIO, DRO, DPO make changes in balance sheet indicators as well. Key indicators after optimisation as well as it's changes to the key indicators before optimisation are represented in the Table 8. All the values are written in millions of rubles.

Table 8. Balance sheet indicators after optimisation and their relative changes

	Supplier	**Distributor**	**Retailer**
Inventories	480	2853	1054
Accounts receivable	1302	2129	105
Account payable	754	5519	445
Working capital	1028	−537	714
Relative change of inventories	−69.5%	−70.1%	0%
Relative change of accounts receivable	−25.9%	274.2%	0%
Relative change of accounts payable	0%	56.7%	387.5%
Relative change of working capital	−60.1%	−108.1%	−33%

The important outcomes of the optimisation are variables connected to application of finance solutions that are found by software. After the first optimisation period it was found that:

- Portion of goods that is delivered by 3PL from a supplier to a distribution the first quarter is 68%;
- Share of the early payment from a financial provider to a supplier in the first quarter is equal 10%;
- Duration of payment from a distributor to a supplier in the first quarter is equal 181 days;
- Share of the early payment from a financial provider to a retailer in the first quarter is equal 10%;
- Duration of payment from a retailer to a distributer in the first quarter is equal 20 days.

Second optimisation period. The second stage of targeted management of joint working capital in the supply chain is to jointly optimize the values of the first and second quarters. This stage is analogical to the previous one. Firstly, it is essential to analyse data before optimisation. A Table 9 represents average balance sheet and P&L indicators for the first and second periods (all the values are given in millions of rubles).

Table 9. Balance sheet and P&L indicators of the first and second periods before optimisation

	Inv	**AR**	**AP**	**WC**	**Cost of sales**	**Net Sales**
Supplier	551	1439	901	1089	3087	3608
Distributer	5115	1194	5085	6566	11495	14904
Retailer	919	125	257	1044	2815	3358

The next step is calculation of financial indicators (DIO, DRO, DPO, CCC, CCCC, FC and TFC) based on the data before optimisation. All these indicators are represented in the Table 10. DIO, DRO, DPO, CCC and CCCC are given in days while FC and TFC – in millions of rubles.

Table 10. Financial indicators of the first and second periods before optimisation

	DIO	**DRO**	**DPO**	**CCC**	**CCCC**	**FC**	**TFC**
Supplier	32.47	72.59	53.13	51.94		16.26	
Distributer	80.98	14.58	80.51	15.05	116.53	2.81	23.77
Retailer	59.39	6.78	16.63	49.54		4.71	

All the individual cash conversion cycles get into the industry liquidity interval (−16.18; 61.5). The aspiration level of total finance costs for the decision maker — 1.19 million of rubles.

Based on this information the decision maker prioritizes the goals in the following way:

Priority 1 goal: To decrease the total financial costs of the supply chain by 95%.

Priority 2 goal: To limit the cash conversion cycle of the distributor to the recommended industry-specific stability interval, where the lower limit is 16.18 days and the upper limit is 61.5 days.

Priority 3 goal: To limit the cash conversion cycle of the retailer to the recommended industry-specific stability interval, where the lower limit is 16.18 days and the upper limit is 61.5 days.

Priority 4 goal: To limit the cash conversion cycle of the supplier to the recommended industry-specific stability interval, where the lower limit is 16.18 days and the upper limit is 61.5 days.

The above goals will be achieved one by one, while minimizing the deviation from the goal with a lower priority cannot affect the result of minimizing the deviation from the goal with a higher priority.

As a result of the subsequent minimization of deviations, all the goals set by the decision-maker were achieved.

Key indicators after optimisation as well as it's changes to the key indicators before optimisation are represented in the Table 11. All the balance sheet indicators and working capital are written in millions of rubles.

Table 11. Balance sheet indicators after optimisation and their relative changes

	Supplier	**Distributor**	**Retailer**
Inventories	228.17	1940.76	902.01
Accounts receivable	888.89	2998.01	122.63
Account payable	926.04	3906.22	2548.52
Working capital	191.02	1032.55	−1523.88
Relative change of inventories	−59%	−62%	−2%
Relative change of accounts receivable	−38%	151%	−2%
Relative change of accounts payable	3%	−23%	891%
Relative change of working capital	−82%	−84%	−246%

The important outcomes of the optimisation are variables connected to application of finance solutions that are found by software. After the first optimisation period it was found that:

– Portion of goods that is delivered by 3PL from a supplier to a distribution the first quarter is 64%;

- Share of the early payment from a financial provider to a supplier in the first quarter is equal 28%;
- Duration of payment from a distributor to a supplier in the first quarter is equal 85.45 days;
- Share of the early payment from a financial provider to a retailer in the first quarter is equal 10%;
- Duration of payment from a retailer to a distributer in the first quarter is equal 40 days.

Third optimisation period. The third stage of targeted management of joint working capital in the supply chain is to jointly optimize the values of the first, second and third quarters. Since this stage is analogical to the previous ones only main optimisation results will be described below.

The Table 12 represents the main financial indicators before optimisation: DIO, DRO, DPO, CCC, CCCC that are given in days and FC and TFC that are given in millions of rubles.

Table 12. Financial indicators of the first, second and third periods before optimisation

	DIO	**DRO**	**DPO**	**CCC**	**CCCC**	**FC**	**TFC**
Supplier	25.94	27.05	35.98	17.01		1.294	
Distributer	64.33	17.82	40.56	41.59	23.61	34.908	23.77
Retailer	43.69	4.01	82.68	−34.98		−10.34	

The value of retailer's cash conversion cycle doesn't get into industry liquidity level (−16.18; 61.5). The aspiration level of total finance costs for the decision maker is 1.29 million of rubles.

The goals of the third quarter are prioritised in the following way:

Priority 1 goal: To limit the cash conversion cycle of the retailer to the recommended industry-specific stability interval, where the lower limit is 16.18 days and the upper limit is 61.5 days.

Priority 2 goal: To decrease the total financial costs of the supply chain by 95%.

Priority 3 goal: To limit the cash conversion cycle of the distributor to the recommended industry-specific stability interval, where the lower limit is 16.18 days and the upper limit is 61.5 days.

Priority 4 goal: To limit the cash conversion cycle of the supplier to the recommended industry-specific stability interval, where the lower limit is 16.18 days and the upper limit is 61.5 days.

As a result of subsequent minimization of deviations not every goal has been achieved. The optimized value of retailer's cash conversion cycle is −21 days with the deviation of 5.16 days. The goal of minimization of total finance costs hasn't been achieved as well. Its value after optimization is 34 million of rubles while the aspiration level is 1.29 million of rubles.

In the table below the main financial indicators after optimization and their relative changes to the values before optimization are represented. All balance sheet indicators as well as working capital are given in millions of rubles.

Table 13. Balance sheet indicators after optimisation and their relative changes

	Supplier	**Distributor**	**Retailer**
Inventories	122.78	961.30	664.92
Accounts receivable	582.66	4645.39	72.82
Account payable	624.52	2873.04	1050.72
Working capital	80.92	2733.65	−312.98
Relative change of inventories	−82%	−84%	−33%
Relative change of accounts receivable	−29%	112%	−33%
Relative change of accounts payable	−33%	−25%	−44%
Relative change of working capital	−86%	−73%	−128%

The important outcomes of the optimisation are variables connected to application of finance solutions that are found by software. After the first optimisation period it was found that:

- portion of goods that is delivered by 3PL from a supplier to a distribution the first quarter is 79%;
- share of the early payment from a financial provider to a supplier in the first quarter is equal 10%;
- duration of payment from a distributor to a supplier in the first quarter is equal 95 days;
- share of the early payment from a financial provider to a retailer in the first quarter is equal 19%;
- duration of payment from a retailer to a distributer in the first quarter is equal 69 days.

Fourth optimisation period. The third stage of targeted management of joint working capital in the supply chain is to jointly optimize the values of the first, second, third and fourth quarters. This stage is analogical to the previous ones, nevertheless, the fourth quarter is the final one, which means that the results of its optimization are identical to the annual results.

In the Table 14 the main financial indicators before optimisation are represented. DIO, DRO, DPO, CCC and CCCC are given in days while FC and TFC are given in millions of rubles.

Table 14. Financial indicators of the first, second, third and fourth periods before optimisation

	DIO	**DRO**	**DPO**	**CCC**	**CCCC**	**FC**	**TFC**
Supplier	17.88	19.61	21.75	15.74		2.23	
Distributer	47.68	19.00	29.21	37.47	66.98	30.09	33.42
Retailer	22.86	2.59	11.68	13.78		1.10	

All the cash conversion cycles get into the liquidity interval (−16.18; 61.5). The aspiration level of total financial costs for the decision maker is 1.69 million of rubles.

Since the fourth quarter is the resulting one, its goals should be identical to the goals set for the year:

Priority 1 goal: To decrease the total financial costs of the supply chain by 95%.

Priority 2 goal: To limit the cash conversion cycle of the distributor to the recommended industry-specific stability interval, where the lower limit is 16.18 days and the upper limit is 61.5 days.

Priority 3 goal: To limit the cash conversion cycle of the retailer to the recommended industry-specific stability interval, where the lower limit is 16.18 days and the upper limit is 61.5 days.

Priority 4 goal: To limit the cash conversion cycle of the supplier to the recommended industry- specific stability interval, where the lower limit is 16.18 days and the upper limit is 61.5 days.

As a result of subsequent optimization of deviations all the goals were achieved.

Key indicators after optimisation as well as it's changes to the key indicators before optimisation are represented in the Table 15. All the balance sheet indicators and working capital are written in millions of rubles.

Table 15. Balance sheet indicators after optimisation and their relative changes

	Supplier	**Distributor**	**Retailer**
Inventories	62.57	533.87	173.11
Accounts receivable	180.33	277.80	23.39
Account payable	189.03	938.98	54.75
Working capital	53.87	−127.31	141.75
Relative change of inventories	−95%	−95%	−82%
Relative change of accounts receivable	−87%	−39%	−80%
Relative change of accounts payable	−79%	−78%	−36%
Relative change of working capital	−97%	−102%	−86%

The important outcomes of the optimisation are variables connected to application of finance solutions that are found by software. After the first optimisation period it was found that:

- portion of goods that is delivered by 3PL from a supplier to a distribution the first quarter is 53%;
- share of the early payment from a financial provider to a supplier in the first quarter is equal 12%;
- duration of payment from a distributor to a supplier in the first quarter is equal 37 days;
- share of the early payment from a financial provider to a retailer in the first quarter is equal 13%;
- duration of payment from a retailer to a distributer in the first quarter is equal 7 days.

Optimisation conclusion. Optimization was successful – all the annual goals were achieved using the goal programming method. The decomposition of the annual goals into quarters allows to control the deviations of aspiration level not once a year but once a quarter.

8. Conclusion

This research was devoted to the improvement of the methodology for multi-objective collaborative working capital management based on the use of supply chain finance solutions.

As a result of accomplishing this goal several objectives were reached.

1. The multi-objective nature of collaborative working capital management has been justified after literature analysis;
2. The methodology for multi-objective collaborative working capital management over the four periods based on the use of supply chain finance solutions has been developed;
3. The methodology for multi-objective collaborative working capital management over the four periods has been tested on a real case.

Theoretical and practical contribution of the research. The research contributes to the existing literature on supply chain management since it pays special attention to the optimization of the financial supply chain and its optimization over time. First, the research fills a gap in practical tools for multi-objective management of collaborative working capital. Moreover, a methodology of collaborative working capital management over time was introduced. This gap is also filled by the development of a model for multi-objective management of collaborative working capital over 4 periods of the year. The model allows to precisely manage working capital at the inter-organizational level, based both on the individual goals of the supply chain participants and on the overall goal of the supply chain. The method of priorities of goal programming allows to consider both the multi-objective nature of working capital management in the supply chain, and the varying degree of importance of goals for the decision maker. It is also important to highlight that the research provides a clear way of achievement of an annual goal when it is decomposed into periods.

Limitations and recommendations for future research. Despite the above stated theoretical and practical contribution of the research it is important to keep in mind that the research is applicable only to mono-product supply chain distribution networks. The future research should aim to expand the context of this work by considering not only mono-product supply chain distribution networks, but also other types of supply chain networks (for example, multi-product production networks). It is also assumed that the number of stages in the supply chain should be significantly increased. This will make the models more applicable to real situations. It should be emphasized that this study considers the use of only two supply chain finance solutions – inventory financing and reverse factoring. As a next step, it will be useful to consider the possibility of implementing other supply chain finance solutions. This will lead to significant results in managing the collaborative working capital in the supply chain.

References

Blackman, I. D., Holland, C. P. and Westcott, T. (2017). *Motorola's global financial supply chain strategy.* IEEE Engineering Management Review, **45**(1).

De Boer, R., Van Bergen, M. and Steeman, M. (2015). *Supply Chain Finance, its Practical Relevance and Strategic Value.* The Supply Chain Finance Essential Knowledge Series. Supply Chain Finance Community, Zwolle.

Garanina, T. and Petrova, O. (2015). *Liquidity, cash conversion cycle and financial performance: case of Russian companies.* Investment Management and Financial Innovations, **12(1)**, 356–347.

Gelsomino, L. M. and Steeman, M. (2017). *The future of SCF is full of opportunities, most of which revolve around integration between the physical and financial supply chain.* SCF Community.

Gelsomino, L. M., de Boer, R., Steeman, M. and Perego, A. (2019). *An optimisation strategy for concurrent Supply Chain Finance schemes*. Journal of Purchasing and Supply Management, **25(2)**, 185–196.

Gelsomino, L. M., Mangiaracina, R., Perego, A. and Tumino, A. (2016). *Supply chain finance: A literature review*. International Journal of Physical Distribution & Logistics Management, **46(4)**, 348–366.

Gupta, S. and Dutta, K. (2011). *Modeling of financial supply chain*. European Journal of Operational Research, **211(1)**, 47–56.

Hill, M. D., Kelly, G. W. and Highfield, M. J. (2010). *Net operating working capital behavior: a first look*. Financial Management, **39(2)**, 783–805.

Hofmann, E. (2009). *Inventory financing in supply chains: A logistics service provider-approach*. International Journal of Physical Distribution & Logistics Management, **39(9)**, 716–740.

Hofmann, E. and Kotzab, H. (2010). *A supply chain-oriented approach of working capital management*. Journal of Business Logistics, **31(2)**, 305–330.

Hutchison, P. D., Farris II, M. T. and Anders, S. B. (2007). *Cash-to-cash analysis and management*. The CPA Journal, **77(8)**, 42–47.

Knauer, T. and Wöhrmann, A. (2013). *Working capital management and firm profitability*. Journal Management Control, **24**, 77–87.

Masri, H. and Abdulla, Y. (2018). *A multiple objective stochastic programming model for working capital management*. Technological Forecasting and Social Change, Elsevier, **131**(C), 141–146.

Monto, S. (2013). *Towards Inter-organizational Working Capital Management*. PhD dissertation, Lappeenranta University of Technology, Lappeenranta, Finland.

Protopappa-Sieke, M. and Seifert, R. W. (2017). *Benefits of working capital sharing in supply chains*. Journal of the Operational Research Society, **68(5)**, 521–532.

Randall, W. and Farris II, T. (2009). *Supply chain financing: using cash-to-cash variables to strengthen the supply chain*. International Journal of Physical Distribution & Logistics Management, **39**, 669–689.

Richards, V. D. and Laughlin, E. J. (1980). *A cash conversion cycle approach to liquidity analysis*. Financial Management, **9(1)**, 32–38.

Talonpoika, A. M., Kärri, T., Pirttilä, M. and Monto, S. (2016). *Defined strategies for financial working capital management*. International Journal of Managerial Finance, **12(3)**, 277–294.

Van der Vliet, K., Reindorp, M. R. and Fransoo, J. C. (2015). *The price of reverse factoring: Financing rates vs. payment delays*. European Journal of Operational Research, **242(3)**, 842–853.

Virolainen, V. M., Pirttilä, M., Lind, L. and Kärri, T. (2019). *Scenario Development for Collaborative Financial Supply Chain Management in the Automotive Industry*. Procedia Manufacturing, **39**, 1538–1544.

Viskari, S. and Kärri, T. (2013). *A cycle time model for analysing the efficiency of working capital management in a value chain*. International Journal of Business Performance and Supply Chain Modelling, **5(3)**, 221–238.

Wuttke, D. A., Blome, C., Foerstl, K. and Henke, M. (2013b). *Managing the innovation adoption of supply chain finance — empirical evidence from six European case studies*. Journal of Business Logistics, **34(2)**, 148–166.