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Implementation of a Multi-Objective Working Capital Management Strategy for Financial Supply Chains*

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Abstract The issue of adequate application of quantitative supply chain (SCF) solutions for cooperative working capital management becomes more and more important in terms of globalization and growing competition between supply chains (SCs). Authors address the problem by developing models for cooperative working capital management (WCM) through SCF adoption for the case of the three-stage supply chain. The grounding for the optimization is multicriteria approach. The multi-objective working capital optimization model (Ivakina et al., 2021) allows to find optimal solution regardless initial financial and liquidity position of SC. In the article, we use this model to quantitatively implement a multi-objective working capital management strategy on the cases of real supply chains. The results obtained in the paper indicate that the model of working capital optimization with concurrent use of multiple supply chain finance solutions can provide an optimal solution for all the cases considered in the research. It allows to decrease the total financial costs on working capital and supply chain finance solutions making individual ones not worse and at the same time achieve greater liquidity.

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

1. Introduction

Over the past two decades, the analysis in the area of supply chain management has been focused mainly on the downstream flow of goods and its numerous perspectives (inventory cost, transportation cost, cost associated with goods procurement, etc.). However, there has been very little research work concentrating on upstream flow of cash (Fairchild, 2005; Kouvelis et al., 2006; More & Basu, 2013; Caniato et al., 2016), which in the finance literature is commonly referred to as "working capital".

Working capital management as a research field has become really popular since the financial crisis of 2008 (Lind et al., 2012). Prior to this, most academics and practitioners were primarily focusing on the area of long-term investment and financial decision-making rather than on short-term finance, in particular, working capital management (Singh & Cumar, 2014; Kayani et al., 2019). At this time, supply chain finance solutions aimed at integration of downstream flow of goods and upstream flow of cash in the supply chain also gained particular popularity.

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The problem of working capital management has been investigated from both a single-company perspective (Hill et al., 2010; Knauer & Wöhrmann, 2013; Seth et al., 2020) and a supply-chain perspective (More & Basu, 2013; Blackman et al., 2013; Wuttke et al., 2013b; Hofmann & Zumsteg, 2015; Huff & Rogers, 2015; Virolainen et al., 2019). In various attempts to develop models for working capital management in a single company, the problem of working capital management was considered to be of multi-objective nature (Arunkumar et al., 2018).

However, 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 supply chain level (Hutchison et al., 2007; Randall & Farris, 2009; Hofmann & Kotzab, 2010; Huff & Rogers, 2015; Lorentz et al., 2016), the discussion still lacks models, mechanisms and tools for inter-organizational working capital management. If to be more precise, some models for working capital management in the supply chain are mainly presented at a conceptual level in most papers.

It should be noted that, currently, there are some models for working capital management in the supply chain that can be used in practice. They were suggested by such scholars as Monto (2013), Viskari and Kärri (2013) and Pirttilä (2014). However, the problem of working capital management at the inter-organizational level was not considered as multi-objective by them. Thus, this paper aims to address a *research gap* in practical tools for multi-objective collaborative working capital management based on the use of supply chain finance solutions.

In this paper, we consider the implementation of a working capital management strategy based on the basic model of working capital multi-objective optimization developed by the authors in the work (Ivakina et al., 2021), on the cases of real financial supply chains.

2. Methodology for multi-objective collaborative working capital management in SC

The problem of collaborative working capital management in the supply chain, involve multiple, usually competing, objectives that need to be addressed simultaneously. In the operations research literature, such problems are commonly referred to as multi-objective optimization problems (Eschenauer et al., 1990). In general, they have many (often infinitely many) Pareto-optimal solutions (Chiandussi et al., 2012) that represent a trade-off between various, often competing, objectives. Hence, "the best solution" is usually chosen according to the preferences of the person typically called the decision maker.

In this paper, it is assumed that, in each case considered further, a decision maker will provide his or her preferences related to the importance of each objective before the optimization runs. Therefore, multi-objective optimization methods with a priori articulation of preferences were explored, and based on their comparison, goal programming was identified as the most suitable method for developing the base and general models for multi-objective collaborative working capital management in the supply chain. The main advantage of using goal programming over other methods is that it reflects the way managers actually make decisions. In addition to this, it is seen as the most practical method with a priori articulation of preferences with a wide range of applications, including supply chain management.

The base model for multi-objective collaborative working capital management based on the use of supply chain finance solutions was developed in (Ivakina et al., 2021). The base model was designed for a three-stage supply chain consisting of a single supplier, distributor and single retailer. In this case, such a supply chain was primarily used for extrapolating the modeling results to a more complex supply chain. The more complex supply chain consisted of multiple suppliers, distributor and multiple retailers and was the basis for the development of the general model for multi-objective collaborative working capital management based on the use of supply chain finance solutions.

The base model (Ivakina et al., 2021) imply the achievement of both the individual goals of the participants of the supply chain and the common goal of the supply chain. With regard to the individual goals, they assume that every member of the supply chain seeks to limit its cash conversion cycle to the recommended industry/company-specific stability interval. The common goal of the supply chain is related to reducing the total financial costs of the supply chain by a certain percentage. In order to achieve all goals as closely as possible, supply chain finance solutions – inventory financing and reverse factoring – are adopted in the supply chain. All of them have a significant impact on both the components of the collaborative cash conversion cycle and the total financial costs of the supply chain.

3. Implementation of the base model for multi-objective collaborative working capital management based on the use of supply chain finance solutions

After developing the base model for multi-objective collaborative working capital management based on the use of supply chain finance solutions, the next step will be to implement this model in practice. However, at first, it will be important to identify who will use this model and, as a consequence, implement it. In this paper, it will be assumed that the base model (Ivakina et al., 2021) will be used by either the logistics service provider or the financial service provider. The fact is that 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. Anyway, each of these organizations can implement the base model in order to deal with collaborative working capital management in the supply chain.

As discussed earlier in (Ivakina et al., 2021), the logistics service provider or the financial service provider should use pre-emptive goal programming for practical implementation of the base model. Thus, in order to implement the model in practice, each of the organizations will have to provide preferences related to the importance of each goal or, in other words, prioritize the goals. However, in the course of prioritizing goals, the logistics service provider or the financial service provider will certainly encounter a number of dilemmas that will need to be addressed. In order to address them, the decision maker will first need to understand what lies behind each of the dilemmas. Only after that, decisions regarding the priorities of goals can be made.

As can be understood, the way in which the goals are prioritized will greatly influence the further implementation of the base model. The point is that depending on the priorities of the goals, the unwanted deviation variables will be assigned

into a number of priority levels and then minimized one by one, while respecting all constraints (Sherali, 1982). In more detail, the influence of prioritizing on the course of optimization can be seen in the example below. Suppose that the logistics service provider responsible for collaborative working capital management in the supply chain wants to implement the base model in practice. Then, first of all, the decision maker will need to decide what the supply chain is striving for – to obtain short-term profit or to provide long-term liquidity for each member of the supply chain. Suppose that based on the supply chain strategy, the logistics service provider has decided that the supply chain is striving for short-term profit. Then, the goal of decreasing the total financial costs of the supply chain by $\alpha\%$ will be assigned the priority 1. Consequently, the unwanted deviation variable corresponding to this goal will be assigned the same priority. As a result, its minimization will occur at the first step of optimization under all the constraints of the base model (1):

$$
\begin{aligned}
&\text{Find: } P_2, P_3, x, y, z \\
&\qquad d_1^-, d_1^+, d_{2.1}^-, d_{2.1}^+, d_{2.2}^-, d_{2.2}^+, d_{3.1}^-, d_{3.1}^+, d_{3.2}^-, d_{3.2}^+, d_{4.1}^-, d_{4.1}^+, d_{4.2}^-, d_{4.2}^+ \\
&\text{to minimize} \quad d_1^+ \\
&\text{subject to} \quad 0 \le x \le 1 \\
&\qquad\qquad 0,1 \le y \le 0,95 \\
&\qquad\qquad 0,1 \le z \le 0,95 \\
&\qquad\qquad FC_1 \le FC_1^0 \\
&\qquad\qquad FC_2 \le FC_2^0 \\
&\qquad\qquad FC_3 \le FC_3^0 \\
&\qquad\qquad TFC + d_1^- - d_1^+ = TFC^0 \times (1-\alpha) \\
&\qquad\qquad CCC_1 + d_{2.1}^- - d_{2.1}^+ = CCC_{1\_low} \\
&\qquad\qquad CCC_1 + d_{2.2}^- - d_{2.2}^+ = CCC_{1\_up} \\
&\qquad\qquad CCC_2 + d_{3.1}^- - d_{3.1}^+ = CCC_{2\_low} \\
&\qquad\qquad CCC_2 + d_{3.2}^- - d_{3.2}^+ = CCC_{2\_up} \\
&\qquad\qquad CCC_3 + d_{4.1}^- - d_{4.1}^+ = CCC_{3\_low} \\
&\qquad\qquad CCC_3 + d_{4.2}^- - d_{4.2}^+ = CCC_{3\_up},
\end{aligned}
\tag{1}
$$

where FC_1 is the financial costs at the supplier stage, FC_1^0 is the financial costs at the supplier stage before optimization, FC_2 is the financial costs at the distributor stage, FC_2^0 is the financial costs at the distributor stage before optimization, FC_3 is the financial costs at the retailer stage, FC_3^0 is the financial costs at the retailer stage before optimization (for more details on the meaning of variables and parameters, see (Ivakina et al., 2021)).

Once the first dilemma has been addressed, the logistics service provider will continue to prioritize goals. Next, the decision maker will have to assign a higher priority to one of the three individual goals of members of the supply chain. However, in this case, prioritizing will be greatly simplified. In the supply chain distribution network, the distributor will be considered as the most important member of the supply chain. The truth is that all flows – the downstream flow of goods, as well as the upstream flow of cash – usually pass through this participant of the supply

chain. Hence, the goal of limiting the cash conversion cycle of the distributor to the recommended industry-specific stability interval will be given a higher priority by the decision maker. This decision will have the following implications for the practical implementation of the base model. First, the unwanted deviation variables corresponding to the individual goal of the distributor will be assigned the priority 2. Second, minimizing their sum will be subject to some constraints – both already known and introduced for the first time. As for the new constraint, the constraint associated with achieving the priority 1 goal should be added. All in all, the second step of optimization can be represented as follows (2):

$$
\begin{aligned}
&\text{Find: } P_2, P_3, x, y, z \\
&\qquad d_1^-, d_1^+, d_{2.1}^-, d_{2.1}^+, d_{2.2}^-, d_{2.2}^+, d_{3.1}^-, d_{3.1}^+, d_{3.2}^-, d_{3.2}^+, d_{4.1}^-, d_{4.1}^+, d_{4.2}^-, d_{4.2}^+ \\
&\text{to minimize} \quad d_{2.1}^- + d_{2.2}^+ \\
&\text{subject to} \quad 0 \le x \le 1 \\
&\qquad\qquad 0,1 \le y \le 0,95 \\
&\qquad\qquad 0,1 \le z \le 0,95 \\
&\qquad\qquad FC_1 \le FC_1^0 \\
&\qquad\qquad FC_2 \le FC_2^0 \\
&\qquad\qquad FC_3 \le FC_3^0 \\
&\qquad\qquad TFC + d_1^- - d_1^+ = TFC^0 \times (1-\alpha) \\
&\qquad\qquad CCC_1 + d_{2.1}^- - d_{2.1}^+ = CCC_{1\_low} \\
&\qquad\qquad CCC_1 + d_{2.2}^- - d_{2.2}^+ = CCC_{1\_up} \\
&\qquad\qquad CCC_2 + d_{3.1}^- - d_{3.1}^+ = CCC_{2\_low} \\
&\qquad\qquad CCC_2 + d_{3.2}^- - d_{3.2}^+ = CCC_{2\_up} \\
&\qquad\qquad CCC_3 + d_{4.1}^- - d_{4.1}^+ = CCC_{3\_low} \\
&\qquad\qquad CCC_3 + d_{4.2}^- - d_{4.2}^+ = CCC_{3\_up} \\
&\qquad\qquad d_1^+ = d_{1\_step1}^+,
\end{aligned}
\tag{2}
$$

where $d_{1\_step1}^+$ is the value of the unwanted deviation variable from the first step of optimization.

After assigning the priority to the goal of limiting the cash conversion cycle of the distributor to the recommended industry-specific stability interval, the logistics service provider will have to prioritize only two goals – the goal of limiting the cash conversion cycle of the supplier to the recommended industry-specific stability interval and the goal of limiting the cash conversion cycle of the retailer to the recommended industry-specific stability interval. In order to do this, the logistics service provider will need to decide which of the participants of the supply chain is more important for the distributor – the supplier or the retailer. Suppose that based on the bargaining power of each member of the supply chain, the logistics service provider has decided that the retailer is more important for the distributor. Then, the goal of limiting the cash conversion cycle of the retailer to the recommended industry-specific stability interval will be assigned the priority 3. Accordingly, the sum of the unwanted deviation variables corresponding to this goal will be assigned the priority 3 and will be minimized subject to two groups of constraints. The first

group of constraints will include all constraints of the base model. The second group of constraints, in turn, will be associated with achieving the higher priority goals – the priority 1 and priority 2 goals. In sum, the third step of optimization will be performed in the following way (3):

$$
\begin{aligned}
&\text{Find: } P_2, P_3, x, y, z \\
&\qquad d_1^-, d_1^+, d_{2.1}^-, d_{2.1}^+, d_{2.2}^-, d_{2.2}^+, d_{3.1}^-, d_{3.1}^+, d_{3.2}^-, d_{3.2}^+, d_{4.1}^-, d_{4.1}^+, d_{4.2}^-, d_{4.2}^+ \\
&\text{to minimize} \quad d_{3.1}^- + d_{3.2}^+ \\
&\text{subject to} \quad 0 \le x \le 1 \\
&\qquad\qquad 0,1 \le y \le 0,95 \\
&\qquad\qquad 0,1 \le z \le 0,95 \\
&\qquad\qquad FC_1 \le FC_1^0 \\
&\qquad\qquad FC_2 \le FC_2^0 \\
&\qquad\qquad FC_3 \le FC_3^0 \\
&\qquad\qquad TFC + d_1^- - d_1^+ = TFC^0 \times (1-\alpha) \\
&\qquad\qquad CCC_1 + d_{2.1}^- - d_{2.1}^+ = CCC_{1\_low} \\
&\qquad\qquad CCC_1 + d_{2.2}^- - d_{2.2}^+ = CCC_{1\_up} \\
&\qquad\qquad CCC_2 + d_{3.1}^- - d_{3.1}^+ = CCC_{2\_low} \\
&\qquad\qquad CCC_2 + d_{3.2}^- - d_{3.2}^+ = CCC_{2\_up} \\
&\qquad\qquad CCC_3 + d_{4.1}^- - d_{4.1}^+ = CCC_{3\_low} \\
&\qquad\qquad CCC_3 + d_{4.2}^- - d_{4.2}^+ = CCC_{3\_up}, \\
&\qquad\qquad d_1^+ = d_{1\_step1}^+ \\
&\qquad\qquad d_{2.1}^- + d_{2.2}^+ = d_{2.1\_step2}^- + d_{2.2\_step2}^-,
\end{aligned}
\tag{3}
$$

where $d_{2.1\_step2}^-$ is the value of the first unwanted deviation variable from the second step of optimization, $d_{2.2\_step2}^-$ is the value of the second unwanted deviation variable from the second step of optimization.

Based on all the decisions of the logistics service provider, the last priority to be assigned will belong to the goal of limiting the cash conversion cycle of the supplier to the recommended industry-specific stability interval. Therefore, the sum of the unwanted deviation variables corresponding to this goal will be minimized at the last, fourth step of optimization. As in the previous steps, some constraints will have to be met when minimizing. First of all, all constraints of the base model will have to be taken into account. Then, the constraints associated with achieving the higher priority goals – the priority 1, priority 2 and priority 3 goals – should also be considered. In relation to this, the last, fourth step of optimization will be

accomplished in the following way (4):

$$
\begin{aligned}
&\text{Find: } P_2, P_3, x, y, z \\
&\quad d_1^-, d_1^+, d_{2.1}^-, d_{2.1}^+, d_{2.2}^-, d_{2.2}^+, d_{3.1}^-, d_{3.1}^+, d_{3.2}^-, d_{3.2}^+, d_{4.1}^-, d_{4.1}^+, d_{4.2}^-, d_{4.2}^+ \\
&\text{to minimize} \quad d_{4.1}^- + d_{4.2}^+ \\
&\text{subject to} \quad 0 \le x \le 1 \\
&\qquad\qquad 0,1 \le y \le 0,95 \\
&\qquad\qquad 0,1 \le z \le 0,95 \\
&\qquad\qquad FC_1 \le FC_1^0 \\
&\qquad\qquad FC_2 \le FC_2^0 \\
&\qquad\qquad FC_3 \le FC_3^0 \\
&\qquad\qquad TFC + d_1^- - d_1^+ = TFC^0 \times (1-\alpha) \\
&\qquad\qquad CCC_1 + d_{2.1}^- - d_{2.1}^+ = CCC_{1\_low} \\
&\qquad\qquad CCC_1 + d_{2.2}^- - d_{2.2}^+ = CCC_{1\_up} \\
&\qquad\qquad CCC_2 + d_{3.1}^- - d_{3.1}^+ = CCC_{2\_low} \\
&\qquad\qquad CCC_2 + d_{3.2}^- - d_{3.2}^+ = CCC_{2\_up} \\
&\qquad\qquad CCC_3 + d_{4.1}^- - d_{4.1}^+ = CCC_{3\_low} \\
&\qquad\qquad CCC_3 + d_{4.2}^- - d_{4.2}^+ = CCC_{3\_up}, \\
&\qquad\qquad d_1^+ = d_{1\_step1}^+ \\
&\qquad\qquad d_{2.1}^- + d_{2.2}^+ = d_{2.1\_step2}^- + d_{2.2\_step2}^- \\
&\qquad\qquad d_{3.1}^- + d_{3.2}^+ = d_{3.1\_step2}^- + d_{3.2\_step2}^-,
\end{aligned}
\tag{4}
$$

where $d_{3.1\_step2}^-$ is the value of the first unwanted deviation variable from the third step of optimization, $d_{3.2\_step2}^-$ is the value of the second unwanted deviation variable from the third step of optimization.

4. Quantitative implementation of the base model on the cases of real supply chains

To show how the base model for multi-objective collaborative working capital management based on the use of supply chain finance solutions works in practice, two cases of real supply chains will be used. The first case will be a supply chain operating in the information and communication technology industry, while the second one – a supply chain operating in the fast-moving consumer goods industry. For each of the two cases, two types of data will be used – primary and secondary. The secondary data was obtained from the Balance Sheets and the Profit and Loss Statements of companies involved in supply chains. The primary data, for example, the weighted average cost of capital of a particular company or the rate for the use of a particular supply chain finance solution, was received during interviews with representatives of supply chains. The practical implementation of the base model on both cases is shown below.

Case 1 for the base model: Information and communication technology supply chain

The first case that will be considered in order to implement the base model in practice is a 3-member supply chain operating in the information and technology industry. The distributor of the supply chain 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, in turn, 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.

At the end of 20XX, working capital management in the supply chain could be characterized as collaborative, but not multi-objective (see Table 1). What is more important, the supply chain did not seem to benefit from the use of supply chain finance solutions. The point is that internal payment periods among supply chain members were equal to each other and did not influence the collaborative cash conversion cycle at all. In general, it can be stated that the collaborative cash conversion cycle at the end of 20XX was very long (280,3 days). And the reason for such a long collaborative cash conversion cycle was that each member of the supply chain had the cash conversion cycle, the value of which was higher than the upper limit of the industry-specific stability interval defined by Garanina and Petrova (2015). Regarding the total financial costs of the supply chain, they also seem prohibitively high (274,08 million rubles), given that the supply chain did not even incur the additional financial costs on supply chain finance solutions. Hence, in an amicable way, at the end of 20XX, the supply chain needed a multi-objective collaborative working capital management based on the use of supply chain finance solutions.

Table 1. Data before optimization in case 1 for the base model

	INV	AR	AP	WC	COGS	Net Sales	WACC
Supplier	1342,0	1374,0	901,0	1815,0	6345,0	7419,0	0,082
Distributor	11 593,0	458,1	4 256,1	7 795,0	22 981,0	29 792,0	0,047
Retailer	972,0	119,0	85,0	1 006,0	5 528,0	6 588,0	0,034
	TINV	TAR	TAP	TWC			
Supply chain	13 907,0	1 951,1	5 242,1	10 616,0			
	DIO	DRO	DPO	CCC	FC		
Supplier	77,2	67,6	51,8	92,97	32,6		
Distributor	184,1	5,6	67,6	122,14	235,7		
Retailer	64,2	6,6	5,6	65,16	5,8		
				CCCC	TFC		
Supply chain				280,3	274,08		

*Data from financial statements are presented in millions of rubles

The intermediary which could be responsible for multi-objective collaborative working capital management based on the use of supply chain finance solutions in 20XX is the logistics service provider. The fact is that this intermediary was in charge of collaborative working capital management in the supply chain then and continues to do so now. Hence, in order to implement the base model on the case of the supply chain operating in the information and communication technology

industry, the logistics service provider was asked to prioritize all goals suggested by the base model, as it would have done in 20XX. All in all, the logistics service provider prioritized the goals in the following way:

Priority 1 goal: To decrease the total financial costs of the supply chain by 90% to 27,41 million rubles.

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 results of optimization are shown in Table 2.

Table 2. Data after optimization in case 1 for the base model

	INV	AR	AP	WC	COGS	Net Sales	WACC	
Supplier	435,5	1655,4	901,0	1189,9	6345,0	7419,0	0,082	
Distributor	3641,1	1948,1	6162,5	-573,3	22 981,0	29 792,0	0,047	
Retailer	972,0	119,0	1316,9	-225,9	5 528,0	6 588,0	0,034	
	TINV	TAR	TAP	TWC				
Supply chain	5 048,6	3722,5	8380,4	390,7				
	DIO	DRO	DPO	CCC	FC on WC	FC on IF	FC on RW	FC
Supplier	25,1	81,4	51,8	54,66	21,6		11,0	32,6
Distributor	57,8	23,9	97,9	-16,18	-43,9	41,9	14,8	12,7
Retailer	64,2	6,6	87,0	-16,18	-4,7			-4,7
				CCCC				TFC
Supply chain				22,3				40,60

In general, it can be concluded that almost all of the goals of collaborative working capital management based on the use of supply chain finance solutions were achieved during optimization. To prove this, Table 3 will be used. As can be seen from this table, all deviations from the individual goals of the participants of the supply chain are equal to 0. This means that the individual cash conversion cycle of each member of the supply chain fell into the industry-specific stability interval due to optimization. However, a significant deviation from the priority 1 goal equal to 13,19 million rubles can be observed too. As a result, it can be claimed that the total financial costs of the supply chain could not be decreased by 90%. The maximum reduction they could experience would be only 85,2%, which is fully confirmed by the optimization.

Table 3. Goals achievement in case 1 for the base model

	Priority 1 goal	Priority 2 goal	Priority 3 goal	Priority 4 goal
Deviation	13,19	0,00	0,00	0,00

As can be understood, supply chain finance solutions were a catalyst in achieving almost all of the goals of collaborative working capital management in this case. Hence, it will be crucial to emphasize which conditions for the use of supply chain finance solutions could be most beneficial for the participants of the supply chain and the supply chain as a whole at the end of 20XX (Table 4). Based on the results of optimization, in the supplier-distributor pair, it could be preferable to have the share of goods delivery through the logistics service provider equal to 0,69, while the share of the early payment from the bank – equal to 0,1. Along with this, the payment term for the distributor specified in the reverse factoring contract should have been equal to 225,4 days. As for the distributor-retailer pair, the optimization showed that the most beneficial share of the early payment from the bank would be 0,75. The 'best' payment term for the retailer specified in the reverse factoring contract, in turn, would be 87 days.

Table 4. Supply chain finance solutions in case 1 for the base model

	Supplier-Distributor			Distributor-Retailer	
IF	0,69	share of delivery via the LSP	RF	0,75	share of the early payment
	0,31	share of direct delivery (sup-dis)		0,25	share of the remaining payment
	0,13	IF rate		0,18	RF rate
	126,3	duration of the financing contract		87,0	payment term for the retailer
RF	0,10	share of the early payment			
	0,90	share of the remaining payment			
	0,13	RF rate			
	225,4	payment term for the distributor			

To demonstrate how exactly supply chain finance solutions made almost all of the goals suggested by the base model achievable, Table 5 will be used. First of all, supply chain finance solutions allowed to decrease the days inventory outstanding of the supplier and distributor by 67,5% and 68,6%, respectively. What is more, they contributed to an increase in the days payable outstanding of the distributor and retailer by 44,8% and 1 449,3%, respectively. Such changes in the components of the collaborative cash conversion cycle influenced significantly both the individual cash conversion cycle of each member of the supply chain and the collaborative cash conversion cycle of the supply chain. The same happened with the individual financial costs of the participants of the supply chain. Some of them decreased significantly (by 94,6% and 182,1%) only due to the implementation of supply chain finance solutions. And this resulted in an impressive decrease in the total financial costs of the supply chain, which, as already mentioned, was 85,2%.

Case 2 for the base model: Fast-moving consumer goods supply chain

The second case that will be considered in order to implement the base model in practice is a 3-member supply chain operating in the fast-moving consumer goods industry. The distributor of the supply chain is a Russian company specializing in the distribution of beverages across all regions of the Russian Federation and the CIS countries. The supplier, in turn, is a small domestic company involved in the distributor's procurement process through supplying produced and packaged beverages ready for distribution. The retailer in the considered supply chain is a

Table 5. Comparative change in case 1 for the base model

	INV	AR	AP	WC	
Supplier	-67,5 %	20,5 %	0,0 %	-34,4 %	
Distributor	-68,6 %	325,3 %	44,8 %	-107,4 %	
Retailer	0,0 %	0,0 %	1449,3 %	-122,5 %	
	TINV	TAR	TAP	TWC	
Supply chain	-63,7 %	90,8 %	59,9 %	-96,3 %	
	DIO	DRO	DPO	CCC	FC
Supplier	-67,5 %	20,5%	0,0 %	-41,2 %	0,0 %
Distributor	-68,6 %	325,3%	44,8 %	-113,2 %	-94,6 %
Retailer	0,0 %	0,0 %	1449,3 %	-124,8 %	-182,1 %
				CCCC	TFC
Supply chain				-92,0 %	-85,2 %

Russian beverages company. It sells beverages to both individual consumers and corporate clients in the Belarusian market.

Describing working capital management in the supply chain, it can be said that at the end of 20XX, working capital management in the supply chain was carried out in a collaborative manner, but, unfortunately, without the use of supply chain finance solutions. Because of this, collaborative working capital management did not produce the desired results (Table 6). Specifically, all members of the supply chain had the cash conversion cycles that were above the upper limit of the industry-specific stability interval defined by Garanina and Petrova (2015). This, in turn, resulted in a very long collaborative cash conversion cycle equal to 209,2 days, which of course needed to be shortened. The total financial costs of the supply chain, although not very large (74,53 million rubles), also showed a value that could be reduced with the help of supply chain finance solutions. Hence, at the end of 20XX, the supply chain definitely needed a multi-objective collaborative working capital management based on the use of supply chain finance solutions.

Table 6. Data before optimization in case 2 for the base model

	INV	AR	AP	WC	COGS	Net Sales	WACC
Supplier	394,0	445,5	321,0	518,5	1918,0	2350,0	0,136
Distributor	4749,0	8766,9	6651,0	6864,9	35084,0	74519,0	0,137
Retailer	156,0	157,0	84,0	229,0	714,0	866,0	0,146
	TINV	TAR	TAP	TWC			
Supply chain	5299,0	9369,4	7056,0	7612,4			
	DIO	DRO	DPO	CCC	FC		
Supplier	75	69,2	61,1	83,09	14,4		
Distributor	49,4	42,9	69,2	23,15	52,8		
Retailer	79,7	66,2	42,9	102,98	7,3		
				CCCC	TFC		
Supply chain				209,2	74,53		

*Data from financial statements are presented in millions of rubles

The intermediary which could organize multi-objective collaborative working capital management based on the use of supply chain finance solutions in 20XX

is the financial service provider. The fact is that this intermediary was responsible for collaborative working capital management in the supply chain at that time and continues to do so at the moment. Therefore, in order to implement the base model on the case of the supply chain operating in the fast-moving consumer goods industry, the financial service provider was asked to assign priorities to all goals suggested by the base model, as it would have done in 20XX. As a result, the financial service provider prioritized the goals as follows:

Priority 1 goal: To limit the cash conversion cycle of the distributor to the recommended industry-specific stability interval, where the lower limit is -36,05 days and the upper limit is 22,95 days.

Priority 2 goal: To limit the cash conversion cycle of the supplier to the recommended industry-specific stability interval, where the lower limit is -36,05 days and the upper limit is 22,95 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 -36,05 days and the upper limit is 22,95 days.

Priority 4 goal: To decrease the total financial costs of the supply chain by 20% to 59,63 million rubles.

The results of optimization are demonstrated in Table 7.

Table 7. Data after optimization in case 2 for the base model

	INV	AR	AP	WC	COGS	Net Sales	WACC	
Supplier	229,4	260,0	321,0	168,4	1 918,0	2 350,0	0,136	
Distributor	2 792,7	6 698,0	9 411,3	79,4	35 084,0	74 519,0	0,137	
Retailer	156,0	157,0	200,2	112,8	714,0	866,0	0,146	
	TINV	TAR	TAP	TWC				
Supply chain	3 178,0	7 115,0	9 932,5	360,6				
	DIO	DRO	DPO	CCC	FC on WC	FC on IF	FC on RW	FC
Supplier	43,6	40,4	61,1	22,95	0,3		14,1	14,4
Distributor	29,1	32,8	97,9	-36,05	-223,4	0,8	275,3	52,8
Retailer	79,7	66,2	102,3	43,57	0,8			0,8
				CCCC				TFC
Supply chain				30,5				68,09

In general, it can be concluded that not all goals of collaborative working capital management based on the use of supply chain finance solutions were achieved during optimization. To prove this, it will be necessary to refer to Table 8. In this table, deviations from the priority 3 and 4 goals are equal to 20,62 days and 8,47 million rubles, respectively. Based on this, several conclusions can be made. First of all, it can be argued that the retailer would be the only member of the supply chain whose cash conversion cycle would not fall into the industry-specific stability interval even with the use of supply chain finance solutions. Moreover, it can be claimed that the supply chain as a whole could not decrease its total financial costs by 20%. The point is that in this case, the possible decrease would be much less and would be equal to 8,6%.

As in the previous case, supply chain finance solutions can be called the basis for achieving the goals of collaborative working capital management in the supply chain. In relation to this, the conditions for their use should be presented here separately

Table 8. Goals achievement in case 2 for the base model

	Priority 1 goal	Priority 2 goal	Priority 3 goal	Priority 4 goal
Deviation	0,00	0,00	20,62	8,47

as well (Table 9). To be begin with, it should be pointed out that the achievement of half of the goals of collaborative working capital management in this case became possible with the share of goods delivery through the logistics service provider equal to 0,43. For reverse factoring in both pairs, the shares of early payments from the bank were even higher. To be more specific, in the supplier-distributor pair, this share was equal to 0,73, while in the distributor-retailer pair, it was equal to 0,7. With regard to payment terms, their values also varied in pairs. In particular, the payment term in the supplier-distributor pair was equal to 132,2 days, while the payment term in the distributor-retailer pair – to 102,3 days.

Table 9. Supply chain finance solutions in case 2 for the base model

Supplier-Distributor			Distributor-Retailer		
IF	0,43	share of delivery via the LSP	RF	0,70	share of the early payment
	0,57	share of direct delivery (sup-dis)		0,30	share of the remaining payment
	0,09	IF rate		0,16	RF rate
	20,4	duration of the financing contract		102,3	payment term for the retailer
RF	0,73	share of the early payment			
	0,27	share of the remaining payment			
	0,12	RF rate			
	132,2	payment term for the distributor			

To demonstrate how exactly supply chain finance solutions made half of the goals suggested by the base model achievable, Table 10 will be used. First, for the supplier and distributor, a significant decrease not only in the days inventory outstanding (by 41,8% and 41,2%), but also in the day's receivables outstanding (by 41,6% and 23,6%) can be observed. In addition to this, a dramatic increase in the days payable outstanding of the distributor and especially of the retailer (41,5% and 138,3%) can be seen. All of this results in the limitation of the individual cash conversion cycles of two members of the supply chain to the recommended industry-specific stability interval, as well as the reduction of the collaborative cash conversion cycle by 85,4%. The changes in the individual financial costs of members of the supply chain are not so large-scale, but they are still there. For instance, it can be stated that the financial costs of the retailer were reduced by 88,4% due to the use of supply chain finance solutions. This, in turn, led to a small but still 8,6% decrease in the total financial costs of the supply chain.

Table 10. Comparative change in case 2 for the base model

	INV	AR	AP	WC	
Supplier	-41,8 %	-41,6 %	0,0 %	-67,5 %	
Distributor	-41,2 %	-23,6 %	41,5 %	-98,8 %	
Retailer	0,0 %	0,0 %	138,3 %	-50,7 %	
	TINV	TAR	TAP	TWC	
Supply chain	-40,0 %	-24,1 %	40,8 %	-95,3 %	
	DIO	DRO	DPO	CCC	FC
Supplier	-41,8 %	-41,6 %	0,0 %	-72,4 %	0,0 %
Distributor	-41,2 %	-23,6 %	41,5 %	-255,7 %	0,0 %
Retailer	0,0 %	0,0 %	138,3 %	-57,7 %	- 88,4 %
				CCCC	TFC
Supply chain				-85,4 %	-8,6 %

5. Conclusion

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

First, to achieve the research goal, models for working capital management in the supply chain were investigated. Based on the analysis, both the individual objectives of the participants of the supply chain and the common objective of the supply chain were included in the base model for multi-objective collaborative working capital management in the supply chain. In addition to this, the analysis of supply chain finance solutions was also conducted. As a result, inventory financing and reverse factoring were adopted in the base model. The main reason for this was that these solutions give an opportunity to manage and improve all three components of the individual cash conversion cycles of all members of the supply chain. After that, the base model for multi-objective collaborative working capital management based on the use of supply chain finance solutions was finally developed. The model was designed for a three-stage supply chain consisting of a single supplier, distributor and single retailer.

The base model itself was developed on the basis of pre-emptive goal programming. In this respect, objectives that were identified based on the literature review were transformed into goals having certain aspiration levels. With regard to the individual goals of the participants of the supply chain, the base model assumed that every member of the supply chain seeks to limit its cash conversion cycle to the recommended industry-specific stability interval. The company needs to follow this interval in order to maintain the highest possible rate of return and the necessary level of liquidity (Garanina & Belova, 2015). Otherwise, profitability will be maximized at the cost of liquidity decrease or vice versa, which should not be the option for any company involved in the supply chain (Raheman & Nasr, 2007). As for the common goal of the supply chain, it was related to reducing the total financial costs of the supply chain by a certain percentage. This goal was especially important, since the companies involved in the supply chain present anyway separate and independent economic entities that are more interested in improving their individual performances than overall performance of the supply chain.

Finally, the base model was implemented on the cases of real supply chains. Based on the results of the optimization, it was concluded that supply chain finance solutions make it possible to achieve almost all of the goals of collaborative working capital management in the supply chain. Basically, they contribute to the decrease of the days inventory outstanding and the days receivables outstanding of the participants of the supply chain, as well as allow to increase the days payable outstanding for almost all of them. This results not only in the limitation of the individual cash conversion cycles of members of the supply chain to the recommended industry-specific stability interval, but also in the reduction of the collaborative cash conversion cycle. As a result, the participants of the supply chain get a chance to maximize their individual profits without violating the necessary level of liquidity. The implementation of supply chain finance solutions also has a significant impact on the total financial costs of the supply chain. Through decreasing the individual financial costs of members of the supply chain, they provide an opportunity not only to improve the individual performances of members of the supply chain, but the overall performance of the supply chain too.

Theoretical and practical contribution of the research

This research contributes to existing supply chain management literature by focusing on financial supply chain and studying its optimization. First of all, the research integrates supply chain and financial perspectives to advance working capital management from the level of the individual company to the level of the supply chain. What is more, it fills the gap in practical tools for multi-objective collaborative working capital management in the supply chain. In particular, the gap is filled by the development of the base model for multi-objective collaborative working capital management. The aforementioned model allows for more precise working capital management at the inter-organizational level based on both the individual goals of the participants of the supply chain and the common goal of the supply chain. In addition to this, it takes into account not only the multi-objective nature of working capital management in the supply chain, but also the varying degrees of importance of goals for the organization in charge of working capital management. It is also important to mention that research provides clear ways to achieve the goals suggested by the base model. Specifically, the adoption of two supply chain finance solutions – inventory financing and reverse factoring – is modeled in the study.

The base model for multi-objective collaborative working capital management based on the use of supply chain finance solutions can be implemented in practice using Microsoft Office Excel. Thus, the model itself can become a practical tool for multi-objective collaborative working capital management based on the use of supply chain finance solutions. This tool can be used by either the logistics service provider or the financial service provider, which are usually in charge of collaborative working capital management in the supply chain. Using it, any of these intermediaries will get an opportunity to plan the individual cash conversion cycles of the participants of the supply chain, as well as the total financial costs of the supply chain based on the use of supply chain finance solutions. This, in turn, will allow members of the supply chain and the supply chain as a whole to decrease the total financial costs making individual ones not worse and at the same time achieve greater liquidity.

Limitations and future research

Notwithstanding the aforementioned theoretical and practical contribution, it should be borne in mind that the present research is limited only to supply chain distribution networks. Thus, future research should seek to extend the context of this paper by considering not only supply chain distribution networks, but also other types of supply chain networks. In addition to this, it is assumed that the number of stages in the supply chain should be significantly increased. This will allow to make the base model for multi-objective collaborative working capital management based on the use of supply chain finance solutions more applicable to real-world supply chains. What also needs to be stressed is that the present paper investigates the adoption of only two supply chain finance solutions – inventory financing and reverse factoring. As a next step, it will be particularly useful to consider the implementation of other supply chain finance solutions in the supply chain or even include more of them. This will lead to even more impressive results in working capital management in the supply chain.

References

Arunkumar, O. N., Divya, D., & Mathew, T. C. (2018). *Goal Programming Model for Optimizing Working Capital Management: Case of Tire Retreading Company.* Journal of Operations and Strategic Planning, **1**, 148–167.

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

Caniato, F., Gelsomino, L., Perego, A., & Ronchi, S. (2016). *Does finance solve the supply chain financing problem?* Supply Chain Management: An International Journal, **21(5)**, 534–549.

Chiandussi, G., Codegone, M., Ferrero, S., & Varesio, F. (2012). *Comparison of multi-objective optimization methodologies for engineering applications.* Computers and Mathematics with Applications, **63**, 912–942.

Eschenauer, H., Koski, J., & Osyczka, A. (1990). Multi-criteria Design Optimization. Procedures and Applications, *Springer-Verlag*, Berlin.

Fairchild, A. (2005). *Intelligent matching: integrating efficiencies in the financial supply chain.* Supply Chain Management: An International Journal, **10(4)**, 244–248.

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

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

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

Hofmann, E., & Zumsteg, S. (2015). *Win-win and no-win situations in supply chain finance: the case of accounts receivable programs.* Supply Chain Forum: An International. Journal, **16(3)**, 30–50.

Huff, J., & Rogers, D. S. (2015). *Funding the organization through supply chain finance: a longitudinal investigation.* Supply Chain Forum: An International Journal, **16(3)**, 4–17.

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

Ivakina, A., Smirnova, M., Zenkevich, N. (2021). *The multi-objective model of working capital optimization.* Contributions to Game Theory and Management, **14**, 155–182.

Kayani, U. N., De Silva, T.-A., & Gan, C. (2019). *A systematic literature review on working capital management – an identification of new avenues.* Qualitative Research in Financial Markets, **11(3)**, 352–366.

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

Kouvelis, P., Chambers, C., & Wang, H. (2006). *Supply Chain Management Research and Production and Operations Management: Review, Trends, and Opportunities.* Production and Operations Management, **15(3)**, 449–469.

Lind, L., Pirttilä, M., Viskari, S., Schupp, F., & Kärri, T. (2012). *Working capital management in the automotive industry: Financial value chain analysis.* Journal Of Purchasing And Supply Management, **18(2)**, 92–100.

Lorentz, H., Solakivi, T., Töyli, J., & Ojala, L. (2016). *Trade credit dynamics during the phases of the business cycle – a value chain perspective.* Supply Chain Management: An International Journal, **21(3)**, 363–380.

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

More, D., & Basu, P. (2013). *Challenges of Supply Chain Finance: A Detailed Study and a Hierarchical Model Based on the Experiences of an Indian Firm.* Business Process Management Journal, **19**, 624–647.

Pirttilä, M. (2014). *The Cycle Times Of Working Capital: Financial Value Chain Analysis Method.* PhD dissertation, Lappeenranta University of Technology, Lappeenranta, Finland.

Raheman, A., & Nasr, M. (2007). Working capital management and profitability case of Pakistani firms. *International Review of Business Research Papers*, **3(1)**, 16–21.

Randall, W., 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.

Seth, H., Chadha, S. & Sharma, S. (2020c). *Benchmarking the efficiency model for working capital management: data envelopment analysis approach.* International Journal of Productivity and Performance Management.

Sherali, H. (1982). *Equivalent weights for lexicographic multi-objective programs: Characterizations and computations.* European Journal of Operational Research, **11(4)**, 367–379.

Singh, H. P., & Kumar, S. (2014). *Working capital management: a literature review and research agenda.* Qualitative Research in Financial Markets, **6(2)**, 173–197.

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

Viskari, S., & 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., & 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.