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The Multi-Objective Model of Working Capital Optimization*

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Abstract In recent years, the topic of supply chain finance has gained a lot of attention from academia, but still, there are a lot of unexplored areas. For example, the literature demonstrates a clear gap of adequate application of numerous supply chain finance solutions for collaborative working capital management (Gelsomino et al., 2019). This issue becomes more and more important, specifically in terms of globalization and growing competition between supply chains when liquidity and profitability improvement is of paramount relevance. Companies focusing on their individual supply chain issues and taking their own interests into account rather than understanding the whole supply chain and collaborating with their partners are missing fruitful areas for improvements (Wuttke et al., 2016). The authors address this gap by developing a model for collaborative working capital management through supply chain finance adoption for the case of the three-stage supply chain. At the same time, the process of working capital optimization is received as a multi-objective problem. The results obtained indicate that the model of working capital optimization with concurrent use of multiple supply chain finance solutions is able to 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, multi-objective optimization, goal programming.

1. Introduction

Over a long period of time, in the supply chain management literature, the supply chain has been recognized as a set of three of more entities directly involved in the upstream and downstream flows of products, materials and/or information from a source to a customer (Mentzer, et al., 2001). In relation to this, the analysis in the area of supply chain management has been focused mainly on the downstream flow of goods and information flow (Kouvelis et al., 2006; Caniato et al., 2016). However, having experienced improvements by applying supply chain management principles to the physical supply chain, companies are now turning their attention to the financial supply chain to attain similar benefits (Otto & Kotzab, 2003; Hofmann & Belin, 2011). The study of financial supply chains is also fueled by the recent financial crisis, which has led to a considerable decline in granting of new loans, as

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well as a significant increase in the cost of corporate borrowing. Thus, the problem of financial supply chain management becomes more and more relevant every day.

Nowadays, the need for financial supply chain management is highlighted by both practitioners and the academia. From a consultancy perspective, Hartley-Urquhart (2006) admits that financial supply chains should be managed as closely as physical supply chains. The academia represented by Gupta and Dutta expresses the similar view. Specifically, it concludes that management of upstream flow of cash is of the same importance as management of downstream flow of goods (Gupta & Dutta, 2011). As a result, many scholars have attempted to develop a conceptual framework of financial supply chain management. And here one of the most important aspects has become working capital management in the supply chain.

Nowadays, it can be argued that the supply-chain perspective of working capital management is becoming more and more popular (Wuttke et al., 2013b; Blackman et al., 2017; Virolainen et al., 2019). First of all, practitioners and academics recognize that working capital management cannot be performed properly at the intra-organizational level due to the fact that 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 as a whole (Hofmann & 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 & Seifert, 2017).

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 inter-organizational level (Hutchison et al., 2007; Randall & Farris II, 2009; Vázquez et al., 2016), 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 (Knight, 1972; Mihir et al., 2009; Masri et al., 2018).

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 order to do this, the following *research question* is formulated:

RQ: What is the model for multi-objective collaborative working capital based on the use of supply chain finance solutions and the algorithm for its practical implementation?

In general, the main *goal* of the research is to improve the methodology for multi-objective collaborative working capital management based on the use of supply chain finance solutions.

2. Problem statement and literature review

2.1. Financial supply chain management

In accordance with Gupta and Dutta (2011), there are three main types of flows connecting entities in the supply chain: downstream *flow of goods*, upstream *flow of cash* and *information flow* that goes in both directions. 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 (Kouvelis et al., 2006; Caniato et al., 2016).

In many cases, the upstream flow of cash in the supply chain is denoted by the term ***"financial supply chain"***. Such an interpretation of the financial supply chain was put forward by Pfohl et al. (2003). However, as it often takes place in science, the scholars could not come up with a common definition of the financial supply chain. Most of them based their conclusions on different concepts and, as a result, offered different definitions in the literature (Blackman et al., 2017). For example, some papers considered technical aspects of financial supply chains and failed to refer to strategic and operations management issues (Lee, 1998; Segev et al., 1998). Other investigators also examined the specific details of financial supply chains such as integration of financial and manufacturing data (Fairchild, 2005), financing arrangements (Hofmann, 2005), risks of electronics payments (Johnson, 2008), risk and supplier financing (Hofmann, 2011), etc.

The first definition of the financial supply chain was developed by research company Killen & Associates in 2001. Following this definition, the financial supply chain "parallels the physical or materials supply chain and represents all transaction activities related to the flow of cash from the customer's initial order through reconciliation and payment to the seller" (Weiss, 2012). While the first definition highlights the parallelism between physical and financial supply chains, the other one, given by another research company Aberdeen Group, emphasizes collaboration and communication in the financial supply chain. Thus, the financial supply chain is presented as "a range of B-to-B trade-related intra- and inter-company financial transaction-based functions and processes that begin before buyers and suppliers establish contact and proceed beyond the settlement process" (Popa, 2013).

The study exploring Motorola's global financial supply chain strategy provides a more modern approach to the financial supply chain. In accordance with Blackman et al. (2017), the financial supply chain can be recognized as a network of organizations, banks and financial providers that coordinate the upstream flow of cash through financial processes and shared information systems to ensure the downstream flow of goods and/or services between supply chain participants in the physical supply chain. This approach to the financial supply chain does not view the upstream flow of cash as the only element of the financial supply chain. It also takes into account the set of actors and mechanisms needed for alignment of physical and financial supply chains. For this reason, this approach to financial supply chain will be applied in this work for further investigation of financial supply chain perspectives.

As an integral part of the supply chain, the financial supply chain requires proper management. From a consultancy perspective, Hartley-Urquhart (2006) admitted that financial supply chains should be managed as closely as physical supply chains.

The academia represented by Gupta and Dutta expressed the similar view. It concluded that management of upstream flow of cash is of the same importance as management of downstream flow of goods (Gupta & Dutta, 2011). As a result, many scholars started to develop a conceptual framework of financial supply chain management. Despite this, this research area still has great potential for further development.

One of the most common definitions of ***financial supply chain management*** was issued by Wuttke et al. (2013a). They defined financial supply chain management as "optimized planning, managing, and controlling of supply chain cash flows to facilitate efficient supply chain material flows". Thus, the researchers again focused their attention on the importance of integrating the downstream flow of goods and the upstream flow of cash. The point is that considerable effort has been made in the past towards integrating the downstream flow of goods and information flow that goes in both directions (Bailey & Francis, 2008; Stavrulaki & Davis, 2010). However, the same cannot be said about the upstream flow of cash, which path towards alignment with the downstream flow of goods and information flow is lagging far behind the alignment of the downstream flow of goods and information flow (Pfohl & Gomm, 2009; Wuttke et al., 2013a, 2013b).

In his treatment of financial supply chain management, Popa concentrated on other attributes of financial supply chain management. The scientist claimed that financial supply chain management can be described as comprehensive and holistic activities of planning and controlling all financial transactions and processes that are relevant for a particular company and for communication with other organizations in the supply chain (Popa, 2013). Financial supply chain management is thus opposed to traditional financial flow management aimed at optimizing the cash flow of a single company. Because of the need to collaborate with suppliers, customers and third-party providers, it tends to extend to the entire supply chain rather than a single firm.

A more formal definition of financial supply chain management can be found in Definitions for Techniques of Supply Chain Finance. According to this document, financial supply chain management refers to "the range of corporate management practices and transactions that facilitate the purchase of, sale and payment for goods and services, such as the conclusion of contractual frameworks, the sending of purchase orders and invoices, the matching of goods sent and received to these, the control and monitoring of activities including cash collections, the deployment of supporting technology, the management of liquidity and working capital, the use of risk mitigation such as insurance and guarantees, and the management of payments and cash-flow" (International Chamber of Commerce, 2016).

As Institute for Supply Chain Management (ISCM) reports, financial supply chain management can be identified as an interdisciplinary area of research. Being more precise, financial supply chain management involves the combination of two academic disciplines – supply chain management and corporate finance. In this paper, one of the key perspectives of financial supply chain management will be investigated further, namely working capital management including the adoption of supply chain finance solutions as well.

2.2. Working capital management as a financial supply chain management perspective

The term ***"working capital"*** originates from the field of corporate finance and was first introduced at the beginning of the 20$^{\text{th}}$ century (Firth, 1976). However, in line with Bhattacharya (2009), the concept of working capital was mentioned by Karl Marx back in 1914, albeit in a slightly different form and using a different term "variable capital". Nowadays, working capital is often described as "the capital of a business which is used in its day-to-day trading operations" (Pirtillä, 2014). In other words, working capital usually represents money available to the organization for funding its daily activities. It is one of the main indicators of liquidity, operational efficiency and short-term financial position of the company.

There are two views of working capital in academia. The first view refers to working capital as short-term balance sheet items, namely current assets on the assets side and current liabilities on the liabilities side (Preve & Sarria-Allende, 2010; Brealey et al., 2011). As a result, working capital is defined as the difference between current assets and current liabilities:

$$Working\ Capital = Current\ Assets - Current\ Liabilities. \tag{1}$$

The components of current assets and current liabilities that make up working capital often differ from researcher to researcher in this view. In this research, current assets and current liabilities will be classified according to Jones. Jones (2006) states that current assets include cash and cash equivalents, short-term marketable securities, accounts payable and inventory. Current liabilities, on the other side, contain notes payable, accounts payable, accruals and short-term debt.

The second view of working capital points out that working capital consists of inventory, accounts receivable and accounts payable (Hill et al., 2010; Knauer & Wöhrmann, 2013). In the finance literature, these items are often called "operational components of working capital". Consequently, it is suggested to calculate working capital as follows:

$$Working\ Capital = Inventory + Accounts\ Receivable - Accounts\ Payable. \tag{2}$$

This view of working capital proceeds 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 the second view recognize working capital as an investment tied up into inventory and accounts receivable and released with accounts payable (Monto, 2013). In this paper, this view of working capital will be applied further as well.

Working capital management as a research field has become really popular since the financial crisis of 2008 (Pirttilä, 2014). 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). However, due to a significant decrease of corporate performance during and after the 2008 financial crisis, interest towards working capital management increased. Many studies like Ajilore and Falope (2009), Gill et al. (2010), Ebben and Johnson (2011) demonstrated that working capital management can notably affect the profitability of a company as well.

Working capital management is usually associated with "all management decisions that influence the size and effectiveness of the working capital" (Kaur, 2010). Management of working capital plays a very important role in a company's activity. The primary reason for this is that an organization's current operations (production process, financial relations with suppliers and customers, etc.) are mainly determined by its working capital. In general, two opposing perspectives of working capital management are distinguished. Researchers of one camp consider working capital management from a single-company perspective (Belt & Smith, 1991; Moss & Stine, 1993; Baños-Caballero et al., 2012). Departing from the predominant single-company perspective, scholars from the second camp pay more attention to the supply chain and claim that analysis and optimization of working capital should take place at the inter-organizational level (Wuttke et al., 2013b; Blackman et al., 2017; Virolainen et al., 2019).

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***. It was introduced by Richards and Laughlin in order to criticize the use of current and quick ratios as key indicators of the company's liquidity position. 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 of time 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 (Shin & Soenen, 1998; Hofmann & Kotzab, 2010; Viskari et al., 2012).

The concept of the cash conversion cycle (CCC) also known as cash-to-cash (C2C) is shown in Fig. 1. As can be seen from the figure, the cash conversion cycle is divided into three components: the days inventory outstanding (DIO), the days receivables outstanding (DRO) and the days payable outstanding (DPO). The first component, the days inventory outstanding, measures how long it will take the organization to turn its entire inventory into sales. The second component, the days receivables outstanding, shows the number of days it will take the organization to collect its accounts receivable. The last but not the least component, the days payable outstanding, demonstrates the number of days it will take the organization to pay off its accounts payable. Thus, the 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 (Charituo et al., 2012).

Following the above description of the cash conversion cycle concept, the cash conversion cycle can be represented as a collection of three ratios: the days inventory outstanding plus the days receivables outstanding less the days payable outstanding. For the purposes of this paper, the approach to calculating the aforementioned ratios proposed by Farris II and Hutchison (2003) will be used. Therefore, the DIO will be calculated as Inventory$\times$365/COGS (cost of goods sold), the DRO as Accounts Receivable$\times$365/Net Sales, and the DPO as Accounts Payable$\times$365/COGS.

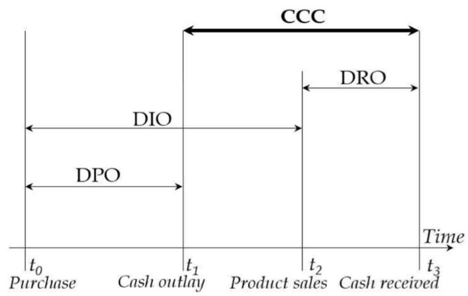

Fig. 1. Cash conversion cycle

Consequently, the cash conversion cycle will be characterized:

$$CCC = DIO + DRO - DPO =$$
$$= \frac{Inventory \times 365}{COGS} + \frac{Accounts\ Receivable \times 365}{Net\ Sales} - \frac{Accounts\ Payable \times 365}{COGS}. \quad (3)$$

The cash conversion cycle can be either negative or positive. A negative cash conversion cycle means that the organization has low level of inventory and gets money from its customers before it has to pay its accounts payable. In other words, in the negative cash conversion cycle scenario, the firm collects accounts receivable earlier than it must pay accounts payable. A large number of researchers believe that the lower the cash conversion cycle is, the better the company can manage its working capital (Volkov & Nikulin, 2012; Garanina & Petrova, 2015). However, a positive cash conversion cycle is normal for some industries. In such a way, for example, through pre-financing of production, the smooth running of business is usually ensured (Charifzadeh & Taschner, 2017).

Generally, 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 (Tangsucheeva & Prabhu, 2013). 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 (4):

$$FC = INV \times \left[(1+c)^{\frac{DIO}{365}} - 1\right] + AR \times \left[(1+c)^{\frac{DRO}{365}} - 1\right] - AP \times \left[(1+c)^{\frac{DPO}{365}} - 1\right]. \quad (4)$$

In the literature, less attention is paid to working capital management in the supply chain. Although adherents of the supply-chain perspective of working capital management (Wuttke et al., 2013b; Blackman et al., 2017; Virolainen et al., 2019) claim that analysis and optimization of working capital should take place at the inter-organizational level, nowadays, just a few studies are dedicated to the investigation of the cash conversion cycle and the financial costs on working capital for the whole supply chain.

Despite this, it can be argued that the supply-chain perspective of working capital management is becoming more and more popular today. First of all, practitioners and academics recognize that working capital management cannot be performed properly at the intra-organizational level due to the fact that 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 as a whole (Hoffman & Kotzab, 2010; Talonpoika et al., 2016; Protopappa-Sieke & Seifert, 2017).

One of such fundamental studies considering working capital management from a supply-chain perspective was conducted by Hofmann & Kotzab (2010). In this research, 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 & Kotzab, the ***collaborative cash conversion cycle*** is calculated a sum of the individual cash conversion cycles and can be described as:

$$CCCC = \sum_{l=1}^{n} \sum_{k=1}^{m} CCC_l^k, \tag{5}$$

where l is the stage of the supply chain, k is the particular 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 (6):

$$TFC = \sum_{l=1}^{n} \sum_{k=1}^{m} FC_l^k, \tag{6}$$

where l is the stage of the supply chain, k is the particular company at the particular 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). However, this benefit cannot be considered as the only one when making a decision on onboarding of supply chain finance solutions. There are also other benefits of such solutions, which will be discussed in the next paragraph.

2.3. Working capital management through supply chain finance solutions

Supply chain finance solutions have become very popular after the financial crisis of 2008, when the number of loans from banks and financial institutions decreased sharply (Ivashina & Scharfstein, 2010). At this time, alternative forms of financing, especially trade credits from suppliers, were really demanding. However, an extension of trade credit was subjected to the bargaining power whereby weaker suppliers were forced to increase the payment period or even delay the repayment (Fabbri & Klapper, 2016). All of this could create risk or disruption in the supply chain (Caniato et al., 2016). As a result, there was a need for solutions and programs that could optimize working capital in the supply chain (Polak et al., 2012).

According to Pfohl and Gomm (2009), Stemmler and Seuring (2003) were among the first scholars to use the term ***"supply chain finance"*** in academic literature. By the term "supply chain finance" they mainly understood the control and optimization of financial flows induced by logistics. However, nowadays supply chain finance can be defined in many different ways. The analysis carried out on different definitions of supply chain finance highlights two major perspectives of supply chain finance – finance-oriented perspective and supply chain-oriented perspective (Gelsomino et al., 2016).

As a rule, the *finance-oriented perspective of supply chain finance* considers the supply chain finance as a set of financial solutions, very often provided by financial institutions (Camerinelli, 2009; Lamoureux & Evans, 2011; Wuttke et al., 2013b). The *supply chain-oriented perspective of supply chain finance*, in turn, highlights the role of collaboration among supply chain participants, with a particular focus on inventory optimization rather than on financial products (Hofmann, 2005; Pfohl & Gomm, 2009; Randall & Farris II, 2009).

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) describe the selected supply chain finance solutions as the most popular among practitioners. In concordance with Chen et al. (2019), 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. In light of the above, the implementation of inventory financing and reverse factoring will be described below.

Inventory financing. For a long period of time, inventory financing has been recognized only as a short-term loan from a financial institution to finance inventory. Nowadays, this form of inventory financing is usually called the traditional one. The idea of an innovative form of inventory financing, in turn, was first introduced by Hofmann in 2009. In this form of inventory financing, a traditional financial institution is replaced by a logistics service provider, which purchases goods from a manufacturer and obtains an interim legal ownership of them before selling the goods to manufacturer's customers (Hofmann, 2009). Thus, in this case, the logistics service provider not only performs transport, handling and storage services for the supply chain, but also takes care of inventory financing (Gelsomino et al., 2019).

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 of time 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 (Chen & Cai, 2011). The scheme of inventory financing is shown in Fig. 2. As can be seen from the scheme, 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 has to store the goods for 2 days on its own and transfer ownership to the logistics service provider only after this period of time.

When the buyer realizes the need for the goods produced by the supplier, it can immediately buy them from the logistics service provider. In order to do this, the buyer, first of all, 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 has to pay the premium (interest) to this intermediary for the process of inventory financing to be considered complete.

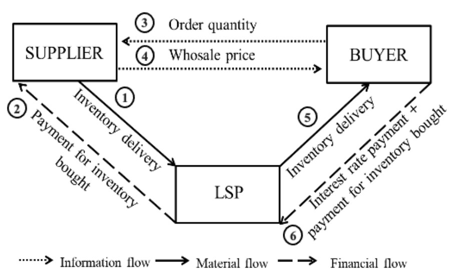

Fig. 2. Inventory financing scheme. Source: de Boer et al. (2015)

Reverse factoring. Nowadays, most practitioners and academics recognize reverse factoring as a supply chain finance solution that was developed based on conventional factoring arrangements. On the one hand, factoring and reverse factoring can indeed be characterized as very similar supply chain finance solutions. The point is that both factoring and reverse factoring aim to facilitate a longer payment term for the buyer and a shorter period of cash recovery for the supplier through the involvement of a financial intermediary (Tseng et al., 2018). However, on the other hand, factoring and reverse factoring differ in several ways, namely the initiator and the type of collateral. In particular, factoring can be described as a supply chain finance solution that is typically initiated by the supplier whose accounts receivable are sold at a discount to the financial service provider and used as collateral in a financial agreement (van der Vliet et al., 2015). Reverse factoring, in contrast, is initiated by the buyer and his accounts payable, not accounts receivable, are used as collateral in a financial agreement (Klapper, 2006).

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 suppliers, 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 (Liebl et al., 2016).

The scheme of reverse factoring is demonstrated in Fig. 3. As can be seen from the scheme, reverse factoring 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.

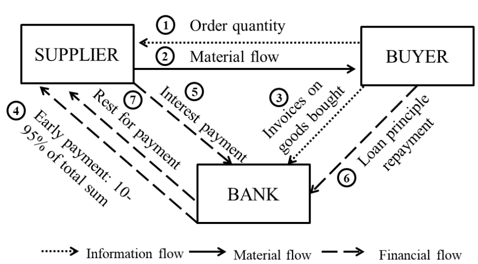

Fig. 3. Reverse factoring scheme. Source: de Boer et al. (2015)

3. Methodology for multi-objective working capital optimization

3.1. Multi-objective nature of working capital management in supply chains

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 Viskari and Kärri (2012, 2013), Pirttilä (2014). However, the problem of working capital management at the inter-organizational level was not considered as multi-objective by them. Along with this, the problem of working capital management in a single organization is most often viewed as multi-objective

(Knight, 1972; Mihir et al., 2009; Masri et al., 2018). In this regard, it can be concluded that working capital management in the supply chain should also have a multi-objective nature.

After the analysis of models for working capital management in the supply chain, it was decided that both the individual objectives of the participants of the supply chain and the common objective of the supply chain should form the basis for working capital management in the supply chain. Based on this, in this research, the following objectives will underlie the multi-objective collaborative working capital management at the inter-organizational level:

1. Limiting the individual cash conversion cycle of each member of the supply chain to the recommended industry-specific stability interval;
2. Minimizing the total financial costs of the supply chain on working capital and supply chain finance solutions.

Many real-world problems, such as 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***, as well as *multi-criteria*, *multi-performance* or *vector optimization problems* (Eschenauer et al., 1990). As a rule, multi-objective optimization problems imply several objective functions. All of them need to be optimized simultaneously, while respecting some constraints.

Depending on the type of preference articulation, multi-objective optimization can be carried out in different ways. To be more precise, there are different methods of multi-objective optimization, which can be divided into three groups: methods with a priori articulation of preferences, methods for a posteriori articulation of preferences and methods with no articulation of preferences (Odu & Charles-Owaba, 2013).

Based on the results of the study of the most famous methods with a priori articulation of preferences, ***goal programming*** was identified as the most suitable method for developing the base model 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. What is more, goal programming can be seen as the most practical method with a priori articulation of preferences that has a wide range of applications, including supply chain management. Arguments in favour of goal programming can also be found in academia. Since 1991, goal programming has been called one of the most powerful methods for dealing with multi-objective optimization problems (Min & Storbeck, 1991). In addition to it, it has also been recognized as the most widely used method of multi-objective optimization (Romero, 1991).

3.2. Goal programming as a method of multi-objective optimization

Goal programming is one the first methods which was expressly developed for multi-objective optimization (Charnes et al., 1955). Lee (1972), Ignizio (1976), Gass (1986) and many other researchers have been instrumental in the development of various approaches of goal programming. In order to define the theoretical framework of goal programming, it is necessary to introduce two terms – the aspiration level and the goal.

The ***aspiration level*** is usually referred to as the target value determined by the decision maker with regard to the objective function under consideration (Crowder, 1986). Along with this, the objective function together with its aspiration level is typically called the ***goal*** (Ogryczak & Lahoda, 1992). However, in goal programming, goals are usually formulated not in the form of "hard" constraints as in Formula 2.5, but in the form of ***"soft" constraints*** (Edelkamp & Schrödl, 2012). Such constraints are recognized as "soft" (flexible), since they do not have to be fulfilled exactly as "hard" or rigid (inflexible) constraints (Kliestik et al., 2015). Also known as *goal constraints*, they typically allow to determine how close a given solution comes to achieving stated goals (Goh, 2019).

In order to account for deviations from predefined aspiration levels, in "soft" constraints, ***deviation variables*** are used (Taha, 2017). Deviation variables can be of two types – negative and positive (Rifai, 1996). A *negative deviation variable* represents the amount of deviation for a given goal by which it is less than the aspiration level. To put it differently, it is the underachievement of the goal. A *positive deviation variable* represents the amount of deviation for a given goal by which it exceeds the aspiration level. In other words, it is the overachievement of the goal (Ignizio & Romero, 2003). As can be understood, deviation variables never take on negative values. What is more, one deviation variable in the "soft" constraint is always equal to zero (Orumie & Ebong, 2014).

Since the decision maker wants to achieve his or her goals as closely as possible, goal programming is concerned with minimizing ***goal deviation variables*** (Charnes & Cooper, 1961). The concept of the goal deviation variable can be easily illustrated with Table 1. If the goal type implies that anything below the aspiration level is unacceptable, the negative deviation variable becomes the goal deviation variable and has to be minimized. Exactly the opposite happens if the goal type implies that anything above the aspiration level is unacceptable. In this case, the goal deviation variable is the positive deviation variable, and it has to be minimized. There can also be the goal type that implies that anything below or above the aspiration level is unacceptable. In this incident, both negative and positive deviation variables become the unwanted ones and their sum has to be minimized. In goal programming, the goal is thought to be fully accomplished only if the goal deviation variable (the sum of the goal deviation variables) is minimized to zero (Orumie & Ebong, 2014).

Table 1. Goal types and goal deviation variables to be minimized

Goal type	Goal programming form	Goal deviation variable(s) to be minimized
$c_1x_1 + \ldots + c_kx_n \geq g$	$c_1x_1 + \ldots + c_kx_n + d^- - d^+ = g$	d^-
$c_1x_1 + \ldots + c_kx_n \leq g$	$c_1x_1 + \ldots + c_kx_n + d^- - d^+ = g$	d^+
$c_1x_1 + \ldots + c_kx_n = g$	$c_1x_1 + \ldots + c_kx_n + d^- - d^+ = g$	$d^- + d^+$

As goal programming involves several goals to achieve, there are several goal deviation variables that must be minimized. "The function that measures the degree of minimization of the goal deviation variables" is usually called the ***achievement function*** (Romero, 2004). However, depending on the goal programming approach, the achievement function can be structured in different ways. According to many researchers, one of the most popular goal programming approaches are weighted goal programming and pre-emptive goal programming (Schniederjans & Kwak, 1982; Tamiz & Jones, 1997; Charles et al., 2005). These approaches differ from each other, since they usually do not produce the same solution. However, neither approach is superior to the other, as each is designed to meet certain decision maker's preferences (Taha, 2017).

In *weighted goal programming*, the goal deviation variables are assigned positive weights according to their relative importance to the decision maker and then minimized as a sum (Tamiz et al., 1998). For instance, suppose that the decision maker has two goal deviation variables to be minimized – a negative one that corresponds to the first goal and a positive one that corresponds to the second goal. Then, the achievement function in weighted goal programming will be written as follows (7):

$$\min z = \min(w_1 d_1^- + w_2 d_2^+), \tag{7}$$

where w_1 is the weight assigned to the goal deviation variable corresponding to the first goal, d_1^- is the goal deviation variable corresponding to the first goal, w_2 is the weight assigned to the goal deviation variable corresponding to the second goal, d_2^+ is the goal deviation variable corresponding to the second goal.

In *pre-emptive goal programming*, the goal deviation variables are assigned into several priority levels and then minimized one by one, while respecting all constraints (Sherali, 1982). For example, suppose that the goal deviation variable corresponding to the first goal was assigned the priority 1 in the example above, while the goal deviation variable corresponding to the second goal – the priority 2. Then, the goal deviation variable corresponding to the first goal would be minimized first and only then the goal deviation variable corresponding to the second goal would be minimized. The fact is that minimizing the goal deviation variable in a higher priority level is infinitely more important than minimizing any goal deviation variables in lower priority levels. Therefore, lower priority minimizations never degrade minimal values reached by all higher priority level minimizations (Lee, 1972). In general form, the achievement function for such a case can be written as follows (8):

$$\min z = \min\{P_1 d_1^-, P_2 d_2^+\}, \tag{8}$$

where P_1 is the priority 1 assigned to the goal deviation variable corresponding to the first goal, P_2 is the priority 2 assigned to the goal deviation variable corresponding to the second goal.

In this paper, pre-emptive goal programming will be used for the base model for multi-objective collaborative working capital management in the supply chain. The point is that the decision maker usually has a natural ordering of goals in his or her mind rather than their relativistic comparison. What is more, in most cases, the decision maker is unable or even unwilling to assign weights that reflect the relative importance of goals in a particular situation (Tamiz & Jones, 2003). It is also worth noting that pre-emptive goal programming has historically been the most used approach of goal programming (Tamiz et al., 1995).

4. Base model for multi-objective collaborative working capital management

The base model for multi-objective collaborative working capital management based on the use of supply chain finance solutions (hereinafter referred to as the base model) will be developed. This model will be called base, since it will be designed for collaborative working capital management in a reduced version of the supply chain distribution network. By the *reduced version of the supply chain distribution network*, a three-stage supply chain consisting of a single supplier, distributor and single retailer will be understood. In real life, it is almost impossible to find such a supply chain operating on the market. However, in this case, it can be extremely useful for extrapolating the modeling results to a more complex supply chain consisting of multiple suppliers, distributor and multiple retailers (in other words, to a real-world supply chain distribution network).

The basis for the development of the base model will be the concept of the collaborative cash conversion cycle. According to this concept, the collaborative cash conversion cycle is usually defined as the sum of the individual cash conversion cycles of all members of the supply chain (Hofmann & Kotzab, 2010). The individual cash conversion cycle, in turn, is represented as the collection of three ratios: the days inventory outstanding plus the day's receivables outstanding less the days payable outstanding (Farris II & Hutchison, 2003). All this knowledge needs to be applied to the base model. As mentioned above, the base model will be designed for the three-stage supply chain, in which each stage will be represented by only one company. In order to denote each stage of the supply chain, the index l will be used. The values for this index will vary from 1 to 3 ($l = \overline{1,3}$), where 1 will mean the supplier stage, 2 – the distributor stage, 3 – the retailer stage. Taking into consideration all the above, the collaborative cash conversion cycle of the base model (9) based on the individual cash conversion cycles of all members of the three-stage supply chain (10) will be calculated as follows:

$$CCCC = \sum_{l=1}^{3} CCC_l \tag{9}$$

$$CCC_l = DIO_l + DRO_l - DPO_l, \tag{10}$$

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

As discussed earlier, the adoption of supply chain finance solutions usually has a significant impact on the components of the collaborative cash conversion cycle. For example, the days receivables outstanding and the days payable outstanding stop being equal in each pair of the supply chain due to the adoption of supply chain finance solutions. However, at first, it will be fundamental to determine which supply chain finance solutions will be used in the base model. Previously, it was identified that inventory financing and reverse factoring give an opportunity to manage and improve all the components of the collaborative cash conversion cycle. Therefore, inventory financing and reverse factoring will be adopted in the three-stage supply chain consisting of a single supplier, distributor and single retailer. Their impact on the components of the collaborative cash conversion cycle will be accounted for further down the line.

Inventory financing will be the first supply chain finance solution to consider in the base model. However, before modeling its adoption in the supplier-distributor pair, it will be necessary to refer to the scheme of inventory financing itself. According to the scheme, the logistics service provider will buy only a portion of the goods produced by the supplier, while the other portion of the goods will be delivered by the supplier directly to the distributor. Along with this, the logistics service provider will need 2 days after production to take the goods from the supplier, while the goods obtained from the logistics service provider will be stored by the distributor for no more than 1 day (Gelsomino & Steeman, 2017). In this model, it will be assumed that at least 2 days will be needed for the distributor to sell the goods further down the supply chain. In relation to this, the days inventory outstanding at the supplier stage (11) and the days inventory outstanding at the distributor stage (12) will be calculated in the following way:

$$DIO_1 = x \times 2 + (1 - x) \times DIO_1^0, \quad (11)$$

$$DIO_2 = x \times 2 + (1 - x) \times DIO_2^0, \quad (12)$$

where DIO_1 is the days inventory outstanding at the supplier stage, x is the share of goods delivery from the supplier to the distributor through the logistics service provider, $(1-x)$ is the share of goods delivery from the supplier directly to the distributor, DIO_1^0 is the days inventory outstanding at the supplier stage before optimization, DIO_2 is the days inventory outstanding at the distributor stage, DIO_2^0 is the days inventory outstanding at the distributor stage before optimization.

The days inventory outstanding at the supplier stage and the days inventory outstanding at the distributor stage will not be the only components of the collaborative cash conversion cycle that will be affected by inventory financing. The impact of inventory financing on the days receivables outstanding at the supplier stage and the days payable outstanding at the distributor stage should also be taken into account. Here it will be essential to remember that the logistics service provider will need 10 days to pay for the goods to the supplier, while the distributor 30 days for the goods purchased from the logistics service provider. Reverse factoring will have an even greater impact on the day's receivables outstanding at the supplier stage and the days payable outstanding at the distributor stage. Like inventory financing, reverse factoring will imply that the bank will provide only a portion of the distributor's payment to the supplier, while the remainder of the payment will be covered by the distributor later in accordance with the payment term specified in the contract with the supplier. However, if the duration of the early payment from the bank will be known and will be equal to 3 days, the payment term for the distributor will be considered as a decision variable in the base model. Therefore, its value will need to be found during optimization. All in all, being affected by the shares of using inventory financing and reverse factoring and the conditions that these supply chain finance solutions require, the days receivables outstanding at the supplier stage (13) and the days payable outstanding at the distributor stage (14) will be expressed as the following equations:

$$DRO_1 = x \times \left(x \times 10 + (1 - x) \times DRO_1^0\right) + (1 - x) \times (y \times 3 + (1 - y) \times P_2), \quad (13)$$

$$DPO_2 = x \times \left(x \times 30 + (1 - x) \times DPO_2^0\right) + (1 - x) \times P_2, \quad (14)$$

where DRO_1 is the days receivables outstanding at the supplier stage, DRO_1^0 is the days receivables outstanding at the supplier stage before optimization, y is the share of the early payment from the bank to the supplier on behalf of the distributor, $(1-y)$ is the share of the remaining payment from the distributor to the supplier, P_2 is the payment term for the distributor specified in the reverse factoring contract with the supplier, DPO_2 is the days payable outstanding at the distributor stage, DPO_2^0 is the days payable outstanding at the distributor stage before optimization.

After modeling the adoption of inventory financing and reverse factoring in the supplier-distributor pair, this procedure should also be performed for the distributor-retailer pair. However, not all of the aforementioned supply chain finance solutions will be adopted in the distributor-retailer pair. To be more specific, it will not make sense to adopt inventory financing there. The point is that the demand from a large number of end customers usually arises unevenly, which makes it almost impossible for the retailer to order goods from the logistics service provider at a certain point of time. As a result, the days receivables outstanding at the distributor stage, as well as the days inventory outstanding and the days payable outstanding at the retailer stage will not be affected by inventory financing in the base model. In particular, the days receivables outstanding at the distributor stage and the days payable outstanding at the retailer stage will only be influenced by reverse factoring, the adoption of which has already been modeled earlier. Similarly, the payment term for the retailer specified in the reverse factoring contract with the distributor will be considered as a decision variable in the base model. In this way, the days inventory outstanding at the retailer stage (15), the days receivables outstanding at the distributor stage (16) and the days payable outstanding at the retailer stage (17) will be calculated as follows:

$$DIO_3 = DIO_3^0, \tag{15}$$

$$DRO_2 = z \times 3 + (1 - z) \times P_3, \tag{16}$$

$$DPO_3 = P_3, \tag{17}$$

where DIO_3 is the days inventory outstanding at the retailer stage, DIO_3^0 is the days inventory outstanding at the retailer stage before optimization, DRO_2 is the days receivables outstanding at the distributor stage, z is the share of the early payment from the bank to the distributor on behalf of the retailer, $(1 - z)$ is the share of the remaining payment from the retailer to the distributor, P_3 is the payment term for the retailer specified in the reverse factoring contract with the distributor, DPO_3 is the days payable outstanding at the retailer stage.

As can be noted, the only components of the collaborative cash conversion cycle that have not been considered up to this point are the days payable outstanding at the supplier stage and the days receivables outstanding at the retailer stage. The fact is that managing and improving these components of the collaborative cash conversion cycle requires the participation of contractors outside the specified supply chain perimeter. Due to this, the base model will assume that companies in the supply chain will pursue an inward-oriented approach to optimization. In other words, members of the supply chain will restrain from exploiting the capacities of contractors outside the specified supply chain perimeter. As such, the values of the days payable outstanding at the supplier stage (18) and the days receivables outstanding at the retailer stage (19) after optimization will be equal to their values before optimization:

$$DPO_1 = DPO_1^0, \tag{18}$$

$$DRO_3 = DRO_3^0, \tag{19}$$

where DPO_1 is the days payable outstanding at the supplier stage, DPO_1^0 is the days payable outstanding at the supplier stage before optimization, DRO_3 is the days receivables outstanding at the retailer stage, DRO_3^0 is the days receivables outstanding at the retailer stage before optimization.

Concluding the overview of supply chain finance solutions' influence on the components of the collaborative cash conversion cycle, it should be highlighted separately that the share of goods delivery from the supplier to the distributor through the logistics service provider (x), the share of the early payment from the bank to the supplier on behalf of the distributor (y) and the share of the early payment from the bank to the distributor on behalf of the retailer (z) will be considered as decision variables in the base model. However, depending on the type of supply chain finance solution, each variable will have a different range of possible values. Since supplier can either deliver the goods to the distributor on his own or take full advantage of the services of the logistics service provider, the possible values for the share of goods delivery from the supplier to the distributor through the logistics service provider may vary from 0 to 1. Range of possible values for the share of the early payment from the bank to the supplier on behalf of the distributor and the share of the early payment from the bank to the distributor on behalf of the retailer will be even smaller. The point is that the share of the early payment in the reverse factoring scheme usually varies from 10% to 95% of the entire delivery. Accordingly, the first "hard" constraints of the base model will be formulated as follows (20, 21, 22):

$$0 \leq x \leq 1, \tag{20}$$

$$0,1 \leq y \leq 0,95, \tag{21}$$

$$0,1 \leq z \leq 0,95. \tag{22}$$

It will be impossible not to emphasize that the logistics service provider and the bank mentioned above usually charge interest for their services. Thus, the financial costs on supply chain finance solutions should also be taken into account in the base model. First of all, it will be necessary to determine which participants of the supply chain will bury the financial costs on specific supply chain finance solutions. According to the scheme of inventory financing, the interest to the logistics service provider is usually paid by the buyer. Consequently, the financial costs on inventory financing will be imposed on the distributor. In the scheme of reverse factoring, the interest to the bank is always covered by the supplier. Hence, in the supplier-distributor pair, the financial costs on reverse factoring will be buried by the supplier, while in the distributor-retailer pair – by the distributor. The size of the financial costs on supply chain finance solutions for these members of the supply chain will be influenced by several factors (Pfohl & Gomm, 2009). The first factor will be the amount of short-term asset (inventory or accounts receivable) to be financed by the particular intermediary. Another factor will be the time for which the financing is necessary. The last factor will be the cost of financing set by the intermediary. With regard to all of the above, the financial costs on inventory financing at the distributor stage (23), the financial costs on reverse factoring at the supplier stage (24) and the financial costs on reverse factoring at the distributor stage (25) will be computed in the following way:

$$FC\_IF_2 = INV_1^0 \times x \times \frac{t}{365} \times i_2, t = DIO_2^0 - DIO_2, \tag{23}$$

$$FC\_RF_1 = AR_1^0 \times y \times \frac{P_2}{365} \times r_1, \tag{24}$$

$$FC\_RF_2 = AR_2^0 \times z \times \frac{P_3}{365} \times r_2, \tag{25}$$

where FC_IF_2 is the financial costs on inventory financing at the distributor stage, INV_1^0 is the level of inventory at the supplier stage before optimization, t is the number of days that the logistics service provider stores the goods purchased from the supplier before the delivery to the distributor (the duration of the inventory financing contract), i_2 is the inventory financing rate for the distributor paired with the supplier, FC_RF_1 is the financial costs on reverse factoring at the supplier stage, AR_1^0 is the level of accounts receivable at the supplier stage before optimization, r_1 is the reverse factoring rate for the supplier 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, r_2 is the reverse factoring rate for the distributor paired with the retailer.

As can be seen, in the base model, there will be no costs on supply chain finance solutions at the retailer stage. But this does not mean that the retailer will not bear any financial costs at all. The fact is that each participant of the three-stage supply chain will bear the financial costs associated with working capital. As discussed earlier, 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). In relation to this, they are typically determined by the amount of capital tied up in the organization, the cycle time, as well as the weighted average cost of capital (26). As a result, the financial costs of each member of the supply chain in the base model will necessarily include the financial costs on working capital. In addition to this, they may include the financial costs on supply chain finance solutions, but only if the participant of the supply chain is obliged to pay interest to one or more intermediaries. In more detail, the financial costs at the supplier stage (27), the financial costs at the distributor stage (28) and the financial costs at the retailer stage (29) are presented below:

$$FC\_WC_l = INV_l \times \left[(1+c_l)^{\frac{DIO_l}{365}} - 1\right] + \\ + AR_l \times \left[(1+c_l)^{\frac{DRO_l}{365}} - 1\right] - AP_l \times \left[(1+c_l)^{\frac{DPO_l}{365}} - 1\right], l = \overline{1,3}, \tag{26}$$

$$FC_1 = FC\_WC_1 + FC\_RF_1, \tag{27}$$

$$FC_2 = FC\_WC_2 + FC\_IF_2 + FC\_RF_2, \tag{28}$$

$$FC_3 = FC\_WC_3, \tag{29}$$

where FC_WC_l is the financial costs on working capital for company at stage l, INV_l is the level of inventory for company at stage l, c_l is the cost of capital for company at stage l, AR_l is the level of accounts receivable for company at stage l, AP_l is the level of accounts payable for company at stage l, FC_1 is the financial costs at the supplier stage, FC_WC_1 is the financial costs on working capital at the supplier 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 is the financial costs at the retailer stage, FC_WC_3 is the financial costs on working capital at the retailer stage.

It will be also essential to state that the financial costs at each stage of the supply chain will be subject to "hard" constraints in the base model. The fact is that in most cases, participants of the supply chain will not be ready to engage in collaborative working capital management based on the use of supply chain finance solutions, if they do not see any tangible benefits for themselves, for example, the reduction of the financial costs, which is mainly possible due to lower financial costs on working capital. They also claim that there will be no point in collaborative working capital management based on the use of supply chain finance solutions if the financial costs of companies involved in the supply chain become worse than when they operated independently. In this regard, the base model will assume that members of the supply chain will engage in collaborative working capital management based on the use of supply chain finance solutions only if the values of their financial costs after optimization will not exceed the values of their financial costs before optimization (30):

$$FC_l \leq FC_l^0, l = \overline{1,3}, \tag{30}$$

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

As can be seen from the above, companies participating 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. In relation to this, at some point, the overall performance of the supply chain may suffer a lot. In order to avoid this, one of the goals of the base model will be to reduce the total financial costs of the supply chain by $\alpha\%$. However, at first, the total financial costs of the supply chain should be determined. Following the concept of the collaborative cash conversion cycle, the total financial costs of the supply chain can be recognized as the sum of the individual financial costs of all members of the supply chain. Therefore, the total financial costs of the supply chain will be calculated as follows (31):

$$TFC = \sum_{l=1}^{3} FC_l, \tag{31}$$

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

Since collaborative working capital management in the supply chain has a multi-objective nature, reducing the total financial costs of the supply chain by $\alpha\%$ will not be the only goal to be achieved in the base model. Along with this, the base model will also imply that every participant 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 & Petrova, 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).

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

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

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

Goal 3: To limit the cash conversion cycle of the distributor to the recommended industry-specific stability interval.

Goal 4: To limit the cash conversion cycle of the retailer to the recommended industry-specific stability interval.

Once the goals have been stated, the development of the base model can be completed. First of all, it should be claimed that the base model will imply that the goals listed above may sometimes not be fully achieved. As a result, positive and negative deviation variables will be incorporated in the base model in order to formulate all the goals in the form of "soft" constraints. In addition to this, the base model will assume that goals, if not fully achievable, should be achieved as closely as possible. Therefore, based on the initial goal type, the unwanted deviation variable(s) to be minimized will be determined for each of the goals. The results of formulating the "soft" constraints and determining the unwanted deviation variable(s) for the achievement function of the base model are presented in Table 2. Since the first goal in its initial form implies that the financial costs of the supply chain above the aspiration level are unacceptable, the positive deviation variable was determined as the unwanted deviation variable for it. For each of the remaining three goals, the situation was slightly different. To be more concrete, the negative deviation variable was identified 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, it was decided to minimize the sum of the unwanted deviation variables for each of the three goals in order to achieve them as closely as possible.

5. Conclusion

Many real-world problems, such as 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 (Ramos et al., 2018).

In this paper, it is assumed that, in each case 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 i, 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.

After that, two models – base and general – for multi-objective collaborative working capital management based on the use of supply chain finance solutions were developed. 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

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

Goal №	**Goal type**	**Goal programming form**	**Goal deviation variable(s) to be minimized**
1	$TFC \le TFC^0 \times (1-\alpha)$	$TFC + d_1^- - d_1^+ = TFC^0 \times (1-\alpha)$	d_1^+
2	$CCC_1 \ge CCC_{1\_low}$	$CCC_1 + d_{2.1}^- - d_{2.1}^+ = CCC_{1\_low}$	$d_{2.1}^- + d_{2.2}^+$
	$CCC_1 \le CCC_{1\_up}$	$CCC_1 + d_{2.2}^- - d_{2.2}^+ = CCC_{1\_up}$	
3	$CCC_2 \ge CCC_{2\_low}$	$CCC_2 + d_{3.1}^- - d_{3.1}^+ = CCC_{2\_low}$	$d_{3.1}^- + d_{3.2}^+$
	$CCC_2 \le CCC_{2\_up}$	$CCC_2 + d_{3.2}^- - d_{3.2}^+ = CCC_{2\_up}$	
4	$CCC_3 \ge CCC_{3\_low}$	$CCC_3 + d_{4.1}^- - d_{4.1}^+ = CCC_{3\_low}$	$d_{4.1}^- + d_{4.2}^+$
	$CCC_3 \le CCC_{3\_up}$	$CCC_3 + d_{4.2}^- - d_{4.2}^+ = CCC_{3\_up}$	

TFC^0 is the total financial costs of the supply chain before optimization, α 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 is the cash conversion cycle at the supplier stage, CCC_{1_low} is the lower limit of the cash conversion cycle at the supplier stage, $d_{2.1}^-$ 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} is the upper limit of the cash conversion cycle at the supplier stage, $d_{2.2}^-$ is the amount by which goal 2.2 is underachieved, $d_{2.2}^+$ is the amount by which goal 2.2 is overachieved, CCC_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, $d_{3.1}^-$ is the amount by which goal 3.1 is underachieved, $d_{3.1}^+$ is the amount by which goal 3.1 is overachieved, CCC_{2_up} is the upper limit of the cash conversion cycle at the distributor stage, $d_{3.2}^-$ is the amount by which goal 3.2 is underachieved, $d_{3.2}^+$ is the amount by which goal 3.2 is overachieved, CCC_3 is the cash conversion cycle at the retailer stage, CCC_{3_low} is the lower limit of the cash conversion cycle at the retailer stage, $d_{4.1}^-$ is the amount by which goal 4.1 is underachieved, $d_{4.1}^+$ is the amount by which goal 4.1 is overachieved, CCC_{3_up} is the upper limit of the cash conversion cycle at the retailer stage, $d_{4.2}^-$ is the amount by which goal 4.2 is underachieved, $d_{4.2}^+$ is the amount by which goal 4.2 is overachieved.

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.

In general, both models 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.

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