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Supply Chain Finance Solutions in Joint Working Capital Management *

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Abstract The research is devoted to joint working capital management in supply chains aiming to improve joint working capital management methods through minimization of financial supply chain costs on working capital using Supply Chain Finance (SCF) Solutions. Though SCF applicability in Financial Supply Chain management has recently been studied to relieve access to capital sources, managerial perspective of SCF solutions is still uninvestigated as well as few other areas. The research suggests a managerial algorithm that contains four developed models: the model of Collaborative cash conversion cycle two models of SCF solutions and the model of Joint Working Capital optimization. The models imply using such SCF solutions as Factoring, Reverse Factoring and Inventory Financing to improve Joint Working Capital in terms of costs on it and liquidity of both supply chain members and entire chain, providing the optimal conditions of SCF solutions. Quantitative optimization with SCF solutions demonstrates on the cases of supply chains the improvement of financial position and liquidity of all chain members. The research has a potential to de applied in businesses since the algorithm represents a comprehensive managerial tool for Joint Working capital management in supply chains. It might be used to achieve optimal cash conversion cycle values for minimal supply chain costs on working capital constrained by liquidity and profitability target levels.

Keywords: Collaborative Cash Conversion Cycle, Supply Chain Finance, Working Capital Management, Supply Chain Finance Solutions, Reverse Factoring, Inventory Financing.

1. Introduction

The recent economic downturn caused considerable reduction in granting of new loans, with a significant increase in the cost of corporate borrowing. Consequently, it is becoming more difficult for the companies all over the globe to find sources for financing their operational activity facing such problems as difficulties with access to capital, limited financial infrastructure, and legal regulatory and accounting uncertainties (ACCA, 2017). For this reason, companies aim to apply different methods, which might be helpful for effective working capital management in order to release more cash tied up in it, e.g. in inventory and accounts receivable.

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Since no company works individually on a market, it is reasonable to consider a whole supply chain. Whereas a lot of attention in the field of supply chain management is paid to studying inventory management, transportation costs or costs associated with procurement procedures, a few research papers, however, are focused on the flows of money (Kouvelis et al., 2006). Along with that, for fast changing business environment that money flows are of the same importance as the management of flows of goods Gupta and Dutta (2011). Consequently, working capital management has become a crucially important term in financial supply chain management gaining a lot of attention from the academia side.

Managing working capital and liquidity is an essential part of companies' activity because the majority of their daily operations depends on and is determined by working capital, in such a manner influencing companies' results. Considering a supply chain the situation is no way different: all members of a supply chain strive to their individual higher liquidity, individual lower costs on working capital and maximal profit. At the same time, they all aim at higher liquidity, lower costs on working capital and maximal profit of a whole supply chain, which they operate in.

With the reference to the foregoing, it is worth studying different approaches to support operational activity of the supply chain members through improving its working capital. According to Caniato et al. (2016) there is a lack of methodology to identify proper way of working capital management in supply chains in practice. In this regard, new tool of working capital management – supply chain finance, which allows companies to finance its operational activity under more attractive conditions and, therefore, may be used to optimize working capital in supply chain is going to be studied. Thus, the research gap is expressed in uninvestigated managerial perspective of supply chain finance solutions adoption and in a lack of understanding which particular solutions may be applied and how in order to improve working capital in a supply chain. Therefore, research goal is to improve joint working capital management methods through minimization of financial supply chain costs using supply chain finance solutions. Research Objectives are as follows:

- To identify suitable supply chain finance solutions based on literature review;
- To establish the model of collaborative cash conversion cycle;
- To model supply chain finance solutions;
- To develop the optimization model of joint working capital in supply chain;
- To verify the developed models using case study analysis.

The subject of the master thesis is working capital of a supply chain. It is defined as the sum of individual companies' working capital, which are included in one supply chain. The object of the research is two-stage supply chain that includes either the relations between supplier and manufacturer or those of manufacturer and distributor. Being characterized by bilateral relations between partners, this type of supply chain allows to assume high level of coordination that is crucially important for the present study.

The method used in the research is optimization modeling. Besides, the results of methodology developed are verified by case study method. Cases are presented by six two-stage supply chains taken from three different industries: Automotive, ICT, and FMCG sector.

The paper consists of the following parts: three chapters, introduction, conclusion and bibliography.

2. Working Capital Management in Supply Chain: Theoretical Review and Practice

Concept of working capital management applied in supply chain management has gained a lot of attention recently and became fundamental in financial supply chain management. One of the main reasons to that is the problem of liquidity and free access to cash. While investigating the correlation between proper management of supply chain and financial indicators of companies involved in a chain Lewinski and Wassenhove (2003) claim that growth rate of market capitalization is higher for companies which pay a lot of attention to supply chain management. However, following this reasoning it should be taken into account that supply chain management is based on establishment steady partnership relations. Thus, improvements (especially in the field of working capital management) may be achieved entirely through cooperative efforts when all members of supply chain are interested not only in personal short-term benefits but also in final result of a supply chain activity. Otherwise, short term financial improvements are achieved through displacement of risks and costs to other members of a chain; e.g. such practices as extreme extension of payment terms for accounts payable, enforced recovery of accounts receivables and poor inventory management are used.

2.1. Supply Chain Management Concept

For the purpose of the research we introduce widely used definition of SCM given by Council of supply chain management professional. "SCM encompasses the planning and management of all activities involved in sourcing and procurement, conversion, and all logistics management activities, it also includes coordination and collaboration with channel partners: suppliers, intermediaries, third party service providers, and customers. In essence, supply chain management integrates supply and demand management within and across companies." (SCSMP, 2019)

Mentzer (2001) proposes three main types of SC structure which differ in the complexity (Figure 1). "Direct SC" is the most common structure which implies 3 stages: supplier, manufacturer and customer, and flows of different nature between them: material (products), financial and/or informational. This structure is basic for its simplicity and fundamental idea at the same time. The next level of complexity of SC is "Extended SC". Two other stages are assumed: supplier of an already existing supplier and customer of an already existing customer are added; therefore, "Extended SC" is 5-stage supply chain. The supply chain on the bottom "Ultimate SC" is one of maximal complexity. It shows some of functions, which are to perform within SC, being accomplished by third party firms. In this example there are three types of such firms for different reasons. Relationship between two entities is supported by a financial provider which offers financial solutions and support assuming financial risks. Also there is a 3PL logistics provider (logistics service operator) which takes responsibilities of warehousing, transportation and other logistics activities. Finally, a market research firm collects and analyzes information about ultimate customer to provide the whole SC with customers' preferences and expectations.

As it follows from SCM definition and types of SC structures proposed by Mentzer (2001), SCM is about coordination of various flows between entities within a chain. Pfol & Gomm (2009) underline the importance to recognize the effects on

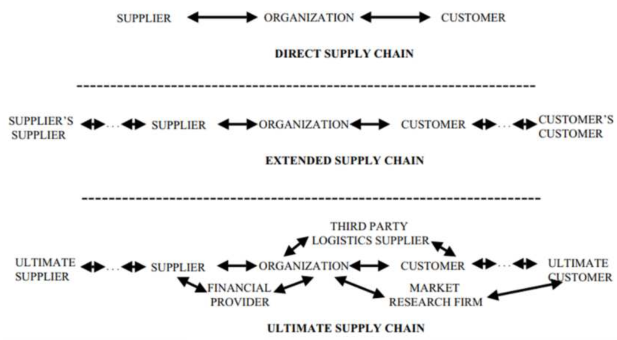

Fig. 1. Supply chain structures. Source: Mentzer, (2001)

financial performance and costs which originat through considering supply chain as an entire entity but not as separate parts.

Figure 2 presents the organization of material and financial flows on the example of 3-stage SC. Depending on the type of flow not only material, but also financial supply chain may be considered for researches and practical improvement. In addition, Gupta and Dutta (2011) identified three main types of flow in SC: downstream flow of goods, upstream financial flow and flow of information which is upstream as well as downstream.

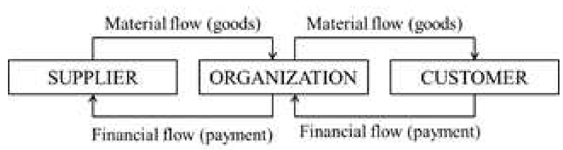

Fig. 2. Flows in SC. Source: created by the author

In a material SC the study subject is the processes of physical movement of goods through the chain (shipment, transportation, inventory management, etc.) whereas in a financial supply chain – financial flows accompanying these materials flows. In material SC it begins with sourcing of materials or components and ends with bringing finished goods to a customer. As no company plays individually at the market, it is assumed that almost all the firms have suppliers as well as customers; hence, there are financial flows between them tying physical operations.

We define FSCM following of Wuttke et. al (2013) as optimized planning and control of financial flows in SC for effective management of material flows. Two aspects of the connotation are of prime importance: focus on the integration of the managerial processes of finance and goods in SC and interdisciplinary approach to definition.

2.2. Coordination in Supply Chain to Maximize Profit

On the early stages of SCM formation many authors emphasized that SCM is a management philosophy according to which SC is considered as an entity rather than a number of single firms involved (Ellram and Cooper, 1990; Tyndall et al. 1998).

Following this philosophy and adopting it to business reality to establish supply chain management several activities are to be performed. Mentzer (2001) develops a list of such activities, which includes but is not limited to integrated behavior, building and maintaining partnership, information sharing, and cooperation. The latter empowers us to assume integrated reasoning and unity of purposes and efforts within a supply chain.

Anderson and Narus (1990) define cooperation as some coordinated activities (similar or complemented), which are performed by supply chain partners aiming at "superior mutual outcome". In other words, the whole result of a supply chain is greater than the sum of the results of single firms within SC. Existing in different forms such as joint planning and control, design of quality control, delivery and payment systems, joint work of product development, which compose three key elements: information systems, inventory management and supply chain relationships, cooperation pursue supply chain cost reduction and customer service level improvement mainly. (Power, 2005).

Taken into consideration that firms included in supply chain present single individual organizations, they are highly motivated to improve their own results, therefore, the results of the whole supply chain are not their first priority and whole performance of SC may suffer. In this regard, one of the most important tasks for SCM is to elaborate a tool for motivating all independent members of a chain in order to optimize whole supply chain performance through coordination. (Labiad et al., 2012). Since decentralized supply chains, which are characterized by many independent decision makers with different objectives in a chain, are widely known in practice, the mechanism of coordination is vital to motivate them for joint work to increase total performance. According to Giannoccaro et al. (2004) among coordination mechanisms as well as tools of motivating supply chain members contracts are essential instruments which are in general use in practice over the decades and may be tailored for different industries and purposes.

Supply chain contracts are usually to regulate bilateral business relations, e.g. between manufacturer and its supplier or between manufacturer and its distributor. There terms of payment, terms of delivery, obligations of parties concerned and so on are determined. However, in the recent years the coordination theories in SC and their application to achieve common goals have got widespread (Taleizadeh et al., 2017, Sarkar et al, 2018). It is noteworthy, that the majority of these coordination theories are based on different types of supply chain contracts. There are many contracts forms used in practice and studied by researchers which are effective to employ in compliance with different issues to be regulated or improved. Thus, Ladiad et al. (2012) divided coordinating contracts into two main groups: Quantity dependent (Quantity Discounts, Quantity flexibility contracts) and Price dependent (Wholesale price, Buyback or Return policies, Revenue Sharing, Sales rebate, Quantity Discount). Furthermore, Taleizadeh et al. (2018) adds one more group of incentive contracts which includes Delay in payment and Market segmentation contracts. However, the scope of this paper is restricted to revenue sharing contracts, because by definition it ensures motivation of all supply chain member for joint actions to maximize common profit.

Under revenue sharing contract it is determined that one agent shares with another one a given percentage of the generated revenue often in exchange of lower prices (Govindan & Popiuc, 2011). For example, a distributor buys some goods from a manufacturer and has to pay for them; however, in these settings a distributor also pays additionally to manufacturer predefined in the contract percentage of revenue. On the example of 3-stage SC Giannoccaro & Pontrandolfo (2004) proved that this type of contracts allows to coordinate supply chain and through profit allocation improve financial results not only of single members of a chain but also their common profit.

Maximization of profit generally means minimization of costs, and that is the key factor in today's highly competitive environment, consequently, one of the most important goals of any organization or supply chain. Aiming at increasing profitability companies start to apply different strategies in marketing, manufacturing, inventory management, expansion of activities etc., or they look for different possibilities for cost reduction. That is why, being motivated to maximize total profit of a supply chain, its members can find such a possibility in the field of working capital management, in particular in financial costs associated with working capital. Thus, the next paragraph of the paper is devoted to discussion of joint working capital in supply chains.

2.3. Costs on Working Capital and Cash Conversion Cycle: from a Single Company's Perspective to a Supply Chain.

Pirttilä (2014) defines working capital (WC) as "the capital of a business which is used in its day-to-day trading operations, calculated as current assets less current liabilities". Using another specification WC may be identified as "amount of cash that is tied up at each stage of SC" (Viskari, 2012). Basically, WC is financial support of day-to-day company's activity.

In the literature a distinction is made between two main perspectives of working capital which are different in the interpretation. The first one is defined by Jones (2006) as "the ability of the company to cover its short-term debt with current assets" and may be evaluated as follows:

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

Jones (2006) includes cash, total inventory, accounts receivable, securities and cash equivalents in current assets, and, on the other side, current liabilities comprise of accounts payable, accruals, notes payable and short-term debt.

Another perspective of working capital is studied by Pirttilä (2014). Consisting of the total level of inventory, accounts receivable (AR) and accounts payable (AP), which are often called in the literature "operation components of WC" (Monto, 2013), WC is defined as the following equation (Pirttilä, 2014):

$$Working\ capital = Inventory + AR - AP. \tag{2}$$

WC may be either positive or negative. Negative value of WC indicates inability to pay off short-term debt (Talonpoika & Kärri, 2014); whereas positive value of working capital is indicative of sufficient liquidity meaning that the amount of cash which is going to be got by the company during the next year is larger than liabilities to cover. (Monto, 2013). In other words, level of inventory kept plus AR to be received is sufficient to cover liabilities. However, keeping high level of inventory is associated with high storage costs, moreover, inventory is not cash clearly, it is rather cash tied up in physical inventory. Hence, there is a tradeoff between low and high levels of inventory to keep. Lack of well-regulated inventory management may negatively affect financial health of a company and supply chain as well, especially its working capital profitability (Nemtajela, 2016). According to Kumar (2017) high level of coordination in supply chain may insure achievement of well-established inventory management. Motivation to increase the final results of a supply chain allows to make mutual decisions, share necessary information and plan jointly, as a result, to decrease inventory levels. (Kumar, 2017)

To measure and control the effectiveness of working capital management Richards and Laughlin (1980) introduced the operational approach to evaluate working capital on the basis of relative ratios - time-based measure of cash conversion cycle (CCC). According to the authors CCC can be defined as follows: "The CCC, 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 cash inflow from a firm's regular course of operations" (Richards, Laughlin, 1980). Now many researches agree that CCC is an appropriate dimension for working capital management which presents the time interval (in days) between a firm expands money for purchase of goods (or build up inventory) and it recovers cash from selling the goods (inventory) (Yazdanfar & Ohman, 2014). From a different angle, CCC shows the number of days when capital is tied-up within business activities of a firm (Wang, 2019). In any respect, CCC consists of three sub-cycles: the cycle time of inventories (DIO) plus the cycle time of accounts receivable (DRO) minus the cycle time of accounts payable (DPO). Thus, the following equation evaluated CCC as:

$$CCC = DIO + DRO - DPO. \tag{3}$$

CCC can be either negative or positive. Negative CCC means that a company keep low level of inventory and/or recover cash from its customers for goods sold before it has to pay off its AP (relevant to prepayment scheme). Many researches hold to an opinion that the lower CCC is, the better a company can manage its cash, although extremely low CCC can indicate the problems with each component of CCC. At the same time, reasonably low CCC implies low costs to finance its business operation or, said differently, low costs on working capital (Tangsucheeva & Prabhu, 2013). In these circumstances, the problem of identification an optimum level of CCC occurs with an effect on profitability and liquidity level of any company.

Hofmann & Kotzab (2010) prove that the minimization of the CCC cycle from a single company perspective does not add value to all members in a supply chain. They propose to apply collaborative approaches because there is a huge difference between CCC in a single company and CCC of a whole supply chain, and improvements of working capital using pushing methods such as accounts payable extensions to suppliers or enforcement the collection of money from customers are inefficient practices which may result in higher supply-based risks or even loss of financial stability.

The authors for the first time ever introduce the collaborative cash conversion cycle (CCCC) model. They define CCCC as a sum of the cash conversion cycles of all exchange partners (members of supply chain). They conclude that reduction of cash conversion cycle for a single company in a chain (possibly due to the expense of suppliers or customers) does not add value to other SC partners. Thus, the optimal collaborative CCC as "the one that minimizes the cost of tied up capital while maximizing the gains of received cash across all collaboration members" (Hofmann and Kotzab, 2010).

Although CCCC is defined as a sum of CCC of all partners in SC, it is assumed that in collaborative SC internal payments between partners do not influence CCCC, and consequently, may be neglected (Hofmann and Kotzab, 2010). Therefore, CCCC for the 3-stage supply chain is defined by the following equation:

$$CCC = DIO_1 + DIO_2 + DIO_3 + DRO_3 - DPO_1. \tag{4}$$

To elicit total financial supply chain costs on working capital we introduce the formula of financial costs on working capital for a single company. Viskari et al. (2013) define the costs as the following equation:

$$FC = INV* \left[(1+c)^{\frac{DIO}{365}} - 1\right] + AR* \left[(1+c)^{\frac{DRO}{365}} - 1\right] - AP* [(1+c)^{\frac{DPO}{365}} - 1]. \tag{5}$$

where c – annual cost of capital.

Following Hofmann and Kotzab (2010) and considering CCCC as a sum of CCC of all the members of supply chain, we define total financial supply chain costs on working capital as follows (assuming 3-stage supply chain with single company on each stage):

$$TFC = \sum_{l=1}^{3} FC_l, \tag{6}$$

where l –the stage of SC.

2.4. Cash Conversion Cycle and Profitability

Since it is proved in a large number of researches that WCM influences organization's profitability and liquidity, decisions about it are crucial for business. Relationship between CCC and profitability of organization is important. Although some authors claim that minimal length of CCC leads to higher profitability (e.g Muscettola, 2014; Zeidan and Shapir, 2017), some researchers study optimal length of CCC and values of its components to achieve greater financial results and company's value (e.g. Garanina & Petrova, 2015; Shah et al., 2018). According to Pavlis et al. (2018) apparent contradiction between the results may be explained as follows: increase in CCC implies increase in DIO and DRO, which means, thereby, increase in costs on working capital maintenance. Thus, the longer the CCC is, the higher financial costs on working capital are, and the lower profitability of a firm is.

When considering association between WC and profitability the problem of liquidity-profitability tradeoff occurs. Banos-Caballero (2012) reports U-shaped relationship between these variables analyzing the sample of non-financial firms. The optimal amount of WC should be found in order to improve profitability.

In this regard, the research of Garanina and Petrova (2015) proves that working capital determines current company's operations and, as a consequence, influences the financial result of a business. Also the research justifies that the use of incorrect working capital management models may lead to return ratios of an organizationdecline. Thus, the authors in the study answers the major question: "what volume of working capital does a company need to ensure effectiveness, on the one hand, and maintain its solvency, on the other" (Garanina & Petrova, 2015); aiming at identification of what influence current liquidity ratio and cash conversion cycle has on the return on net operating assets (RNOA's) of the Russian companies. As one of the main results of the research the authors confirm that cash conversion cycle is in direct relations with company's current ratio. Moreover, with the help of regression analysis optimum values of cash conversion cycle to maintain required level of liquidity (current ratio) were calculated. Thus, to reach maximal rate of return it is necessary that the target values of the cash conversion cycle should be in the borders of the recommended intervals of values.

2.5. Supply Chain Finance Solutions: Concept and Practical Usage

No need to prove that supply chain management has high influence on financial performance of a company (Hofmann and Kotzab, 2010). However, as of now financial decision making and supply chain management are important to be integrated because of many reasons while the weightiest argument in its favor is that the value of a whole supply chain is greater than the sum of its members, if properly managed.

In this regard, it is essential for maintaining and strengthening business position to integrate material flows with information and financial ones within the supply chain, which is the primary goal of solutions and programs for working capital management (Wuttke et al., 2013). Among these solutions supply chain finance (SCF) needs to be highlighted as one of the most important approaches. For the first time this term was introduced by Hofmann (2005). He identifies its applicability as follows: "SCF aims to optimize financial flows at an inter-organizational level through solutions implemented by financial institutions or technology providers" (Hofmann, 2005). Obviously, the instrument provides different benefits for supply chains which can be not only measurable and cost reduction-oriented but also focused on strengthening the financial position and improvement relationships between members of a chain (new opportunities for obtaining loans, trust and commitment throughout a chain) (Randall and Farris, 2009).

For the recent years SCF has been actively gaining traction from the sides of both practitioners and academics along with the expansion of the whole SCF market. Researchers focus mainly on description the variety of SFC solutions. However, in the literature it was found controversial definitions of SCF which treat the phenomenon from different perspective: finance-oriented and supply chain-oriented. The first one is oriented mainly to financial side and treat SCF as a range of financial solutions provided by financial institutions. Moreover, by Lamoureux & Evans (2011) SCF concerns financial solutions mainly. Wuttke (2013) holds to even more conservative opinion and defines SCF as just reverse factoring; however, the conviction is that reverse factoring is one of many SCF solutions. One more characteristic of financial perspective is orientation to accounts payable and accounts receivable mostly but not to inventory at all (Lamoureux & Evans, 2011).

At the same time, according to supply chain perspective SCF is considered a set of solutions aiming for improvement chain's financing; therefore, the range of solution is not limited by those which provide participation of financial institution, and therefore inventory management can be taken into account.

Nowadays aligning material and financial flows of SC is one of the main challenges for organizations, which often cannot be overcome without any type of external support. Having an ultimate goal of the extension of working capital to inter-organizational level (Hoffman, 2005) SCF is the essential tool to smoothen business operations and increase the value of companies through integration of financial processes along a supply chain (Pfohl & Gomm, 2009) with the creation of monetary-related win-win strategy. SCF allows to get faster access to cash for suppliers while enabling the delay of payment for buyer, which can improve supply chain performance. According to Wuttke et al. (2016) and Gelsomino et al. (2018) SCF is to optimize working capital with the help of implemented solutions offered by financial intermediaries, logistics operators or other possible members of SC. Caniato et al. (2016) identify three main benefits which companies get by adopting certain types of supply chain finance solutions:

- reduction of CCC due to decrease of DRO/increase of DPO or decrease of inventory and DIO. This benefit for SC is also discussed by the other researchers (e.g. Klapper & Randall (2011); Kiesmüller & Broekmeulen (2010)).

- increase of joint profit through reduction of costs on working capital due to achievement better values of CCC components adopting SCF solutions.

- strategic benefits associated with improvement of partnership relations and financial risk management is SC, achievable through better access to finance. The researches of Phohl & Gomm (2010); Hofmann (2005); Wuttke et al. (2013) also demonstrate these issues.

There are many types of SCF solutions which are applied in the real world and widely discussed by academia. In this paragraph the range of existing in business area SCF solutions is analyzed following the logic of Caniato et.al (2016) that SCF solutions may be divided into two main groups where the first one covers the decisions in working capital components (AR, AP, Inventory) with the participation of an intermediary – in this paper we call these SCF solutions traditional, and the second one is based purely on collaboration among SC partners – this group of SCF solution is called collaborative one. Thus, the Table 1 represents SCF solutions in terms of its group, definition, benefits and third party participation.

Table 1. Range of SCF solutions

Group	**SCF solution**	**Definition**	**Main benefits**	**Financial third-party involvement**	**Key researches**
Traditional	Factoring	Form of Receivables purchase, when sellers of goods sell their AR at a discount to finance provider (GSCFF, 2019)	Longer payment terms for buyer and faster cash recovery for supplier; reduction of risks and costs on asymmetric information	Always	Klapper (2006); Mian & Smith (1992)
	Reverse Factoring	A financial arrangement that helps a firm pay in advance its AP to its suppliers (Zhan et al., 2018)	Longer payment terms for buyer and faster cash recovery for supplier; reduction of risks and costs on asymmetric information; lower cost of finance for supplier due to buying firms'credit rating	Always	Klapper (2006); Wuttke et al. (2016); Zhan et al. (2018)
	Inventory financing	Solution in which a third party provider buys and possess goods from a manufacturer and then resell them to customer (Hoffman, 2009)	Reduction of inventory levels of buyer and supplier, faster cash recovery for buyer and supplier for goods sold and bought via third party provider	Not necessarily (logistic service operator is possible)	Hoffman (2009), Chen & Cai (2011), Gelsomino et al. (2018)
	Dynamic discounting	Solution, which describes a discounts for early payment: the early the payment occurs, the higher the amount of discount (GSCFF, 2019)	Reduction of Cost of goods sold due to discount	Not compulsory	Templar et al. (2016);

Collaborative	VMI	A supplier takes responsibility for inventory management, replenishment, monitoring decisions, decisions of order quantities and shipping for its buyer	Reduction the risks associated with information asymmetry; aligning planning procedures (reducing inventory levels for supplier and buyer)	No	Waller et al. (1999)
	Consignment stock	A buyer holds and maintains inventory of its supplier while supplier retains ownership until inventory is sold out	Relocation of inventory, fast access to inventory for buyer to fulfill the demand	No	Valentini & Zavanella (2003)

For the purpose of this paper the following three SCF solutions are chosen: Factoring, Reverse Factoring and Inventory Financing. The logic behind the choice is that these solutions allow to manage all three CCC components (AR, AP and Inventory) of all the members of SC and improve those. Moreover, they do not require high level of collaboration with joint material planning as it group of collaborative supply chain finance instruments does. At the same time, Gelsomino et al. (2019) describe the same SCF solutions as the most popular among practitioners. In addition, according to Chen (2019), the companies from retail industry emphasize that both types of Factoring an Inventory Financing are the most effective solutions in terms of improvement of working capital and partnership relations along a supply chain. In light on the foregoing, practical use of the chosen SCF solutions is going to be described hereafter.

Factoring and Reverse Factoring. The main idea of these two SCF instruments is to facilitate longer payment terms for buyer and shorter period of cash receipt for supplier through involvement of financial intermediary. (Tseng et al. 2018). The difference between those is characterized by an initiator and type of collateral. Therefore, Factoring is the solution which implies that account receivables of a supplier are sold to financial service provider and used as collateral in an agreement. The decision of implementation is initiated by supplier. At the same time, at Reverse Factoring collateral in financial agreement is buyer's accounts payable and in this settings buyer is decision maker. Thus, in situation when supplier is small or medium firm while buyer is more powerful the reverse factoring is an appropriate decision, because financial service provider uses buyer's credit rating, which is better than supplier's one, to adopt the SCF solution. Instead of paying to the supplier directly, a financial intermediary provides certain amount of fund on behalf of the buyer (Grueter & Wuttke, 2019). Next, the buyer pays off the loan principle to financial intermediary and the supplier pays the interest, where interest rate is calculated based on buyer's credit rating. If reverse situation, Factoring is recommended to use. When considering supply chain Factoring and Reverse Factoring are used to work properly for different stages of SC, e.g. to improve supplier-manufacturer payment terms Reverse Factoring is used, while for manufacturer-distributor relations Factoring is an appropriate solution (Strategic Treasurer, 2017).

Traditional model of Factoring and Reverse factoring typically includes 3 members: supplier, buyer and financial institution (e.g. bank). The scheme of both solutions is demonstrated by Figure 3. After buyer makes an order and supplier delivers it (steps 1 and 2), buyer provides the bank with the invoices which cover delivery (step 3). Supplier decides the amount of delivery which will be received immediately (step 4), in practice early payment may vary from 10% to 95% of delivery, and it takes 3 days for bank to pay. At the step 5 supplier covers the interest (the rate depends on buyer's credit rating and the time period which buyer needs to repay the loan). After this time period is up, buyer pay off loan principle to the bank, and the bank covers rest for payment for supplier (steps 6 and 7).

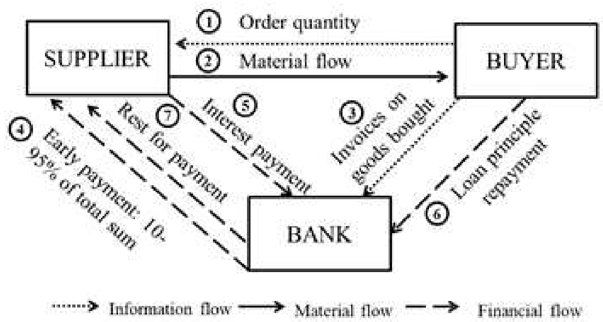

Fig. 3. Factoring and Reverse Factoring scheme. Source: created by the author

Nowadays, the vast majority of banks worldwide offers described solutions. They benefit from interest payment received for short-term loans and under lowest risks and opportunities to attract new clients. The only requirement for companies is maintenance of electronic workflow; however, there are plenty of platforms in the market, who offer this service. According to Commercial Capital LLS USA & Canada due diligence costs of Factoring/Reverse Factoring is minimal: it may vary from 100 dollars to a few thousand dollars for complex solution.

Inventory Financing. The idea of an innovative form of Inventory Financing as SCF solution was introduced by Hoffman (2009) for the first time. An innovative form implies that logistics service provides (LSP) takes responsibilities of financial function, although recently inventory has been as collateral for banks to grant a loan. Hoffman (2009) highlights, that the main benefit from this solution is adoption of "network perspective" which helps to improve inventory management within SC; however, it also aims at pursuing different goals of two members of SC (whose relations defined by contracts, e.g. supplier and manufacturer or manufacturer and distributor) as well as goals of LSP and overcome potential conflict of interests. In this regard, supplier tries to sell its inventory to manufacturer and get money for it as fast as possibly while manufacturer wants to take the ownership as closer to the moment of demand occurrence. Actually they both aim at decreasing the time period during which capital is tied-up in inventory. In far as is concerned LSP its goal is to maximize profit through providing a large number of services to its customer (including financial ones). Chen & Cai (2011) proved that this innovative form of Inventory Financing allows to achieve higher joint profit of SC, because the solution allows to reduce the level of inventory on hand of individual companies included in SC due to increased turnover, which has positive impact on collaborative cash conversion cycle.

Figure 4 shows how Inventory Financing can be implemented in practice. The scheme is based on typical structure of Inventory Financing adoption offered by Gelsomino & Steeman (2017) under control of Supply Chain Finance Community.

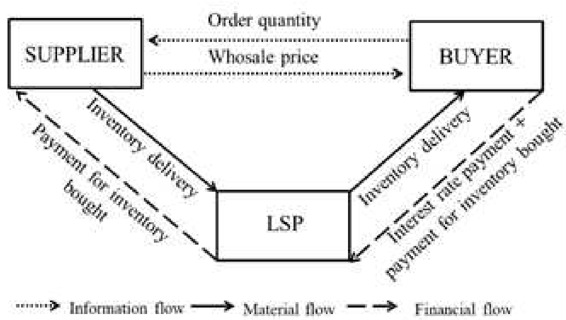

Fig. 4. Inventory Financing scheme. Source: created by the author

After buyer and supplier have agreed about quantity they deliver through LSP and prices, supplier produces inventory and sell it to LSP and LSP pays for it (according to Gelsomino &Steeman, typically it takes days 2 days after production to take inventory and 10 days to pay). It means that supplier needs to keep inventory for two days on its own and after that transfers the rights of legal ownership to LSP. At the moment buyer realizes the need of inventory it can immediately buy it from LSP and has an obligation to pay off in 30 days period. Hoffman (2009) proved, that there is no interest for LSP to sell inventory at a higher price then it buys it. LSP is rather interested in interest payment which is calculated in proportion to the amount delivered through LSP. Nowadays, such SCF solution as Inventory Financing is offered by a number of relevant LSP around the globe, e.g. SwissPost, DHL, UPS.

3. Joint Supply Chain Finance Solutions

Analysis of the existent literature in the field of working capital management in supply chain and supply chain finance solutions applicability, shows there is no explicit tool of joint working capital management as well as models of supply chain finance solutions and their applicability in supply chain. Here the models for joint working capital management through supply chain finance solutions adoption in supply chain will be developed.

3.1. The Model of Collaborative Cash Conversion Cycle

Hoffman and Kotzab (2010) proved in the research that WC optimization of one member of SC is not beneficial for common result of whole supply chain. At the same time, by proposing collaborative cash conversion cycle (CCCC) as a measure of joint working capital in SC the authors claimed that CCCC optimization lies in the area of joint actions and solutions of all members of a chain. Based on this idea, the model of CCCC is to be developed.

Thereafter, for the purpose of this research we consider two-stage supply chain because any bilateral relations are defined by the contracts and amenable to manage. The analysis of Cachon & Lariviere (2005) showcases that revenue sharing contracts seem to be very attractive to coordinate supply chain and increase joint profit and are suitable for any part of supply chain. Moreover, evidence comes from the research of Mortimer (2000), who estimates an increase in aggregate profit of one chosen industry as 7% due to change of terms of trade to revenue-sharing contract.

According to Cachon & Lariviere (2005) we are not limited to any part on supply chain. Thus, type of two-stage SC for this research may include either a number of suppliers and one manufacturer or one manufacturer and a number of distributors. Figure 5 shows the example of upstream part of the traditional three-stage supply chain, which is presented by relationship between numerous suppliers and one buyer. The relationship is described by CCCC components: DIO_l^k, DRO_l^k and DPO_l^k, where internal payments between SC partners DRO_l^k and DPO_{l+1}^k are equal due to being defined by specific existing contract. Apart from that, we cannot influence external flows such as DRO_2^1, DPO_1^1, DPO_1^2, DPO_1^n because they define relationship with other organizations outside considerable supply chain.

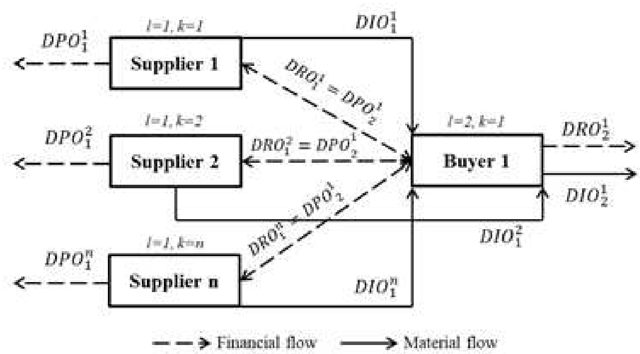

Fig. 5. Example of two-stage SC. Source: created by the author

Aiming at optimization of joint working capital objective function is total financial costs (TFC) on working capital of supply chain. Assuming that the members of a supply chain are interesting to maximize their joint profit objective function is to be minimized. We define TFC as a sum of financial costs on working capital of each member of supply chain based on the formula proposed by Viskari et al. (2013). Thus, objective function of the model of CCCC may be expressed as the following equation:

$$TFC = \sum_{l=1}^{m} \sum_{k=1}^{n} FC_l^k, \tag{7}$$

where l is the stage of SC, and k is the number of companies which is comprised in one stage. The formula of individual financial costs on working capital is presented by the equation (2).

Following Hoffman and Kotzab (2010) CCCC is defined as a sum of CCC of each individual company included in SC:

$$\begin{gathered} CCCC = \sum_{l=1}^{m} \sum_{k=1}^{n} CCC_l^k, \\ CCC_l^k = DIO_l^k + DRO_l^k + DPO_l^k, \end{gathered} \tag{8}$$

where l is the stage of SC, and k is the number of companies which is comprised in one stage.

For the purpose of this research in the model l may take two values: 1 or 2, as we consider two-stage supply chain, and k is always equals to 1, because we consider the only company at each stage. Obviously, the model can be enlarged and include more companies at stages; however, if it works for the only company at each stage, it can be easily replicated by adding other participants.

Hoffman and Kotzab (2010) proved that internal payments between two SC partners do not affect the result of CCCC. Thus, to ensure we analyze bilateral relations between exchange partners we denote the equality of lengths of DRO and DPO of two exchange partners as follows:

$$DRO_l^k = DPO_{l+1}^k. \tag{9}$$

Moreover, the model of CCCC is focused on managing internal relations between SC partners, exploiting possible change in contracts, which define relations between them. Therefore, DPO of the SC member at the first stage and DRO of the company in the downstream flow direction stage should remain stable after optimization. Mathematically it is expressed as follows:

$$\begin{gathered} DPO_1^k = DPO_1^{0k}, \\ DRO_2^k = DRO_2^{0k}. \end{gathered} \tag{10}$$

Referring to what is mentioned above, we assume that all the members of supply chain are motivated for joint actions, and therefore, are interested in reduction of any type of costs including total financial costs on working capital. In the previous chapter of the paper it is proved that coordinating contracts increase the level of motivation to boost total profit of supply chain. Consequently, we set the following constraint meaning that aiming at total costs on working capital of SC reduction individual financial costs on working capital remain no worse than it was before the optimization. This is expressed by the equation (11).

$$FC_l^k \leq FC_l^{0k}. \tag{11}$$

In response to theoretical review we are aware of association between WC and profitability and the problem of liquidity-profitability tradeoff. Therefore, while managing working capital, specific boundaries within its value may vary should be set up in order to ensure company's effectiveness and solvency at the same time (Garanina & Petrova, 2015). In this regard, we set the constraint which lets CCC of individual company in supply chain change within predefined stability interval:

$$CCC_{low} \leq CCC_l^k \leq CCC_{up}. \tag{12}$$

Table 2. Parameters of the model of CCCC

Model element	Notation	Description
Objective function	TFC	Total financial costs on working capital for supply chain
Indexes	l	stage of supply chain
	k	company at certain stage of supply chain
Variables	DIO_l^k	Days of inventory outstanding for company k at stage l
	DRO_l^k	Days of receivables outstanding for company k at stage l
	DPO_l^k	Days of accounts payable outstanding for company k at stage l
Parameters	CCC_l^k	cash conversion cycle of company k at stage l
	$CCC_{low}; CCC_{up}$	predefined stability interval for company k at stage l
	$Inventory_l^k$	year-end amount of inventory of company k at stage l
	AR_l^k	year-end amount of accounts receivable of company k at stage l
	AP_l^k	year-end amount of accounts payable of company k at stage l
	$COGS_l^k$	year-end amount of cost of goods sold of company k at stage l
	$Revenue_l^k$	year-end amount of revenue of company k at stage l
	c_l^k	cost of capital of company k at stage l
	FC_l^k	financial costs on working capital of company k at stage l
	FC_l^{0k}	financial costs on working capital of company k at stage l before optimization
	WC_l^k	amount of working capital of company k at stage l

Table 2 presents the elements of the model of collaborative cash conversion cycle.

Thus, the optimization model of CCCC works as follows: to minimize total financial costs on working capital (7) by changing variables (Table 2) under the constraints 9 – 12. As a result of modeling optimal values of CCCC components are found to achieve minimal total financial costs on working capital under specific constraints of liquidity for one-year planning period. Overall, the model allows to estimate if the optimization is possible and to analyze which joint actions in terms of managing components of WC in supply chain are to take in order to achieve minimal total supply chain costs on working capital.

Nevertheless, the model does not provide any approaches to achieve the results, which it gives. Basically, it demonstrates only optimal collaborative cash conversion cycle components, therefore, may be used predominantly as analytical tool. As a consequence, there is a necessity to develop further models which are to show clear ways to achieve desirable results in terms of joint working capital management. For this reason, based on the results of theoretical review in the first chapter supply chain finance solutions are used.

3.2. The Models of Supply Chain Finance Solutions

Based on the schemes of SCF solutions practical use the models of chosen SCF solutions are to be developed. In this regard, these models are to show whether adoption of a particular SCF solution allows to find optimal solution aiming at minimization of total supply chain financial costs on working capital and how these minimal costs may be achieved providing the conditions of SCF solution adoption.

Model of Factoring/Reverse Factoring. Generally, the model of Factoring/Reverse Factoring is based on the model of CCCC, however, we assume adding here one of SCF solutions. It implies additional costs imposing and changes of some variables due to influence of solution adoption. Therefore, we develop the model of Factoring/Reverse Factoring considering two-stage supply chain as previously. Although for this model the objective function basically remains the same – it is minimization of TFC, this value is to include new type of costs associated with Factoring or Reverse Factoring use. It is expressed in the interest rate (r), which is dependent on buyer's credit rating, and the time period which buyer needs to repay the loan. Equation 13 represents the formula for costs on Factoring/Revers Factoring calculation based on AR of supplier:

$$FC_{F/RF} = \frac{DPO_{l+1}^{k} \times r}{365} \times AR_{l}^{0k} \times x, \tag{13}$$

where r is interest rate, and x is the share of using Factoring or Reverse factoring, which may take values from 0,1 to 0,95 according to the scheme of its practical use (see Fig. 3). In other words, x is a share of early payment which supplier gets from bank immediately (in three days after it received invoices). Considering it the objective function for the model of Factoring and Reverse Factoring changes as follows:

$$TFC = \sum_{l=1}^{m} \sum_{k=1}^{n} FC_{l}^{k} + FC_{F/RF}. \tag{14}$$

From the Table 1 it is acquainted that both Factoring and Reverse factoring are to achieve longer payment terms for buyer and faster recovery of cash for supplier, influencing directly DRO_l by selecting the amount of early payment and DPO_{l+1} by selecting new appropriate length of payment term to improve joint working capital. Therefore, we denote that DRO_l is now the function of $DRO_l{}^0$, DPO_{l+1} and x:

$$DRO_{l}^{k} = x \times 3 + (1 - x) \times DPO_{l+1}^{k}, \tag{15}$$

where $x \in [0{,}1;0{,}95]$.

Table 3 presents the elements of the model of collaborative cash conversion cycle such as objective function, variables, and parameters providing the list of notations.

Thus, the optimization model of Factoring or Reverse Factoring works as follows: to minimize total supply chain financial costs on working capital (14) by changing two variables (Table 3): share of the early payment from bank x and length of payment term DPO_{l+1} under the constraints (11) and (12). As a result of modeling we expect to get optimal conditions of adoption of such a SCF solution as Factoring or Reverse Factoring to achieve minimal total supply chain financial costs on working capital under specific constraints of liquidity for one-year planning period. In contrast to previous model developed in the research, apart from optimal CCCC components for minimal total supply chain costs on working capital, the model of

Factoring/Reverse Factoring demonstrates specific conditions of SCF instrument use, which allow to achieve joint working capital improvement.

Table 3. Parameters of the model of Factoring/Reverse Factoring

Model element	Notation	Description
Objective function	TFC	total financial costs on working capital for supply chain (including costs of Factoring/Reverse Factoring Adoption)
Indexes	l	stage of supply chain
	k	company at certain stage of supply chain
Variables	x	share of the early payment from bank to supplier
	P	length of payment term
Parameters	CCC_l^k	cash conversion cycle of company k at stage l
	$CCC_{low}; CCC_{up}$	predefined stability interval for company k at stage l
	$Inventory_l^k$	year-end amount of inventory of company k at stage l
	AR_l^k	year-end amount of accounts receivable of company k at stage l
	AP_l^k	year-end amount of accounts payable of company k at stage l
	$COGS_l^k$	year-end amount of cost of goods sold of company k at stage l
	$Revenue_l^k$	year-end amount of revenue of company k at stage l
	c_l^k	cost of capital of company k at stage l
	FC_l^k	financial costs on working capital of company k at stage l
	FC_l^{0k}	financial costs on working capital of company k at stage l before optimization
	WC_l^k	amount of working capital of company k at stage l
	r	interest rate for Factoring/Reverse Factoring use
	DRO_l^k	Days of receivables outstanding for company k at stage l
	DIO_l^k	Days of inventory outstanding for company k at stage l
	DPO_l^k	Days of accounts payable outstanding for company k at stage l

Thus, the optimization model of Factoring or Reverse Factoring works as follows: to minimize total supply chain financial costs on working capital (14) by changing two variables (Table 3): share of the early payment from bank x and length of payment term DPO_{l+1} under the constraints (11) and (12). As a result of modeling we expect to get optimal conditions of adoption such a SCF solution as Factoring or Reverse Factoring to achieve minimal total supply chain financial costs on working capital under specific constraints of liquidity for one-year planning period.

Model of Inventory Financing. Following the same logic as it was while modeling Factoring/ Reverse Factoring and in alignment with the scheme of practical SCF solution adoption (Figure 1.4) the model of Inventory Financing is developed.

Like any SCF solution adoption of Inventory Financing implies additional costs for supply chain members that should be paid to intermediary which provides the service. In this case it is logistics service provider (LSP). Hoffman (2009) defined the premium which LSP receives proving the service of Inventory Financing as "the difference between the value of the financed goods and the present value of the financed inventory". Based on this definition we determine costs associated with SCF solution Inventory Financing use. It is demonstrated by equation 16:

$$FC_{IF} = (1-x) \times Inventory_{total} - \frac{(1-y) \times Inventory_{total}}{(1+i)^t}, \tag{16}$$

where i is interest rate defined by LSP, $(1-y)$ is a share of inventory amount financed, $y \in [0;1]$, and t is duration of the contract in periods. Thus, the cost of this SCF solution depends on the amount of inventory to deliver via LSP and the interest rate, which is determined by. Therefore, including this type of costs the objective function for the model of Inventory Financing changes as follows:

$$TFC = \sum_{l=1}^{m} \sum_{k=1}^{n} FC_l^k + FC_{IF}, \tag{17}$$

Since Inventory Financing is the solutions of higher complexity it affects four components of CCCC simultaneously: DRO_l , DPO_{l+1}, DIO_l, and DIO_{l+1}. According to Gelsomino & Steeman (2017), typically for LSP it takes days 2 days after production to take inventory and 10 days to pay. Based on this scheme we denote that DIO_l is now the function of DIO_{0l} and y, where y is the share of inventory amount which is not financed and delivered as it is (from supplier to buyer directly); while DRO_l is the function of DIO_{0l} and x. These CCCC components are expressed by equations (18) and (19) respectively.

$$DIO_l^k = y \times DIO_l^{0k} + (1-y) \times 2, \tag{18}$$

$$DRO_l^k = y \times DRO_l^{0k} + (1-y) \times 10. \tag{19}$$

Hoffman (2009) claimed that buyer aims to take inventory from LSP as closer to demand occurrence as possible in order to keep it as shorter as possible. To resolve the conflict of interests between partners in supply chain is an ultimate goal of Inventory Financing as SCF solution. Although Gelsomino & Steeman (2017) state that the inventory obtained from LSP should be kept by buyer no more than one day, for the model we assume at least two days before inventory is sold further downstream along supply chain. As for payment terms, we follow Gelsomino & Steeman (2017) and assume that buyer has to pay off its Accounts Payable to LSP in 30 days. Thus, DIO_{l+1} and DPO_{l+1} are denoted as equations (20) and (21) respectively:

$$DIO_{l+1}^k = y \times DIO_{l+1}^{0k} + (1-y) \times 2, \tag{20}$$

$$DPO_{l+1}^k = y \times DPO_{l+1}^{0k} + (1-y) \times 30. \tag{21}$$

Table 4 presents the elements of the model of collaborative cash conversion cycle.

Thus, the optimization model of Inventory Financing works as follows: to minimize total supply chain financial costs on working capital (17) by changing the only

Table 4. Parameters of the model of Inventory Financing

Model element	Notation	Description
Objective function	TFC	total financial costs on working capital for supply chain (including costs of Inventory Financing adoption)
Indexes	l	stage of supply chain
	k	company at certain stage of supply chain
Variables	y	share of inventory amount which is not financed and delivered as it is
Parameters	CCC_l^k	cash conversion cycle of company k at stage l
	$CCC_{low}; CCC_{up}$	predefined stability interval for company k at stage l
	$Inventory_l^k$	year-end amount of inventory of company k at stage l
	AR_l^k	year-end amount of accounts receivable of company k at stage l
	AP_l^k	year-end amount of accounts payable of company k at stage l
	$COGS_l^k$	year-end amount of cost of goods sold of company k at stage l
	$Revenue_l^k$	year-end amount of revenue of company k at stage l
	c_l^k	cost of capital of company k at stage l
	FC_l^k	financial costs on working capital of company k at stage l
	FC_l^{0k}	financial costs on working capital of company k at stage l before optimization
	WC_l^k	amount of working capital of company k at stage l
	i	interest rate for Inventory Financing use
	DRO_l^k	Days of receivables outstanding for company k at stage l
	DIO_l^k	Days of inventory outstanding for company k at stage l
	DPO_l^k	Days of accounts payable outstanding for company k at stage l

variable y (4) under the constraints 11 and 12. As a result of modeling we expect to get optimal conditions of adoption such a SCF solution as Inventory Financing to achieve minimal total supply chain financial costs on working capital under specific constraints of liquidity for one-year planning period.

3.3. Joint Working Capital Optimization in SC

This model combines the model of CCCC and both models of SCF solutions: Factoring/Reverse Factoring and Inventory Financing. Even though for the purpose of modeling Factoring and Reverse Factoring are the same in terms of influence on CCCC components, they are used for different parts of supply chain. Thus, if the object of analysis is the upstream part of supply chain which concerns suppliers – focal company (manufacturer or wholesaler), Reverse Factoring is used; if it is downstream part which is about focal company (manufacturer or wholesaler) – distributor relations, Factoring is an appropriate solution. At the same time, Inventory Financing may be applied to both parts of supply chain.

For the model of joint working capital objective function is the same: total supply chain financial costs on working capital; but now it contains a sum of financial costs on working capital of each member of supply chain as well as costs associated with the use of two SCF solutions simultaneously (eq. 13 and 16 respectively): Factoring/Reverse Factoring and Inventory Financing:

$$TFC = \sum_{l=1}^{m} \sum_{k=1}^{n} FC_l^k + FC_{F/RF} + FC_{IF}. \tag{21}$$

Adoption of two SCF solutions simultaneously affects four CCCC components: DRO_l, DPO_{l+1}, DIO_l, and DIO_{l+1}. Although DIO_l, and DIO_{l+1} are expressed here exactly as they were in model of Inventory Financing (equations 18 and 19 respectively), because they are under the only SCF solution, DRO_l and DPO_{l+1} combine the influence of two solutions. Being affected by the shares of using two SCF instruments and conditions which these instruments require, DRO_l and DPO_{l+1} are expressed as the following equations:

$$\begin{aligned} DRO_l^k = & \big(\big(3 \times x + DPO_{l+1}^k \times (1-x)\big) \times y\big) + \\ & + \big(\big(y \times DRO_l^{0k} + (1-y) \times 10\big) \times (1-y)\big), \\ DPO_{l+1}^k = & \big(y \times DPO_{l+1}^{0k} + (1-y) \times 30\big) \times (1-y)) + (P \times y), \end{aligned} \tag{22}$$

where P new appropriate length of payment term when using Factoring/Reverse Factoring.

Thus, the optimization model of joint working capital works as follows: to minimize total supply chain financial costs on working capital (21) by changing three variables: *x, y,* and P (Table 5) under the constraints 11 and 12. As a result of modeling we expect to get optimal strategy of joint working capital management for a two-stage supply chain which contains the conditions of using two SCF solutions simultaneously (Factoring/Reverse Factoring and Inventory Financing) aiming at minimal total supply chain financial costs on working capital under specific constraints of liquidity for one-year planning period. As opposed to the model of CCCC, the model of joint working capital optimization represents not simply analytical tool but provides clear approaches to improve joint working capital in supply chain. Moreover, what differentiates the model from ones of SCF solutions is simultaneous influence of Factoring/Reverse Factoring and Inventory Financing on CCCC components. It enhances the prospects of achievable and realistic results.

3.4. Joint Working Capital Improvement in SC

Today companies start to realize benefits which they can get through cooperation with supply chain partners and financial intermediaries when managing their financial flows and to strengthen financial position in doing so (de Boer et al.,2015). It is important to work in cooperation making concessions to meet different interests of partners. Hence, SCF solutions pose a tool to resolve conflicting financial interests of partners improving overall financial performance of supply chain (Caniato et al., 2019). The demonstrative examples of such conflicting financial interests are payment terms and inventory holding. Whereas buyer wants to extend the period to pay, supplier is interesting in faster cash recovery; as for inventory holding, supplier aims to sell it to buyer as fast as possible in order not to keep it while buyer want

Table 5. Parameters of the model of Joint WC optimization

Model element 4	**Notation**	**Description**
Objective function	TFC	total financial costs on working capital for supply chain (including costs of Factoring/Reverse Factoring and Inventory Financing adoption)
Indexes	l	stage of supply chain
	k	company at certain stage of supply chain
Variables	x	share of the early payment from bank to supplier
	y	share of inventory amount which is not financed and delivered as it is
	P	length of payment term
Parameters	CCC_l^k	cash conversion cycle of company k at stage l
	$CCC_{low}; CCC_{up}$	predefined stability interval for company k at stage l
	$Inventory_l^k$	year-end amount of inventory of company k at stage l
	AR_l^k	year-end amount of accounts receivable of company k at stage l
	AP_l^k	year-end amount of accounts payable of company k at stage l
	$COGS_l^k$	year-end amount of cost of goods sold of company k at stage l
	$Revenue_l^k$	year-end amount of revenue of company k at stage l
	c_l^k	cost of capital of company k at stage l
	FC_l^k	financial costs on working capital of company k at stage l
	FC_l^{0k}	financial costs on working capital of company k at stage l before optimization
	WC_l^k	amount of working capital of company k at stage l
	i	interest rate for Inventory Financing use
	r	interest rate for Factoring/Reverse Factoring use
	DRO_l^k	Days of receivables outstanding for company k at stage l
	DIO_l^k	Days of inventory outstanding for company k at stage l
	DPO_l^k	Days of accounts payable outstanding for company k at stage l

to obtain it as late as possible in order to keep it short time before the demand occurrence. These two main conflicts may be compromised through SCF solutions adoption as they aim for amount of working capital reduction of each member of supply chain while optimizing the overall supply chain financial performance (Hoffman, 2018).

Aiming to cover the gap of managerial side of SCF solutions adoption this paper is to provide the algorithm for joint working capital improvement in a supply chain based on the optimization models. Thus, four models may be used to analyze the possibility of joint working capital optimization and to make a decision. Therefore, the algorithm of joint working capital improvement may be expressed in the following way.

The first step is to analyze whether the optimization under specific constraints is possible for a particular supply chain. For this purpose the model of CCCC is proposed to be used. If the optimization is possible, it shows optimal WC components for minimal total supply chain financial costs on WC under the constraints. Although all the constraints are specified above in the text (eq. 9 – 12), it is worth emphasizing that the model provides the optimal solution in accordance with two main requirements: first, CCC stability interval, which allows to solve liquidity – profitability tradeoff in a way that each member of SC achieves greater liquidity individually falling in optimum intervals of CCC, secondly, financial costs on WC of each member of a chain which should be not worse than they were before optimization. Thus, based on the optimal solution, which is provided by the model of CCCC, the decision maker can conclude about actions to manage WC components in order to achieve greater financial performance. Moreover, he/she can additionally realize whether the optimal solution is self-maintained or it implies unrealistic change of WC components. If the latter is a matter of fact, it is reasonable to move on the next step.

For the second step the models of SCF instruments are recommended to be applied. Specifically, when understanding that achievement of minimal total supply chain costs on working capital corresponds to providing unreal conditions for the members of supply chain (e.g. abandoning of the inventory or its significant reduction, extended or too short payment terms which are not beneficial for supplier or buyer respectively), it is recommended to adopt SCF solutions. Thus, the model of Factoring/Reverse Factoring and the model of Inventory Financing are proposed for the improving joint WC. In this regard, both models show optimal WC components for minimal total supply chain financial costs on WC as well as optimal conditions of the solution's use under the constraints if the optimization is possible. Basically, two constraints are used for the model (eq. 11 and 12), which concern individual costs on WC maintenance and liquidity - profitability tradeoff. Even though the former (eq. 11) is considered in the model there are additional costs associated with SCF solution use which should be taken into account when calculating total supply chain costs on WC. It means that in case of supply chain partners' willingness to achieve greater liquidity falling in optimum CCC intervals they are ready to pay additionally. It not necessarily implies increase of total financial costs on WC but it should be counted. After the analysis of the results provided by the models, a decision maker can either stay with the adoption of that instrument which model demonstrates better results for him/her or try to analyze another alternative which is adoption of two SCF solutions simultaneously. If the latter is worthwhile or the optimization is impossible in any of the models, it is reasonable to move on the next step.

The third step concerns joint working capital improvement through the adoption of the range of SCF solutions: Factoring/Reverse Factoring and Inventory Financing in particular. The model of joint working capital optimization provides optimal WC components for minimal total supply chain financial costs on WC as well as optimal conditions of the solutions use under the constraints if the optimization is possible. Based on the results obtained from the model a decision maker can see how it is possible to minimize total financial costs on WC. Basically, the model shows the design of SCF solutions adoption which influence WC components in such a way to minimize total financial costs on WC and achieve higher liquidity both individual and one of supply chain due to falling in CCC stability range intervals. Comparing the results which were got at the second step (the result of the only solution adoption) with the current results of joint working capital optimization model and following the goals of a supply chain a decision maker can choose the best alternative for him/her.

Moving through the steps of the algorithm allows to answer two questions: is it possible to optimize joint working capital and how is it possible to do it. With the algorithm a decision-maker can get clear understanding of possibilities to reduce total supply chain costs on working capital and of approaches to achieve it.

4. Joint Working Capital Optimization on the Examples of Supply Chains

Here developed algorithm of joint working capital improvement in supply chain, which is based on the optimization models, is illustrated with real examples of supply chains. Case study analysis allows to test how developed models can be applied in practice.

For this research two types of data are necessary to be collected: primary and secondary data. The former is based on the interviews with company's representatives whereas the latter can be obtained from companies' financial statement (Balance sheet and Profit & Loss Statement). Considering the interviews, they were organized in structured form with representatives of central companies' operational and finance departments of three different coordinated supply chains. During conversation, the following issues were discussed: the design of supply chain in order to identify exact supplier and distributor of the company, and payment terms defined in contracts that regulate supply chain members' relationships. After getting the results of primary data collection, the annual financial reports of all the members of determining supply chain are obtained using SPARK database to calculate the values necessary for the optimization models: working capital, CCCC components, and individual and total supply chain financial costs on working capital.

Case study analysis represents three supply chains from three industries in Russia: ICT, Automotive and FMCG. For every industry both parts of supply chain are considered separately: supplier – focal company (manufacturer or wholesaler), and focal company (manufacturer or wholesaler) – distributor, because the research focuses on managing bilateral relations.

The motivation of industries choice involves both theoretical and practical evidences. Thus, Talonpoika (2014) and Pirtillä et al. (2014) characterize ICT industry as fast developing and highly service-oriented that allows to make an assumption of being motivated for joint actions to fulfill customer needs efficiently, increase competitive strength, and consequently, joint profitability. As far as is concerned automotive industry choice, we rely on the research of Lind et al. (2012) who prove that the competition in the industry is based on supply chain to supply chain rather than on company to company. Moreover, practical experience shows, that members of automotive industry's supply chain are eager to cooperate, what is clearly demonstrated by implementation of Just-in-time and Just-in-Sequence production systems, which allow to plan jointly and to decrease inventory amount for the SC members. In this regard, it is worth studying different ways to increase supply chain efficiency by managing working capital jointly. When considering FMCG sector, we aim to find a solution for liquidity problem. During the interview with the representative of FMCG supply chain's central company it was identified that typical problem for FMCG supply chains is weaker suppliers meaning rising problem of conflict financial interests of SC members.

4.1. Beverage Producer's Supply Chain

To provide an example of optimization models applicability, we look at supply chain from FMCG sector. Although the tree-stage supply chain is constructed based on data collection, we consider two parts of the chain separately managing bilateral relations: the first one is that of supplier – manufacturer, and second one is that of manufacturer – distributor.

The central company of supply chain is a Russian producer of various beverages. It covers a whole production cycle, starting from raw material processing and finishing with bottling and packaging. The suppliers are mainly companies, which provide the producer with raw and packaging materials, whereas the distributors are retail stores. Thus, we construct the following two-stage supply chains: supplier, which is a producer of raw materials – manufacturer, which is a beverage producer; and manufacturer (beverage producer) – distributor – a retail store. All companies are located in Russia.

Financial data, which is needed for modeling, was collected as it is described above and in accordance with tables 2 – 5, which reflects models' parameters. Thus, initial data for supplier, manufacturer and distributor of beverage producer supply chain is summarized in table 6. It represents 2017 year-end financial data, given in million rubles if another is not stated.

Table 6. Initial data for Beverage producer SC

Parameter	Supplier	Manufacturer	Distributor	Total (SC)
$Inventory_l^k$	494	3 749	156	4 399
AR_l^k	579	8 779	157	9 515
AP_l^k	321	8 651	84	9 055
$COGS_l^k$	1 918	35 084	714	-
$Revenue_l^k$	2 350	74 519	866	-
WC_l^k	752	3 877	229	4 858
c_l^k, %	0,056	0,147	0,146	-
DIO_l^k, days	94	39	80	-
DRO_l^k, days	90	43	66	-
DPO_l^k, days	61	90	43	-
CCC_l^k, days	123	-8	103	218
FC_l^k	11,9	99,0	7,3	118,2

Considering liquidity – profitability tradeoff, which is a basis for one of main constraints of all the optimization models, we rely on the paper of Garanina & Petrova (2015), who define stability intervals for CCC for different industries in Russia. Indeed, in realistic scenario each company defines this interval on its own, however, this sort of information is highly confidential and is not to disclose. Due to this fact, for the purpose of the research we assume CCC of all members of supply chain changes within industry average stability interval. Thus, for FMCG sector Garanina & Petrova (2015) denote CCC changing within the interval of -36 to 23 days.

When analyzing initial data of beverage producer's supply chain from FMCG sector, it is obvious that the manufacturer's CCC lies inside stability interval while that of the supplier and the distributor do not (see table 6). Moreover, the industry is characterized by relatively high value of DIO, especially ones of supplier and distributor, that negatively affects the length of CCCC (218 days for the considered supply chain). What is also noticeable is that manufacturer, being stronger player, tends to extend its DPO, which makes CCC of supplier longer and negatively affects its individual financial position as well as joint result of supply chain.

Processing the data of beverage producer's supply chain through the optimization models which are included in the algorithm of joint working capital improvement in supply chain gives the following outcomes.

First, we consider upstream part of supply chain meaning supplier – manufacturer relations. Following the algorithm we assess the possibility of joint working capital optimization using the model of CCCC. Table 7 presents the data before optimization, after optimization and comparative change.

Table 7. CCCC model results for upstream Beverage producer SC

Initial data (before optimization)					
	DIO	**DRO**	**DPO**	**CCC**	**FC**
Supplier	94	90	61	123	11,9
Manufacturer	39	43	90	-8	99,0
				CCCC	**TFC**
				115	111,0
After optimization data					
	DIO	**DRO**	**DPO**	**CCC**	**FC**
Supplier	0	63	61	2	0,9
Manufacturer	7	43	63	-13	0,1
				CCCC	**TFC**
				-11	1,0
Comparative change					
	DIO	**DRO**	**DPO**	**CCC**	**FC**
Supplier	-100%	-30%	0%	-98%	-92%
Manufacturer	-83%	0%	-30%	66%	-99%
				CCCC	**TFC**
				-109%	-99%

Although optimization is possible, the results obtained are very hard to achieve. Following the optimal solution supplier should refuse from keeping the inventory while the model recommends manufacturer to decrease its level dramatically. It is highly questionable that the members of supply chain will be able to maintain such conditions. Therefore, we see a necessity to move on to the next step of the algorithm.

At the second step, we process the data through the models of SCF solutions. As for using the model of Reverse Factoring, optimization is not possible. Under specific constraints of liquidity, adoption of Reverse Factoring does not allow to find optimal solution to minimize total supply chain costs on working capital. Moreover, it does not work even on the assumption of supply chain members' readiness to increase their individual costs on working capital. Building on the results, the need to manage inventory is observed. Thus, when applying the model of Inventory Financing, optimization is possible (see Table 8).

Table 8. Inventory Financing model results for upstream Beverage producer SC

After optimization data						
	DIO	**DRO**	**DPO**	**CCC**	**FC**	**Cost of SCF solution**
Supplier	41	43	61	23	0,2	-
Manufacturer	17	43	55	5	43,1	16,4
				CCCC	**TFC**	**-**
				28	59,7	-
Comparative change						
	DIO	**DRO**	**DPO**	**CCC**	**FC**	**-**
Supplier	-57%	-51%	0%	-81%	-98%	-
Manufacturer	-55%	0%	-38%	+162%	-56%	-
				CCCC	**TFC**	**-**
				-75%	-46%	-

As is shown by the table 8, adoption of Inventory Financing allows to improve each company's liquidity position, since both CCC is inside stability interval after optimization, to decrease total supply chain financial costs on WC providing, however, not worse individual results in terms of financial costs on WC. The improvement is achieved due to Inventory financing adoption observing the following conditions: 42% of overall inventory amount is delivered as it is (from supplier to manufacturer directly), while 58% of inventory is delivered through LSP, herewith LSP possess inventory legally 22 days on average when transaction takes place. Annual costs of this SCF solution use is 16,4 million rubles.

The next step is the model of joint working capital optimization. Using two types of SCF solutions simultaneously allows to achieve greater results in terms of total supply chain financial costs on WC (see table 9). Optimal solution implies improvement of each company's liquidity position, since both CCC are inside stability interval after optimization, and decrease of total supply chain financial costs on WC. Along with that, the model provides optimal conditions of both SCF solutions adoption. Thus, as for Inventory financing, 48% of overall inventory amount is delivered as it is (from supplier to manufacturer directly), while 52% of inventory is delivered through LSP, herewith LSP possess inventory legally 19 days on average when transaction takes place. Annual costs of this SCF solution use are 13 million rubles. At the same time, the conditions of Reverse Factoring are as follows: supplier gets 67% of overall value of order quantity immediately from bank and the rest (33%) – in 73 days. Annual costs of Reverse Factoring use are 8,4 million rubles.

As a result, joint working capital declines by 17% when total supply chain financial costs on WC are reduced by 80%.

Table 9. Joint WC optimization results for upstream Beverage producer SC

After optimization data							
	DIO	**DRO**	**DPO**	**CCC**	**FC**	**Cost of IF**	**Cost of RF**
Supplier	46	38	61	23	0,2	-	8,4
Manufacturer	20	43	66	-3	0,1	13,0	-
				CCCC	**TFC**	**-**	**-**
				28	21,7	-	-
Comparative change							
	DIO	**DRO**	**DPO**	**CCC**	**FC**	**-**	**-**
Supplier	-50%	-58%	0%	-81%	-98%	-	-
Manufacturer	-49%	0%	-27%	+65%	-99%	-	-
				CCCC	**TFC**	**-**	**-**
				-82%	-80%	-	-

Further to the analysis of beverage producer's supply chain, we consider downstream part of supply chain meaning manufacturer – distributor relations. It is worth mentioning that for this part of supply chain Factoring instead of Reverse Factoring is used. The change of the SCF instrument is built on the theoretical analysis of the range of SCF solutions.

Following the same logic we assess the possibility of joint working capital optimization using the model of CCCC at first. Table 10 presents the data before optimization and after optimization. Again, despite the optimal solution is found, the results are unachievable. When following optimal solution both SC members should refuse to keep the inventory as well as to extend payment terms. Admitting that manufacturer will be ready to tolerate slower cash recovery, which is beneficial for distributor, operating with zero level of inventory turns to be impossible for both. That is why, we see a necessity to move on to the next step of the algorithm developed in order to apply more sophisticated tools.

Thus, we apply two SCF solutions separately as the next step. However, under specific constraints of liquidity neither adoption of Factoring nor use of Inventory financing allows to find feasible solution. Moreover, both models do not work separately even on the assumption of SC members' readiness to increase their individual costs on working capital. Therefore, we continue with the third step of the algorithm to achieve greater results in terms of total supply chain financial costs on WC through simultaneous use of two types of SCF solutions. In this case optimization is possible, the results are demonstrated by table 11.

Optimal solution obtained from the model of joint working capital optimization implies improvement of the companies' liquidity position, since both CCC are inside the stability interval after optimization, decrease of CCCC due to coordinated actions, however, it does not provide decline of total supply chain financial costs on WC. As is shown by the table 3.6, they remain the same because of SCF solutions use costs, while members' individual costs on WC decrease by more than 90%. Although the model does not provide significant improvement in total costs,

Table 10. CCCC model results for downstream Beverage producer SC

Initial data (before optimization)					
	DIO	**DRO**	**DPO**	**CCC**	**FC**
Manufacturer	39	43	90	-8	99,0
Distributor	80	66	43	103	7,3
				CCCC	**TFC**
				95	106,3
After optimization data					
	DIO	**DRO**	**DPO**	**CCC**	**FC**
Manufacturer	0	62	90	-28	0,1
Distributor	0	66	62	4	1,1
				CCCC	**TFC**
				-24	1,2

Table 11. Joint WC optimization result for downstream Beverage producer SC

After optimization data							
	DIO	**DRO**	**DPO**	**CCC**	**FC**	**Cost of IF**	**Cost of RF**
Manufacturer	22	60	90	-8	0,1	-	86,7
Distributor	45	66	88	23	0,4	19,1	-
				CCCC	**TFC**	**-**	**-**
				15	106,3	-	-
Comparative change							
	DIO	**DRO**	**DPO**	**CCC**	**FC**	**-**	**-**
Manufacturer	-43%	40%	0%	0%	-99%	-	-
Distributor	-44%	0%	104%	-77%	-95%	-	-
				CCCC	**TFC**	**-**	**-**
				-83%	0%	-	-

the solution still has right of existence because it allows to achieve greater liquidity due to coordinated actions through SCF solutions adoption. Along with that, the model provides optimal conditions of both SCF solutions use. Thus, as for Inventory financing, 55% of overall inventory amount is delivered as it is (from supplier to manufacturer directly), while 45% of inventory is delivered through LSP, herewith LSP possesses inventory legally 35 days on average when transaction takes place. Annual costs of this SCF solution use are 19 million rubles. At the same time, the conditions of Reverse Factoring are as follows: a supplier gets 34% of overall value of order quantity immediately from bank and the rest (66%) – in 129 days. Annual costs of Reverse Factoring use are 86 million rubles. As a result, the joint working capital increases by 40%, CCCC reduces by 83% when total supply chain financial costs on WC remain the same.

4.2. Telecom Operator's Supply Chain

Now we analyze another example - Telecom operator's SC. The central company of a supply chain is one of the largest telecom operators in Russia, which provides local and long-distance mobile phone coverage, TV and Internet connection. Moreover, the company's business scope comprises a retail business of value-added products, a long-term innovative development of new services, and an IT business, including e-commerce services. The supplier is a Russian company involved in procurement process of the central company, which deals with development and implementation of telecom infrastructure, data security services and engineering platforms. The distributor is a Russian mobile phone company, which offers services of mobile communication, high-speed Internet, etc. Based on the three-stage supply chain we consider the following two-stage ones: supplier – wholesaler (central company), wholesaler (central company) – distributor.

Financial data is summarized in table 12. It represents 2017 year-end financial data, which is given in million rubles if not specified.

Considering liquidity – profitability tradeoff, we rely again on the paper of Garanina & Petrova (2015), who define stability intervals for CCC of companies from ICT industry as the range from -16 to 62 days.

Table 12. Initial data for Telecom operator SC

Parameter	Supplier	Wholesaler	Distributor	Total (SC)
$Inventory_l^k$	1 342	11 593	972	13 907
AR_l^k	1 374	458	119	1 951
AP_l^k	901	4 256	85	5 242
$COGS_l^k$	6 345	22 981	5 528	-
$Revenue_l^k$	7 419	29 792	6 588	-
WC_l^k	1 815	7 795	1 006	10 616
c_l^k, %	0,082	0,047	0,034	-
DIO_l^k, days	77	184	64	-
DRO_l^k, days	68	6	7	-
DPO_l^k, days	52	68	6	-
CCC_l^k, days	93	122	65	280
FC_l^k	32,5	237,7	5,7	275,9

It is evident that no company has its CCC falling into stability interval (see table 12). Moreover, the industry is characterized by relatively high value of DIO, especially one of a wholesaler, what affect the length of CCCC negatively (280 days for the supply chain considered).

First of all, following the algorithm we assess possibility of joint working capital optimization for upstream part of the supply chain (supplier – wholesaler) using the model of CCCC at first. Table 13 presents the data before optimization, after optimization and comparative change.

Although optimization is possible, the results obtained are very hard to achieve. If following optimal solution, the supplier should refuse from keeping the inventory while for manufacturer it is recommended by the model to decrease its level dramatically. It is highly questionable that the members of a supply chain will be able to maintain such conditions. That is why, we need to move to the next step of the algorithm and try adoption of SCF solutions.

Optimization is not possible with the model of Reverse Factoring. Under specific constraints of liquidity adoption of Reverse Factoring does not allow to find the optimal solution to minimize total supply chain costs on working capital. More-

Table 13. CCCC model results for upstream Telecom operator SC

Initial data (before optimization)					
	DIO	**DRO**	**DPO**	**CCC**	**FC**
Supplier	77	68	52	93	32,5
Wholesaler	184	6	68	122	237,7
				CCCC	**TFC**
				215	270,2
After optimization data					
	DIO	**DRO**	**DPO**	**CCC**	**FC**
Supplier	0	36	52	-16	4,5
Wholesaler	35	6	36	5	0,1
				CCCC	**TFC**
				-11	4,6
Comparative change					
	DIO	**DRO**	**DPO**	**CCC**	**FC**
Supplier	-100%	-47%	0%	-117%	-86%
Wholesaler	-81%	0%	-47%	-96%	-99%
				CCCC	**TFC**
				-105%	-98%

over, it does not work even on the assumption of supply chain members' readiness to increase their individual costs on working capital. Building on the results, the need to manage inventory is observed. Thus, when applying the model of Inventory Financing, optimization is possible (see Table 14).

Table 14 shows that adoption of Inventory Financing allows to improve the companies' liquidity position, since both CCC are inside stability interval after optimization, to decrease total supply chain financial costs on WC providing, however, not worse individual results in terms of financial costs on WC. The improvement is achieved due to Inventory financing adoption observing the following conditions: 58% of overall inventory amount is delivered as it is (from supplier to manufacturer directly), while 42% of inventory is delivered through LSP, herewith LSP possesses inventory legally 76 days on average when a transaction takes place. Annual costs of this SCF solution use are 125,2 million rubles.

The next step is application of the model of joint working capital optimization. Using two types of SCF solutions simultaneously allows to achieve greater results in terms of total supply chain financial costs on WC (see table 15). Optimal solution implies improvement of the companies' liquidity position, since both CCC are inside stability interval after optimization, and decrease of total supply chain financial costs on WC. Along with that, the model provides the optimal conditions of both SCF solutions adoption. Thus, as for Inventory financing, 75% of overall inventory amount is delivered as it is (from supplier to manufacturer directly), while 25% of inventory is delivered through LSP, herewith LSP possesses inventory legally 45 days on average when a transaction takes place. Annual costs of this SCF solution use is 43 million rubles. At the same time, the conditions of Reverse Factoring are as follows: supplier gets 55% of overall value of order quantity immediately from bank and the rest (45%) – in 120 days. Annual costs of Reverse Factoring use is 26

Table 14. Inventory Financing model results for upstream Telecom operator SC

After optimization data						
	DIO	**DRO**	**DPO**	**CCC**	**FC**	**Cost of SCF solution**
Supplier	46	44	52	38	6,2	-
Wholesaler	108	6	52	62	73,1	125,2
				CCCC	**TFC**	**-**
				100	204,5	-
Comparative change						
	DIO	**DRO**	**DPO**	**CCC**	**FC**	**-**
Supplier	-41%	-35%	0%	-59%	-80%	-
Wholesaler	-41%	0%	-23%	-49%	-69%	-
				CCCC	**TFC**	**-**
				-54%	-24%	-

million rubles. As a result, joint working capital declines by 59%, decrease in CCCC is 52% when the total supply chain financial costs on WC reduce by 43%

Table 15. Joint WC optimization results for upstream Telecom operator SC

After optimization data							
	DIO	**DRO**	**DPO**	**CCC**	**FC**	**Cost of IF**	**Cost of RF**
Supplier	59	55	52	62	16,3	-	26,1
Wholesaler	139	6	105	40	68,6	43,6	-
				CCCC	**TFC**	**-**	**-**
				102	154,6	-	-
Comparative change							
	DIO	**DRO**	**DPO**	**CCC**	**FC**	**-**	**-**
Supplier	-24%	-19%	0%	-33%	-50%	-	-
Wholesaler	-24%	0%	+55%	-67%	-71%	-	-
				CCCC	**TFC**	**-**	**-**
				-52%	-43%	-	-

Further to Telecom operator's supply chain example, we consider downstream part of the supply chain meaning wholesaler – distributor relations. Table 16 presents the data before and after optimization when using the model of CCCC.

Again, despite the optimal solution, the obtained results seem to be not realistic. Following optimal solution, a distributor should refuse to keep the inventory while a wholesaler should reduce it twice. However, operating with zero level of inventory turns to be impossible. That is why, we move to the next step of the algorithm developed in order to apply more sophisticated tools.

Table 17 reflects the optimal solutions when using Factoring and Inventory Financing separately. However, it is worth mentioning that the models of SCF solutions are able to provide optimal solution only under the assumption to increase individual costs on WC. Despite increase in the distributor's costs on WC, it is possible for both members to achieve greater liquidity and decrease total supply

Table 16. CCCC model results for downstream Telecom operator SC

Initial data (before optimization)					
	DIO	**DRO**	**DPO**	**CCC**	**FC**
Wholesaler	184	6	68	122	237,7
Distributor	63	7	6	65	5,7
				CCCC	**TFC**
				187	243,4
After optimization data					
	DIO	**DRO**	**DPO**	**CCC**	**FC**
Wholesaler	67	8	68	7	0,2
Distributor	0	7	8	-1	0,1
				CCCC	**TFC**
				6	0,3

chain financial costs on WC including SCF solution costs (20 million rubles) by 48%, adopting Factoring as follows: wholesaler gets 90% of overall value of order quantity immediately from bank and the rest (10%) – in 150 days. Using Inventory Financing such that 57% of overall inventory amount is delivered as it is, 43% of inventory is delivered through LSP, herewith LSP possess inventory legally 27 days on average when transaction takes place works better in comparison to Factoring as it implies 67% distributor's cost on WC rise while 64% total SC financial costs on WC reduction.

Table 17. Models of SCF solutions results for downstream Telecom operator SC

After optimization data (the model of Factoring)									
	DIO	**DRO**	**DPO**	**CCC**	**Change**	**FC**	**Change**	**Cost of IF**	**Cost of RF**
Wholesaler	77	17	52	43	-65%	13,6	-94%	-	20,4
Distributor	184	6	150	40	-39%	92,5	+93%	-	-
				CCCC		**TFC**		**-**	**-**
				102	-56%	154,6	-48%	-	-
After optimization data (the model of Inventory Financing)									
	DIO	**DRO**	**DPO**	**CCC**	**Change**	**FC**	**Change**	**Cost of IF**	**Cost of RF**
Wholesaler	106	7	52	62	-49%	33,0	-86%	-	-
Distributor	38	6	16	27	-58%	9,6	+67%	44,1	-
				CCCC		**TFC**		**-**	**-**
				89	-52%	86,7	-64%	-	-

Therefore, seeing a room for further improvement, in terms of individual costs on WC, we continue with the third step of the algorithm. In the settings of joint working capital optimization model optimal solution is found, the results are demonstrated by table 18.

Optimal solution obtained from the model of joint working capital optimization implies improvement of each company's liquidity position, since both CCC is inside stability interval after optimization, decrease of CCCC due to coordinated actions, and decline of total SC financial costs on WC making individual financial costs on WC not worse. Besides, the model provides optimal conditions for both SCF solutions adoption. Thus, as for Inventory financing, 64% of overall inventory amount is delivered as it is, while 36% of inventory is delivered through LSP, herewith LSP possess inventory legally 22 days on average when transaction takes place. Annual costs of this SCF solution use are 31 million rubles. At the same time, the conditions of Factoring are as follows: wholesaler gets 95% of overall value of order quantity immediately from bank and the rest (5%) – in 58 days. Annual costs of Factoring use are 6 million rubles. As a result, joint working capital declined by 82% when total supply chain financial costs on WC are reduced by 69%.

Table 18. Joint WC optimization results for downstream Telecom operator SC

After optimization data							
	DIO	**DRO**	**DPO**	**CCC**	**FC**	**Cost of IF**	**Cost of RF**
Manufacturer	119	6	68	57	36,0	-	6,1
Distributor	42	7	43	6	0,1	31,4	-
				CCCC	**TFC**	**-**	**-**
				63	73,6	-	-
Comparative change							
	DIO	**DRO**	**DPO**	**CCC**	**FC**	**-**	**-**
Manufacturer	-35%	+11%	0%	-53%	-84%	-	-
Distributor	-35%	0%	+86%	-90%	-99%	-	-
				CCCC	**TFC**	**-**	**-**
				-66%	-69%	-	-

Analyzing the results obtained at each step of the algorithm it can be concluded that simultaneous use of SCF solutions provides greater joint working capital improvement in terms of both individual and total SC financial costs on WC along with greater liquidity achievement.

4.3. Auto Manufacturer's Supply Chain

Herein we are to analyze features of the automotive industry when managing working capital jointly through application of the optimization models developed. The central company of supply chain considered is a car manufacturing company which has a number of plants worldwide, in Saint Petersburg in particular. Currently the plant in Saint Petersburg, which is taken for supply chain construction, is the full-cycle plant including stamping, welding, painting and assembly shops, which allow to produce 5 types of vehicle models in annual amount greater than 150 thousands units. Its supplier is a multinational car parts producer with a plant in Saint Petersburg. It provides manufacturer with vehicle's fuel tanks and elements of suspender. The distributor is integrated with the manufacturer company, which activities are focused on dealership. Practically, it is a Russian car dealership group. Thus, based on the three-stage supply chain we consider the following two-stage ones: supplier – manufacturer (central company), manufacturer (central company) – distributor.

Initial data for supplier, wholesaler and distributor of automotive supply chain is summarized in table 19. It represents 2017 year-end financial data, which is given in million rubles if another is not stated.

Table 19. Initial data for Auto manufacturer SC

Parameter	Supplier	Manufacturer	Distributor	Total (SC)
$Inventory_l^k$	304	14 288	12 691	27 283
AR_l^k	411	12 425	9 655	22 491
AP_l^k	490	18 049	9 286	27 825
$COGS_l^k$	2 710	137 244	112 980	-
$Revenue_l^k$	3 127	151 166	121 519	-
WC_l^k	225	8 664	13 060	21 949
c_l^k, %	0,130	0,116	0,165	-
DIO_l^k, days	41	38	41	-
DRO_l^k, days	48	30	29	-
DPO_l^k, days	66	48	30	-
CCC_l^k, days	23	20	40	83
FC_l^k	0,1	14,4	219,8	234,3

Considering liquidity – profitability tradeoff we again rely on the paper of Garanina & Petrova (2015), because the companies are not ready to disclose this sort of information. Due to this fact we assume CCC of all members of supply chain changes within industry average stability interval, which ranges from -11 to 24 days (Garanina & Petrova, 2015).

It is evident that supplier and manufacturer have their CCC falling into the stability interval (see table 19) while CCC of distributor exceeds recommended upper border. Moreover, the industry is characterized by relatively low values of CCCC components. Especially low inventory levels encourage attention.

Processing the data of Auto manufacturer SC through the optimization models which are included in the algorithm of joint working capital improvement in supply chain gives the following outcomes. To begin with, we consider upstream part of supply chain (supplier – manufacturer). Table 20 presents the data before optimization, after optimization and comparative change when applying the model of CCCC.

For the Auto manufacturer's supply chain the model of CCCC provides realistic results. In order to minimize total supply chain financial costs on WC the only thing to do is to reduce the inventory of manufacturer by 2%, which seems to be possible to put into action. It allows the supply chain to decrease total financial costs on WC significantly (by 99%) while reducing CCCC by 3%.

In this settings application of the models of SCF solutions provides worse results in terms of total supply chain financial costs on WC. Although it is possible to find optimal solution using both Reverse Factoring and Inventory Financing separately, due to the fees to intermediary associated with SCF solutions use total financial costs on WC are greater than ones when applying the model of CCCC. (TFC=2 when using Reverse Factoring and TFC=5, when using Inventory Financing). Processing the data through the model of joint working capital optimization provide

Table 20. CCCC model results for upstream Auto manufacturer SC

Initial data (before optimization)					
	DIO	**DRO**	**DPO**	**CCC**	**FC**
Supplier	41	48	66	23	0,1
Manufacturer	38	30	48	20	14,4
				CCCC	**TFC**
				43	15,5
After optimization data					
	DIO	**DRO**	**DPO**	**CCC**	**FC**
Supplier	41	48	66	23	0,1
Manufacturer	37	30	48	18	0,1
				CCCC	**TFC**
				42	0,2
Comparative change					
	DIO	**DRO**	**DPO**	**CCC**	**FC**
Supplier	0%	-0%	0%	0%	0%
Manufacturer	-2%	0%	-0%	-7%	-99%
				CCCC	**TFC**
				-3%	-99%

the same outcomes as the model of Reverse Factoring use, meaning that it is not necessary to adopt two SCF solutions simultaneously.

We link such results to the fact, that companies of automotive industry pay special attention to inventory management following such production systems as Just-in-Time and Just-in Sequence, which allow not to keep large amount of inventory. The second reason is that both companies of two-stage supply chain already have their CCC falling into specific stability intervals meaning that they rather do not have solvency and liquidity problem which can be addressed by SCF solutions adoption. Keeping almost the same conditions provides supply chain with greater results in terms of total supply chain financial costs on WC.

Further to Auto manufacturer SC example, we consider downstream part of supply chain meaning manufacturer – distributor relations. At first, we assess the possibility of joint WC optimization using the model of CCCC (see Table 21).

Despite optimal solution found, the results obtained seem unrealistic to achieve. If following optimal solution manufacturer should reduce the inventory more than twice as well as to admit the extension of period to collect the receivables. Assuming that manufacturer will be ready to tolerate slower cash recovery, which is beneficial for distributor, significant inventory decline turns to be impossible. Therefore, we move on the next step the algorithm developed in order to apply SCF solutions and analyze the results.

Table 22 indicates the optimal solutions when using Factoring and Inventory Financing separately. However, it is worth mentioning that the model of Inventory Financing is able to provide optimal solution only under the assumption to increase individual costs on WC while adoption of Factoring does not allow to find feasible solution. Although manufacturer's costs on WC remain the same while for distrib-

Table 21. CCCC model results for downstream Auto manufacturer SC

Initial data (before optimization)					
	DIO	**DRO**	**DPO**	**CCC**	**FC**
Manufacturer	38	30	48	20	14,4
Distributor	41	16	30	27	137,8
				CCCC	**TFC**
				47	152,2
After optimization data					
	DIO	**DRO**	**DPO**	**CCC**	**FC**
Manufacturer	12	44	48	9	0,1
Distributor	41	16	44	13	0,1
				CCCC	**TFC**
				21	0,2

utor it is possible to achieve greater liquidity and decrease individual costs on WC by 99%, total supply chain financial costs on WC including SCF solution costs (90 million rubles) decline by 21%, adopting Factoring as follows: manufacturer gets 44% of overall value of order quantity immediately from bank and the rest (56%) – in 51 days. Using Inventory Financing such that 92% of overall inventory amount is delivered as it is, 8% of inventory is delivered through LSP, herewith LSP possess inventory legally 3 days on average when transaction takes place works even worse than Factoring as it implies 39% manufacturer's cost on WC rise along with smaller total SC financial costs on WC reduction (TFC = 105 under Factoring, TFC = 129 under Inventory Finance).

Table 22. Models of SCF solutions results for downstream Auto manufacturer SC

After optimization data (the model of Factoring)									
	DIO	**DRO**	**DPO**	**CCC**	**Change**	**FC**	**Change**	**Cost of IF**	**Cost of RF**
Manufacturer	38	30	48	20	0%	14,4	0%	-	90,2
Distributor	41	29	51	19	-34%	0,1	-99%	-	-
				CCCC		**TFC**		-	-
				39	-20%	104,7	-21%	-	-
After optimization data (the model of Inventory Financing)									
	DIO	**DRO**	**DPO**	**CCC**	**Change**	**FC**	**Change**	**Cost of IF**	**Cost of RF**
Manufacturer	35	28	48	16	-22%	20,0	+39%	-	-
Distributor	38	16	30	24	-11%	106,8	-22%	1,9	-
				CCCC		**TFC**		-	-
				40	-16%	128,7	-15%	-	-

Therefore, it is worth checking whether there is possibility for further improvement in terms of individual costs on WC, continuing with the third step of the algorithm. In these settings optimization is possible, the results are demonstrated by table 23.

Optimal solution given by joint working capital optimization implies improvement of each company's liquidity position, since both CCC is inside stability interval after optimization, decrease of CCCC due to coordinated actions, and decline of total SC financial costs on WC. However, the optimal solution does not provide improvement of manufacturer's individual financial costs on WC, they remain the same. The model also provides optimal conditions for both SCF solutions adoption. Thus, as for Inventory financing, 85% of overall inventory amount is delivered as it is, while 15% of inventory is delivered through LSP, herewith LSP possess inventory legally 6 days on average when transaction takes place. Annual costs of this SCF solution use are 7 million rubles. At the same time, the conditions of Factoring are as follows: wholesaler gets 10% of overall value of order quantity immediately from bank and the rest (90%) – in 40 days. Annual costs of Factoring use are 16 million rubles. As a result, joint working capital declined by 25% when total supply chain financial costs on WC are reduced by 75%.

Table 23. Joint WC optimization results for Auto manufacturer SC

After optimization data							
	DIO	**DRO**	**DPO**	**CCC**	**FC**	**Cost of IF**	**Cost of RF**
Manufacturer	33	35	48	20	14,4	-	15,9
Distributor	35	16	39	12	0,1	7,2	-
				CCCC	**TFC**	**-**	**-**
				32	37,6	-	-
Comparative change							
	DIO	**DRO**	**DPO**	**CCC**	**FC**	**-**	**-**
Manufacturer	-14%	+18%	0%	-0%	-0%	-	-
Distributor	-14%	0%	+30%	-54%	-99%	-	-
				CCCC	**TFC**	**-**	**-**
				-31%	-75%	-	-

Analyzing the results obtain at each step of the algorithm it can be concluded that simultaneous use of SCF solutions provides greater joint working capital improvement in terms of total SC financial costs on WC and greater individual and joint liquidity achievement.

5. Conclusions

The research is devoted to joint working capital management in supply chains aiming to improve joint working capital management methods through minimization of financial supply chain costs using supply chain finance solutions.

Main Findings. First, theoretical review indicates that scientific literature has a clear gap of adequate application of numerous SCF solutions or any other methods for managing elements of CCCC that aim to improve working capital management. Although in recent years the topic of supply chain finance has gained a lot of academic attention, there are a lot of uninvestigated areas such as managerial perspective of SCF solutions use (Zulqurnain et al., 2018). Moreover, in reliance upon the research articles three particular SCF solutions (Factoring, Reverse Factoring and Inventory Financing) were chosen since they affect all the components of CCC when using, staying in line with the ultimate goal of the research.

Secondly, four different optimization models were developed and combined into an algorithm in order to demonstrate how they can be applied for joint working capital optimization in supply chains. These models are: the model of CCCC, two model of SCF solutions (Factoring/Reverse Factoring and Inventory Financing in particular), and the model of joint working capital optimization. The former shows optimal WC components to achieve minimal total supply chain financial costs on WC under the specific constraints, including liquidity – profitability tradeoff and individual costs on WC maintenance, whereas three latter models are to provide clear ways to achieve minimal total supply chain costs on WC and higher liquidity giving the optimal conditions of SCF solutions adoption. As a result, representing sequential application of the models, which are developed to analyze different scenarios for achievement of minimized total supply chain costs on WC, proposed algorithm is a managerial tool for joint working capital optimization in supply chains.

Application of the algorithm to six two-stage supply chains from three different industries (FMCG sector, ICT, and Automotive one) allows to check the robustness of joint working capital management methods developed in the research and to conclude about their implications. So, the results indicate that the model of CCCC allows to find optimal solution for all cases regardless initial financial and liquidity position of supply chain members; however, the model provides unrealistic results for those supply chains where CCC of at least one SC member lies outside stability interval, which resolves liquidity – profitability tradeoff. Aiming to avoid unrealistic results and to reach clear ways to achieve improvements the data was processed through the models of SCF solutions and joint working capital optimization. Notwithstanding this fact, separate adoption of SCF solutions cannot fully improve joint working capital in supply chains in terms of greater liquidity and minimized costs on WC. Generally, the models either are not able to provide feasible solution under the specific constraints or are able to find optimal solutions but admitting individual financial costs on WC increase. In contrast, the model of joint working capital optimization is able to provide optimal solutions for all the cases considered in the research. It allows to minimize total supply chain financial costs on WC making individual ones not worse and to achieve greater liquidity at the same time, as well as provides the optimal conditions of SCF solutions adoption to achieve the results of joint WC improvement in supply chain. Thus, quantitative optimization demonstrates on the cases of supply chains that the model with SCF solutions use improve financial position and liquidity of all supply chain members.

Theoretical and managerial implications. The research contributes to the existing studies dedicated to the fields of supply chain finance and working capital management by focusing on optimization of financial flows between supply chain members in terms of total supply chain costs on working capital minimization. Integration of financial and operational perspectives on supply chain management allows to advance working capital management to the level of supply chain from the level of single company. Thus, the study emphasizes the importance to manage working capital jointly in order to response to highly competitive and volatile economic environment and be able to adjust operations.

First, the research demonstrates that there is a possibility to improve joint working capital in a supply chain minimizing total financial costs on working capital and allowing greater liquidity achievement. Furthermore it provides a clear way of reaching optimal results using supply chain finance solutions. Secondly, the authors fulfilled the research gap expressed in adequate application of SCF solutions for managing elements of working capital, and lack of a managerial perspective of SCF solutions having developed the models of SCF solution along with the model of their simultaneous adoption, which shows how it improves joint working capital. The developed models are applicable to two-stage supply chains.

Managerial actions aiming to improve working capital are of absolute importance, as the most of company's daily operations depends on and is determined by working capital, in such a manner influencing companies' results. Fast cash recovery and absence of insolvency problems allow companies to develop long-term strategies investing them from internal sources. Indeed, companies show high expertise in estimating affordable cycle times dealing with working capital management at the level of single company, but joint actions toward working capital management at inter-organizational level still raise difficulties.

The research provides optimization models, which are combined into the algorithm, allowing supply chain members to use it as a comprehensive managerial tool for joint working capital management in a supply chain. The algorithm may be used by different two-stage supply chains with the goal of achieving optimal cash conversion cycle values for minimal supply chain costs on working capital constrained by liquidity and profitability target levels. The algorithm allows users to estimate the possibility of joint working capital optimization. It identifies appropriate directions to manage, and to reach clear ways of joint working capital management through supply chain finance solutions aiming at total SC financial costs reduction and greater liquidity achievement.

Supply chain members benefit from the tool developed in a way of financial performance improvement, costs decrease, and stable financial position achievement. Apart from that, they can build stronger relationship between each other due to coordinated actions. It allows to ensure more stable supply of products and to improve fulfillment of the customers demand and response to its changes making supply chain competitiveness higher. Thus, the developed methods are applicable to two-stage supply chains in different industries, and may be used by businesses and decision-makers, consulting companies, different intermediaries as banks or logistics service providers.

Limitations and future research. Notwithstanding the above-indicated results, it is to take into consideration that the present paper is limited to those supply chains, which consist of two stages. Therefore, we suggest that the study should be continued. As a next step we consider an involvement of more than two SC members into the research. This will give an opportunity to improve the present models and to increase its applicability for the business. Besides, it is to be stressed that the present paper discusses only few SCF solutions. Further research can consider other tools and solutions in order to assess other ways of joint working capital improvement.

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