St. Petersburg University

Graduate School of Management

Master in International Business Program

# WORKING CAPITAL MANAGEMENT IN SUPPLY CHAINS

Master's Thesis by the 2nd year student

Concentration MIB-ILSCM

Nataliia G. Silaeva

Research advisor:

Nikolay A. Zenkevich, Associate Professor

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ЗАЯВЛЕНИЕ О САМОСТОЯТЕЛЬНОМ ХАРАКТЕРЕ ВЫПОЛНЕНИЯ ВЫПУСКНОЙ КВАЛИФИКАЦИОННОЙ РАБОТЫ

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# АННОТАЦИЯ

| | |
|---|---|
| **ФИО студента** | Силаева Наталия Геннадьевна |
| **Тема магистерской диссертации** | Управление рабочим капиталом в цепях поставок |
| **Факультет** | Высшая школа менеджмента |
| **Программа** | Международная логистика и управление цепями поставок |
| **Год окончания** | 2016 |
| **ФИО научного руководителя** | Зенкевич Николай Анатольевич |
| **Описание цели, задач и основных результатов**<br>Цель: разработка координирующей модели управления рабочим капиталом в совместной цепочке поставок<br>Задачи исследования: идентифицировать пробелы в научных исследованиях управления рабочим капиталом в цепи поставок; улучшить методологию управления рабочим капиталом в цепях поставок через создание координирующей модели модифицированного коллаборативного цикла оборота денежных средств в цепях поставок; проанализировать координационное моделирование управления рабочим капиталом в цепях поставок, используя подход тематического исследования.<br>Основные результаты: обнаружен пробел в исследованиях - управление рабочим капиталом в совместных цепях поставок; создана координирующая модель управления рабочим капиталом в цепях поставок с 3PL-провайдером в роли координатора децентрализованной цепи поставок; результаты применения координационного моделирования показали значительное сокращение издержек модифицированного коллаборационного цикла оборота денежных средств в каждой из четырёх коллаборативных цепочек поставок. | |
| **Ключевые слова** | Управление рабочим капиталом, координационное моделирование, коллаборация, 3PL провайдер, коллаборативная цепочка поставок, модифицированный коллаборативный цикл оборота денежных средств |

# ABSTRACT

| | |
|---|---|
| **Master Student's Name** | Nataliia G. Silaeva |
| **Master Thesis Title** | WCM in supply chains |
| **Faculty** | Graduate School of Management |
| **Program** | International Logistics & Supply Chain Management |
| **Year** | 2016 |
| **Academic Advisor's Name** | Nikolay A. Zenkevich |
| **Description of the goal, tasks and main results**<br>Goal: the development of coordinating model of WC management (WCM) in collaborative supply chains<br>Research objectives: To identify the research gaps of WCM in supply chains based on the literature review devoted to WCM in supply chains; to improve methodology of WCM in supply chains trough creation of coordinating supply chain modified collaborative CCC (mCCCC) model; to analyze in coordination modeling of working capital management in supply chains using case study approach.<br>Main results: Revealed research gap of coordinating mechanism of WCM in collaborative supply chains; created coordinating supply chain mCCCC model with 3PL provider as a coordinator of a decentralized supply chain; results of coordination modeling showed significant cost reduction of running the mCCCC of each of 4 collaborative supply chain. | |
| **Keywords** | Working capital management, coordination modeling, collaboration, 3PL provider, collaborative supply chain, modified collaborative cash conversion cycle |

## Content

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# Introduction

During the last decade the increased volatility in business environment followed by the financial crisis of 2008-2009 and recent oil crisis increased the competition among the companies. Companies seek additional ways to gain competitive advantage, decrease costs and increase profitability. The common way of financing operations through credit and loans is no longer easy accessible due to the financial crisis and tight economic situation thus companies try to find new ways of operations financing.

One of ways to obtain competitive advantage through faster and more efficient financing of supply chain (SC) is working capital management (WCM) in SCs as a part of financial supply chain management (FSCM). (Sigurin, 2009). The WCM in SCs cannot be performed properly at the intra-organizational level due to the fact that it involves liabilities at the inter-organizational level of a SC and requires collaboration at all stages of a SC (Seifert, 2010).

From the academic perspective the WCM as a part of FSCM has gained a lot of attention (Matyac, 2015). This approach was developed in the terms of a new research field – FSCM which recently has gained a lot of attention. Viskari et al. (2012) predicted that there would be a lot of studies dedicated to FSCM and particularly management of working capital (WC) in SCs as a way to accelerate the cycle time of WC and increase the profitability of the company in respond to recent financial volatility in business environment.

The **subject** of the master thesis is *FSCM* which defines by Hoffman (2005) as "located at intersection of logistics, SC management, collaboration and finance, FSCM is an approach for two or more organizations in a SC, including external service providers, to jointly create value through means of planning, steering, and controlling the flow of financial resources on an inter-organizational level".

The **object** of the study is *WCM in SCs* which can be measured using WC ratios or operational evaluation such as cash conversion cycle (CCC). Christopher and Ryals (1999) defined WCM as one of the factors of shareholder value creation. Karl Max introduced the idea of WC and Pirttilä (2014) identifies WC as "the capital of a business which is used in its day-to-day trading operations, calculated as current assets less current liabilities". The WCM in SCs in done using operational level measure of CCC, which modifications of concepts and evaluation approach are developed in this master thesis. The **scope** of the research derives from three main fields of FSCM, corporate finance and SC management and is illustrated at Figure 0.1.

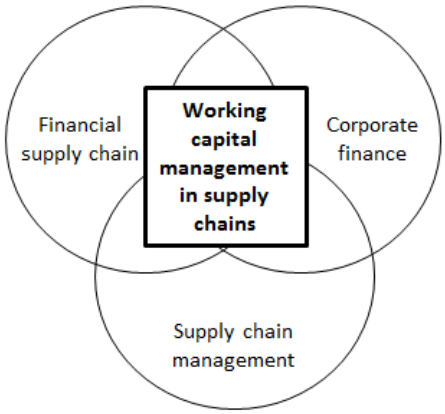


Figure 0.1. The scope of the research

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The **goal** of the study is *development of the coordinating model of WCM in collaborative SCs*. In terms of the goal stated the following **objectives** of the master thesis were set:

1. To identify the research gaps of WCM in SCs based on the literature review devoted to WCM in SCs;
2. To improve the methodology of WCM in SCs through creation of coordinating SC modified collaborative CCC (mCCCC) model;
3. To analyze coordination modeling of WCM in SCs using case study approach.

The **methods** applied for achievement of goals are *design-science* and *archival* approaches. The results of methodology development are verified with the *case study* method – the research based on four different cases – project, ICT, automobile and pulp&publishing industries collaborative SCs.

The **theoretical relevance** of the master thesis is justified with the fulfillment of the research gap identified as a result of theoretical review of WC in SCs – the absence of works dedicated to the coordinating model of WCM in collaborative SCs. The **managerial applicability** of the work is supported by the results of testing the concept and the model on four different cases and advantages the companies can obtain using the developed coordinating model to evaluate their length of collaborative cycle and ways of reduction of total financial costs associated with the length of the cycle.

The **structure** of the research is following. The master thesis consists of introduction, 3 chapters, conclusion, references list and appendixes. The introduction reveals the goal, research objectives and managerial problem of the master thesis. First chapter entails the theoretical review of financial SC and identifies the research gap which corresponds to the first objective of

investigation of literature devoted to financial SC (FSC) and identification of research gaps in FSC field. Chapter 2 consists of research approaches description and ways of the improvement of the methodology of FSC and development of optimization model based on cost criterion summarized in research design. Improved methodology of FSC then tested on four different cases of collaborative SCs in Chapter 3. The main findings, theoretical and managerial contribution of this master thesis alongside with the ways of future research are summarized in conclusions. The structure of the research is illustrated in Figure 0.2.

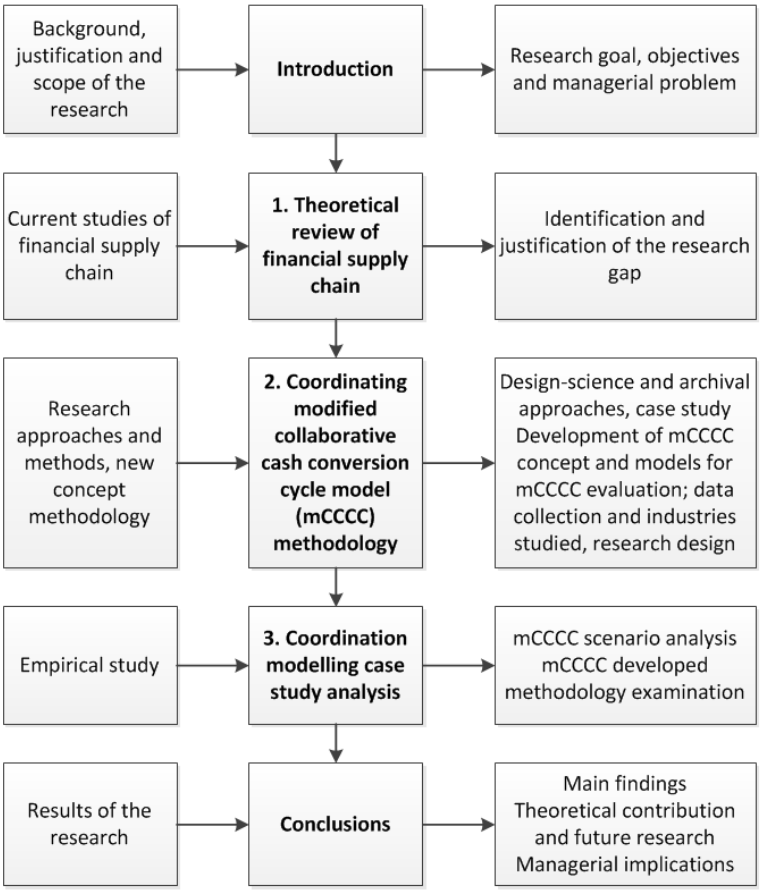


Figure 0.2. The structure of the master thesis

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# 1. Theoretical review of financial supply chain

This chapter is dedicated to the justification of the theoretical relevance of the chosen topic and to the identification of the research gap in the existing literature about WCM in SC. The structure of literature review is following: the first goal is to identify all stages leading to SC collaboration. This chapter also identifies the main perspectives if FSCM. Thirdly, there is a theoretical foundation for one of dimensions of FSCM – WC. The CCC model and its modifications are reviewed as a part of analyzing WCM in SCs.

## 1.1. Collaboration in supply chains

The SC concept has steadily appealed the attention from both researchers and companies' management due to increasing importance of the role it plays in companies' performance. Increasing demand and constant improvement of technologies increase the complexity of business environment and these companies who can create and manage effective SCs can gain a sustainable competitive advantage.

The development of SC and SC management definition has started in 1960s and the term itself was firstly introduced by consultants in the beginning of 1980s. At this time the researchers have started to align the processes which were perceived as separate such as transportation, warehousing, purchasing, etc. In the 1980 to the beginning of 2000s the concept of SC was integrated as "an integration of business processes from end user through original suppliers that provides products, services and information that add value for customer and other stakeholders". (Lambert, Stock, Ellram, 1998)

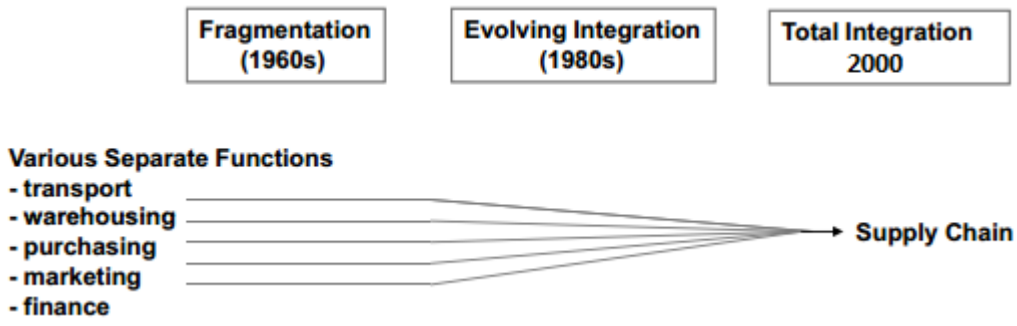



Figure 1.1.The evolution of SC management definition

Source: Branch, (2009)

One of the most common definition of SC which is widely used in many studies is the one stated by Jain (2009) – "SC is a dynamic process and involves the constant flow of

information, materials, and funds across multiple functional areas both within and between chain members" which is elaborated from the definition provided by Mentzer et al.. (2001) – "SC is a set of three or more entities (organizations or individuals) directly involved in the upstream and downstream flows of products, services, finances and information from a source to a customer".

The SC is closely associated with the SC management concept. One of the widely used definitions to SC management is stated by the Council of SC Management Professionals – a worldwide association of SC management professionals who defined the SC management as "encompasses the planning and management of all activities involved in sourcing and procurement, conversion and all Logistic Management activities. Importantly, it also includes coordination and collaboration with channel partners, which can be suppliers, intermediaries, third party service providers and customers. In essence, SC management integrates supply and demand management within and across companies" (GSCMP, 2016).

This definition of SC management which will be used in this master thesis includes logistics activities as a part of SC management. Although there are a lot of contradiction between researches whether logistics is a part of SC management or there are two separate dimensions or SC management is included into logistics. There are four different perspectives of SC management and logistics relationship (Larson, Halldorsson, 2004).

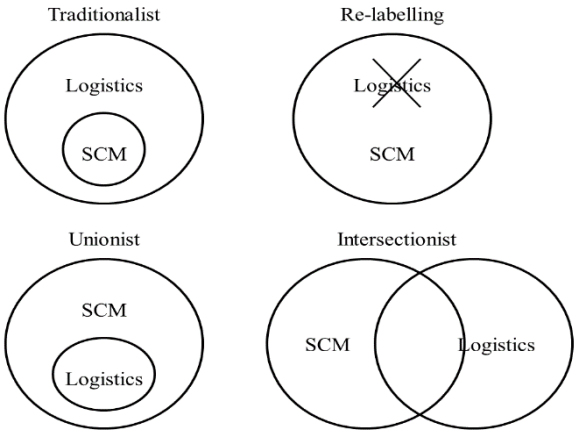



Figure 1.2. Four perspectives of SC management and logistics relationship

Source: Larson, Halldorsson (2004).

According to Larson and Halldorsson (2004), the traditional view includes the SC management into logistics as a part of it. The re-labelling is a view of substitution of logistics by SC management. Intersection view for SC management and logistics relationship suggests that SC management does not include business processes such as logistics, purchasing, inventory or

others. Rather this perspective is about strategic elements from all organizational perspective. The last one – unionist view which incorporate logistics as a part of SC management will be used in this thesis in compliance with the definition stated by GSCMP (2016) and supported by Mentzer et al. (2001). According to Larson (1998) the logistics focuses on the processes at the company level and the SC management operates inter-organizationally.

The concept of SC management includes the simple (direct) SC structure and its broaden versions with multiple participants of the SC (Hugos, 2011). The simple version of the SC consists usually of three members: a company, a supplier of this company and company's customers. The broaden versions of the SCs include several steps of the SC including financial and service providers. Mentzer et al. (2001) provide three main types of SC relationships.

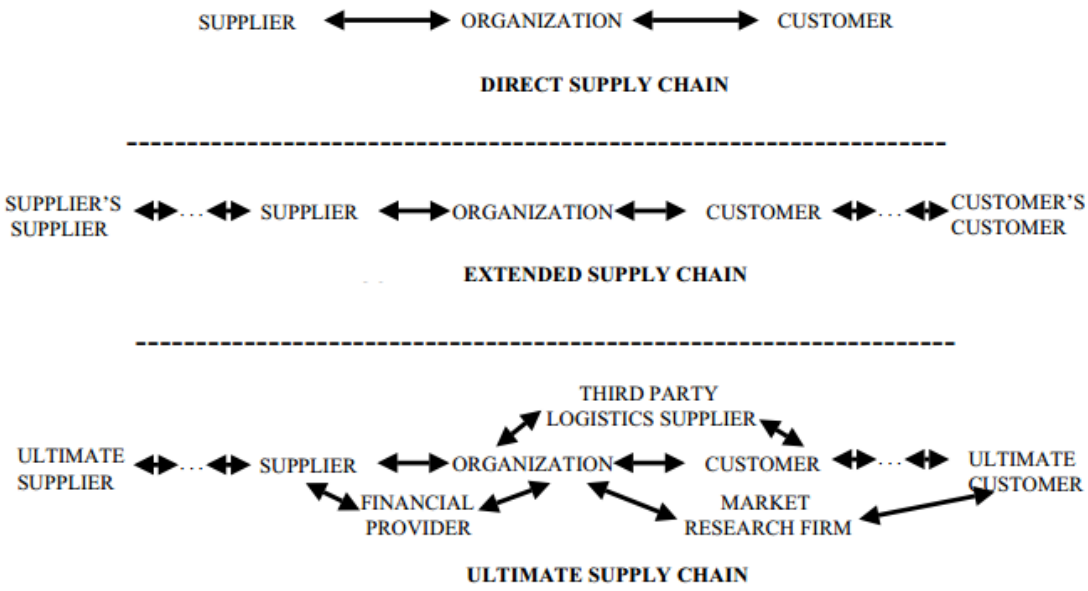



Figure 1.3. Types of SC structure

Source: Menzer et al., (2001)

The perceptions of the way the SC's structures are also varied among researchers and highlight two main approaches – integrated and dynamic. The concept of integrated model of SC was introduced by Akkermans (2003) when he stated that SC consists of 5 participants which are suppliers, companies (as a manufacturers), distributors (or warehouses), retailers and end customers. Three types of flows are circulated through this network – physical (as goods or services), information and financial. The financial flow has recently been highlighted as a separate flow in SC processes and the new perspective was introduced – FSCM which is going to be reviewed separately. These networks are supported by organizational structure of the

company and all participants of the SC, technologies which enables the business processes of the SC.

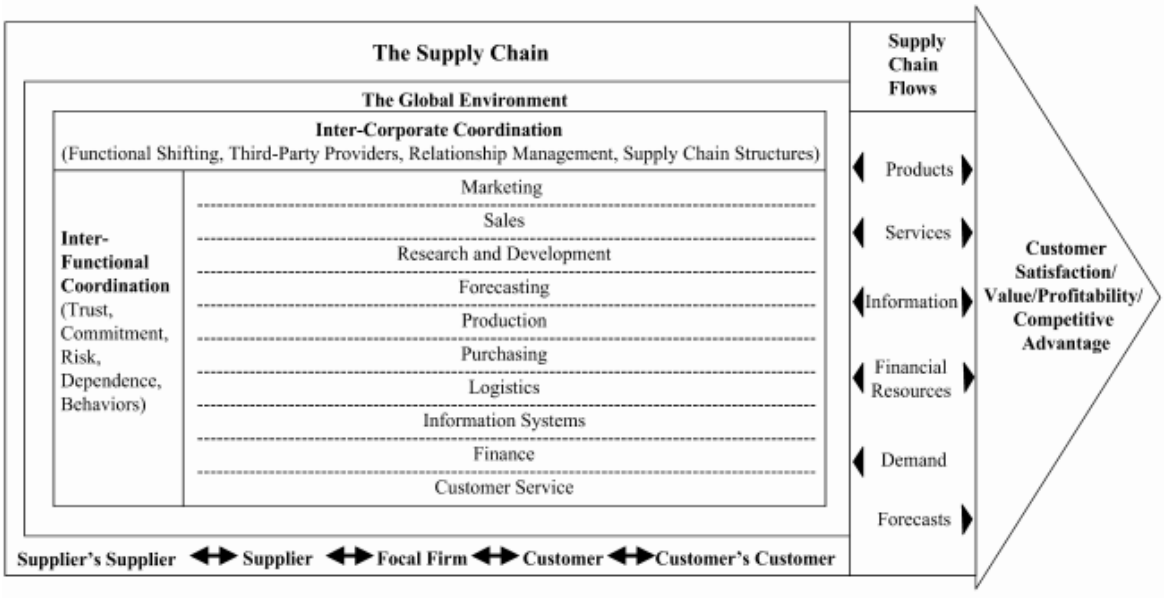



Figure 1.4. SC networks

Source: Menzer et al., (2001)

Another view to SC process is reviewed by Harrison, Lee and Neale (2003) and is about the dynamic nature of SC. The dynamic SC design should not only be about collaboration among the companies but also about the dynamic processes of aligning capability chains.

The goal of the SC management is to align intra- and inter-organizational level of company's activities which allow effective management of all flows in SC and meet the demand of its customers (Burgess, 2006). Thus, to achieve effectiveness a SC should be managed at the system level. Mentzer et al. (2001) emphasize the critical role of systematic approach as a tool to manage a SC in order to gain a sustainable competitive advantage not only for the participants of a SC, but also for a whole SC which could be achieved through collaboration (Simatupang, Sridharan, 2002).

**1.1.1. Collaborative SC management**. After the total integration of activities into aggregated SC the role of it has increasingly started to play in gaining an advantage in a competitive landscape. The importance of the SC proper management could affect not only the operations but also the activities involved into business processes at all stages of value and SC (Barratt, 2004).

To achieve the effectiveness and competiveness of SC the management should consider several factors prior – fast information exchange, decreased lead-time alongside with decreased transportation costs, responsiveness of goods or services. To meet these goals and improve the financial and economic performance of the company the companies inside a SC should start to collaborate with each other (Seifert, 2010).

According to Simatupang and Sridharan (2004) the SC collaboration assumes that the SC members manage coordination among participants in order to meet customer demand by spanning the boundaries. In other words "collaboration is a cooperative strategy of SC partners with a common goal of serving customer through integrated solutions for lowering cost and increasing revenue" (Simatupang et al.., 2004). Samaddar and Kadiyala (2006) in their research add that knowledge exchange plays an explicit role in SC management collaboration. Besides, Fawcett et al. (2011) state that the collaboration allows companies creating and managing unique processes that bring value for companies by better meeting customer goals.

Most of the studies perceive the collaboration at the inter-organizational level, but importance of collaborative networks inside the company is hard to be overestimated. Besides, in the study of Simatupang et al.. (2004) the survey was conducted and most of the respondents who have managed to achieve strong supplier-retailer collaboration stated that they have recently enjoyed increasing sales, decreased lead time and increased on-time delivery and inventory levels, etc. The process of achieving collaboration is consists of four stages which were stated in the study of Spekman et al.., (1998).

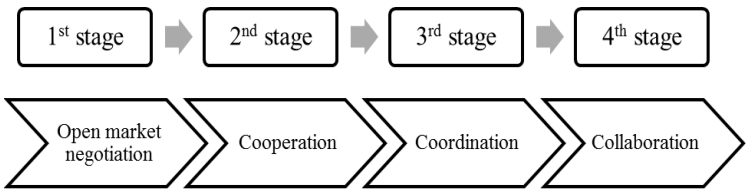



Figure 1.5. Stages of collaboration achievement

Source: Spekman et al.., (1998)

At the first stage of open market negotiation companies start to discuss optimal prices which result in adversarial relationships among participants. The stage of cooperation companies start to decrease boundaries of information exchange and develop long-term contracts with some suppliers. Spekman et al.., (1998) emphasize the fact that the beginning of the SC management is at the stage of cooperation. Although it is still not enough to provide the goals of SC management and the companies transit to the next part of collaboration achievement –

coordination. In addition to the previously opened information exchange channels participants of the SC start specified material flows to provide better results. Although this stage is still fulfill the requirements of the SC integration due to the lack of constant information exchange among participants.

At the fourth stage of collaboration the integration of SC is finally achieved. The integration means that all participants of the SC are involved in other participants' business processes. As for example of SC integration the members of SC not only the joint production plan for the product but also sharing technologies available, creation future design and long-term strategic actions. The final level of collaboration requires companies to trust each and share information with their partners. (Horvath, 2001).

Anupindi and Bassok (1999) stated that the management of SCs deals with the flows of information and physical goods while managing financial flows of the SC network. Höhn (2010) pointed that the decisions of volumes and price of any pair of network members should be made by a single decision maker who was all information available. In other words, the case of the management of supply chain with a single decision maker is called centralized or integrated. Otherwise, if there are many decision makers who do not have the holistic perspective of all information available the supply chain management is decentralized.

According to Anupindi and Bassok (1999) the single decision maker management is preferable because it optimized the SC with all information available of all members involved. Furthermore as it was mentioned by Corbett et al. (2004) in the case of decentralized SC the information holders often refuse to share private pieces of information which creates obstacles for optimal SC performance. To paraphrase the decentralized SC is not efficient enough due to incomplete cooperation which can affect profitability. Thus, Höhn (2010) concludes, the centralized decision making can be used for sustainable competitive advantage achievement.

Popa (2013) in his study reflects that the integration of a bank or other financial institution as a financial 3PL provider for FSCM should be investigated further. One of the main reasons he provides is that to achieve collaborative management in the volatile economic environment companies should not only exchange information flows but also integrate financial ones which is possible when a bank or other financial institution is in a role of financial 3PL operator for a collaborative supply chain which. The financial 3PL provider as a coordination mechanism will be implemented in the coordination modeling of WCM in SCs and discussed in details in chapter 2.2.

**1.1.2. SC collaboration typology.** Researches identify the types of SC collaboration differently. The theoretical framework of joint ventures offered by Doz and Hamel (1998) describes the inter-organizational collaboration as a development tool for new market opportunities. The example of this type of collaboration could be describes with a situation when a company which is seeking for a new market collaborate with a local one which provides market knowledge and networks. Usually participants of this type collaborate at one point of the SC to establish production or distribution economies of scale (Hennart, 1988).

Another type of collaboration among SC members refers to strategic alliances. Recently this topic has received larger attention from the researchers but the field is still fragmented. The most common definition of strategic alliances comes from the work of Spekman and Celly (1995) and states that the strategic alliances assumed to be in a long-term perspective where participants of the partnership share resources, technologies and information in order to gain a competitive advantage for each other. It was mentioned by Li and Qian (2013) that strategic alliances can be used for faster spread of new technologies, exploration and penetration of new markets.

In the constantly changing business environment there are a lot of the companies who would like to cooperate with other companies to response to these fast changes. For example, with the rise of telecommunication technologies enables virtual collaboration to happen. There is a situation where a company temporary is involved in a close collaboration with independent entity because of this type of technology. Usage of telecommunication technology allows companies involved to share and decrease costs, exchange skills and get access to global markets. Bal et al. (1999) specifically mention that there are two stages of virtual collaboration – information networks at the first stage and after the specific market goal was obtained the dissolution of the collaborative network.

When it comes to long-term collaboration it is aligned with the strategies of the companies which participate in the SC. Baratt (2004) in his study highlights three main strategies of SC collaboration. Horizontal collaborative strategy or often called horizontal integration happens when two companies which are not related but produce close to similar or similar products create a collaboration in order to logistics resources or manufacturing capabilities (Simatupang, Sridharan, 2002). Using horizontal integration may result in reduced operation costs, improved procurement and overcome financial barriers for each company.

Lateral collaboration combines the advantages of both vertical and horizontal SC collaborative strategies. Intermodal transportation mode is one of the examples of effective lateral SC integration.

Another view on the collaboration is about splitting it into internal and external dimensions. Internal collaboration is achieved on the intra-organizational level aligning the different departures within the company such as marketing, customer development, SC and others. External level of collaboration is based on the inter-organizational level and usually connects manufacturer with its suppliers and customers. The common feature both collaborative dimensions share is that at all levels including production planning, new products integration and shared distribution. There are techniques that allow aligning of both levels of collaboration such as Vendor Managed Inventory (VMI) and Collaborative Planning, Forecasting and Replenishment (CPFR) (Flynn, Hou, Zhao, 2010).

Successful achievement of collaboration among partners is based on three main features when at least one should be satisfied to ensure increased company's performance. Spekman (1998) in his study classified these features in three main factors of SC collaboration. The first condition is information exchange which includes access to the data of the companies. The second one is collaborative decision making in response to external factors using internal capabilities. The last dimension is the ability of each SC member to take risks and share costs of financial flows of the SC management. Recently researchers have started to highlight financial flows as a separate flow alongside with information and physical flows of goods and services. The financial flows of the SC are one of the main topics of this master thesis thus it is essential to provide the review on one of the most recent study field in SC literature – FSCM.

## 1.2. Financial supply chain management (FSCM)

In the era of SC integration there were two main flows of physical goods or services and information flows inside the SC. The new studies in the beginning of 21$^{st}$ century revealed the need of investigation into one more separate flow – financial due to increased speed of constantly changing business environment and demand of faster cash-to-cash cycles as a response.

Collaboration among partners of SC and SC management allows connection of all parties of the SC such as suppliers, manufacturers, distributors, retailers, 3PL providers and financial intermediaries. There are three main streams of flows into SC – downstream flow of cash,

upstream flow of goods or services and information flow which goes both directions (Gupta, Dutta, 2011).

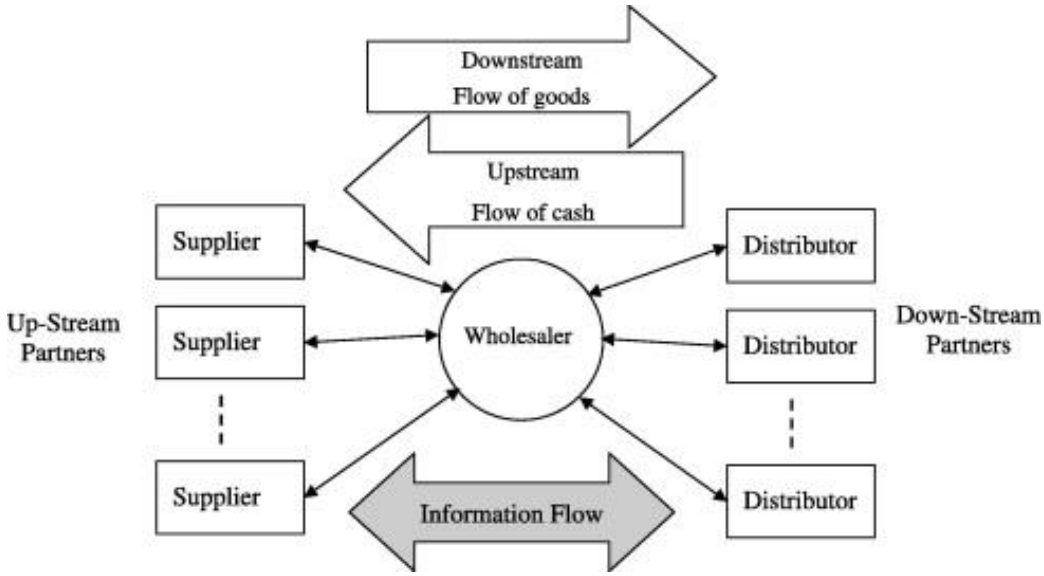



Figure 1.6. The downstream and upstream directions of flows in SC

Source: Gupta and Dutta, (2011)

Although the main focus of researchers' attention is still paid to information and physical goods or services flows the FSCM is gaining its fair amount of attention of the recent studies – in the study of Wuttke et al. (2013) the financial flow is acknowledged as the one of the main pillars that ensures the efficient performance of the SC. The authors also mention that in order to achieve competitive advantage in SC management companies should have their concentration not only on downstream but also on upstream financial flow. Randall and Farris (2009) support this view and state that companies who are able to manage both directions could gain additional competitive advantage based on cost reduction and increased profits.

Due to increased volatility in global economics companies that do not have efficient FSCM will not be able to perform well in long-term conditions. Global financial crisis of 2008-2009 has boosted the investigations in the study of FSCM in order to provide techniques to strengthen business processes inside SCs. Collaboration among the companies at this stage has become increasingly important due to the fact the financial flows ensures constant performance of all companies participating and most companies are seeking the way of financial optimization at all stages of collaborative SCs (Fairchild, 2005). Some companies prefer managing its financial flows themselves – others delegate the duties to 3PL providers or financial intermediaries to achieve better collaboration in information and financial flows exchange.

**1.2.1. Definition of FSCM.** The literature dedicated to FSCM is scarce and most of the research studies focus on one specific factor rather than pertain a holistic view. Most of the financial papers dedicated to financial SC topics focus on the technical factors of the SC and ignore its operations and strategic importance.

As it often happens in the science the researchers have not managed to evolve a common definition of FSCM because many authors base their conclusions on different concepts (Blackman, Holland, Westcott, 2013). The first definition was introduced by Killen&Associates in 2000. They stated that the financial SC should be perceived as a chain where "parallels the physical or materials SC and represents all transaction activities related to the flow of cash from the customer's initial order through reconciliation and payment to the seller" (Weiss, 2012). The authors are mainly focused on intra-organizational nature of financial SC whereas other researchers suggest interpretation of it also on the inter-organizational level (Popa, 2013).

One of the most cited definitions of inter-organizational financial SC is offered by Hoffman (2005). He suggests the definition as "located at intersection of logistics, SC management, collaboration and finance, FSCM is an approach for two or more organizations in a SC, including external service providers, to jointly create value through means of planning, steering, and controlling the flow of financial resources on an inter-organizational level".

Management accounting studies interpret FSCM from the perspective of global value chain as "a series of financial events that are based on financial and information flow between members of global value chain" (Matayac, 2015). The technology also plays a role in connection of financial flows with other flows as many of the studies of it operates the databases from different IT platforms such as Enterprise Resource Planning SaaS. Many banks and consulting services offer their clients optimization of FSCM to increase cash cycles and thus liquidity and to fix risks.

In their study of investigating a financial SC strategy of Motorola company Blackman et al.. (2013) state the definition of it as "a financial SC is the network of organizations and banks that coordinate the flow of money and financial transactions via financial processes and shared information systems in order to support and enable the flow of goods and services between trading partners in a product SC". This definition combines the features associated with the financial flows in SCs and will be used in this master thesis in the further investigation of FSCM perspectives.

**1.2.2. Scope and perspectives of FSCM.** To identify the scope and intersections of financial SC in order to define the perspectives of this field Institute of SC Management linked it with other disciplines such as SC management, corporate finance and risk management (ISCM, 2012). The intersections are illustrated in Figure 1.7. According to their study, there are two main perspectives of FSCM: financing of trade operations and WCM in SC are included in FSCM and risks of financing SCs relate to financial risk management in SCs.

Financial risk in SCs concerns risks of trade and possible supplier default risks. As for FSCM, it includes pre- and post-shipment financial management and mutual activities such as cash flow forecast and WCM in SCs (Sugirin, 2009)

Pre-shipment is a term of SC financing when a supplier or a buyer pays for products or services right after the order came before the actual shipment happens. Thus, post-shipment financial term means that supplier or buyer does financing operations after shipment to the customer. According to Wuttke et al. (2013), pre-shipment includes "inventory finance, advanced payments, trade enablement and WC financing" and post-shipment consists of such financing activities as "factoring, reverse factoring, SCF, electronic payment platforms, trade credit and trade settlement" (Camerinelli, 2009)

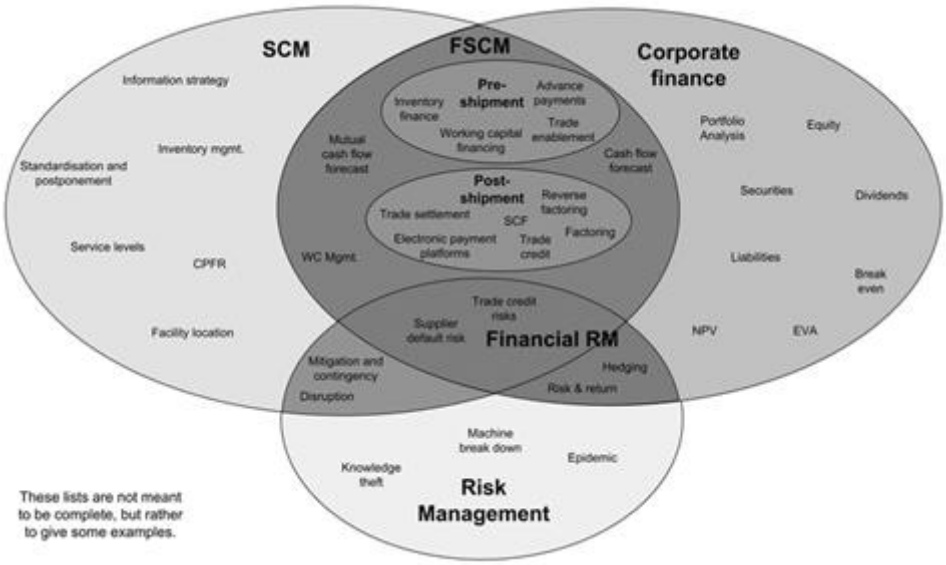



Figure 1.7. Intersections of FSCM with other disciplines

Source: Institute of SC Management, (2012).

The WC financing is about the amount of cash that is necessary for each stage of company's daily operations. Many companies lack sufficient WC due to late payments. To

overcome this kind of problem Sagner (2011) suggest financing WC through credits and loans (secured or open-ended)), accounts receivable (A/R) – the amount of money a company should receive after the purchase was made. Besides, pre-shipment finance activities also include advance payments (A/E) – which perceived by some authors as the part of WC and inventory finance, which is additional stock to prevent economic volatility and get constant cash flow.

Trade credit is one of the most widely used tactics for short-term SC financing. Yan (2015) defines trade credit as "Under trade credit, a supplier adopts the complete financing function, traditionally assumed by a third-party financial institution – hereafter referred to as the bank – or by customer herself drawing from its own cash reserves". Seifert et al. (2013) identified six main reasons for supplier and buyer to initiate trade credit relationship – "capital access, product market position, price elasticity, collateral value, credit information and non-salvageable investment". Seifert et al. (2013) also state that there are additional advantages for buyer side in case trade credit conditions are proper – "transaction pooling, credit rationing and control protection".

Some researchers define SC Finance as the part of post-shipment activities. The direction of this field is different in some studies; authors refer to the SC finance as a related field to WCM, others perceive it as cash flows among the participants of the SC. Kouvelis and Zhao (2011) provide the description of SC finance as "At the center of SCF is the management of WC and financial flows, but equally important is the management of the respective information across the SC and the documents and data involved that support these flows, such as POs, invoices and payment approval processes". Besides, the authors highlighted five main factors of SC finance:

- Using paper for documents is obsolete;
- Automated and transparent flows of information;
- Liquidity risk control;
- Data is predictable;
- Collaboration among all parts of SC.

Although for many researchers the definition of SC finance is still ambiguous. The main difference between SC finance and financing SC is that SC finance has its base on IT solution that provides the information exchange among all SC partners (Figure 1.8).

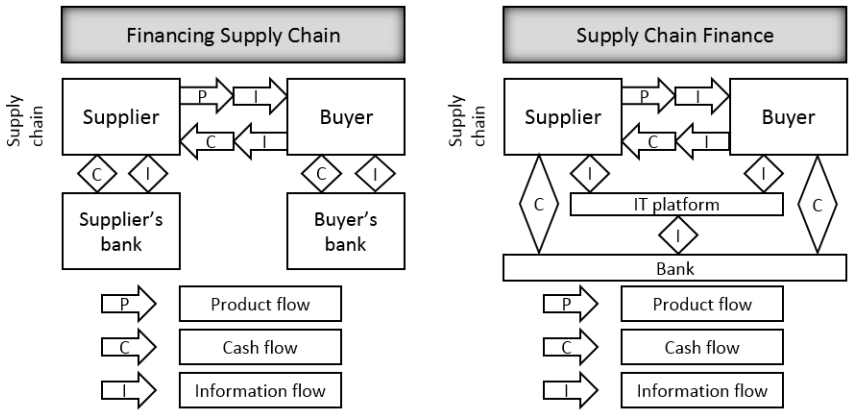



Figure 1.8. The definition difference of SC finance and financing SC

Source: Created by the author

According to Figure 1.8., banks in financing SC framework make a credit decisions using information that buyer and supplier provide separately. On the other hand in SC finance there is one bank that makes decisions about credit issue for both players of SC due to the fact that bank receives information from both supplier and buyer through various IT platforms.

Post-shipment also includes one more practice of factoring. The definition of factoring is that "factoring entails the sale of A/R to another firm, called the factor, who then collects payment from the customer" (Pritchard, Mendez, 1990). Usually companies take the factoring possibility when they need immediate cash and sale their A/R to third companies with a discount.

Recently the reverse factoring has started to develop and now is one of the most common practices of SC finance. Buyers hire a third party or financial intermediary such as bank to finance invoices from suppliers. The scheme is following – a buyer approves invoices and a supplier immediately starts to process an order with the support of a third party or a bank. Reverse factoring brings advantages for both parties because suppliers shorten the time of A/R with the help of financial intermediary and the buyer can prolong their payments without negative effect on cash flows, WC and collaborative network.

**1.2.3. Financial risks associated with SC.** Different practices aimed to develop and ensure financial flows in SCs have their risks that could happen internally and externally depending on inter- or intra-organizational level. Previously the intersection of field showed that the main financial risks associated with SC are supplier default risk and trade credit risks.

A company may face supplier default in case of external or/and internal disruptions. Some of them may be the result of nature disasters, but mostly supplier default happens in case of poor management and results in production failures and bankruptcy. In these situations a buyer is forced to switch a supplier which may result in high switching costs, production and sales losses, etc. Although in some cases a buyer can support a supplier in turbulence period but there is no guarantee the companies in SC have completely fixed this risk. McKinsey&Company in their report (2011) emphasize the fact that financial instability of one member of a collaborative SC strongly affects other companies' performance. Babich et al. (2007) also mention that supplier default risks can be fixed by better SC network control.

Trade credit risks consists of two dimensions – supply (accounts payable (A/P)) and demand (A/R) and can occur at different parts of SC (Yang, Dai, 2015). Furthermore, trade credit is still the preferable source of short-term financing debt which increases the possibility of risk to occur. To fix trade credit risk the companies use trade credit insurance from banks and special services which decrease the volatility in a SC by providing a stable financial flow among the participants. Although according to McKinsey&Company (2011) the financial crisis increased the volatility of SCs and decreased efficiency of risk mitigating measures.

## 1.3. Working capital management as a FSCM perspective

The WCM concept is one of the main perspectives connected to the FSCM and is the main topic of this master thesis. The liquidity problem became especially important for most of the companies because of the financial crisis of 2008-2009 and oil crisis that has started in 2014. Christopher and Ryals (1999) defined WCM as one of the factors of shareholder value creation.

Karl Max introduced the idea of WC and Pirttilä (2014) identifies WC as "the capital of a business which is used in its day-to-day trading operations, calculated as current assets less current liabilities". In other words it is "amount of cash that is tied up at each stage of SC" (Viskari, 2012). WC connects with the short-term need of a company to maintain its business processes. According to Brandenburg and Seuring (2010) companies that failed the cost and WCM balance resulted having significant value losses.

There are two main perspectives of WC. The first one defines the ability of the company to cover its short-term debt with current assets. Jones (2006) defines the concept of this WC perspective and described it with the equation.

$$Working\ capital = Current\ assetss - Current\ liabilities \tag{1.1}$$

According to Jones (2006) current assets comprised of cash, total inventory, A/R, securities and cash equivalents. On the other side, current liabilities refer to A/P, accruals, notes payable and short-term debt. The positive result of WC means that the amount of cash the company will receive in the next 12 months is bigger than that company needs to cover its liabilities. The negative meaning of WC means that company will not be able to cover its short-term debt (Monto, 2013).

Another perspective of WC is widely used on the most of the studies dedicated to operational WC and comprises of total level of inventory, A/R and A/P. These components are called WC operational components (Monto, 2013). According to Pirttilä (2014) the equation is following:

$$Working\ capital = Inventories + Accounts\ receivable - Accounts\ payable \qquad (1.2)$$

The recent study of Talonpoika et al. (2014) include A/E as a separate component into WC cycle (usually is a part of A/P) and this case will be reviewed in the next sections. Pirttilä (2014) state that WC cycle describes the main parts of company's performance connected with financial flows.

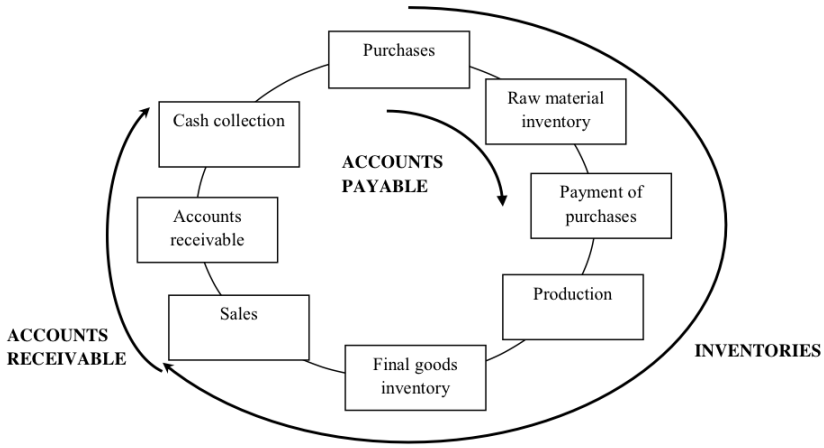



Figure 1.9. WC cycle flows

Source: Pirttilä, (2014)

The cycle of WC starts with the inventory which consists of raw material inventory, work-in-progress products and finished goods. At the transition point of every stage inventories appear. A company may hold large amount of inventories for two main reasons – to avoid stockouts and some customers require immediate deliver. However, large inventories in both

cases increase the amount of WC and low inventory may cause sales losses thus the SC inventory optimization may increase the profitability of WC (Brodetskiy, 2015).

The next part of the cycle begins when a company sells its finished goods to a customer and a customer pays for it. In a supplier – buyer relationship, with the flows of products or services and information flow towards the customer occur – A/R occur on credit. In opposite relationship of buyer – supplier with the flows of cash and information towards the supplier – A/P happen (Jahfer, 2015).

The optimal level of WC depends on several factors – such as industry, competition, economic situation and company's strategy. Hill et al. (2010) run a survey to reveal the dependency of WC on industry. The results are that companies that produce goods are tent to have more inventories meanwhile service companies usually have low or now level of inventory thus operational WC varies over industries. Al-Shubiri and Aburumman (2013) point the industry factor as the most important external factor influencing the WC level.

WC can be negative and positive. When the value of WC is positive it means that the amount of inventories and A/R exceed the level of A/P. The main advantage of high positive WC is high levels of inventory and A/R can ensure ability of the company to cover its short-term debt. The negative effect may result in high costs of inventory storage. The negative WC means that short-term liabilities of the company exceed the level of inventory and A/R. This case positively effect on low storage costs but too low inventory level may cause sales losses (Kroes, Manikas, 2014).

To define the optimal level of WC for each company the WCM was implemented. WCM depends on the strategy and policy of the company and WC Policy. There are three main types of WC policy – aggressive – with high risks and possible high profitability, moderate – with balanced risk and profitability and conservative – with low risks possible low profitability (Baveld, 2012).

According to Viskari (2011) the scientific research fields related to WCM divide into four groups. Three of the fields are mostly concerned with the financial aspects of WCM and practices. The last one in centered with the operational WC and investigates its relationships with SC management. This field includes the studies in empirical archival research – the case studies from different industries and countries, qualitative conceptual research – focuses mainly on CCC at all stages of collaboration in SC and mathematical modeling.

Viskari (2011) made the assumption which was confirmed lately that a lot of articles about WCM will occur in time period of 2011-2014 due to the consequences of financial crisis and approaches to fix future risks associated with economic turbulence. The WC investigation approaches divide into two groups: based on different perspectives of the company's performance and investigation using CCC approach (Lind et al., 2012).

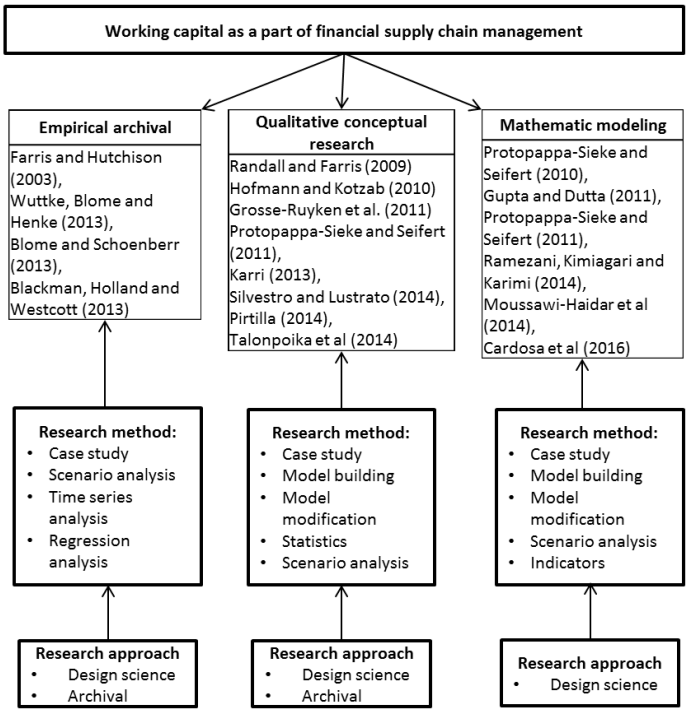



Figure 1.10. Summary of the studies of WC in SCs

Source: Created by the author

Hill (2010) mentions that previously each component of the WC cycle was estimated separately, and in 1983 Sartoris developed an approach where all components were analyzed as a whole. In the literature there are two approaches towards WCM – WC ratios and WC cycle time (Pirttilä, 2014).

Pirttilä (2014) mentions that the ratios for assessing WC are "current ratio, current ratio, quick ratio, net WC per net sales, net WC to total assets, and sales to net WC". She also mentions that these ratios have received a lot of criticism and a new measure circulating capital ratio which is more dynamic was introduced.

The most frequently and considered as indicates of financial health and stability of the company current ratio and quick ratio indicate the ability of the company to cover its short-term obligations. The higher the ratio the more company is able to pay back its liabilities. The value of these ratios equal more than two is preferable – in this case the company is able to cover its

liabilities without financial strain. Ratio which equals less than 1 assumes that a company is unlikely to pay its short-term debt.

The operational approach to measure WC is WC cycle time – the CCC approach is one of the main topics of this master thesis and modification and optimization of it in collaborative SCs will be discussed in the next chapters.

## 1.4. Cash conversion cycle (CCC) as a WC measure

The CCC concept was developed by Richards and Laughlin (1980) as a measure to address the criticism of relative ratios as key indicators of a company's profitability. According to the authors CCC can be defined as: "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).

There definition of CCC among researchers is ambiguous. Stewart (1995) defines CCC as a "composite metric describing the average days required to turn a dollar invested in raw material into a dollar collected from a customer". Schilling (1996) in his study provides broaden definition as "The CCC, which mirrors the operating cycle, measures the interval between the time cash expenditures are made to purchase inventory for use in the production process and the time funds are received from the sales of the finished products. This time internal is measured in days and is equal to the net of the average age of the inventory plus the average collection period minus the average of A/P". One of the most recent definitions is provided by Hofmann and Kotzab in 2010 - they define CCC as "as the time elapsed from the payment of cash for materials or components through to the receipt of cash for sale of the finished product".

One of the most cited definition which is used on financial dictionaries is stated in the study of Pirttilä (2014). According to Pirttilä (2014) the definition of CCC is "the CCC presents the length (in days) of time a firm has funds tied up in WC, starting from the payment of purchases to the supplier and ending when remittance of sales is received from the customers".

CCC as WC can be either negative or positive. Negative CCC means that the company has a low amount of inventory and a company receives money from its customers before it has to pay its A/R or make A/E. In other words, in negative CCC scenario, a company receives its A/R before it should pay A/P. Many authors provide a view that the lower CCC the better and a

company can manage it cycles efficiently although the too low CCC can cause problems with each component of CCC.

The CCC consist of three components – DIO – days of sales outstanding, DSO – days sales outstanding and DPO – days payable outstanding and visualized at Figure 1.11.

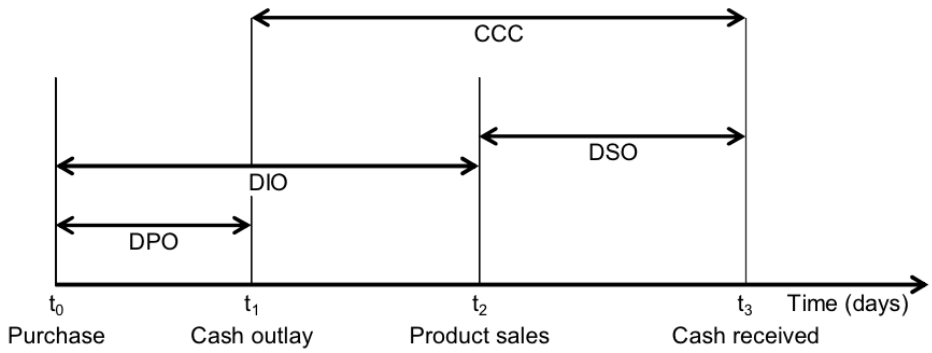



Figure 1.11. CCC approach

Source: Adapted from Richards and Laughlin, (1980)

There are a lot of discussions for these components' denominators among researchers. Shin and Soenen (1998) developed the net trade cycle (NTC) framework – in their equation all the components of CCC should be sales percentages – but as long as all denominators are different – the modification is not useful. Farris and Hutchison (2002) and lately Ding et al. (2013) introduce the calculation where inventories and A/P are divided by cost of goods sold (COGS). The list of equations is structured in Table 1.1.

Back to 2003 there was a problem due to the fact that only in US GAAP the cost of goods statement was obligatory in the profit and loss account although nowadays International Financing Report Standards allow the cost of sales method and this equation can be applied. Pirttilä (2014) notices that in the research of Hofmann and Kotzab they based the definition of Farris and Hutchison (2003) equation but in reality they use the definition of NTC framework. Although the revenue data is more available than cost of goods sold it can result in shorter CCC due to the fact that revenue value is usually bigger than that of cost of goods sold (Ding et al., 2013). To avoid the unintentional decrease the equation of Farris and Hutchison (2003) is used.

$$CCC = DIO + DSO - DPO = \frac{Inventories}{COGS} * 365 + \frac{Accounts\ Receivable}{Net\ sales} * 365 - \frac{Accounts\ Payable}{COGS} * 365 \qquad (1.3)$$

Table 1.1. Different CCC calculations

| Source | Formula |
|---|---|
| Richards and Laughlin (1980) | $\frac{\text{Inventories}}{\text{COGS}} \times 360 + \frac{\text{Notes and accounts receivable}}{\text{Net sales}} \times 360 - \frac{\text{Accounts payable + Salaries, benefits and payroll tax}}{\text{COGS + Selling, general and administrative expense}} \times 360$ |
| Shin and Soenen (1998), Monto (2013) | $(\text{inventories + accounts receivable - accounts payable}) \times \frac{365}{\text{sales}}$ |
| Farris and Hutchison (2003); Ding et al. (2013) | $\frac{\text{Inventories}}{\text{COGS}} \times 365 + \frac{\text{Accounts receivable}}{\text{Net sales}} \times 365 - \frac{\text{Accounts payable}}{\text{COGS}} \times 365$ |
| Deloof (2003); Kroes and Manikas [1] (2014) | $\frac{\text{Inventory}}{\text{COGS}} \times 365 + \frac{\text{Accounts receivable}}{\text{Sales}} \times 365 - \frac{\text{Accounts payable}}{\text{COGS+change in inventory}} \times 365$ |
| American Association of Individual Investors (2011) | $\frac{\text{average inventory}}{\text{COGS}} \times 365 + \frac{\text{average accounts receivable}}{\text{revenue}} \times 365 - \frac{\text{average accounts payable}}{\text{COGS}} \times 365$ |

Source: Pirttila, (2014)

Several studies have investigated the relationship between WCM cycle time and found a negative relationship between the CCC and the relative profitability of a company. The studies point the companies can improve their profitability effectively managing WC, i.e. by shortening the cycle time of WC (Deloof, 2003; García-Teruel, Martínez-Solano, 2007; Talha et al., 2010; Yazdanfar, Öhman, 2014). However, the components of CCC and their impact on company's profitability have not been investigated enough and the correlation of these components is ambiguous (Monto, 2013). Ruyken, Wagner, and Jonke (2011) also stated that in order to increase profitability the relation between DIO and profitability and DSO and profitability should be negative and assumes that relation of DPO and profitability should be positive. Figure 1.12 describes the diverse effect of the cycle times of WC – directly on profitability and indirectly on sales and costs.

Monto (2013) also pays attention that WCM has inter-organizational context due to the fact the cycle times are result of the decisions not only of one focal company. Besides, the policies, strategy and management approach of companies and of WC in particular affect the other members of the SC. To review the operation of WC cycle times for all participants of SC the collaborative CCC concept was introduced.

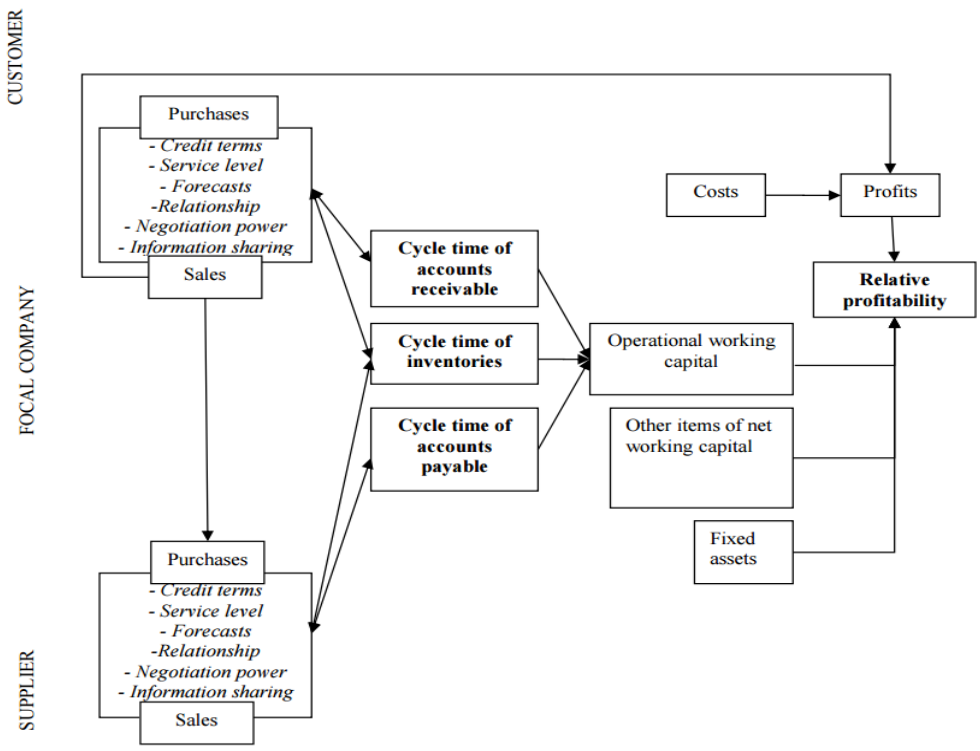



Figure 1.12. The relationship of WC cycle times and relative profitability

Source: Monto (2013)

**1.4.1. Collaborative CCC.** In existing literature about WCM and SC management there are few works investigating CCC at the level of collaboration among all SC partners. Although there are financial studies that investigate the inter-organizational level of CCC using accounting perspective but not from collaborative SC view. A lot of authors though state that CCC research in SC should be done with a holistic point of view.

The collaborative CCC was introduced by Hofmann and Kotzab in 2010. In their study they discuss that in collaborative SC the risks and costs spread through all stages of SC because of late payments and changes in inventories. In their study they claim the fact that the reduction of CCC only for one company in a SC does not add value to other SC participants. It is critical to consider the bargaining power of each company in SC because if the company has a goal to improve its CCC only at an intra-organizational level it may result in ethical disruptions for other SC members. (Hofmann, Kotzab, 2010).

Optimization of collaborative CCC can be achieved not only buy reduce of inventories. On the contrary, Hofmann and Kotzab (2010) state that "the synchronization of the goods/material and financial (payment) flows within the SC is the key to reducing net WC and enhancing value for the affiliated SC companies".

The external management of collaborative CCC should follow the principles of CCC objectives – increase the time of A/P as far as possible meanwhile getting cash from A/R as fast as possible. At the intra-organizational level management should try to achieve the optimal level of CCC minimizing the cost of WC at each stage (Hofmann, Kotzab, 2010). It is critical for all SC members as it was stated in the part of collaborative SC to have equal power and trust among SC partners. Figure 1.13 illustrates collaborative CCC.

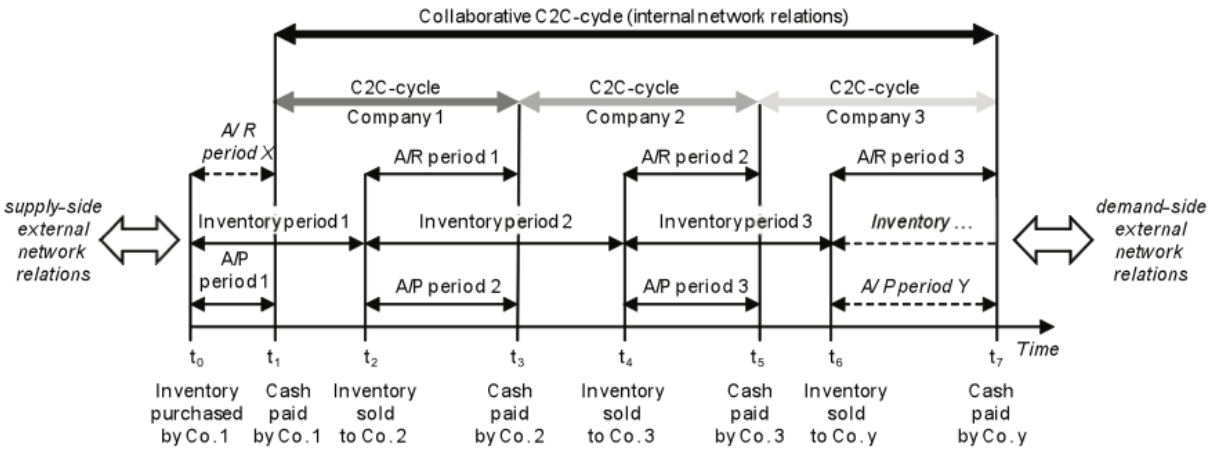



Figure 1.13. Collaborative CCC framework

Source: Hofmann and Kotzab, (2010)

Figure 1.13 provides the internal – among the SC participants and external relationships – that happen outside of collaborative SC. The collaborative CCC for whole SC is calculated as the sum of every CCC in the SC, but the authors provide the justification of the approach to calculate the collaborative CCC as the sum of all inventories in the SC plus the A/R of a company 3 with the subtraction of A/P of company 1. Hofmann and Kotzab (2010) mention that internal payments among the participants do not affect the collaborative CCC and are not counted. If assume that there are three companies in collaborative SC the final equation is.

$$CCCC = DIO_1 + DIO_2 + DIO_3 + DSO_3 - DPO_1 \quad (1.4)$$

The limitations of the collaborative CCC approach include the difficulties in accounting information exchange and the factor of competition also takes place if the company operates with several suppliers and customers. To fix the limitations it is preferable to start the estimation of collaborative CCC at the focal company level and continue it in the industries in which its suppliers and customers operate.

The investigation and modification of collaborative CCC do not limit only at the study of Hoffman and Kotzab (2010). In 2012 Viskari et al. introduced the new metric – Advanced CCC

while developing Financial cycle time model. The main improvement of the approach is that ACCC takes into account not only the cycle times of WC but also consider the amount of capital tied up in each stage of WC. Viskari et al. (2012) support the Hofmann and Kotzab view (2010) that the internal payments should not be included in calculations and provide a view of overlapping periods illustrated at Figure 1.14.

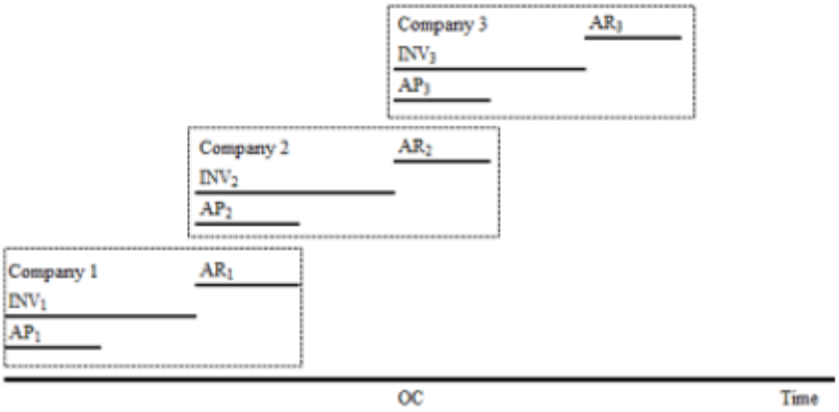



Figure 1.14. Overlapping periods of CCC components

Source: Viskari et al. (2012)

Based on the automotive industry SC, Viskari et al. (2013) developed the weights for each CCC component based on the ratios of costs of each stage to total costs of whole SC. The modification helps companies compare the participants of SC and are financial costs of collaborative SC.

$$ACCC = AOC - w_{AP}(D_{AP}) \tag{1.5}$$

$$AOC = \sum_{k=1}^{n} \sum_{l=n-k+1}^{1} w_k \, D_i \tag{1.6}$$

$$w_k = c_k / P \tag{1.7}$$

where *AOC*-adjusted operating cycle; *k* - stage number; *n* - the number of stages included in the operating cycle; $D_i$ - days of funds committed to AP; $w_k$ - weight of stage *k*; $c_k$ - cost for stage *k*; *P*- cost price.

Although due to the fact that ACCC uses only weighted days it turn a model into theoretical approach instead of real life case. Besides, the ACCC calculations were done only at the level of one order and efforts to transfer it to the inter-organizational level it will be extremely time-consuming and may face the limitations of accounting information exchange.

Thus for optimization purposes it is preferable to use simple CCC. Although in the study of Talonpoika et al. (2014) the modified version of CCC including A/E was stated.

The Financial cycle time model allows estimation of the costs of each stage of collaborative SC and Viskari et al. (2013) introduced the formula of financial costs.

$$FC = INV * [(1+c)^{d_1} - 1] + AR * [(1+c)^{d_2} - 1] - AP * [(1+c)^{d_3} - 1] \quad (1.8)$$

where $c$ - annual cost of capital; $d_1$ = DIO/365; $d_2$ = DSO/365; $d_3$ = DPO/365

**1.4.2. Modified CCC.** A lot of companies were affected by the financial crisis of 2008-2009 and recent economic turbulence. The availability of credit was not easy and companies were obliged to find new sources of finance. Received A/E are one of the ways to finance business processes. A/E were not included in the calculations of WC although a lot of companies acknowledge the fact that A/E play significant role in WCM of these firms (Talonpoika et al., 2014).

The new measure – modified CCC (mCCC) consider a new component in CCC calculations – A/E in order to reflect the real cash flow movements and operational efficiency. The measure was tested by the authors using sample of 108 companies listed at Helsinki stock exchange and revealed a more accurate view on the WCM in these companies.

The mCCC is calculated in the same way as CCC does (1.3.). The new component of days A/E outstanding is add to the calculation of the CCC and is analogous to other components. A/E component follows the same logic as the DPO components does and provides the reduction in time cash is tied up into the operating cycle. The formula of modified CCC is following:

$$DAO = \frac{Advance\ payments}{Sales} * 365 \quad (1.9)$$

$$mCCC = DIO + DSO - DPO - DAO \quad (1.10)$$

The logic of the equation is that other components of the CCC remain the same and the DAO is subtracted. A/E are often include in the total accrued expenses and payables but many companies have started to separate A/E in their balance sheets. The process of mCCC is illustrated at Figure 1.15.

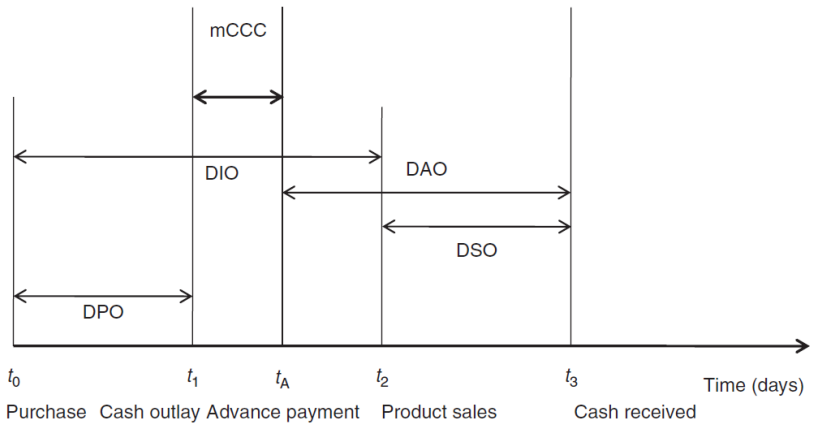



Figure 1.15. Modified CCC

Source: Talonpoika et al. (2014)

The advantage of A/E is beneficial not only for the supplier who can receive cash when there is a need in operating cycle and for the buyer who does not need to pay the whole price at once. The benefits of smoothed cash flow can also please both SC participants. Furthermore, A/E prevent supplier of a credit risk associated with a customer. For the customer, A/E can ensure the availability of the product or service in different circumstances meanwhile preventing itself from supply delays risk.

The empirical test of a new measure provided the results that A/E has significant impact on WC cycle time and the efficiency is different if measured by CCC or mCCC. This measure is especially important in industries where A/E is common practice – ICT, publishing, automotive and project companies (Talonpoika et al., 2014). The authors also mention that "A/E could have a significant role when aiming at efficient SC management and this should be studied further".

To conclude the theoretical review of financial SC three main points are outlined:

- There is a lack of literature to investigate the WCM from collaborative SC perspective. This master thesis introduces the coordination mechanism of WCM in SCs that includes financial 3PL operator as a coordinator of a collaborative SC;
- The literature review of CCC estimation models revealed a new approach of modified CCC with new component DAO included. This master thesis reviews it an holistic SC perspective;
- This master thesis provides a study that uses goal and linear programming as a tool for optimization of resources in collaborative SCs with mCCCC components as variables and costs as criterion.

# 2. Coordinating modified collaborative cash conversion cycle model (mCCCC) methodology

The purpose of this chapter is to provide a holistic view of methodology of mCCCC concept examination. In the first part of the chapter the new measure of cycle time evaluation is introduced – modified collaborative CCC. The next part is dedicated to the adaptation of existing scenario analysis framework to mCCCC evaluation. During adaptation several flaws in scenario analysis framework appeared. The new coordinating mCCCC model is introduced to optimize financial costs through mCCCC components from a holistic view.

## 2.1. mCCCC evaluation methods

The research in this master thesis assumes to be a full, scientific and exploratory study. Besides, the research is planned, organized and conducted using the positivist's paradigm. The master thesis applies design-science and archival approaches due to the fact the one of the main objectives of the study is to provide the modification of two SC systems – modification of existing methodology of cycle time in collaborative SC evaluation.

Design-science approach is a common method for the industry and science of management (Geerts, 2011). The meaning was firstly mentioned by Simon, 1969. The purpose of described approach is to provide structural solutions to practical problems (Simon, 1969). In later research papers the investigators suggested the idea that the main aim of design-science approach is theoretical development of a model that can provide solutions of the organizational problems of the specific industry. This kind of solution can be direct, indirect or instrumental.

The outcome of design-science approach provides the solid theoretical base for model or framework development, modifying and implementation. In accordance with Van Aken and Romme (2009) there are three main points of design-science approach:

1. "Research question are guided by the field problems;
2. The research aims at solution-oriented knowledge;
3. The explanation of research results is done through practice" (Daae, Boks, 2015);

Based on the critical literature review conducted in the first chapter, many of the previous studies of collaborative SCs and cycle times applied design-science approach (Talonpoika et al., 2014; Wuttke, Blome and Henke, 2013; Hoffman and Koztab, 2011; Randall and Farris, 2009;

Farris and Hitchison, 2002; etc.). Besides, the relevance of choosing design science approach was proved by its practical implications and applicable outcomes.

Viskari (2012) in his study highlighted four stages of design-science approach:

1. Problem justification
2. Design development
3. Solution representation
4. Evaluation of the solution

Archival method is widely used in researches of management accounting (Hesford et al., 2007). Moers (2006) defines archival approach as "an empirical study that uses archival data as the primary source of data applying quantitative methods to analyze these data". Archival data is data which purpose originally was not for the academic research. The information could be either for public or for confidential purposes. Besides, the requirement of archival data is to be quantifiable (Monto, 2013).

Moers (2006) reveals a negative view towards the archival approach – the usage of public sources is inadequate. In this master thesis this risk is fixed by using only official financial statements of the companies with the annual reports and collecting all the information manually (Monto, 2013). These actions ensure the reliability of data collected. Besides, the information about the companies involved in collaborative SC is confidential and the names of the companies participated are excluded from the data description.

According to Saunders, Lewis and Thornhill (2009) in the study about research methods which can be applied to business inferred seven types of research methods: experiment, survey, case study, action research, grounded theory, ethnography and archival research. In compliance with the goal of master thesis, research questions and critical literature review the case method is preferable one.

In the terms of design-science approach the modified model should be applied and assessed based on the case study (Van Aken, Romme, 2009) Furthermore, the case study approach of research method is implacable for this master thesis research due to the fact that it assumes empirical investigation of theoretical statement or phenomena which contribute to real life situations.

Yin (2003) in one of his studies derived four main types of case studies: single, multiple, holistic and embedded (Saunders, Lewis and Thornhill, 2009). In accordance with the aim of the

study and in order to answer research questions the preferable case study method is holistic due to the fact that the modified model is applied to the real life cases of the multinational companies. Besides, they are evaluated as the whole in terms of authority – the collaboration among all partners of the SC.

In the critical literature review it was stated that many authors used holistic case study approach for the purposes of the development or modification of the existing models. The method of mCCCC and the modification of the model are new to the research and should be evaluated on real life problems to validate their applicability. Thus it is possible to conclude that the master thesis research is conducted using holistic multiple-case study with design-science and archival approach.

## 2.2. mCCCC evaluation models

This part dedicates to the introduction of mCCCC concept and two models for the evaluation of theoretical and managerial applicability of the mCCCC concept.

According to the literature review conducted and Talonpoika et al. (2014) suggestions for future research the mCCC there is a research gap of applying the mCCC approach to a) SCs b) collaborative SCs. One of the objectives of this thesis is to develop a collaborative mCCC approach which is introduced further. Talonpoika et al. (2014) state that additional component of mCCC is built using the same logic as other three components of CCC. Hofmann and Kotzab (2010) developed collaborative CCC and the combination of mCCC and collaborative SC using design-science introduced the new metric – modified collaborative CCC or mCCCC.

The calculation of mCCCC has similar logic as collaborative CCC does including the overlapping periods of payments mentioned by Viskari et al. (2012) and is illustrated on the example of three-stage collaborative SC of a supplier (1), manufacturer (2) and customer (3).

$$mCCCC = DIO_1 + DIO_2 + DIO_3 + DSO_3 - DPO_1 - DAO_1 \tag{2.1}$$

The same logic applies to the formula of total financial costs for each participant of SC introduced by Viskari et al. (2012)

$$TC = INV * [(1+c)^{d_1} - 1] + AR * [(1+c)^{d_2} - 1] - AP * [(1+c)^{d_3} - 1] - AE * [(1+c)^{d_4} - 1] \tag{2.2}$$

where $c$ - annual cost of capital; $d_1$ = DIO/365; $d_2$ = DSO/365; $d_3$ = DPO/365; $d_4$ = DAO/365

The mCCCC approach has the same advantages as mCCC does but on the collaborative SC scale. From the side of mCCC the benefits of using mCCCC are – more precise calculation of cycle time and thus WC associated with each stage of a SC. The collaborative approach provide a holistic view to the SC and ensure information exchange and high level of trust which is critical if there is an objective to improve the performance of a whole SC.

Similarly to collaborative CCC the main goal of mCCCC is to be close to 0 (or negative). In the past the CCC measure of WC was used as a measure of efficiency and profitability of the company and was reviewed in Chapter 1.4. At the company and SC level the zero or negative mCCC or mCCCC value that the companies hold cash before payment to suppliers and have ability to invest WC before the time of DPO and DAO expires.

The evaluation of applicability of mCCCC approach is done by two ways. The first one – the adapted scenario analysis proposed by Randall and Farris (2009) allows validation the efficiency of using DAO component in SC as Talonpoika et al. (2014) proposed. However, the scenario approach has several critical limitations and the author of master thesis developed a new model for mCCCC evaluation – optimization mCCCC framework. Both of the mCCCC evaluations are tested empirically on the multiple case study data of 4 collaborative SCs.

**2.2.1. mCCCC scenario analysis.** The Randall and Farris (2009) in their study introduced a scenario analysis framework which allows simulation of managerial actions towards each component of CCC. The same logic is applied to the mCCCC concept and the scenarios for each component. The practical application of the scenario modelling allows evaluation of the impact of each scenario on the cycle time of WC and financial costs associated with the collaborative SC. The framework of adapted scenario approach is illustrated at Figure 2.1.

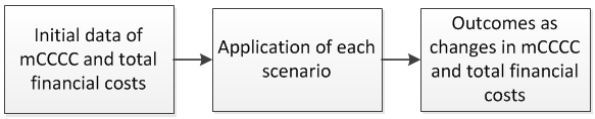



Figure 2.1. Scenario analysis framework

Source: Randall and Fariss, (2009)

Each scenario describes the impact of the each component to the overall changes of the mCCCC (2.1) and total FC, which is the sum of total financial costs of each member of a collaborative SC (2.31). The initial amount of scenarios introduced by Randall and Farris is four, but for the purposes of mCCCC evaluation the author of master thesis uses design-science approach and adds the fifth scenario. The aim of fifth scenario is to evaluate the impact of DAO

component on collaborative SC conversion cycle and total financial costs. Thus there are five scenarios to be applied to evaluate the mCCCC.

1. Shortening the DIO component in collaborative chains
2. Shifting the inventory from key customer to manufacturer
3. Shortening the DSO component in collaborative chains
4. Extension of DPO component in collaborative chains
5. Extension of DAO component in collaborative chains

The objective function of scenarios is "is to optimize financial management-based cost saving at the SC level" (Randall and Farris, 2009). A lot of studies of CCC differ in the terms of what leverage affect the SC most. Moss and Stine (2003) state receivables are critical to affect cycle time. Randall and Farris (2009) argue this view and based on their simulation research state that inventories have the most significant impact on cycle time and WC costs because the receivables are less manageable is SC members do opportunistic actions. They also point the fact that for the company it is easier to manage its inventories and A/P rather than A/R. In addition Bougheas, Mateut and Mizen (2009) suggest A/P is the most influential factor. The influence of amount of accrued expenses (the balance sheet name of A/E) on collaborative mCCCC will be studied using the scenario analysis.

Although after conducting the collaborative SC analysis using Randall and Farris framework (2009) the author revealed three main problems of this method:

1. Using a 10-day reduction/addition approach makes sense only in case if all companies did not optimized their components at all – during the case study some of scenarios were not applicable and thus provide no managerial result. The absolute change has it limits, for the managerial purposes it is better to use relative measures (Field, 2009).
2. Reduction of DSO component does not provide the proportional increase for DPO and DAO components and vice versa - the requirement of collaborative SCs according to Viskari (2012) of overlapped payments is not satisfied. In other words, the managerial actions of each scenario are done for each company separately and do not provide a holistic view for the collaborative SC.
3. Each scenario is done separately and there is no optimization model which integrates all the scenarios together in terms of collaborative SC.

To fix the problems of Randall and Farris model (2009) the author suggests the improvement to existing methodology by development of coordination modeling called optimization mCCCC model. The model is built using goal programming based on cost criterion and is described in 2.2.2.

**2.2.2. Coordinating mCCCC model description.** The idea of mCCCC optimization has at least two goals: the shortening of mCCCC cycle and reduction of total financial costs. In other words, there are two functions that need to be minimized according to the literature review of mCCC and developed concept of mCCCC. The basic linear programming (LP) is not suitable for that purpose because the usage of this approach maximizes or minimizes one objective function whereas goal programming (GP) minimized the fluctuations of objective functions values and the realized results which is a satisfying solution (Tamiz, Jones, Romero, 1998)

GP characterizes as a special case of multi-objective optimization and is a part of multi-criterion decision analysis. The basic concept of GP is stated by Orumie and Ebong (2014) in their research study – the GP is "one of the oldest multi criterion decision making techniques used in optimization of multiple objective goals by minimizing the deviation for each of the objectives from the desired target". In other words, the purpose of GP is to convert several objectives into a single one (Ignizio, 1983).

The terminology of MCDM varies in different studies and Figueira, Greco and Ehrgott (2005) introduced the most important definitions of goal programming. The classification below includes the description of definitions' application to the problem statement:

*Decision Maker* (DM) – refers to a person, organization, stakeholders, financial intermediary for collaborative SC to whom the right to state the goal belongs. In this case the author assumes there is a financial intermediary such as 3PL provider who took the management of collaborative SC to optimize its costs and mCCCC;

*Decision Variable* (DV) – a factor through the DM performs the optimization. The purpose of goal programming is to find all possible combinations of DVs in decision space values to define the point where all constraints and goals are satisfied. In optimization mCCCC model DVs are the components of mCCCC calculation (2.1.);

*Criterion* – is a measure of goodness of the optimization model. There are many criterions to base a model on but such as cost, profit, time, etc. However, one of the main purposes of mCCCC optimization is cost reduction thus the main criterion is cost. Adding more criterions would be the problem statement of multi-criteria decision making (MCDM);

*Objective* – it is the criterion with the direction stated – either maximization or minimization. In this master thesis the objective is to minimize the total financial costs function;

*Goal* – refers to a target level which the DM desires to achieve on criterion. The optimization mCCCC model assumes the goals of optimization of total inventory, A/R, A/P and A/E with the constraints of not exceeding existing level of costs;

*Deviation Variable* (DEV) – measures the difference of target level and the value achieved in final solution. If the value is higher than that of target level than the difference is positive DEV. Otherwise it is negative DEV;

*Constraints* – a set of restrictions of decision variables that should be satisfied in order to ensure the reduction of costs. In this case the constraint is not exceeding existing level of costs. A sign restriction limits the decision or DVs to take certain values within the range. The most common used sign constraint is for variable to be nonnegative and continuous. The same constraint applies to the optimization of mCCCC model;

*Feasible region* – Figueira, Greco and Ehrgott (2005) stays it as "the set of solutions in decision space that satisfy all constraints and sign restrictions in a goal programming form the feasible region. Any solution that falls within the feasible region is deemed to be implementable in practice".

The abovementioned definitions refer to the methodology of optimization mCCCC model description. The problem statement of this framework is following – the DM (in this case either or financial intermediary or consultancy) decided to minimize the objective total financial costs function – total financial costs of the SC which is the sum of financial costs associated with each mCCC cycle of every participant of 3-stage collaborative SC based on cost criterion using the DVs of collaborative mCCCC.

The DVs of the model are components of mCCCC calculation (2.1.). Changing these components using optimization mCCCC model it is possible to obtain the goals stated which are the specific percentage decrease of total inventory (*TI*) and total A/R (*TAR*) and specific percentage increase for total A/P (*TAP*) and total accrued expenses (*TAE*) of each member of a collaborative SC. The constraint is a requirement of all variables to be nonnegative and continuous as Figueira, Greco and Ehrgott (2005) recommend.

$$x_1, x_2, x_3, x_4, x_5, x_6 \geq 0 \tag{2.3}$$

where $x_1$ - DIO of supplier; $x_2$ - DIO of manufacturer; $x_3$ - DIO of customer; $x_4$ - DSO of customer; $x_5$ - DPO of supplier; $x_6$ - DAO of supplier.

The DM set constraints for costs of running cycle that no costs after *f(z)* optimization should exceed their values before optimization in order to satisfy the requirement to provide the centralized decision for decentralized supply chain.

$$INV_1 * [(1+c_1)^{x_1/365} - 1] + AR_1 * [(1+c_1)^{DSO_1/365} - 1] - AP_1 * [(1+c_1)^{x_5/365} - 1] - AE_1 * [(1+c_1)^{x_6/365} - 1] \leq INV_1 * [(1+c_1)^{DIO_1/365} - 1] + AR_1 * [(1+c_1)^{DSO_1/365} - 1] - AP_1 * [(1+c_1)^{DPO_1/365} - 1] - AE_1 * [(1+c_1)^{DAO_1/365} - 1] \tag{2.4}$$

$$INV_2 * [(1+c_2)^{x_2/365} - 1] + AR_2 * [(1+c_2)^{DSO_2/365} - 1] - AP_2 * [(1+c_2)^{DPO_2/365} - 1] - AE_2 * [(1+c_2)^{DAO_2/365} - 1] \leq INV_2 * [(1+c_2)^{DIO_2/365} - 1] + AR_2 * [(1+c_2)^{DSO_2/365} - 1] - AP_2 * [(1+c_2)^{DPO_2/365} - 1] - AE_2 * [(1+c_2)^{DAO_2/365} - 1] \tag{2.5}$$

$$\begin{aligned} INV_3 * [(1+c_3)^{x_3/365} - 1] + AR_3 * [(1+c_3)^{x_4/365} - 1] - AP_3 * [(1+c_3)^{DPO_3/365} - 1] \\ - AE_3 * [(1+c_3)^{DAO_3/365} - 1] \\ \leq INV_3 * [(1+c_3)^{DIO_3/365} - 1] + AR_3 * [(1+c_3)^{DSO_3/365} - 1] - AP_3 \\ * [(1+c_3)^{DPO_3/365} - 1] - AE_3 * [(1+c_3)^{DAO_3/365} - 1] \end{aligned} \tag{2.6}$$

The DM states the goals that need to be achieved through collaborative actions – the value after specific percentage decrease of total inventory (TI) and total A/R (TAR) and the value after specific percentage increase for total A/P (TAP) and total accrued expenses (TAE) of each member of a collaborative SC.

$$TI = INV_1 + INV_2 + INV_3 = \frac{DIO_1 * COGS_1}{365} + \frac{DIO_2 * COGS_2}{365} + \frac{DIO_3 * COGS_3}{365} \tag{2.7}$$

$$TAR = AR_1 + AR_2 + AR_3 = \frac{DSO_1 * Sales_1}{365} + \frac{DSO_2 * Sales_2}{365} + \frac{DSO_3 * Sales_3}{365} \tag{2.8}$$

$$TAP = AP_1 + AP_2 + AP_3 = \frac{DPO_1 * COGS_1}{365} + \frac{DPO_2 * COGS_2}{365} + \frac{DPO_3 * COGS_3}{365} \tag{2.9}$$

$$TAR = AR_1 + AR_2 + AR_3 = \frac{DAO_1 * Sales_1}{365} + \frac{DAO_2 * Sales_2}{365} + \frac{DAO_3 * Sales_3}{365} \tag{2.10}$$

where 1 – supplier, 2 – manufacturer, 3 - distributor

There are two main solutions which a model can get as a result of optimization – local optimal (feasible) and global optimal (optimal) (Taha, 1971). The local optimal solution is any element of a feasible region of the optimization problem. Feasible region is the diapason of all solutions possible with satisfaction of all constraints. An optimal solution either minimizes or

maximizes the objective function (Taha, 1971). The restrictions for feasible solution are to find first solution which improves the model and are following:

$$\frac{x_1 * COGS_1}{365} + \frac{x_2 * COGS_2}{365} + \frac{x_3 * COGS_3}{365} = lTI; lTI \leq TI \tag{2.11}$$

$$\frac{DSO_1 * Sales_1}{365} + \frac{DSO_2 * Sales_2}{365} + \frac{x_4 * Sales_3}{365} = lTAS; lTAS \leq TAS \tag{2.12}$$

$$\frac{x_5 * COGS_1}{365} + \frac{DPO_2 * COGS_2}{365} + \frac{DPO_3 * COGS_3}{365} = lTAP; lTAP \geq TAP \tag{2.13}$$

$$\frac{x_6 * Sales_1}{365} + \frac{DAO_2 * Sales_2}{365} + \frac{DAO_3 * Sales_3}{365} = lTAE; lTAE \geq TAE \tag{2.14}$$

This constraints are for feasible solution and do not minimize the objective function. In case if there is a feasible solution the researcher may proceed to the minimization of total financial cost function. If there is no feasible solution the DM should take a priority of each goal to be stated and as a result the DM has a compromised solution.

If there is no feasible solution which satisfies all the constraints Steuer (1986) suggests trying to find compromise solution and to convert each inequality into flexible goal using DEVs which can be violated if necessary with constraints (2.12.):

$$lTI + s_1^- - s_1^+ = TI \tag{2.15}$$

$$lTAS + s_2^- - s_2^+ = TAS \tag{2.16}$$

$$lTAP + s_3^- - s_3^+ = TAP \tag{2.17}$$

$$lTAE + s_4^- - s_4^+ = TAE \tag{2.18}$$

$$s_i^-, s_i^+ \geq 0, i = 1, 2, 3, 4 \tag{2.19}$$

The nonnegative variables $s_i^-$ and $s_i^+$ are DEVs because they describe the deviations below and above the right-hand side of constraint *i* and are dependent thus are unable to be basic variables simultaneously. This limit means that in "any simplex iteration at most one of the two deviational variables can assume a positive value. If the original *i*th inequality is one of the type ≤ and its $s_i^- > 0$, then *i*th goal is satisfied, otherwise, if *i*th $s_i^+ > 0$, then *i*th goal is not satisfied" (Cohon, 1978). In other words, the definition of both DEVs allows either satisfying or violating the *i*th goal. This allows flexibility which is a feature of goal programming when it comes to finding of compromise solution. A compromise solution aims to minimize as much as possible the violation of each component.

In the model, given the fact that the first two constraints are the type of ≤ and the other two are of the type pf ≥, the DEVs $s_1^+, s_2^+, s_3^-, s_4^-$ represent the amount by which the goals are

violated. Hence, the solution seeks a compromise where following objectives are satisfied as much as possible and the functions are minimized in compliance with the constraint equations of the model.

$$\text{Minimize } G_1 = s_1^+ \tag{2.20}$$

$$\text{Minimize } G_2 = s_2^+ \tag{2.21}$$

$$\text{Minimize } G_3 = s_3^- \tag{2.22}$$

$$\text{Minimize } G_4 = s_4^- \tag{2.23}$$

There are two ways of prioritization of goals. There is either the weights method which is a single objective function with a weighted sum of goals or preemptive method which first optimizes the goal with the highest priority and eliminates one with the lowest, because preemptive approach never compromises the quality of the higher-prioritized goal. However, neither method is better that another one because each technique is suitable for different purposes.

The weights method is the approach applied to the optimization model has *4* goals and then the *i*th goal is:

$$\text{Minimize } z = w_1 G_1 + w_2 G_2 + w_3 G_3 + w_4 G_4 \tag{2.24}$$

The parameters $w_i, i = 1, 2, 3, 4$ are positive values that represent the DM's decisions about the relative importance of each goal. Hence, the determination of specific weights is highly subjective. Thus goal programming is only feasible rather than optimum solution to the problem. Taha (2005) states that "what goal programming does is to find a solution that simply satisfies the goals of the model with no regard to optimization".

The preemptive method uses the ranking approach where the DM should rank to goals in order of importance. For example, the objectives are written as:

$$\text{Minimize } G_1 = \rho_1 \text{ (Highest priority)} \tag{2.25}$$

$$\vdots$$

$$\text{Minimize } G_4 = \rho_4 \text{ (Lowest priority)} \tag{2.26}$$

According to Taha (1971) "the variable $\rho_1$ is the component of the deviational variables $s_i^+$ or $s_i^-$ that represents goal *i*". The process of solution obtaining considers the goal with the highest priority $G_1$ and elimination of the lowest $G_4$. The process differs from the weights

method in the way that the solution of lower-priority goal never degrades higher-priority solutions.

The goals of optimization of *TI*, *TAR*, *TAP* and *TAE* are restricted with the percentage of either decrease or increase stated by the DM and can vary from case to case. The advantage of the optimization mCCCC model before scenario analysis is that it is adjusted to each case initial characteristic instead of using the robust measure of 10 days as Randall and Farris (2009) suggest.

In order to optimize the function the optimal solution constraints are set which means the DM should specify goals as certain numbers to be achieved. In this model the specific numbers are reduced *TI* and *TAR* and increased *TAP* and *TAE*.

$$lTI \geq k_1 * TI \tag{2.27}$$

$$lTAS \geq k_2 * TAS \tag{2.28}$$

$$lTAP \leq k_3 * TAP \tag{2.29}$$

$$lTAE \leq k_4 * TAE \tag{2.30}$$

where *k* – coefficient of % change set by the DM, 1,2,3,4 – goals to be achieved

All the constraints are set to achieve the main cost criterion – the minimization of the objective cost function of total financial cost (TC) of running the mCCCC cycle which sums financial costs (2.2.) of each participant's costs of mCCCC in a collaborative SC of supplier, manufacturer and distributor

$$\text{Minimize}\, f(x) = TC_1 + TC_2 + TC_3 = INV_1 * [\left(1 + c_1\right)^{\frac{x_1}{365}} - 1\Big] + AR_1 * [\Big(1 + c_1\Big)^{\frac{DSO_1}{365}} - 1\Big] - AP_1 * [\Big(1 + c_1\Big)^{\frac{x_5}{365}} - 1\Big] - AE_1 * [\Big(1 + c_1\Big)^{\frac{x_6}{365}} - 1\Big] + INV_2 * [\Big(1 + c_2\Big)^{\frac{x_2}{365}} - 1\Big] + AR_2 * [\Big(1 + c_2\Big)^{\frac{DSO_2}{365}} - 1\Big] - AP_2 * [\Big(1 + c_2\Big)^{\frac{DPO_2}{365}} - 1\Big] - AE_2 * [\Big(1 + c_2\Big)^{\frac{DAO_2}{365}} - 1\Big] + INV_3 * [\Big(1 + c_3\Big)^{\frac{x_3}{365}} - 1\Big] + AR_3 * [\Big(1 + c_3\Big)^{\frac{x_4}{365}} - 1\Big] - AP_3 * [\Big(1 + c_3\Big)^{\frac{DPO_3}{365}} - 1\Big] - AE_3 * [\Big(1 + c_3\Big)^{\frac{DAO_3}{365}} - 1\Big] \tag{2.31}$$

where *i* =1, 2, 3. 1 – supplier, 2 – manufacturer, 3 – distributor; $c_i$ - annual cost of capital

The minimization of total financial cost function allows achievement of the best solution with the constraints set which helps to optimize the financial flows of collaborative SC and get access to working capital previously tied up in mCCCC cycle time. As a result, companies which have troubles in accessing the traditional ways of financing operations – credit and loans can now get cash freed from financial costs and reduced time of mCCCC.

**2.2.3. Optimization mCCCC model design.** The formulation of optimization mCCCC model consists of several consequent parts. First of all, the DM sets the goals of *TI, TAR, TAP* and *TAE*. Next, the DM decides to apply the optimization mCCCC model based on cost criterion. Depending on whether the model with goals and constraints set has a feasible solution the DM either minimize the total financial costs function (in case if the feasible solution is found) or switch to any of two methods of goal programming to find a compromise solution. First a researcher should find a feasible solution with variables (2.3) using constraints for feasible solution developed in 2.2.1 with constraints (2.4-6); (2.11-14):

In case if there is a feasible solution which satisfied all constraints set the researcher should proceed to the minimization of the objective function of collaborative financial costs (2.31) using variables (2.3) with the target level of goals set as constraints (2.4-6); (2.27-30):

In case if there is no feasible solution the researcher should find a compromise by using one of the goal programming approaches – either the weights method or preemptive programming method with the following constraints (2.4-6); (2.11-14):

If apply the weights method than the prioritization of goals is following where the DM sets the weights for each goal by himself with (2.24):

In case if the goals should be prioritized in terms of importance the DM should set the rank and the researcher should implement minimize each goal in order of priority according to (2.25-26).

As a result the model provides a holistic view of how the goals stated may be achieved using mCCCC components based on cost criteria. The DM can fix the problems associated with Randall and Farris (2009) scenario, set the goals which affect collaborative management of a SC, obtain minimization of collaborative financial costs in diapason of goals set and reduce the length of mCCCC which affects the efficiency and profitability of the company.

The coordination modeling allows the companies involved into supply chain to make collaborative decisions when still being in decentralized conditions of SCs. The usage of coordinating modeling with financial 3PL provider allows decision making of WCM in SCs on the collaborative level of a 3-stage SC.

This section provides a theoretical design of optimization mCCCC model. Chapter 3 consists of practical application of both scenarios and optimization mCCCC model on 4 collaborative SCs of different industries. All calculations are made using Excel Solver Add-In using GRG non-linear approach. Besides, the optimization mCCCC model can be calculated using other programs such as MATLAB, TORA and others. The process of data collection and industries studied is discussed in the next parts of Chapter 2.

## 2.3. Data collection and industries studied

**2.3.1. Data collection**. Different sources for analysis and research are requirements of design-science approach as long as for holistic case study method (Yin, 2003). The data collection of this research is based on primary and secondary data.

The primary data for the master thesis goal and objectives was obtained from the conversations with representatives of companies in 4 different collaborative SCs. The conversations were face-to-face structured and conducted with the representatives of financial department and operations/logistics departments. During the conversations the author has managed to obtain the information about the structure and members of collaborative chains to obtain the secondary data from open financial statements and annual reports of the companies involved.

As for secondary data in their research Saunders, Lewis and Tornhill (2009) allocate three types of secondary data: a survey conducted, multiple sources searched and documentary. In compliance with archival approach (Moers, 2006) and for the purposes of goal and objectives satisfaction the last type – documentary – is chosen and based on written materials. This kind of documents usually includes key figures of SC performance and financial outcomes of this performance in the form of the annual report. The secondary data of this type could be obtained from the open sources of companies in the Investor Relations part. The relevance of this kind of documents is sufficient due to the fact that every financial statement is audited before release and all statements are completed in compliance with International Financial Reporting Standards (IFRS) (Pirttilä, 2014).

The author made adjustments to the data to ensure the applicability of the model– the data obtained from financial reports of members of 3-stage collaborative SCs of each industry assumed to be dedicated to each specific collaborative SC with no other operations included.

**2.3.2. Industries studied**. The author has chosen for research purposes four collaborative SCs from different industries. The criteria of choosing the industry for mCCCC evaluation and application of optimization mCCCC model is based on Talonpoika et al. (2014) study where the authors identify four main industries where the impact of A/E as a components of cycle time calculations – project, ICT, publishing and automotive industries is the biggest.

The nature of project business assumes a lot of A/E because they are essential to finance the long operating cycle. The amount of A/E in not constant though and is a subject of negotiation between the supplier and the customer. A/E are usually the percentage of total price and are paid in several parts during the project time.

According to the study of Talonpoika (2014) the ICT companies have the longest average DAO. This value mostly belongs to the nature of the industry and by the constant dependence of customers on ICT services. The main purpose of A/E in ICT industry is the amount of money sufficient enough to finance the projects.

The pulp and publishing industry is closer to the end industry then the previous two industries which are mainly focused on B2B business. The A/E in this industry are mainly from the annual subscriptions. Due to the fact that the A/E in a form of annual subscriptions are very popular among customers the publishing collaborative SCs may achieve negative mCCCC.

The automotive industry is one of the industries where A/E are widely practiced. However the industry is interested by the fact that it was hit especially hard by the economic crisis – the reduction of oil resulted in the decreased real income and decrease of demand (McKinsey, 2011). Hence the companies in collaborative automotive SCs seek the ways of reduction the cycle time of WC and decrease the costs associated.

## 2.4. Research design

Monto (2013) suggests five stages of design-science approach – “identification of the problem, development of the solution to the problem, application of the solution to the problem, evaluation of the solution and introduction to main results and findings”. All process is illustrated at Figure 2.2.

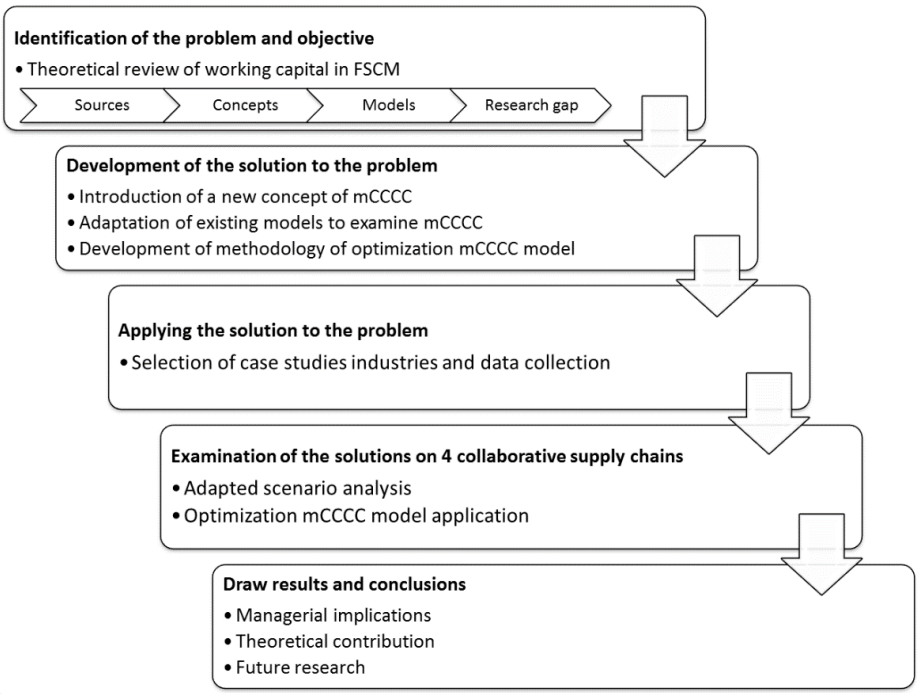



Figure 2.2. Research design based on design-science approach

Source: Created by the author

At the first stage of identification of the problem and objective the author does a theoretical review of WC in FSCM. After identification of main sources, concept and models a research gap reveals – there is no study of collaborative conversion cycle with A/E included. The justification of relevance of the research topic is provided.

At the second stage, the author introduces the concept of mCCCC using design-science and archival approaches. Besides, examination of described in literature models to evaluate the cycle time of collaborative SCs revealed the flaws in the existing measures. To fix the problems, the new model for mCCCC optimization is developed based on total financial cost criteria using goal programming approach.

At the third and fourth stage the developed mCCCC concept is tested on four collaborative SCs from different industries – project, ICT, publishing and automotive. Two approaches are used – scenario analysis for justification of DAO component in collaborative SCs and optimization mCCCC model for total financial costs minimization based on mCCCC components as a variables, target levels of total inventory, total A/R, total A/P and total A/E as goals and current levels of costs as constraints. The fifth part summarizes all parts and provides justification of achieved goals of the master thesis. The managerial implications are provided alongside with theoretical contribution and ways of future research.

# 3. Coordination modeling case study analysis

This chapter provides the examination of the developed modified collaborative CCC (mCCCC) on case companies and consists of two parts. The first part dedicates to examination of mCCCC approach using adapted version of Randall and Farris (2009) scenario analysis for collaborative SCs. The second part is devoted to evaluation of a newly developed model for mCCCC management based on goal and linear programming approach using costs as main Criterion.

## 3.1. Case study of mCCCC scenario analysis

As it was discussed in Chapter 2, Randall and Farris (2009) in their study developed scenario analysis framework which allows simulation of WC collaborative managerial actions can influence the cycle time of WC and reduce the financial costs of running the cycle for each company and collaborative CCC. The scenarios for mCCCC approach for each of case industries are following:

1. Shortening the DIO component in collaborative chains
2. Shifting the inventory from key customer to manufacturer
3. Shortening the DSO component in collaborative chains
4. Extension of DPO component in collaborative chains
5. Extension of DAO component in collaborative chains

The collaborative SC which is a subject to this kind of analysis consists of three members such as supplier, manufacturer and customer – in different cases it could be distributors, food and non-food retailers or following companies in production cycle. The number of SC members is not limited by only three participants and could be broaden at every stage of a SC although it is critical to be sure that all participants are still under collaboration conditions to initiate WC managerial action for a whole SC.

**3.1.1. Project industry.** The first industry to be analyzed is project. The industry characterized by high collaboration and high level of accrued expenses for supplier to ensure the production of essential components for manufacturer. The calculated data for this project collaborative SC is done using equations (2.1) (2.2.) (2.3) is described in Figure 3.1. which includes calculated mCCC components and financial costs for each member of a SC and total modified collaborative CCC and financial costs tied up in each stage of mCCCC.

The dataset is characterized by high level of DIO component for all stages of collaborative SC. DSO component is also high which means that there is a big time lap between actual purchase of goods sold and money received by a seller which is not favorable for minimizing mCCCC purposes. However, the DPO component is all cases bigger than DSO which can be an indicator of the fact that all parties pay their suppliers longer than receives money which one of the goals when optimizing mCCCC. DAO component is high for supplier which could be explained by project features. The author applied 5 scenarios to this case and the results are illustrated in Figure 3.1..

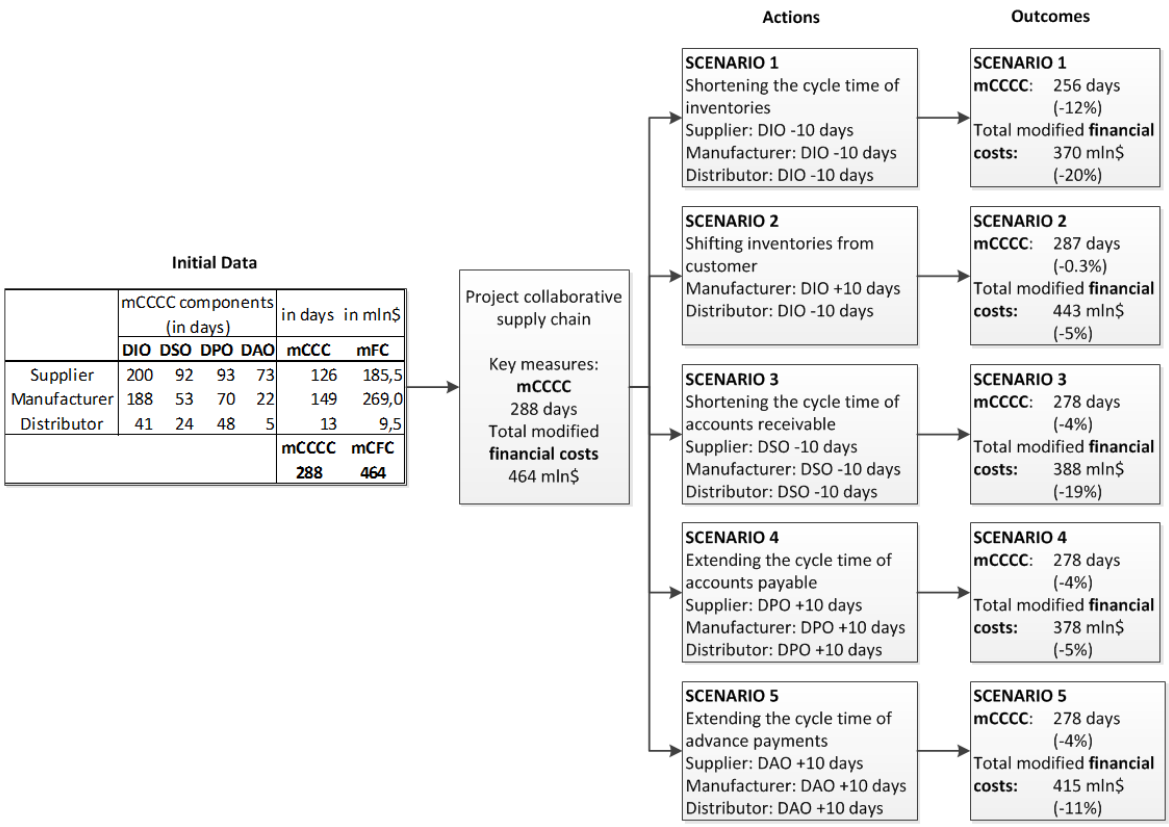



Figure 3.1. Implementation of scenario analysis to project collaborative SC

Source: Created by the author

According to Figure 3.1. the best scenario for managerial WC actions in terms of reducing total financial costs is the shortening of DIO component because the value of financial costs was reduced by 20% in compliance with the simulation results and the mCCCC is now 12% lower than before the actions which means that the cycle from inventory to cash is now done faster. The reduction of inventories is possible when there is no threat of stockouts and could be achieved through efficient control of inventory level and enhancing information exchange to avoid the bullwhip effect.

Another possible scenario when the reduction of inventory is not possible – extension of both DPO and DAO components in collaborative SC – the terms of internal payments. The companies under collaboration conditions may agree to delay the payments ensuring the higher speed of conversion cycle – these actions can bring reduction of mCCCC and mCFC by 4% and 16% retrospectively. Accrued expenses extension could be useful when the payments are making too early to provide the availability of the product for the customers but if there are trust and collaboration among the partners of the SC – if management decide to do this the results could be the reduction of mCCCC by 4% and the reduction of costs by 11%.

**3.1.2. ICT industry.** Another case is from ICT collaborative SC. The industry is characterized by high level of manufacturer inventory and low level of accrued expenses for the customer because it usually buys finished goods. Calculated data for this ICT collaborative SC is done using equations (2.1-4.) is described in Figure 3.2. which includes calculated mCCCC components and financial costs for each member of a SC and total modified collaborative CCC and financial costs tied up in each stage of mCCCC.

This collaborative SC is characterized by high level of inventory of the manufacturer company and it pays its supplier late but receives the money from operations fast. The supplier and manufacturer have low inventory of DSO and will not be reduced. The results of simulation scenarios for ICT collaborative SC are illustrated at Figure 3.2.

The best result for reducing both financial costs and mCCCC for automotive collaborative SC is also scenario of shortening the cycle time of inventories – after simulation the costs decreases by 13% and the time to run the whole cycle reduces by 12%. The best scenario is first again due to the fact that firstly all participants have long inventory days components and secondly DSO component is already minimized in the manufacturer and customer cases. It is important inference which can be made out of this case – switching inventory from customer to manufacturer raises total financial costs by 10% and should not be applied. This increase could be a result of high inventory storage costs and the fact that inventory for manufacturer is already high – the high level of DIO component proves that.

DAO component plays a significant role in reduction of the cycle time of WC – 11%. The result could be obtained by the lack of reduction of DSO component in Scenario 2 and not complete reduction of inventories which customer has already shortened. Nevertheless, the extensions of DAO component can be a great practice in case when there no managerial actions for further reduction of inventories and A/R.

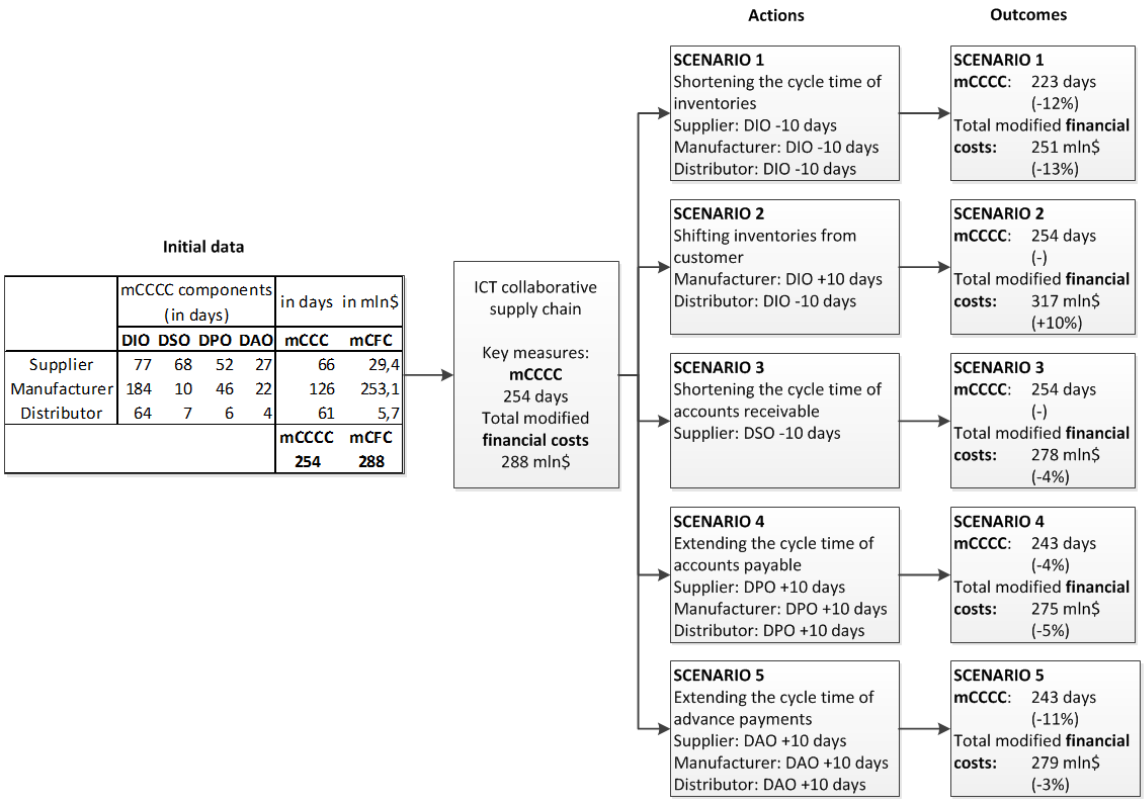



Figure 3.2. Implementation of scenario analysis to ICT collaborative SC

Source: Created by the author

**3.1.3. Automotive industry**. The same procedure as in two first cased was applied to the case of automotive industry. The third automotive case reveals features of short inventory for the customer who is a software company and has negative mCCC. That means that the customer does not pay its suppliers that it purchases until the payment for these product is received. The relation with the automotive industry is that the dealer takes the autos for realization and do not need to hold high level of inventory because the demand is predictable but does accrued expenses while making an order to ensure the autos available when needed. The scenario analysis is illustrated in the Figure 3.3., although the reduction of DIO for supplier was not done due to low inventory level and scenario 2 is skipped because of the same reason.

Due to the relationship between the manufacturer and a supplier in automotive industry specifics the inventory reduction scenario is not the best. The shortening the time of A/R could bring the serious reduction to financial costs – almost two times lower (-46%) and could be done if the credit terms are reviewed and shortened.

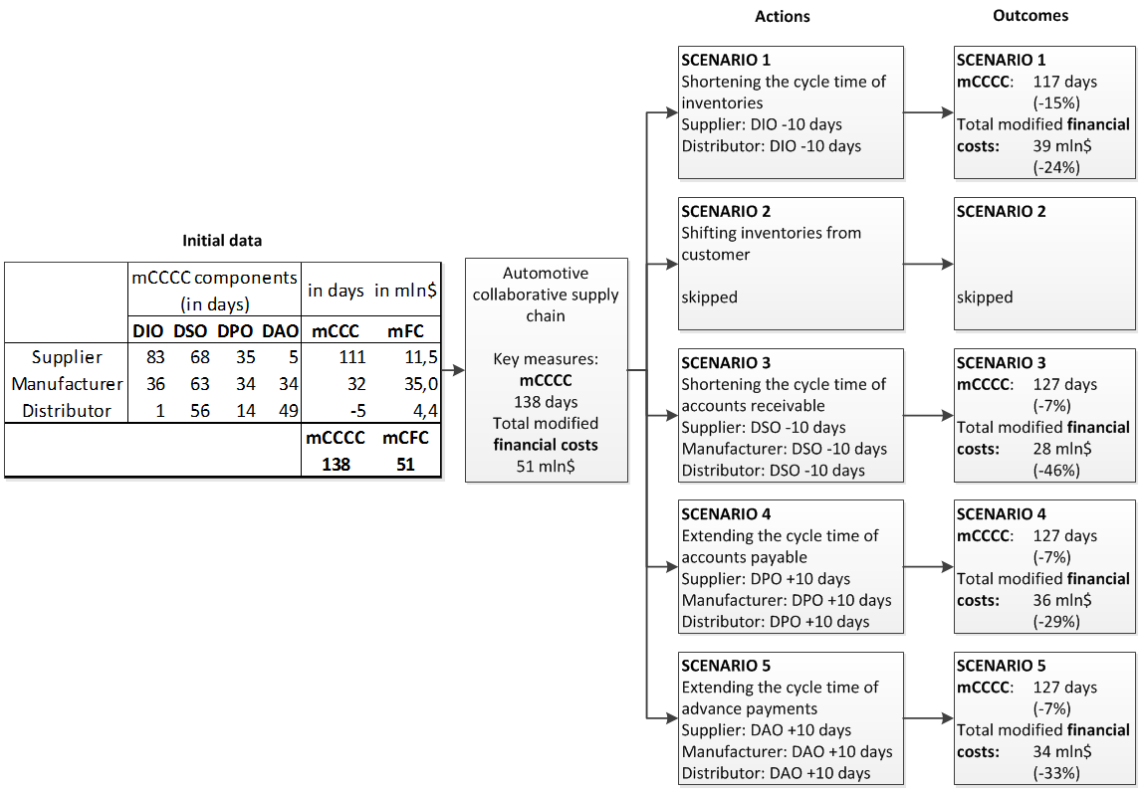


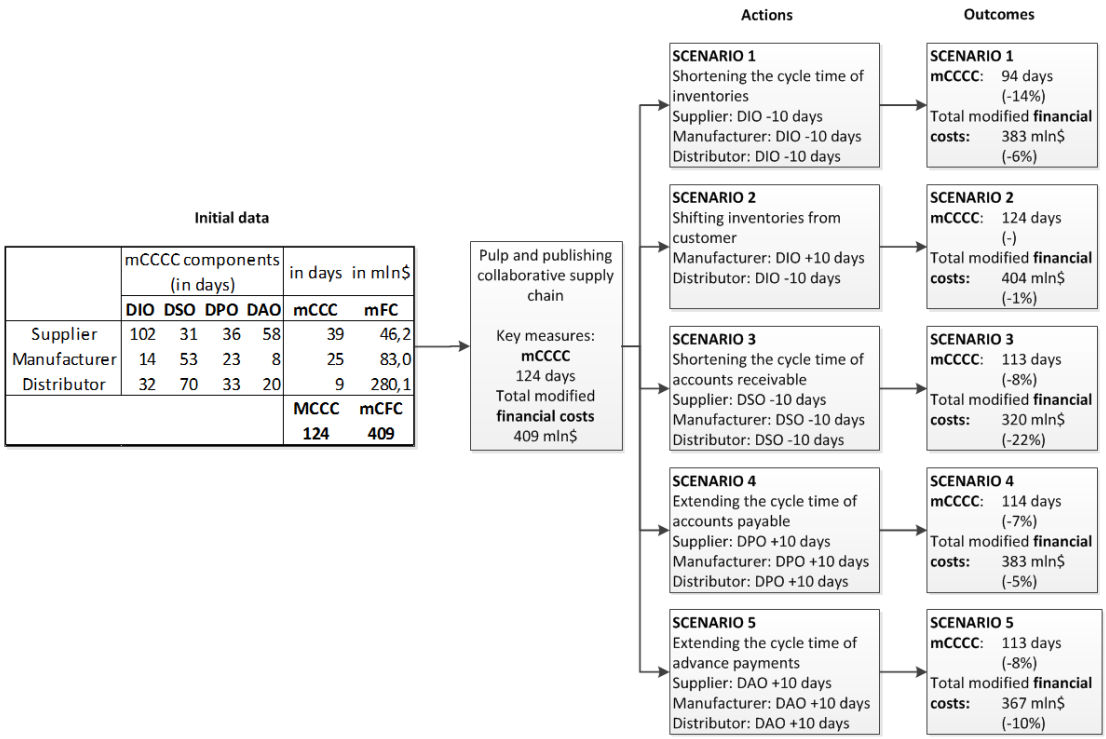

Figure 3.3. Implementation of scenario analysis to automotive collaborative SC

Source: Created by the author

The DAO component provides the result second best in terms of costs reduction (-33%) after the third scenario with shortening the DSO component for members of a SC. The usage of DAO extension can be useful in case when the inventories cannot be shortened no more to prevent stockouts or account receivable component shortening received its minimum. In this case in terms of collaborative SC – information exchange and trust the members can agree to prolong the cycle time of A/E in order to reduce the cycle time of WC and total financial costs for a whole SC.

**3.1.4. Pulp and publishing industry.** The last case is about project business industry – pulp and publishing SC. This case has a relatively high total financial costs of running relatively short cycle compared to previous cases. The results of calculations of mCCCC components show that the supplier has high level of inventory which is a common feature of a production companies (in this case the supplier is a pulp manufacturer company). Besides, the credit terms of the supplier for accrued expenses make them to pay later. The mCCCC components change results according to scenario analysis are illustrated in Figure 3.4.

Figure 3.4. Implementation of scenario analysis to P&P collaborative SC




Source: Created by the author

The results of the case in pulp and publishing industry are controversial. The most significant reduction of the mCCCC was done by the simulation of inventory decrease managerial actions – by 14% but the costs were reduced by 6%. However, the most serious reduction of costs is done while decreasing the level of DSO – 22% and the cycle was reduced by 8%. The preferable option is still the DSO reduction because mCCCC formula consists of all DIOs and only one DSO of a customer because of overlapped payments. The DAO component plays a significant role in decreasing costs- 10%, this approach is preferable if there is no opportunity to reduce the inventory and the companies in collaborative SC has not enough bargaining power to change the terms of payments.

The scenario approach of Randall and Farris (2009) allows evaluation of change and degree of contribution of each component to the cycle time and total financial costs. The purpose of application of this framework was to test applicability of mCCCC to collaborative SCs. The DAO component plays a significant role in reducing the costs associated with the collaborative SC and the increase of this component brings a significant reduction to the mCCCC value. The application of DAO extension scenario is preferable when there is no possibility to shorten cycle time of inventories to avoid stockouts and no opportunity for further reduction of DSO

component because it is already optimized and shorten to minimum. In this case the usage DAO component in terms of collaborative SC can bring its benefits. The variations of this component alongside with others components affect the length of the cycle and for the companies with accrued expenses the evaluation of collaborative SC using mCCCC is more precise rather that common CCCC approach.

To fix the problems of Randall and Farris model (2009) which were describes in Chapter 2 the author suggests the improvement to existing methodology by development of new framework that was described in Chapter 2 and is now tested on four cases in next paragraph of Chapter 3.

## 3.2. Case study of mCCCC coordination modelling

This paragraph dedicates to the evaluation and examination of developed mCCCC methodology for resource optimization based on goal and nonlinear programming and costs as a main Criterion which was described in Chapter 2. The newly developed methodology is tested on four different cases and the minimization of objective function of total financial costs is achieved in all cases with satisfaction of all constraints set.

**3.2.1. Project industry.** The intermediary or management, in other words Decision Maker (DM), decides to apply collaborative CCC optimization framework to the existing collaborative SC in project industry. The calculated data of mCCCC and mCFC components for collaborative SC is illustrated in Table 3.1.

The DM has stated the following objectives for this collaborative SC in order to provide faster mCCCC cycle and to achieve the goal of minimization of total financial costs of whole SC. The DM sets the goals of total inventory and total A/R not exceed the existing costs and for account payable and accrued expenses. Besides, the DM also requires that costs of each stage of mCCCC (mFC) do not exceed its existing values. The first step is to find feasible (local optimal) solution using mCCCC components as variables with satisfaction of all constraints.

Table 3.1. mCCCC and mCFC components for project collaborative SC

| Amount of money (in $ millions) of each component of mCCCC of various players in | | | | | | | |
|---|---|---|---|---|---|---|---|
| | Inventory | Accounts Receivable | Accounts Payable | Accrued expenses | COGS | Revenue | r,% |
| Supplier | 3 463 | 5 112 | 1 613 | 4 075 | 6 309 | 20 263 | 9,67 |
| Manufacturer | 6 989 | 5 266 | 2 585 | 2 204 | 13 534 | 36 582 | 7,32 |
| Distributor | 8 678 | 6 849 | 10 093 | 1 357 | 76 524 | 103 442 | 11,58 |
| Total | 19 130 | 17 227 | 14 291 | 7 636 | | | |
| | mCCCC components | | | | | | |
| | DIO | DSO | DPO | DAO | mCCC | mFC | |
| Supplier | 200 | 92 | 93 | 73 | 126 | 185,5 | |
| Manufacturer | 188 | 53 | 70 | 22 | 149 | 269,0 | |
| Distributor | 41 | 24 | 48 | 5 | 13 | 9,5 | |
| | | | | | MCCC | mCFC | |
| | | | | | 288 | 464 | |

Source: Created by the author

$$TI \leq 19\,130$$

$$TAR \leq 17\,227$$

$$TAP \geq 14\,921$$

$$TAE \geq 7\,636$$

$$TC_1 \leq 185.5$$

$$TC_2 \leq 269.0$$

$$TC_3 \leq 9.5$$

$$x_1, x_2, x_3, x_4, x_5, x_6 \geq 0$$

There is a feasible solution which satisfied all the constraints (App. 1) and this means that further optimization is possible. Now the formulation of the problem is more complex, because the DM requires the participants of the collaborative SC to achieve the specific target levels of total inventories, A/R, A/P and accrued expenses to improve the performance of the company by reduced costs and the length of collaborative mCCCC:

- Decrease of total inventories by 5% to 18 174$mln
- Decrease of total A/R by 5% to 16 366$mln
- Increase of total A/R by 5% to 15 005$mln
- Increase of total accrued expenses by 5% to 8 017$mln

The formulation of the minimization the total financial costs function now is following:

$$\text{Minimize } f(x) = TC_1 + TC_2 + TC_3$$

$$lTI \geq 18\,174$$
$$lTAR \geq 16\,366$$
$$lTAP \leq 15\,005$$
$$lTAE \leq 8\,017$$
$$TC_1 \leq 185.5$$
$$TC_2 \leq 269.0$$
$$TC_3 \leq 9.5$$
$$x_1, x_2, x_3, x_4, x_5, x_6 \geq 0$$

The optimal solution is found and all constraints are satisfied. The optimal results mean that there is the best solution in the observed diapason. The results of the minimization of the objective function using mCCCC components as variables are listed in the Table 3.2.

The model changed the mCCCC components as variables of mCFC function and the results of application of the collaborative CCC optimization framework are following:

- The objective function is minimized. The total financial costs are now decreased by 38% and mCCCC is decreased by 42%. That means that in this case company decreased the total amount of costs tied up in each stage of operating cycle and now the cycle time is faster which can positively affect the performance company in terms of liquidity and profitability.
- The achievement of all goals stated. The optimized model has managed to achieve all criteria which were stated by the DM – the reduction of total inventory and total A/R by 5% and increase of total A/P and total accrued expenses by 5%.
- The Criterion of not exceeding the current level of costs were satisfied fully. Furthermore, the optimal solution provides the reduction of costs – for the supplier the decrease is 82%, for manufacturer is 8% and for the customer which inventory was increased the costs are still the same.

The optimized model allows having not only financial outcomes but also managerial guidelines. The allocation of all components of total inventory, A/R, A/P and A/E are different when the objective is minimized and if the SC operates in collaboration the resource relocation may bring the goal results. For example the amount of inventory for supplier is reduced and the inventory for manufacturer and retailer are increased but decisions based on the trust and information exchange in collaborative SC bring better results if all the companies operate separately – the example of this decision was reviewed in Chapter 3.1.

Table 3.2. Optimized collaborative CCC model for project industry

| Amount of money (in $ millions) of each component of mCCCC of various players in | | | | | | | |
|---|---|---|---|---|---|---|---|
| | Inventory | Accounts Receivable | Accounts Payable | Accrued expenses | COGS | Revenue | r,% |
| Supplier | 2 377 | 5 112 | 2 328 | 4 457 | 6 309 | 20 263 | 9,67 |
| Manufacturer | 6 662 | 5 266 | 2 585 | 2 204 | 13 534 | 36 582 | 7,32 |
| Distributor | 9 135 | 5 988 | 10 093 | 1 357 | 76 524 | 103 442 | 11,58 |
| Total | **18 174** | **16 366** | **15 005** | **8 017** | | | |
| | mCCCC components | | | | | | |
| | DIO | DSO | DPO | DAO | mCCC | mFC | |
| Supplier | 137 | 92 | 135 | 80 | 15 | 32,5 | |
| Manufacturer | 180 | 53 | 70 | 22 | 141 | 245,0 | |
| Distributor | 44 | 21 | 48 | 5 | 12 | 9,5 | |
| | | | | | MCCC | mCFC | |
| | | | | | 167 | 287 | |

Source: Created by the author

**3.2.2. ICT industry.** The same procedure is applied to the case of ICT industry. The assumptions of the model are that the DM decided to improve the WC metrics in the collaborative SC in ICT industry and applies the optimization collaborative CCC model. The calculated data of mCCCC and mCFC components for collaborative SC is illustrated in Table 3.3.

Table 3.3. mCCCC and mCFC components for ICT collaborative SC

| Amount of money (in $ millions) of each component of mCCCC of various players in | | | | | | | |
|---|---|---|---|---|---|---|---|
| | Inventory | Accounts Receivable | Accounts Payable | Accrued expenses | COGS | Revenue | r,% |
| Supplier | 1 342 | 1 374 | 901 | 545 | 6 345 | 7 419 | 8,18 |
| Manufacturer | 11 593 | 816 | 2 896 | 1 796 | 22 981 | 29 792 | 4,74 |
| Distributor | 972 | 119 | 85 | 64 | 5 528 | 6 588 | 3,38 |
| Total | **13 907** | **2 309** | **3 882** | **2 405** | | | |
| | mCCCC components | | | | | | |
| | DIO | DSO | DPO | DAO | mCCC | mCFC | |
| Supplier | 77 | 68 | 52 | 27 | 66 | 29,4 | |
| Manufacturer | 184 | 10 | 46 | 22 | 126 | 253,1 | |
| Distributor | 64 | 7 | 6 | 4 | 61 | 5,7 | |
| | | | | | MCCC | mCFC | |
| | | | | | 254 | 288 | |

Source: Created by the author

The DM sets the goals of total inventory and total A/R not exceed the existing costs and for account payable and accrued expenses. Besides, the DM also requires that costs of each stage

of mCCCC (mFC) do not exceed its existing values. Similarly to case 1 the first step is to find feasible (local optimal) solution using mCCCC components as variables with satisfaction of all constraints. The formulation of a problem is following (in mln$):

$$TI \leq 13\,907$$
$$TAR \leq 2\,309$$
$$TAP \geq 3\,882$$
$$TAE \geq 3\,218$$
$$TC_1 \leq 29.4$$
$$TC_2 \leq 253.1$$
$$TC_3 \leq 5.7$$
$$x_1, x_2, x_3, x_4, x_5, x_6 \geq 0$$

The feasible solution is found and all constraints are satisfied (App. 6). If feasible solution is found there is opportunity to found optimal solution while tighten the constraints. The DM requires the participants of collaborative SC to achieve the following results in order to decrease costs and improve collaborative financial cycle:

- Decrease of total inventories by 5% to 13 212$mln
- Decrease of total A/R by 5% to 2 194$mln
- Increase of total A/R by 5% to 4 076$mln
- Increase of total accrued expenses by 5% to 3 379$mln

The formulation of the minimization the total financial costs function now is following:

$$\text{Minimize } f(x) = TC_1 + TC_2 + TC_3$$

$$lTI \geq 13\,907$$
$$lTAR \geq 2\,194$$
$$lTAP \leq 4\,076$$
$$lTAE \leq 3\,379$$
$$TC_1 \leq 29.4$$
$$TC_2 \leq 253.1$$
$$TC_3 \leq 5.7$$
$$x_1, x_2, x_3, x_4, x_5, x_6 \geq 0$$

The optimal solution is found and all constraints are satisfied (App.7). The optimal results mean that there is the best solution in the observed diapason. The results of the minimization of the objective function using mCCCC components as variables are listed in the Table 5.

Table 3.4. Optimized collaborative CCC model for ICT industry

| Amount of money (in $ millions) of each component of mCCCC of various players in | | | | | | | |
|---|---|---|---|---|---|---|---|
| | Inventory | Accounts Receivable | Accounts Payable | Accrued expenses | COGS | Revenue | r,% |
| Supplier | 1 711 | 1 374 | 1 095 | 1 519 | 6 345 | 7 419 | 8,18 |
| Manufacturer | 10 522 | 816 | 2 896 | 1 796 | 22 981 | 29 792 | 4,74 |
| Distributor | 978 | 3 | 85 | 64 | 5 528 | 6 588 | 3,38 |
| **Total** | **13 212** | **2 194** | **4 076** | **3 379** | | | |
| | **mCCCC components** | | | | | | |
| | **DIO** | **DSO** | **DPO** | **DAO** | **mCCC** | **mCFC** | |
| Supplier | 98 | 68 | 63 | 75 | 28 | 17,2 | |
| Manufacturer | 167 | 10 | 46 | 22 | 109 | 204,6 | |
| Distributor | 65 | 0 | 6 | 4 | 56 | 5,7 | |
| | | | | | **MCCC** | **mCFC** | |
| | | | | | **193** | **227** | |

Source: Created by the author

The model changed the mCCCC components as variables of mCFC function and the results of application of the collaborative CCC optimization framework are following:

- The objective function is minimized and total financial costs function is reduced by 21% with the mCCCC decrease by 24%. The optimization allows companies involved in collaborative SC to spend less money on cycle operation and the cycle time itself is reduced thus increasing profitability and liquidity of the companies SC.
- The achievement of all goals stated. The optimized model has managed to achieve the entire criteria which were stated by the DM – the reduction of total inventory and total A/R by 5% and increase of total A/P and total accrued expenses by 5%.
- The criterion of not exceeding the current level of costs was satisfied fully. Furthermore, the optimal solution provides the reduction of costs – for the supplier the decrease is 41%, for manufacturer is 19% and for the customer which inventory was increased the costs are still the same.

The important notification is the optimized model suggests cutting DSO days close to zero. It means that customer should review its external credit terms of payments. The solution suggests increase the amount of inventory thus the purchase could be paid and got at the closely same day. The reduction of total inventory is achieved by the reduction of inventory of a manufacturer and may be a result of more efficient allocation of resources – due to the fact that inventories of supplier and customer increased the manufacturer can distribute some of the inventories to them to achieve better results.

**3.2.3. Automotive industry.** To continue the methodology testing the optimization collaborative CCC model applies to the next case of automotive industry. In order to increase the performance of the whole SC and cut costs which are especially important in the terms of the ongoing financial crisis the DM takes the decision to apply the model to the automotive collaborative SC. The calculated mCCCC and mCFC are represented in Table 3.5.

Table 3.5. mCCCC and mCFC components for automotive collaborative SC

| Amount of money (in $ millions) of each component of mCCCC of various players in | | | | | | | |
|---|---|---|---|---|---|---|---|
| | **Inventory** | **Accounts Receivable** | **Accounts Payable** | **Accrued expenses** | **COGS** | **Revenue** | **r,%** |
| **Supplier** | 402 | 616 | 170 | 43 | 1 770 | 3 306 | 6,25 |
| **Manufacturer** | 2 228 | 2 675 | 2 078 | 1 423 | 22 363 | 15 471 | 10,10 |
| **Distributor** | 45 | 2 407 | 422 | 2 106 | 11 123 | 15 573 | 6,28 |
| **Total** | **2 675** | **5 698** | **2 670** | **3 572** | | | |
| | **mCCCC components** | | | | | | |
| | **DIO** | **DSO** | **DPO** | **DAO** | **mCCC** | **mCFC** | |
| **Supplier** | 83 | 68 | 35 | 5 | 111 | 11,5 | |
| **Manufacturer** | 36 | 63 | 34 | 34 | 32 | 35,0 | |
| **Distributor** | 1 | 56 | 14 | 49 | -5 | 4,4 | |
| | | | | | **MCCC** | **mCFC** | |
| | | | | | **138** | **51** | |

Source: Created by the author

The DM sets the goals of total inventory and total A/R not exceed the existing costs and for account payable and accrued expenses. Besides, the DM also requires that costs of each stage of mCCCC (mFC) do not exceed its existing values. The first step is to find feasible (local optimal) solution using mCCCC components as variables with satisfaction of all constraints. The formulation of a problem is following (in mln$):

$$TI \leq 2\,675$$

$$TAR \leq 5\,698$$

$$TAP \geq 2\,670$$
$$TAE \geq 3\,572$$
$$TC_1 \leq 11.5$$
$$TC_2 \leq 35.0$$
$$TC_3 \leq 4.4$$
$$x_1, x_2, x_3, x_4, x_5, x_6 \geq 0$$

There is a feasible solution which satisfied all constraints (App. 8) and this means that further optimization is possible. In order to decrease costs for each stage of cycle time and get the whole cycle faster, the DM set the following goals of:

- Decrease of total inventories by 5% to 2 407$mln
- Decrease of total A/R by 5% to 5 128$mln
- Increase of total A/R by 5% to 2 804$mln
- Increase of total accrued expenses by 5% to 3 751$mln

The formulation of the minimization the total financial costs function now is following:

$$\text{Minimize } f(x) = TC_1 + TC_2 + TC_3$$

$$lTI \geq 2\,407$$
$$lTAR \geq 5\,128$$
$$lTAP \leq 2\,804$$
$$lTAE \leq 3\,751$$
$$TC_1 \leq 11.5$$
$$TC_2 \leq 35.0$$
$$TC_3 \leq 4.4$$
$$x_1, x_2, x_3, x_4, x_5, x_6 \geq 0$$

The optimal solution is found and all constraints are satisfied. The optimal results mean that there is the best solution in the observed diapason. The results of the minimization of the objective function using mCCCC components as variables are listed in the Table 3.6.

Table 3.6. Optimized collaborative CCC model for automotive industry

| Amount of money (in $ millions) of each component of mCCCC of various players in | | | | | | | |
|---|---|---|---|---|---|---|---|
| | Inventory | Accounts Receivable | Accounts Payable | Accrued expenses | COGS | Revenue | r,% |
| Supplier | 158 | 616 | 304 | 222 | 1 770 | 3 306 | 6,25 |
| Manufacturer | 1 260 | 2 675 | 2 078 | 1 423 | 22 363 | 15 471 | 10,10 |
| Distributor | 990 | 1 837 | 422 | 2 106 | 11 123 | 15 573 | 6,28 |
| Total | 2 407 | 5 128 | 2 804 | 3 751 | | | |
| | mCCCC components | | | | | | |
| | DIO | DSO | DPO | DAO | mCCC | mCFC | |
| Supplier | 33 | 68 | 63 | 24 | 14 | 3,8 | |
| Manufacturer | 21 | 63 | 34 | 34 | 16 | 20,4 | |
| Distributor | 32 | 43 | 14 | 49 | 12 | 0,2 | |
| | | | | | MCCC | mCFC | |
| | | | | | 42 | 24 | |

Source: Created by the author

The model has achieved all goals stated with satisfaction of all constraints. The results of the optimized collaborative conversion cycle model are following:

- The objective function of total financial costs is now minimized in diapason set. The reduction of costs in terms of collaborative SC is 52% and the reduction of mCCCC has achieved 70%. That means that for each mCCCC cycle the collaborative SC now needs to pay nearly two times less money and the speed of converting inventory to cash in collaborative SC increased for 70% which is advantageous in terms of recent financial crisis.
- The achievement of all goals stated. The optimized model has managed to achieve all the Criterion the DM stated – the reduction of total inventory and total A/R by 5% to 9 709mln$ and 32 841mln$ retrospectively and increase of total A/P and total accrued expenses by 5% to 8 057mln$ and 16 454mln$ retrospectively.
- The criterion of not exceeding the current level of costs was satisfied fully. Furthermore, the optimal solution provides the reduction of costs – for the supplier the decrease is 67%, for manufacturer is 42% and for the customer which cycle has increased nevertheless the reduction of costs is 95%.

The optimization collaborative CCC model allows revealing of possible hidden opportunities. In the initial scenario most of the inventory was held at manufacturing facilities.

Now the inventory of customer increased which will help to increase the speed of cycle and positively affect the profitability. The increase of inventory held for customer may reduce the amount of A/R for customer due to the reduced time of receiving finished product – that means that supplier faster gets money.

**3.2.4. Pulp and publishing industry.** The last case for optimization collaborative CCC model is the collaborative SC from pulp and publishing industry. In order to getting the money from purchases faster and especially to decrease costs associated with the collaborative conversion cycle which are relatively high to relatively low mCCCC compared to other cases the DM decided to apply the optimization collaborative CCC model. The calculation of mCCCC components and CFC is summed in Table 3.7.

Table 3.7. mCCCC and mCFC components for P&P collaborative SC

| Amount of money (in $ millions) of each component of mCCCC of various players in | | | | | | | |
|---|---|---|---|---|---|---|---|
| | **Inventory** | **Accounts Receivable** | **Accounts Payable** | **Accrued expenses** | **COGS** | **Revenue** | **r,%** |
| **Supplier** | 5 767 | 4 787 | 2 063 | 8 782 | 20 681 | 55 632 | 11,04 |
| **Manufacturer** | 1 551 | 11 869 | 2 623 | 1 792 | 41 632 | 81 742 | 5,38 |
| **Distributor** | 2 902 | 17 913 | 2 987 | 5 096 | 33 042 | 93 524 | 9,25 |
| **Total** | **10 220** | **34 569** | **7 674** | **15 670** | | | |
| | **mCCCC components** | | | | | | |
| | **DIO** | **DSO** | **DPO** | **DAO** | **mCCC** | **mFC** | |
| **Supplier** | 102 | 31 | 36 | 58 | 39 | 46,2 | |
| **Manufacturer** | 14 | 53 | 23 | 8 | 25 | 83,0 | |
| **Distributor** | 32 | 70 | 33 | 20 | 9 | 280,1 | |
| | | | | | **MCCC** | **mCFC** | |
| | | | | | **124** | **409** | |

Source: Created by the author

The DM sets the goals of total inventory and total A/R not exceed the existing costs and for account payable and accrued expenses. Besides, the DM also requires that costs of each stage of mCCCC (mFC) do not exceed its existing values. The first step is to find feasible (local optimal) solution using mCCCC components as variables with satisfaction of all constraints. The formulation of a problem is following (in mln$):

$$TI \leq 10\,220$$

$$TAR \leq 34\,569$$

$$TAP \geq 7\,674$$

$$TAE \geq 15\,670$$

$$OC_1 \leq 46.2$$

$$OC_2 \leq 83.0$$
$$OC_3 \leq 280.1$$
$$x_1, x_2, x_3, x_4, x_5, x_6 \geq 0$$

There is a feasible solution which satisfied all constraints (App. 9) and this means that further optimization is possible. In order to decrease costs for each stage of cycle time and get the whole cycle faster, the DM set the following goals of:

- Decrease of total inventories by 5% to 9 709$mln
- Decrease of total A/R by 5% to 32 841$mln
- Increase of total A/R by 5% to 8 057$mln
- Increase of total accrued expenses by 5% to 16 464$mln

The formulation of the minimization the total financial costs function now is following:

$$\text{Minimize } f(x) = \sum_{i=1,2,3}^{1} C_i$$

$$lTI \geq 9\,709$$
$$lTAR \geq 32\,841$$
$$lTAP \leq 8\,057$$
$$lTAE \leq 16\,454$$
$$TC_1 \leq 46.2$$
$$TC_2 \leq 83.0$$
$$TC_3 \leq 280.1$$
$$x_1, x_2, x_3, x_4, x_5, x_6 \geq 0$$

The optimal solution is found and all constraints are satisfied (App.7). The optimal results mean that there is the best solution in the observed diapason. The results of the minimization of the objective function using mCCCC components as variables are listed in the Table 3.8. The model has achieved all goals stated with satisfaction of all constraints. The results of the optimized collaborative conversion cycle model are following:

- The objective function of total financial costs is now minimized in diapason set. The application of mCCCC model allows reduction of total financial costs by 41% and the length of CCC decreased by 35%. The reduction allows companies involved to operate and get money faster at lower costs.

- The achievement of all goals stated. The optimized model has managed to achieve all the Criterion the DM stated – the reduction of total inventory and total A/R by 5% to 9 709mln$ and 32 841mln$ retrospectively and increase of total A/P and total accrued expenses by 5% to 8 057mln$ and 16 454mln$ retrospectively.
- The Criterion of not exceeding the current level of costs was satisfied fully. Furthermore, the optimal solution provides the slight reduction of costs for the customer and for the manufacturer there is an increase of mCCC but the costs remain at the same level.

Table 3.8. mCCCC and mCFC components for P&P collaborative SC

| Amount of money (in $ millions) of each component of mCCCC of various players in collaborative supply chain | | | | | | | |
|---|---|---|---|---|---|---|---|
| | **Inventory** | **Accounts Receivable** | **Accounts Payable** | **Accrued expenses** | **COGS** | **Revenue** | **r,%** |
| **Supplier** | 2 822 | 4 787 | 2 447 | 9 566 | 20 681 | 55 632 | 11,04 |
| **Manufacturer** | 1 551 | 11 869 | 2 623 | 1 792 | 41 632 | 81 742 | 5,38 |
| **Distributor** | 5 336 | 16 185 | 2 987 | 5 096 | 33 042 | 93 524 | 9,25 |
| **Total** | **9 709** | **32 841** | **8 057** | **16 454** | | | |
| | **mCCCC components** | | | | | | |
| | **DIO** | **DSO** | **DPO** | **DAO** | **mCCC** | **mCFC** | |
| **Supplier** | 50 | 31 | 43 | 63 | -25 | -120,4 | |
| **Manufacturer** | 14 | 53 | 23 | 8 | 36 | 83,0 | |
| **Distributor** | 59 | 63 | 33 | 20 | 69 | 277,9 | |
| | | | | | **MCCC** | **mCFC** | |
| | | | | | **80** | **240** | |

Source: Created by the author

The last case provides the optimization to the negative mCCC and negative financial costs for supplier due to decrease of DIO component and increase of DPO and DAO components. The negative value for mCCC means that the supplier in the case of optimized collaborative SC model does not pay its suppliers until it receives money from the manufacturer. The negative financial costs mean that the supplier finance its operations through low level of inventories and while receiving the money from A/R it manages to delay the payments and A/E to its suppliers.

The optimization mCCCC model was successfully tested on four collaborative SCs and the results confirm the applicability of the model to real-life cases. The model allows companies in collaborative SCs to achieve target levels of total inventory, A/R, A/P and A/E through minimization of total cost function with the constraints of not exceeding the existing level of costs for each participant of the collaborative SC.

## Conclusions

**Main findings.** The main goal of this master thesis was *development of the coordinating model of WCM in collaborative SCs*. The main objectives of this master thesis were: to identify the research gaps of WCM in SCs based on the literature review devoted to WCM in SCs; to improve the methodology of WCM in SCs through creation of coordinating SC modified collaborative CCC (mCCCC) model; to analyze coordination modeling of WCM in SCs using case study approach. The goal and main objectives of the research were successfully achieved based on the results of empirical study of four collaborative SCs from different industries – project, automotive, ICT and pulp&publishing.

*To identify the research gaps of WCM in SCs based on the literature review devoted to WCM in SCs.* The theoretical review of WCM in FSCM revealed a few studies about WCM in FSCM. Secondly, during the literature review showed lack of the studies dedicated to implementation of modified CCC (Talonpoika et al., 2014) to collaborative SCs. Thirdly, based on theoretical review using design-science approach the author introduced mCCCC concept that provides a holistic view of WCM in collaborative SCs. During development of mCCCC methodology the several flaws of existing models were revealed in terms of holistic view of collaborative SC and the lack of coordination modeling devoted to WCM in SCs. To fix these problems, the author developed a new model of mCCCC evaluation – coordinating mCCCC model which financial 3PL provider as a coordination mechanism.

*To improve the methodology of WCM in SCs through creation of coordinating SC modified collaborative CCC (mCCCC) model.* Using design-science approach the author developed a new concept of cycle time evaluation for collaborative SCs. The improvement of the concept is mainly concerned with more precise evaluation of WC cycle time in SCs – the DAO component is added to the traditional calculation of CCC. Using design-science approach the author developed a concept of modified collaborative CCC that should be used for the estimation of WC in collaborative SCs especially for industries where A/E are common practice and often are the enablers of the business processes – project, ICT, construction, automotive and others.

The existing models of collaborative CCC estimation have several flaws that prevent the estimation of mCCCC from a holistic point of view. The scenario analysis which was adapted for mCCCC evaluation purposes from Randall and Farris (2009) does not consider several critical characteristics of collaborative SC – the lack of overlapped interim payments as Viskari (2012) recommended, using 10-days measure is robust and does not reflect the measures of each

collaborative SC and each scenario is done separately thus no there is no model for mCCCC and costs optimization. To fix these problems and to provide a holistic view the coordinating SC mCCCC model (optimization mCCCC model) based on cost criteria was developed using goal programming.

The optimization mCCCC assumes the coordination mechanism of a 3PL financial provider who is a decision maker (DM) and states the goals to achieve concerning total inventory, A/R, A/P and A/E with the main objective to reduce the total costs associated with the whole cycle. The variables are the components of mCCCC with the constraints of no exceeding the current level of costs for each member of collaborative SC.

Goal programming allows consideration of all the goals stated in one time if there is a feasible solution. The developed methodology of optimization mCCCC model assumes the possibility of lack of feasible solution and provides two methods of prioritizing the goals – the weighted goals or preemptive programming. If there is a feasible solution the methodology offers further minimization of total financial costs function in feasible diapason.

*To analyze coordination modeling of WCM in SCs using case study approach.* The developed mCCCC concept was tested on four collaborative SCs – project, ICT, automotive and pulp&publishing. The results are following – in all four cases the extension of DAO components for 10 days for each player of collaborative SC resulted in reduction of cycle time of WC (-4% for project industry, -11% for ICT, -7% for automotive and -8% for pulp&publishing) and decrease of total financial costs of whole cycle (-11% for project industry, -3% for ICT, -33% for automotive and -10% for pulp&publishing).

The usage of mCCCC concept for collaborative SCs is preferable due to the fact that first of all, based on the results of Talonpoika et al. (2014) it is more accurate than CCC in terms of estimation the cycle time of WC. Secondly, the usage of mCCCC and particularly the extension of DAO component allow companies the reduction of the length of the WC cycle and total financial costs in cases when the inventories and A/R are already optimized and/or could not be shortened to avoid stockouts.

The optimization mCCCC model was tested on four same case industries as in the previous part of justification of mCCCC concept. For all cases there were a feasible solution (see App. 1, 2, 3, 4) thus minimization of total costs function was done. The application optimization mCCCC model results in achievement of all goals stated by the DM in all cases, the reduction of

total financial costs in all cases (-38% for project industry, -21% for ICT, -52% for automotive and -41% for pulp&publishing) and the decrease of mCCCC in all cases (-42% for project industry, -24% for ICT, -52% for automotive and -35% for pulp&publishing).

**Theoretical contribution and future research.** There are two main theoretical implication of this master thesis that correspond the main objectives justified by the empirical study of four cases. Current studies outline the importance of WCM in SCs because companies need to adjust their operations to volatile economic and financial environment.

Firstly, the research gap of lack of the study that connects mCCC approach and 3-stage collaborative SCs in now fulfilled by the development of mCCCC concept. The usage of this concept is preferable for the companies that have a high level of A/E in their operations because it is provide more accurate view of cycle time and total financial costs.

Secondly, the author contributed improved the methodology of WC assessment in collaborative SCs by introduction of the newly developed optimization mCCCC model that provide a holistic view to the collaborative SCs. The developed methodology is suitable for 3-stage collaborative SC and is applicable for usage for business, consultancy, 3PL or bank as an intermediary or the decision maker. The coordination modeling – optimization mCCCC modelling fixed all the flaws identified of the scenario analysis of collaborative evaluation of cycle time of WC – the goals which are stated by the DM and reflect the purposes of mCCCC and total cost function minimization.

There are two main ways of development for mCCCC concept and mCCCC optimization model. The extension of mCCCC concept could be done with the additional component of tax items. Besides, the integration of mCCCC with ACCC of Viskari (2012) may result in efficient estimation of collaborative order cycle time. The further study of optimization mCCCC model concerns the extension of number of members of SC. Besides, additional goals can be implemented and the components can be weighted with the expert opinions or factor of crisis.

**Managerial implications**. The managerial actions towards working capital in collaborative supply chains are critical for the operational level of the companies. Working capital affects mostly every operation such as supply chain management, production, procurement, finance and others. The companies have gained knowledge how to assess the cycle time of working capital at intra-organizational level, but estimation of that at inter-organizational level still causes difficulties for the companies involved in collaborative supply chains. This

master thesis provides insights into collaborative estimation of modified CCC and way of holistic estimation of it using optimization mCCCC model.

The managerial implications of developed mCCCC concept are following. The companies with large amount of A/E who participate in collaborative SC can more precisely assess the length of cycle time of WC and total financial costs associated with the cycle. Besides, the DAO component extension allows influence on the length of the cycle and costs when other components which cannot be changed anymore to avoid stockouts or are already optimized.

The managerial implications of coordination modeling – optimization mCCCC model are next. First of all, the coordination modeling with the implementation of financial 3PL provider allows centralized WCM decision making for companies involved in collaborative SCs when still being in decentralized conditions of SCs.

Secondly, the model allows simultaneous optimization of all components which can be implemented in practice. Thirdly, the model minimized the financial costs associated with the cycle with no exceeding the current costs of each player. Fourthly, the calculation of the model allows not only obtaining the minimized costs but also the relocation of total inventory, A/R, A/P and A/E for each member of collaborative supply chains to achieve the desired goals and minimum of costs. The applicability of the model is wide – could be used by the DM in 3-stage collaborative supply chains and for further academic development.

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# Appendices

## Appendix 1. The feasible solution for Case 1

Amount of money (in $ millions) of each component of mCCCC of various players in collaborative supply chain

| | Inventory | Account Receivable | Accounts Payable | Accrued expenses | COGS | Revenue | r |
|---|---|---|---|---|---|---|---|
| **Supplier** | 3 463 | 5 112 | 1 613 | 4 075 | 6 309 | 20 263 | 0,0967 |
| **Manufacturer** | 6 989 | 5 266 | 2 585 | 2 204 | 13 534 | 36 582 | 0,0732 |
| **Retailer** | 8 678 | 6 849 | 10 093 | 1 357 | 76 524 | 103 442 | 0,1158 |
| **Total** | **19 130** | **17 227** | **14 291** | **7 636** | | | |

**mCCCC components**

| | DIO | DSO | DPO | DAO | mCCC | mFC |
|---|---|---|---|---|---|---|
| **Supplier** | 200 | 92 | 93 | 73 | 126 | 185,5 |
| **Manufacturer** | 188 | 53 | 70 | 22 | 149 | 269,0 |
| **Retailer** | 41 | 24 | 48 | 5 | 13 | 9,5 |
| | | | | | **MCCC** | **mCFC** |
| | | | | | **288** | **464** |

initial data

**mCCCC components**

| | DIO | DSO | DPO | DAO | mCCC | mFC |
|---|---|---|---|---|---|---|
| **Supplier mFC** | 200 | 92 | 135 | 80 | 77 | **128,4** |
| **Manufacturer mFC** | 188 | 53 | 70 | 22 | 149 | **269,0** |
| **Retailer mFC** | 41 | 21 | 48 | 5 | 10 | **-2,3** |
| | | | | | **MCCC** | **mCFC** |
| | | | | | **236** | **395** |

**Acievement of goals**

| | Results | | GOALS |
|---|---|---|---|
| **Total Inventory** | **19 130** | <= | **19 130** |
| **Total A/R** | **16 366** | <= | **17 227** |
| **Total A/P** | **15 005** | >= | **14 291** |
| **Total A/E** | **8 017** | >= | **7 636** |

feasible solution

| | Inventory | Account Receivable | Accounts Payable | Accrued expenses | COGS | Revenue | r |
|---|---|---|---|---|---|---|---|
| **Supplier** | 3463 | 5112 | 2328 | 4457 | 6309 | 20263 | 0,0967 |
| **Manufacturer** | 6989 | 5266 | 2585 | 2204 | 13534 | 36582 | 0,0732 |
| **Retailer** | 8678 | 5988 | 10093 | 1357 | 76524 | 103442 | 0,1158 |

## Appendix 2. The feasible solution for Case 2

Amount of money (in $ millions) of each component of mCCCC of various players in collaborative supply chain

| | Inventory | Account Receivable | Accounts Payable | Accrued expenses | COGS | Revenue | r |
|---|---|---|---|---|---|---|---|
| **Supplier** | **1 342** | **1 374** | **901** | **545** | 6 345 | 7 419 | 0,0818 |
| **Manufacturer** | **11 593** | **816** | **2 896** | **1 796** | 22 981 | 29 792 | 0,0474 |
| **Retailer** | **972** | **119** | **85** | **64** | 5 528 | 6 588 | 0,0338 |
| **Total** | **13 907** | **2 309** | **3 882** | **3 218** | | | |

**mCCCC components**

| | DIO | DSO | DPO | DAO | mCCC | mCFC |
|---|---|---|---|---|---|---|
| **Supplier** | 77 | 68 | 52 | 27 | 66 | 29 |
| **Manufacturer** | 184 | 10 | 46 | 22 | 126 | 253 |
| **Retailer** | 64 | 7 | 6 | 4 | 61 | 6 |
| | | | | | **MCCC** | **mCFC** |
| | | | | | **254** | **288** |

initial data

**mCCCC components**

| | DIO | DSO | DPO | DAO | mCCC | mCFC |
|---|---|---|---|---|---|---|
| **Supplier** | 79 | 68 | 52 | 79 | 16 | 6,0 |
| **Manufacturer** | 184 | 10 | 46 | 22 | 126 | 253,0 |
| **Retailer** | 63 | 7 | 6 | 4 | 60 | 5,4 |
| | | | | | **MCCC** | **mCFC** |
| | | | | | **202** | **264** |

**Acievement of goals**

| | Results | | GOALS | |
|---|---|---|---|---|
| **Total Inventory** | **13 907** | <= | **13 907** | **13 212** |
| **Total A/R** | **2 309** | <= | **2 309** | **2 194** |
| **Total A/P** | **3 882** | >= | **3 882** | **4 076** |
| **Total A/E** | **3 461** | >= | **3 218** | **3 379** |

feasible solution

| | Inventory | Account Receivable | Accounts Payable | Accrued expenses | COGS | Revenue | r |
|---|---|---|---|---|---|---|---|
| **Supplier** | **1 368** | **1 374** | **901** | **1 602** | 6 345 | 7 419 | 0,0818 |
| **Manufacturer** | **11 592** | **816** | **2 896** | **1 796** | 22 981 | 29 792 | 0,0474 |
| **Retailer** | **947** | **119** | **85** | **64** | 5 528 | 6 588 | 0,0338 |

## Appendix 3. The feasible solution for Case 3

Amount of money (in $ millions) of each component of mCCCC of various players in collaborative supply chain

| | Inventory | Account Receivable | Accounts Payable | Accrued expenses | COGS | Revenue | r |
|---|---|---|---|---|---|---|---|
| **Supplier** | **402** | **616** | **170** | **43** | 1 770 | 3 306 | 0,0625 |
| **Manufacturer** | **2 228** | **2 675** | **2 078** | **1 423** | 22 363 | 15 471 | 0,1010 |
| **Retailer** | **45** | **2 407** | **422** | **2 106** | 11 123 | 15 573 | 0,0628 |
| **Total** | **2 675** | **5 698** | **2 670** | **3 572** | | | |

**mCCCC components**

| | DIO | DSO | DPO | DAO | mCCC | mFC |
|---|---|---|---|---|---|---|
| **Supplier** | 83 | 68 | 35 | 5 | 111 | 11,5 |
| **Manufacturer** | 36 | 63 | 34 | 34 | 32 | 35,0 |
| **Retailer** | 1 | 56 | 14 | 49 | -5 | 4,4 |
| | | | | | **MCCC** | **mCFC** |
| | | | | | **138** | **51** |

initial data

**mCCCC components**

| | DIO | DSO | DPO | DAO | mCCC | mFC |
|---|---|---|---|---|---|---|
| **Supplier** | 83 | 68 | 35 | 5 | 111 | 11,5 |
| **Manufacturer** | 36 | 63 | 34 | 34 | 32 | 35,0 |
| **Retailer** | 1 | 56 | 14 | 49 | -5 | 4,4 |
| | | | | | **MCCC** | **mCFC** |
| | | | | | **138** | **51** |

**Acievement of goals**

| | Results | | GOALS | |
|---|---|---|---|---|
| **Total Inventory** | **2 675** | <= | **2 675** | **2 407** |
| **Total A/R** | **5 698** | <= | **5 698** | **5 128** |
| **Total A/P** | **2 670** | >= | **2 670** | **2 804** |
| **Total A/E** | **3 572** | >= | **3 572** | **3 751** |

feasible solution

| | Inventory | Account Receivable | Accounts Payable | Accrued expenses | COGS | Revenue | r |
|---|---|---|---|---|---|---|---|
| **Supplier** | **402** | **616** | **170** | **43** | 1 770 | 3 306 | 0,0625 |
| **Manufacturer** | **2 228** | **2 675** | **2 078** | **1 423** | 22 363 | 15 471 | 0,1010 |
| **Retailer** | **45** | **2 407** | **422** | **2 106** | 11 123 | 15 573 | 0,0628 |

## Appendix 4. The feasible solution for Case 4

Amount of money (in $ millions) of each component of mCCCC of various players in collaborative supply chain

| | Inventory | Account Receivable | Accounts Payable | Accrued expenses | COGS | Revenue | r |
|---|---|---|---|---|---|---|---|
| **Supplier** | **5 767** | **4 787** | **2 063** | **8 782** | 20 681 | 55 632 | 0,1104 |
| **Manufacturer** | **1 551** | **11 869** | **2 623** | **1 792** | 41 632 | 81 742 | 0,0538 |
| **Retailer** | **2 902** | **17 913** | **2 987** | **5 096** | 33 042 | 93 524 | 0,0925 |
| **Total** | **10 220** | **32 234** | **11 277** | **15 670** | | | |

**mCCCC components**

| | DIO | DSO | DPO | DAO | mCCC | mFC |
|---|---|---|---|---|---|---|
| **Supplier** | 102 | 31 | 36 | 58 | 39 | 46,2 |
| **Manufacturer** | 14 | 53 | 23 | 8 | 25 | 83,0 |
| **Retailer** | 32 | 70 | 33 | 20 | 9 | 280,1 |
| | | | | | **MCCC** | **mCFC** |
| | | | | | **124** | **409** |

initial data

**mCCCC components**

| | DIO | DSO | DPO | DAO | mCCC | mFC |
|---|---|---|---|---|---|---|
| **Supplier** | 50 | 31 | 43 | 63 | -25 | -120,4 |
| **Manufacturer** | 14 | 53 | 23 | 8 | 36 | 83,0 |
| **Retailer** | 59 | 63 | 33 | 20 | 69 | 277,9 |
| | | | | | **MCCC** | **mCFC** |
| | | | | | **80** | **240** |

**Acievement of goals**

| | Results | | GOALS | |
|---|---|---|---|---|
| **Total Inventory** | **9 709** | <= | **10 220** | **9 709** |
| **Total A/R** | **32 841** | <= | **34 569** | **32 841** |
| **Total A/P** | **8 057** | >= | **7 674** | **8 057** |
| **Total A/E** | **16 454** | >= | **15 670** | **16 454** |

feasible solution

| | Inventory | Account Receivable | Accounts Payable | Accrued expenses | COGS | Revenue | r |
|---|---|---|---|---|---|---|---|
| **Supplier** | **2 822** | **4 787** | **2 447** | **9 566** | 20 681 | 55 632 | 0,1104 |
| **Manufacturer** | **1 551** | **11 869** | **2 623** | **1 792** | 41 632 | 81 742 | 0,0538 |
| **Retailer** | **5 336** | **16 185** | **2 987** | **5 096** | 33 042 | 93 524 | 0,0925 |