

MASTER

Supply chain finance as a value added service offered by a lead logistics provider

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Eindhoven, January 2016

**Supply Chain Finance as a Value Added Service offered by a
Lead Logistics Provider**

by

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in partial fulfilment of the requirements for the degree of
Master of Science
in Operations Management and Logistics

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Abstract

This study covers the proposition of a Supply Chain Finance (SCF) arrangement from a typically overlooked perspective, the one of a lead logistics provider (LLP). To validate past studies made on idealised models, and to generate better understanding, we measure value creation of SCF solutions under stochastic and complex systems. Our findings convey that companies with lower margins, higher risk profiles, with higher demand uncertainty and low payment terms benefit the most from SCF. Also, we show that payment terms extensions under SCF reduce supplier benefits and induce a non-linear effect on their total cost of managing an inventory and cash system. The magnitude of this effect depends on suppliers cost structure and degree of demand uncertainty. Finally, we present the case of a LLP as a provider of SCF solutions. We discuss two possible scenarios: SCF with no refinancing and SCF with refinancing. We also discuss several managerial implications, potential target groups and strategic considerations.

Executive Summary

Supply chain integration has become crucial to gain competitive advantage in a global economy. While the flows of goods are increasingly integrated and optimised, attention from practitioners and the academy to financial flows has been reduced. Thus, whilst companies cooperate, coordinate their activities and improve visibility of the Physical Supply Chain (PSC), they do not do so for the Financial Supply Chain (FSC), leading to a structural weakness in supply chains (SCs). Typically, large corporations face lower financing costs than what their Small and Medium-sized Enterprise suppliers can realise. However, many corporations follow aggressive cash management practices such as extending payment terms, which hinder overall supply chain performance. Hence, there is a sub-optimal and inefficient allocation of financial resources in SCs.

In an effort to manage the FSC with an equally integrated view similar to the one applied to the PSC, Supply Chain Finance (SCF) has been suggested as a suitable solution to stabilise links in supply chains, reduce counterparty risk to prevent the disruption of production lines resulting from financial problems, and to optimise total costs within the supply chain. The most common SCF solution is reverse factoring (RF), a post-shipment financial arrangement where a creditworthy buyer systematically informs a financial institution of payment obligations to selected suppliers, enabling the latter to receive a discounted payment of an invoice due to be paid by the buyer, at a cheap rate. Literature has reported that SCF and RF create value in SCs by providing funding and liquidity savings, balance sheet improvement, borrowing and transaction costs savings for suppliers, increased cash flow transparency and decreased cash flow volatility and risk. However, several companies have reported concerns about SCF solutions. Some of these include the need of developing a good understanding of finance, working capital management and SCF solutions; increased pressure of buyers to guarantee payments to Financial Service Providers (FSPs) and fear of buyers that suppliers may misuse extra liquidity obtained through SCF. A very common concern for suppliers is that many buyers demand payment terms extension when offering SCF to suppliers, which decreases suppliers' benefits from the financial arrangement.

Despite many reports about promising results from SCF programmes, many companies are still hesitant to embark on SCF solutions, because it is unclear for them how the benefits will materialise and how they should implement them successfully. In this dissertation we argue that logistics companies, especially lead logistics providers (LLPs), are in a good position to offer their customers SCF solutions as a value added service. We believe that by being execution champions with a privileged position in the SC, possessing significant data and integration capabilities, LLPs are good candidates for this task.

With the objective of better understanding the direct benefits emanating from SCF solutions, predicting value creation via SCF and determining target groups for this new service, we simulated the operations and cash flow transactions of a material supplier with uncertain demand. The supplier sells finished goods to a single buyer, sources raw material from a tier 2 supplier and manufactures the goods in an internal plant. We considered two scenarios: business as usual (BAU) and SCF. In the BAU scenario, the supplier has access to conventional financing in the way of a line of credit, and in the SCF scenario the supplier is offered a reverse factoring arrangement, where the supplier obtains cash at a cheaper rate.

We measured value creation at each of the scenarios. Our findings suggest that SCF creates value through financial savings provided by the interest rate arbitrage between the SCF rate and the supplier's cost of borrowing. Also, by giving suppliers the possibility of unlocking cash located in their balance sheets at a cheap rate, they need lower cash levels and financing from the line of credit, generating financial savings. We have found that companies with lower margins, higher borrowing rates, with higher demand uncertainty and low payment terms benefit the most from SCF. Furthermore, SCF arrangements reduce cash flow volatility substantially, which lets suppliers develop a lower risk perception and hence an improved capital sourcing cost, and thus a higher enterprise value. Also, by having lower cash flow volatility, suppliers improve their analytic capabilities, enhance forecasting processes and make better decisions.

We also modelled suppliers' concern on the effect of payment terms extension when being offered SCF. We show that payment terms extensions reduce supplier benefits and induce a non-linear effect on the total cost of managing an inventory and cash system for the supplier. This effect depends on the supplier's cost structure and the magnitude of demand uncertainty. We conclude that managers should study carefully the effects of payment terms extension under a stochastic setting.

Based on our findings, we present the case of a LLP as a provider of SCF solutions. We discuss two possible scenarios: SCF with no refinancing and SCF with refinancing. In the former, the LLP gathers information of the material and financial flows of the supply chain and designs an appropriate SCF solution in collaboration with the SC partners and a FSP. The solution should guarantee that there is value creation for all partners, and that the proposed solution does not hurt (significantly) the interests of a particular partner. In order to do so, the LLP provides (with the support of the FSP) an electronic platform for the exchange of information between the parties, and simultaneously orchestrates the operations and financial activities of the supply chain. By improving information visibility, we expect several efficiencies to be achieved, which would yield improved performance and savings. In the scenario with refinancing, the only difference is that additionally the LLP provides financing directly to the supply chain and refinances this amount from a FSP. Hence, the tier 1 financing is given by the LLP and the tier 2 by the FSP. This lets the LLP obtain a new stream of revenue at a controlled risk, which may significantly affect its margins positively.

We have also identified customer target groups. Mostly, industries with low margins e.g. Automotive, Grocery and Food, General and Online) Aerospace/Defence, Hospitals/Healthcare Facilities, Chemical, Construction and Building, Packaging & Container, Paper, Shipbuilding & Marine, Rubber & Tires, Electronics, Metals & Mining, Semiconductor Equipment and Machinery are good candidates for SCF. Also, commoditising industries are good candidates, as these have shrinking margins over time. Likewise, suppliers located in emerging economies have a substantial benefit, because financing in these geographies is quite limited, expensive and difficult to obtain.

We also pointed several managerial issues to be considered by LLPs. The first is to identify the strategic objective of the buyer: on one hand the buyer may seek to implement SCF as a way of generating transactional benefits in the way of working capital benefits or savings in capital cost. On the other hand, the buyer may seek to improve supply chain competences e.g. agility, for which suppliers are

offered SCF to generate savings and facilitate their investment activity. This has to be taken into account when designing the corresponding SCF arrangement. A second managerial consideration is to define implementation tactics. Implementations may be done in a uniform way, where, where a roughly similar specification is given to all SCF arrangements. Otherwise, implementations can be customised, where tailor made solutions are designed for the objectives and nature of each supplier. This lets achieve higher value creation, albeit at an increased effort. We also discuss that companies' internal sponsorship, especially from CEOs, are crucial for successful implementations and that supplier involvement is a critical success factor. Past literature suggests that at least a 60% of the supplier base needs to be included in the first implementation.

All in all, SCF may prove to be a successful new path for LLPs. If LLPs succeed in meeting the market opportunity and provide innovative solutions that integrate the PSC with the FSC, they will aid their customers in becoming more competitive, and by becoming fully supply chain integrators, they will also differentiate from other firms in a commoditising industry and become more profitable. Being execution champions, LLPs could bring in new possibilities for companies that are still unsure to embark on SCF implementations. Yet, this is not an easy task and it is still necessary that LLPs generate better understanding of SCF solutions. SCF implementations represent also an IT challenge, and only LLPs with good integration and analytical capabilities may provide positive results. Finally, there is a general consensus that the market is not yet fully mature to embark on SCF solutions. This poses a challenge to supply chains and LLPs, as it may be required to educate firms, especially suppliers, on financial and working capital management, to unleash the full potential of SCF solutions.

In any case, there is definitely a market for SCF solutions, but corporations and their CFOs have not yet found ways to integrate their physical and financial supply chains successfully, or have not yet seen the need of integrating them. Considering the discussed structural weakness in supply chains, it is imperative to look for a new design to overcome the described difficulties that suppliers face. In a world where competition is no longer between corporations but between value chains, LLPs may prove to be the entities that achieve a paradigm shift and bring SCF solutions to life.

To My Parents

Preface

This publication presents the results of a MSc graduation project on Supply Chain Finance, which was conducted in cooperation with DHL Lead Logistics. In recent years and with a growing awareness of the importance of Supply Chain Integration, multinationals are increasingly interested in managing their financial supply chains with an equally integrated view similar to the one that they apply to the physical supply chains. Hence, solutions that take a holistic view at managing financial flows in supply chains have grown substantially, leading to the development of Supply Chain Finance solutions, which are arrangements where favourable financing options for SC participants are introduced to achieve mutual benefits for everyone.

As a student with a clear interest in Operations Management and Finance, I became fascinated about doing research about a subject with clear connections to the Operations-Finance interface. Even though the important role of logistics service providers in Supply Chain Finance solutions has been acknowledged in past research, until now no effort had been made to explore in depth the possibilities these firms have in the integration of the Physical with the Financial Supply Chain. Having the possibility of conducting this study at a logistics company like DHL, there was an ideal match for this research.

Being a very innovative subject within the Supply Chain Finance research field, where the role of the logistics service provider has received little attention, this study aims at making an addition to the existing academic literature by approaching this question directly. Also, other research gaps are addressed to provide better understanding of SCF solutions and a more integral view of this subject.

There is definitely a market for SCF solutions, but corporations and their CFOs have not yet found ways to integrate their physical and financial supply chains successfully. Also, some other corporations have not acknowledged this need and still follow aggressive cash management practices. In a world where competition is no longer between corporations but between value chains attention should be given to strengthening the weakest links in a supply chain. We believe that logistics service providers, especially lead logistics partners, may be the entities that serve as facilitators for this task due to their data and integration capabilities. Hence, being execution champions, lead logistics partners may prove to be the entities that are able to bring SCF solutions to life and achieve full supply chain integration.

Victor Gerardo Careaga Franco
Eindhoven, January 2016

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1 Introduction

A supply chain is a network of companies whose aim is the production and delivery of a product or service to an end customer (van der Vliet, 2015). Supply chain integration (SCI) has become crucial to gain competitive advantage in a global economy (Hertz & Alfredsson, 2003; Jayaram & Tan, 2010; Silvestro & Lustrato, 2014). To achieve this, supply chain management (SCM) has emerged as an interdisciplinary management concept which is based on the idea of holistic optimisation of the various flows constituting a supply chain (Pfohl & Gomm, 2009), namely the flow of goods, information and the financial flow, within and between companies by functional and cross-company integration (Lambert, et al., 1998; Mentzer, et al., 2001; Pfohl, 2000; Pfohl & Gomm, 2009). SCM aims at better aligning internal departments and external trading partners to achieve cost reductions and higher efficiency in order to drive firm and supply chain (SC) profitability.

Over the past decades, the operations and supply chain management literature has focused primarily on the design and optimisation of the physical supply chain (PSC), which comprises the flows of goods and information. Remarkably, most research has left aside the financial supply chain (FSC), which runs parallel to the flow of goods and information (Pfohl & Gomm, 2009; Randall & Farris, 2009; Seifert & Seifert, 2011; Caldentey & Chen, 2010; Silvestro & Lustrato, 2014). Meanwhile, whilst considerable managerial effort has been expended on improving supply chain performance in terms of the flow of goods and information, the management of FSCs has lagged behind, hindering the PSC performance (Blount, 2008; Mathis & Cavinato, 2010). Croft (2007) argues that many companies have already wrung out most cost efficiencies from their PSC, by for instance, sourcing from lower-cost economies and removing all waste out of their processes. With competition no longer among individual companies but among entire supply chains, and by facing economic recession and the increasing complexity of global supply chains, buyers and suppliers explore every area of end-to-end cost reduction and efficiency increase. This has led to a growth in the interest in the financial side of the supply chain as an area for further efficiencies (Croft, 2007). Particularly, opportunities to improve the efficiency of working capital (WC) by unlocking cash trapped in the FSC have been recognised as a potential area of improvement.

The integration of the physical and financial supply chain (P/FSC) is a critical and ubiquitous aspect of SCI (Silvestro & Lustrato, 2014). The demand for increasing efficiency of the FSCs, the higher interest in managing the FSC with an equally integrated view similar to the one applied to the PSC, and the goal of integrating the financial flows with the material and information flows, have led to the development of Supply Chain Finance (SCF) solutions, which are arrangements where favourable financing options for SC participants are introduced to achieve mutual benefits for everyone (Dello Iacono, 2012).

Despite reported benefits, many firms are hesitant to embark on SCF solutions, because it is unclear for them how the benefits will materialise and how they should implement them successfully. Being execution and implementation champions, we consider the case of a lead logistics partner (LLP)¹ who offers SCF as a value added service (VAS). Being an innovative product for an LLP, it is required to

¹ LLPs are outsourced partners who assume the organisation of all or key logistics processes for their customers, managing the activities within the end to end supply chain to deliver cost optimizations.

generate deep understanding of the underlying SCF mechanism, as well as the benefits and challenges of SCF to determine the specific role a LLP may follow to maximise SC performance and profitability.

1.1 Structural Weakness in Supply Chains

While the flows of goods are increasingly integrated and optimised, information and finance flows are often fragmented (Steeman, 2014), and unlike the PSC management, SC partners typically do not cooperate to improve the FSC. Immediate consequences for the lack of the P/FSC integration include aggressive cash management practices from buyers, higher prices charged by suppliers and above everything, higher supplier weakness, which leads to higher SC disruption risk and ultimately to higher SC losses. This structural weakness of current SC systems can be envisaged from two perspectives: (1) the opportunity for improvement; and (2) exposure to external (financial) shocks.

Research on small business finance has shown that the financing costs faced by large corporations are significantly lower than what their Small and Medium-sized Enterprise (SME) suppliers can realise (Tarrisever, et al., 2012) as these face higher market frictions such as information asymmetries and more severe transaction costs (Cornell & Shapiro, 1988; Shane, 2003). Consequently, whereas large corporates are often seen as ‘investment grade’, their non-investment grade suppliers have a Weighted Average Cost of Capital (WACC) which approaches 20% or more (Gustin, 2006) – 10 to 50 times the rate of the end buyer (Steeman, 2014) – causing high overhead costs. However, many big firms and corporations have not considered this financial issue when designing their supply chains, and have adopted aggressive cash management policies that have not addressed overall SC financial performance.

Many buyers have sought to decrease their assets to free up cash, and have resorted to practices such as pushing inventory upwards in the supply chain e.g. via vendor-managed inventory (VMI) and consignment stock, or by extending payment terms. The belief is that freeing up cash increases opportunities for investments, dividends pay-outs, or share buybacks (Ng, 2013). Also, many companies under shareholder pressure aim at “cleaning up” their balance sheets by reducing their assets to increase cash and liquidity, which subsequently improves shareholder value. These practices have created higher financial burdens on suppliers, which have mostly reacted by increasing prices to their customers (He, et al., 2011) and similarly squeezing their suppliers. Therefore, SC inventory and working capital are being financed by a weaker party, which signifies that there is a sub-optimal allocation of financial resources in supply chains i.e. there is an inefficient use of capital, which has a detrimental impact in supply chains’ bottom line. This represents a big opportunity to ameliorate SC profitability and performance by approaching the sub-optimal allocation of financial resources in supply chains.

Parallel to the opportunity of improving SC performance, external shocks have also highlighted the need to address the malfunctioning and weakness of this system. The latest financial crisis has had two major negative effects on the world economy: a collapse in the demand for goods and services, severely reducing the order inflow and backlog; and financial institutions tightened their criteria for business financing and an increased cost of financing for SMEs, leading to liquidity scarcity or a “credit crunch”. As a result, many firms adopted even more aggressive cash management strategies to safeguard their

cash levels in the face of declining credit from financial institutions. These strategies include extending (further) payment terms and aggressively pushing inventory upwards in the SC (van Laere, 2012). When customers hold on to cash longer, they create deficits at suppliers, and under a credit crunch, suppliers have been forced to accept reluctantly very unfavourable financing, if possible and accessible. This has led to an increase in supplier disruption risk, and has endangered many supply chains' functionality.

Empirical evidence has confirmed this structural weakness. It has been suggested that credit-constrained firms pass on more than a fourth of liquidity shocks upstream in their supply chain (Boissay & Gropp, 2007). US data also shows that relative accounts receivable (AR) and payable (AP) increase the further upstream they are in the supply chain (Seifert & Seifert, 2011). Also, a recent study in France (Roubert, 2013) has revealed that inefficiencies in inter-company processing, especially poorly managed inventories, payment terms and delays, lead to an excess of working capital of more than 200 billion euros. Consequently, the sheer extension of payment terms and movement of inventory upstream ultimately reduces the liquidity of the supplier, making the company weaker and more susceptible to external shocks during financial crises. This inefficiency in capital use subsequently leaves the buyer vulnerable to supplier disruptions. Thus, aggressive cash management practices may harm the buyer and the whole supply chain in the long run. A supply chain is only as strong as its weakest link.

1.2 Efforts to integrate the Financial Supply Chain

Multinationals are increasingly interested in managing the FSC with an equally integrated view similar to the one that they apply to the PSC (Protopappa-Sieke & Seifert, 2010). In order to overcome the challenges of FSC integration, Supply Chain Finance (SCF) has been suggested as a “[...] suitable solution to reduce counterparty risk and sustainably stabilise the different links in the supply chains, to prevent the disruption of whole production lines resulting from financial problems of one important party involved, and to optimise total costs within the supply chain” (Hofmann, 2013, p. 2). Under SCF, arrangements are designed, where favourable financing options for supply chain participants are introduced to achieve mutual benefits for all SC participants (Dello Iacono, 2012), achieving financial and operational improvements for the whole supply chain.

There are several examples of large multinationals using SCF to improve their financial supply chains. Unilever freed up 2 billion USD in overall WC (Seifert & Seifert, 2011) and firms implementing SCF solutions on average reduce WC by 13% (Seifert & Seifert, 2009). However, most of these have been implemented as pilot projects, or have not covered a significant amount of the value chain (mostly, only Tier 1 and Tier 2 suppliers have been included).

However, there is a growing complexity of global supply networks, which reach up to 25 tiers, often including hundreds of parts suppliers scattered all over the world, who have differing financial technologies, platforms and regulatory frameworks² (Uzureau & Knox, 2009; Mathis & Cavinato, 2010;

² For instance, Incoterms are very often not very well managed by both trading companies with the LSP in between, creating operations and financial frictions.

Fellenz, et al., 2009). Hence, information transparency along the supply chain is becoming a challenge and priority for buyers and suppliers. Also, these SCs work with a very complex string of (financing) arrangements and interdependencies between suppliers, buyers, financial service providers (FSPs) e.g. banks and logistics service providers (LSPs) (Hurtrez & Gesua' sive salvadori, 2010). This large network of agreements creates a clear Information Technology (IT) challenge, with the risk of data being fragmented and the challenges of common sharing and interfacing (Steeman, 2014).

Consequently, many firms have reported concerns towards implementing SCF solutions. Reported main reasons include an insufficient understanding of SCF solutions – especially under complex systems, the difficulty of explaining and predicting performance under SCF due to the complicated string of arrangements in today's supply chain networks, and lack of experience in the implementation of SCF solutions. Hence, several firms in the supply chain are hesitant to embark on SCF solutions, because it is unclear which and how the benefits for each supply chain participant will materialise and how they should implement it successfully (Seifert & Seifert, 2009).

1.3 Motivation for Study

This study explores the possibility that specialised logistics companies such as LLPs introduce SCF solutions to their portfolio of value added services in order to approach the described structural weakness of supply chains. While literature has highlighted the important role of logistics companies in the PSC integration, logistics service providers have rarely been mentioned as contributors to the P/FSC integration (Hofmann, 2009). This is remarkable as LLPs are recognised as execution champions, operate between suppliers and buyers, have a good visibility, knowledge and understanding of their customers' supply chains, and possess significant data and integration capabilities. We argue that these firms are good candidates to fulfil the design, implementation and execution tasks for the introduction of SCF arrangements and thus relieve supply chains from these tasks.

However, LLPs require a deep understanding of SCF before venturing into this direction. There has been a growing volume of research on SCF that has provided with very useful insights with respect to the explanation of the value creation mechanism of SCF solutions, as well as their benefits and concerns for all involved parties. Yet, past studies have had a shortcoming: their mathematic models have been built under idealised and simplified assumptions, for which their validity on a realistic setting may be doubted. In order to follow on this path, LLPs are required to understand the mechanism of value creation of SCF arrangements under a more complex and realistic setting. A study that captures the operations of a supply chain under realistic circumstances in order to describe, explain and predict benefits from SCF would be of great value for LLPs and SC partners. It is also of equal importance to generate understanding about the conditions in which SCF solutions create value, to detect which kind of firms would benefit the most and to produce a design that matches SC characteristics and needs.

This research project contributes to literature by explaining the value creation of SCF in a realistic and complex system under several scenarios to generate better understanding. Later, we position an LLP as the party involved in the design, implementation, execution and orchestration of a SCF arrangement.

1.4 Significance of the study

Research has not yet pointed out the role that a logistics company can have in introducing a SCF solution to the supply chains they serve. Therefore, this research is a pioneering study within the field of SCF as it analyses the subject from the perspective of a LLP. We have achieved new insights into SCF solutions and acquired more understanding on the explanation of value creation of SCF arrangements in complex systems. Also, our study complements the work of existing literature with respect to assessing the impact of payment term extension under a stochastic inventory system. Finally, this study contributes methodologically by modelling with Discrete Event Simulation (DES), a technique that to the best of our knowledge has not yet been applied in the context of Supply Chain Finance.

This project contributes both to a logistics provider and academic research on SCF in the following ways:

1. *Relevance*: by assisting logistics companies in explaining the value creation mechanism of a SCF solution that justifies its implementation. Also, the study explores the possible roles that an LLP could have at the SCF implementation and gives initial insights into possible business models that could derive based on this research's generic findings.
2. *Academic*: by filling gaps in literature on SCF by exploring a) value creation of SCF solutions in complex systems; b) trade-off of payment term extension and price reduction in a continuous-time stochastic inventory and cash system; and c) the role of an LLP in SCF solutions. We do so by following a design of experiments to uncover the underlying structure of an operations-finance model, aiming at theory building within Operations Management (OM).
3. *Methodological*: by following a new methodology for the analysis of a SCF solution, namely discrete event simulation, this research builds a model that better resembles reality.

1.5 Structure of the Thesis

After this introduction, we proceed on Chapter 2 with a Literature Review, wherein we point out several research gaps and state our research questions. In Chapter 3 we delineate the research methodology for this study. In Chapter 4 and 5 we conceptualise the business as usual and SCF models respectively. In Chapter 6 we describe the experiments and discuss the numerical results. In Chapter 7 we discuss the potential role of an LLP in a SCF solution, as well as several managerial and strategic considerations. In chapter 8 we conclude this dissertation by discussing our findings, main takeaways, limitations and possible future research paths.

2 Literature Review

LLPs require a deep understanding of SCF before venturing into this direction. In this chapter, we review past research on supply chain integration and SCF. This chapter is the first step towards providing understanding about the value creation mechanism of SCF solutions, as well as their benefits and concerns for all involved parties in a supply chain. We finalise by pointing out identified research gaps.

2.1 Supply Chain Integration

Supply chains have three parallel flows: goods and services, financial and information (Lambert & Pohlen, 2001; Hofmann & Belin, 2011):

- *Flow of goods and services*: encompasses services or products that move between the suppliers and buyers within the supply chain.
- *Financial flow*: consists of invoices, credit notes, investments and cash payments. It flows typically in the opposite direction of the flow of goods and services.
- *Information flow*: comprises information associated with products and services as well as payments flows through the SC. It includes purchase orders (POs), inventory documents, confirmations and invoices, among others. The information flow initiates the other two flows.

These three elements co-exist, where both the information and financial flows (the financial supply chain) support and underpin the products and services and information that move between the supplier and buyer (the physical supply chain) (Braun, 2008). The FSC moves parallel and in the opposite direction of the PSC (Hofmann & Belin, 2011). As pointed out hereinbefore, organisations have rather focused on improving the PSC and less attention has been given to the FSC performance.

SCI has been advocated as critical to SC performance (Pagell, 2004), and is defined as:

[. . .] the degree to which a manufacturer strategically collaborates with its supply chain partners and collaboratively manages intra- and inter-organisation processes. The goal is to achieve effective and efficient flows of products and services, information, money and decisions, to provide maximum value to the customer at low cost and high speed (Flynn, et al., 2010, p. 59).

Flynn et al. (2010) identify three dimensions of SCI: *customer integration* (between the manufacturer and the buyer), *supplier integration* (between the manufacturer and its supplier) and *internal integration*, which refers to the extent to which a manufacturer integrates its organisational strategies, practices and processes into collaborative, synchronized processes, in order to fulfil customer requirements. Silvestro & Lustrato (2014) argue that despite the financial flows are recognised in the definition of Flynn et al. (2010) as a way of SCI, almost all SCI research is based on the exchange of goods and flows of information, rather than financial transactions and actual cash flows. Despite great improvements in PSC performance, the FSC remains fragmented, complex and not integrated with the

PSC. This has caused on many occasions that goods move faster than money, creating financial pressure on companies awaiting cash inflows.

In a globalised world, with competition no longer among individual companies but among entire supply chains, and by facing economic recession and the increasing complexity of global supply chains, the need to integrate the FSC with the PSC is common ground. Fairchild (2005, p. 244) explains how the physical supply chain can be disrupted through poor integration with the financial supply chain:

The financial information in the supply chain runs parallel to the physical movement of goods, and represents all transactions that occur in relation to that movement. The fact that the information flows at a different rate than the good or service is important, as gaps separating physical supply chain activities from their associated financial information, continue to frustrate companies that have focused on efficiency in their physical supply chains but found only partial success.

There is little or not much literature about P/FSC integration. SCM and Operations literature of the past two decades has conceptualised supply chain as a series of buyer/supplier dyads (Harland, et al., 2007; Choi & Wu, 2009). Consequently, supply chain performance is still mostly analysed purely from the perspective of series of dyadic relationships between suppliers and buyers (Silvestro & Lustrato, 2014) and the flow of material between them, meaning that its performance corresponds only to the material flow. This narrow focus on dyadic relationships and material flows may explain why the FSC has been excluded from supply chain integration and optimisation efforts.

Silvestro & Lustrato (2014) have identified three emergent themes of SCI: (1) the need to integrate activities along the supply chain; (2) the need for organisational integration; and (3) the need for information integration. Furthermore, the authors note that integration of supply chain activities is enabled through supply chain coordination; organisational integration is enabled through collaboration; and information integration is enabled through information sharing and information visibility. Their study acknowledges that these four enablers have been very well studied in within PSC activities.³

Focus on these enablers within the FSC has been reduced. Van der Vliet (2015) notes that models within OM literature do not consider financing alternatives available to a firm e.g. opportunities that arise from inter-company collaboration initiatives. Also, several authors have noted that companies in a supply chain can pro-actively lower each other's interest premiums by sharing information and visibility with capital providers (van der Vliet, 2015; Pfohl & Gomm, 2009; Wuttke, et al., 2013; Hofmann & Belin, 2011). For instance, a creditworthy company can inform a financial service provider of its intention to make a payment to a supplier in the future. Subsequently, the capital provider can make a custom credit offer to the supplier for the corresponding cash flow. Consequently, when firms cooperate and

³ For instance, coordination of the material flow can reduce buffer stock at every location where time buckets differ (Childerhouse & Towill, 2003). With respect to collaboration, Chandra and Kumar (2001) argue that increased collaboration between supply chain partners can lead to cost and lead time reductions and overall SC performance improvement. Furthermore, Fiala (2005) argues that information integration through centralization of IT leads to synergistic SCs and higher effectiveness. Finally, Kim et al. (2011) argue that inter-organisational information systems visibility is an important predictor of SC performance, particularly from the supplier's perspective

coordinate activities to facilitate financing to each other in such a way, new financial opportunities may emerge to create value.

Arrangements and activities that take a cooperative approach to financing in the supply chain are becoming known as Supply Chain Finance. The research stream on SCF proposes several mechanisms that serve to integrate the P/FSC with a clear focus on these four enablers, and in such a way attaining a higher overall supply chain performance and higher profitability for all the involved parties. The most common, well-defined, and standardised SCF arrangement is reverse factoring (RF). The mechanism of RF is covered in detail in the following section.

2.2 Supply Chain Finance

This section reviews the definition of SCF, a framework for SCF, the mechanism of reverse factoring, and the general benefits and concerns of SCF solutions.

2.2.1 Definition of Supply Chain Finance

Supply Chain Finance is defined as the “inter-company optimisation of financing as well as the integration of financing processes with customers, suppliers, and service providers in order to increase the value of all participating companies” (Pfohl & Gomm, 2009, p. 151). From this definition it follows that SCF aims at saving capital costs by means of better mutual adjustment and understanding or developing new financing concepts within the supply chain. SCF is based on the premise that SC collaboration leads to increased profit and competitive advantage, as well as risk reduction (Randall & Farris, 2009). SCF is a business model designed to cope with the problems and risks of funding trade (Hofmann, 2013) by means of supply chain financial integrated arrangements designed collaboratively in order to increase transparency, reduce risks and costs and improve the bottom line of all participants.

The collaborative element of SCF can be discerned in a vast range of activities: pre-shipment finance, such as the pre-shipment micro-financing of rural entrepreneurs (KIT and IIRR, 2010); inventory-in-transit finance, like the case of Swiss Post Logistics (Hofmann, 2009); to post-shipment finance, as occurs in the automotive industry (Wuttke, et al., 2013). Another possibility of SCF practices is investments to support R&D activities at a supplier, like it is practised by Intel and ASML (Nuttall, 2012). SCF is largely ‘event-driven’. Each intervention (finance, risk mitigation or payment) in the financial supply chain is driven by an event in the physical supply chain. The development of advanced technologies to track and control events in the physical supply chain creates opportunities to automate the initiation of SCF interventions (Camerinelli, 2014).

Reverse factoring (also called approved payables finance), the main focus of this study, is a post-shipment kind of SCF where a creditworthy buyer systematically informs a financial institution of payment obligations to selected suppliers, enabling the latter to receive a discounted payment of an invoice due to be paid by a buyer, at a cheap rate (Klapper, 2005). The buyer approves the invoice for

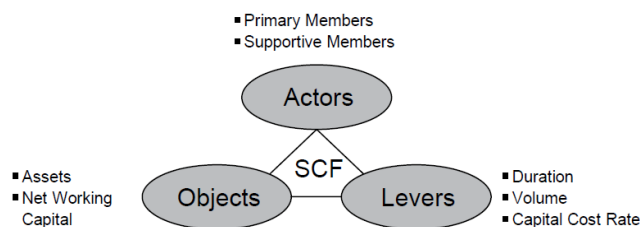
payment and finance is raised separately against the payable by the supplier from a bank or other finance provider, who relies on the creditworthiness of the buyer. The buyer pays at the normal (or another, mutually agreed) invoice due date, whereas the supplier receives a discounted payment through the financing facility. The attraction to the supplier is based on an ‘arbitrage’ between the higher credit rating of the buyer and the typically higher cost of financing for the supplier, as well as the attraction of the availability of the finance (Camerinelli, 2014)

RF is an approach to reduce working capital for SC participants by using a combination of technology solutions and services that link suppliers, buyers, financial institutions and service providers to optimise visibility, financing costs, availability, delivery of cash and improved WC on the occurrence of one or several SC events. (JPMorganChase, 2007; He, et al., 2012). RF enhances enterprise value as it decreases tied-up working capital and enables higher capital efficiency (Hofmann & Belin, 2011).

2.2.2 Framework of SCF

Pfohl and Gomm (2009) conceptualised SCF by identifying which assets (objects) within a supply chain are financed by whom (actors) and on what terms (levers). These are identified in Figure 2-1. Objects under SCF refer to both long-term (fixed) assets and current assets such as working capital of a firm. Actors in a SCF arrangement are divided in two groups, primary members: suppliers and customers; and supporting members: financial service providers, logistics service providers, etc. The levers specify the three dimensions of financing: which amount of assets (volume of financing) needs to be financed, for how long (duration of financing), and at which capital cost rate⁴.

Figure 2-1 A SCF Framework



Source: Pfohl and Gomm (2009)

By multiplying the three levers in SCF, they represent the capital costs that a company has to generate at least for the investment to be profitable:

$$\text{Capital Costs (€)} = \text{Volume (€)} \times \text{Duration (time)} \times \text{Capital cost rate (\%/time)} \quad (2-1)$$

⁴ The capital cost rate depends on the expected return of investment and risk expectation of investors (obtained typically via the Expected Loss model), on the demands of outside creditors, as well as the financial structure of the company (Weighted Average Cost of Capital-approach).

SCM professionals have influence on all three levers of SCF e.g. by decreasing or extending the amount of money raised for financing (volume); by accepting (proposing) a payment terms extension (reduction) from a buyer (duration); or by negotiating a lower capital cost rate with the FSP. It is important to note that the three generic levers are not fully independent of each other. For instance, an extension in duration typically leads to an increase in the capital cost rate offered by a FSP. Firms and SCM professionals aim at reducing capital costs, since a decrease of capital costs leads to an increase in shareholder value (*ceteris paribus*) (Gomm, 2010).

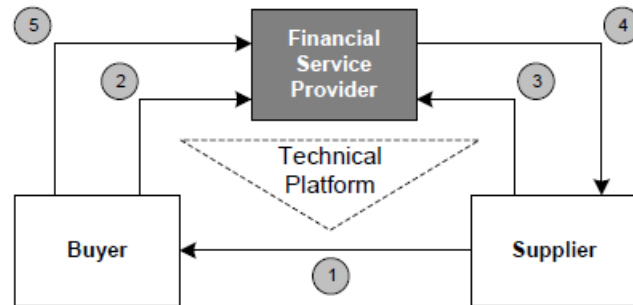
Research on SCF has included the FSP as a supportive member, who provides financing and possibly technical expertise and the electronic platform. Furthermore, although literature acknowledges the importance of LSPs (cf. Pfohl & Gomm, 2009), not much research has been undertaken with respect to the role of logistics companies in SCF. Hofmann (2009) has conducted the only study of SCF initiated by a LSP, where a case study about a Swiss logistics company providing inventory financing is presented. In general, literature has ignored the role of logistics companies in SCF solutions.

2.2.3 Mechanism of reverse factoring

Whilst the underlying mechanism of RF is factoring, it has fundamental differences from conventional factoring as it overcomes the problem of information asymmetry between FSPs and suppliers. First, the company that approaches the factor is a financially strong buyer, not the seller, thus it is reversed. Secondly, the technique is buyer-centric, meaning that factors do not need to evaluate heterogeneous buyer portfolios as in conventional factoring and concentrate solely on the single creditworthy buyer's risk profile (Klapper, 2005). Thirdly, buyers are typically investment grade companies, and since factors carry less risk, they may charge lower interest rates. This is possible because the transaction is fully and transparently collateralised by the payment guarantee of the buyer, irrespective of the financial condition of the supplier. Fourthly, as buyers participate actively, factors obtain better information and can release funds earlier (Seifert & Seifert, 2009; 2011). Hence, reverse factoring serves as a mechanism of mitigating the informational asymmetries regarding the supplier's assets (Pfohl & Gomm, 2009) and thereby enables cheaper financing (Tanrisever, et al., 2012), consequently adding value to firms from an integral perspective (van der Vliet, 2015). The RF process involves several steps, which are depicted in Figure 2-3.

1. A supplier sends the buyer an invoice for goods / services delivered. Typically invoices, and not purchase orders, are used for RF arrangements to obtain financing.
2. The buyer approves the invoice, and thus, creates an irrevocable payment obligation.
3. The seller may present the invoice to the financial service provider in case it desires early payment for the delivered goods / services.
4. The financial service provider pays the supplier the value of the invoice minus a discount. In turn, the financial service provider takes over all the rights and obligations of the receivable from the supplier.
5. The buyer eventually settles the invoice with the financial service provider at maturity.

Figure 2-2: Mechanism of reverse factoring



Source: Dello Iacono (2012)

The core of SCF relies on optimising the working capital of a SC, eventually in combination with a changed role or task sharing or supply chain actors (Pfohl & Gomm, 2009). RF accomplishes this by *interest rate arbitrage* – leveraging the difference in cost of capital between large buyers and their smaller suppliers (Dello Iacono, 2012). RF is a case where companies in the supply chain can pro-actively lower each other’s risk premiums by informing or committing to capital providers (van der Vliet, 2015). Importantly enough, a reverse factoring transaction brings no additional risk for the buyer, since it is already obligated to pay the account receivable held by the supplier (He, et al., 2012).

The terms SCF and reverse factoring are often used interchangeably, especially by practitioners (cf. Seifert & Seifert, 2011). However, the definition of SCF provided by Pfohl and Gomm (2009) positions it as a general concept that can encompass reverse factoring and many other financial supply chain solutions. Nonetheless, for the sake of simplicity, both terms will be used interchangeably for the remainder of this document.

2.2.4 Benefits and concerns of Supply Chain Finance

Literature suggests that benefits of SCF can be separated into direct and indirect benefits for buyers and suppliers. *Direct benefits* are funding and liquidity savings for buyers and suppliers; balance sheet improvement, borrowing and transaction costs savings for suppliers; increased cash flow transparency and decreased cash flow volatility for both parties; decreased risk in the supply chain; and increased analytics capabilities due to less cash flow volatility, as well as reduction of prices, among others. An important advantage as well for the buyer is that through SCF she effectively outsources to the FSP the supplier payment management, decreasing administrative and processing costs (Klapper, 2005). Furthermore, *indirect benefits* include enhanced supply chain relationships, better integrated buyer-supplier information systems, higher supplier portfolio stability for the buyer and funding diversification for the supplier, standardisation of payment terms, improvements of order-to-cash and record-to-report processes and fewer disputes due to more transparency. Finally, FSPs benefit from new relationship development with suppliers, to which they probably had no access before. Also, FSPs can effectively build credit history of firms and serve companies once inaccessible, especially SMEs. Likewise, as

solutions like RF only include high quality receivables, FSPs increase their operations without substantially increasing their risk exposure.

Despite the benefits of SCF, companies also have several concerns when deciding to implement SCF. First, companies require being well-educated in finance and WCM in order to fully understand and successfully apply a SCF solution, especially SMEs. Buyers following a SCF programme also feel an increased pressure to guarantee payments to the FSP. Furthermore, buyers fear a bad financial management by suppliers e.g. by misusing the extra liquidity they earn through SCF e.g. to pay down long-term debt instead of investing to improve performance. Concerns for the supplier are bigger. Milne (2009) has reported that certain corporations have introduced reverse factoring as a 'sweetener' to an unpopular decision to increase payment terms to suppliers from 45 to 90 days. Research has pointed out that small increases in payment delay may entail a relatively large decrease in suppliers' benefit from reverse factoring, proving to be an inefficient strategy, since it interacts with the operations of the supplier and reduces the total benefits available to the supply chain (Tanrisever, et al., 2012; van der Vliet, et al., 2015). Thus, the decision to extend payment terms has to be well studied.⁵

2.3 Supply Chain Finance and SCI

As discussed in Section 2.1, three emergent themes of SCI and four enablers of SCI have been identified. Most research has focused on these enablers within the PSC. Recent research on SCF claims that SCF solutions approach SCI via these enablers. These claims are reviewed now.

A fundamental aim of SCF is to provide liquidity to international trade while adequately addressing the risks associated with the transactions (Global Business Intelligence, 2007) via additional transparency and visibility offered to capital providers on supply chain processes. Hofmann (2013) points out that this is achieved by building a bridge between financial and physical supply chain processes across borders (companies and countries) and sharing the acquired information. Randall & Farris (2009) note that SCF is based on making decisions and coordinating activities at the aggregate; collaborating to obtain better financing opportunities; opening up the flow of information; and encouraging commitment among partners to make decisions; activities that result in the best value for the customer. By taking a more holistic view of flows of trade, overall costs and risks for all affiliated parties can be reduced by focusing on collaboration between trading partners, increased transparency, automation and dematerialization of the entire supply chain.

Therefore, SCF integrates the FSC by coordinating the financial activities that each partner undertakes. For instance, through RF a buyer commits to pay an invoice at a certain date and let the supplier borrow against the receivable. Likewise, SCF provides organisational integration through collaboration. Buyers aim at improving the financial strength of their suppliers by letting the latter utilise their risk profile to borrow against a receivable. Finally, SCF integrates information within the FSC by providing more visibility and supporting information sharing within parties, typically through a shared electronic

⁵ This suppliers' concern is studied in more detail later in this document, specifically in Research Questions 3 and 4.

platform. By emphasising on SC integration, SCF drives supply chain performance and better bottom line for the involved parties. However, despite past research has delivered key insights, there are still important research gaps that have been unaddressed. These are reviewed in the following section.

2.4 Research gaps in SCF literature

Despite past research has delivered key insights, there are still important research gaps that have been unaddressed. Past academic research on SCF has conceptualised SCF and measured the direct benefits of it by employing mathematical models that have simplified reality (e.g. less complex material and financial flows, single periods and products, perfect information visibility and transparency) in order to have a manageable model. This stream of studies have been successful at showing the direct benefits of SCF solutions and under which circumstances and scenarios SCF creates value, albeit in simplified settings. In this sense, despite the great given insights, the liability of these studies has been its reduced and simplified setting, which employs assumptions and predefined inputs that may not fairly represent reality. Therefore, the validity of the given insights depends on the degree of resemblance of the model to reality, its generalizability and the quality of the assumptions made. Consequently, it has not been explained how SCF creates value under a more complex setting.

Considering this research gap, it is hence necessary to generate better understanding of SCF under a complex setting. Thus, this study aims at answering the following research questions:

- RQ 1. To what extent do SCF solutions create value and improve performance in more complex settings, as it is predicted by more simplified models? Under which circumstances do SCF solutions create (more or less) value?
- RQ 2. What are the benefits and concerns of SCF for the involved parties under a complex setting? What influences do these have on firms' bottom-line?

The following to research questions refer to specific circumstances under which SCF arrangements are very often introduced, concerns that very often are raised, and their effect on supplier performance.

As reported hereinbefore, a typical suppliers' concern is when buyers introduce reverse factoring and demand a payment term extension from their suppliers. Thus, there is a trade-off between cheaper financing and longer financing periods. Companies usually analyse the cost of trade credit by multiplying the WACC times the average value of outstanding receivables, which in turn is the product of average daily volume of credit sales and average number of days until payment (Brealey, et al., 2011). This approach assumes that the cost of trade credit is a linear function of payment terms and that it is independent of e.g. demand variability and other operation measures. By doing so it presumes that the configuration of trade credit can be addressed independently from operations (van der Vliet, et al., 2015). Furthermore, there is evidence that inventory decisions can interact with the receipt and/or provision of trade credit (Protopappa-Sieke & Seifert, 2010), making it difficult to predict the overall

impact of payment term extension on firm performance. From stochastic inventory theory it is known that longer replenishment lead times require higher levels of safety stock in order to hedge against demand uncertainty (Zipkin, 2000). Van der Vliet, et al. (2015) have theorised that viewing payment terms as a cash inflow lead time, it can be expected that a firm's financial position is exposed to more variability when extending payment. Hence, cash flow uncertainty can be associated with the need to borrow money and/or hold more cash. Their study has found that payment terms extension induces a non-linear financing cost for the supplier, and that the size of the payment terms extension that they can accommodate depends on demand uncertainty and supplier's cost structure. Therefore, to better understand suppliers' concern regarding payment terms extension in a complex setting, this study aims at answering the following research question:

RQ 3. What impact does extending payment terms have on the suppliers' cost of managing a stochastic inventory operation?

It has been reported that very often suppliers increase prices when customers demand longer payment terms, in such a way that the increased working capital financing is transferred to the customer. When reverse factoring is introduced to reduce financing costs at the supplier, a trade-off emerges in the form of increased payment of payment term and a price cut offered to the buyer. We seek for the price cut y that would also leave the supplier indifferent between conventional financing and reverse factoring with a payment term extension of x periods. Specifically, we look for the supplier indifference curve, where in order to decrease her working capital, a buyer offers reverse factoring with a smaller payment term extension and a price cut. As this relationship may be difficult to predict, we developed a continuous-time stochastic inventory and cash management to test this trade-off. We follow on the steps of van der Vliet, et al. (2015) by measuring the impact of extending payment terms and reducing the unit price on the overall cost of managing a stochastic inventory operation. By doing so, we aim at answering the following research question:

RQ 4. What is the minimum price that a supplier can offer when facing a payment term extension through reverse factoring that would leave him indifferent?

Companies are usually faced with the temporal decoupled flow of goods and cash flows in their supply chains. Firms aim at achieving a certain production level with the lowest possible costs accompanied by a minimal tied-up capital (Wilson, 1991). They aim at minimising asset levels used to deliver value by managing factors such as capital utilisation, cash velocity, inventory turns, and cycle time reduction, which impact how effectively a firm manages its assets (Presutti & Mawhinney, 2007). However, the achievement of these goals is rare (Hofmann, 2009), leading to a strong demand for integrated logistics services, as well as financial services.

Until now the role of logistics companies, especially LLPs, has been to integrate the PSC. The role of the FSC integration by logistics companies has not been explored.⁶ Specialised logistics companies, like third party logistics (3PLs), fourth party logistics (4PLs) and LLPs, have blossomed rapidly by providing solutions for the PSC. Certain logistics companies have offered their clients several conventional financial solutions e.g. on- or off-balance sheet inventory financing, supplier financing, among others. However, the potential of introducing cooperative financial solutions like SCF remains largely unexplored. Despite logistics enterprises have been striving to tap the value of their services, they had never been able to expand accordingly due to the limits of operation scope and funds available (Meng & Hui, 2011). Thus, LLPs have mostly limited their scope of VAS offering to the PSC solely. By taking a more integral approach and shifting their attention also towards the FSC, logistics companies could expand their original service that manages the PSC, and incorporate financial supply chain management within their service portfolio. Their customers on the other hand could benefit from a provider with an integral approach towards the simultaneous optimisation of the PSC and FSC, and who also acts on the best interests of the whole supply chain and not of individual entities.

Business research has only recently started to deal with financing in supply chains in general and with financing working capital from a logistics provider's perspective in particular (Hofmann, 2009). Consequently, only few conceptual or empirical studies have been conducted and logistics firms have been entirely excluded from the existing studies. Additionally, most research has aimed at conceptualising SCF, but it has not been discussed how these firms could participate in SCF arrangements. With the exception of Hofmann (2009), literature has not discussed the possible involvement of logistics companies in a SCF solution. Hence, there is a gap in literature with respect to the role of logistics providers in SCF arrangements, for which additional research into this topic is required. Facing this research gap, this study aims at answering these two research questions:

- RQ 5. What is the role of a logistics company, namely a LLP, under a SCF arrangement? To what extent are LLPs in the position to design SCF solutions for their clients?
- RQ 6. What is the most appropriate SCF structure for a given scenario? What is the role of other players, such as FSPs?

Literature has to a large extent only concentrated on direct financial benefits of SCF. However, on a practical setting, apart from these direct benefits, there are many other aspects and managerial issues that need to be considered. In the case of an LLP offering SCF as a value added service, there are more specific managerial issues that need to be observed when e.g. approaching customers, deciding which role to follow, among others. As literature has not yet fully concentrated on this matter, we recognise this as another research gap. Hence, we aim at answering this final research question:

- RQ 7. Which other (non-financial) aspects and managerial issues should LLPs consider when offering SCF as a value-added service to their customers? What are the customer target groups that would best benefit from a SCF offered by a LLP?

⁶ However, LLPs have integrated the financial flows between their clients and the transportation providers e.g. 3PLs and carriers.

3 Methodology

The purpose of this chapter is to outline the methodology used in this study in more detail. A discussion of the overall research design is carried out in Section 3.1. Section 3.2 briefly outlines the approach towards the design of experiments. Finally, Section 3.3 gives a brief introduction to Discrete Event Simulation (DES), as well as a justification for the selection of DES as this research's tool.

3.1 Research Design

This study is carried out within the field of Operations Management. Bertrand and Fransoo (2002) state that Operations Research (OR) should study models that are closer to real-life processes, and that their analysis results should be tested in real life. Thus, theoretical quantitative research should be combined with empirical quantitative research⁷. Specifically, two models were developed to analyse the stated problem. We assumed that relationships are casual and quantitative, for which we sought to accurately explain and predict future performance and behaviour. We have designed a set of experiments that approaches a theoretic case study of a supplier of certain characteristics in order to facilitate theory building in OM (Eisenhardt & Graebner, 2007; Meredith, 1998). Although the scope of this study is to strive for generic findings through the design of experiments, our model was designed in such a way that it can easily be tested in the field. Likewise, our approach does not only aim at contributing to academic literature, but also we seek to support and guide LLPs at recognising opportunities, engineering solution designs and improving managerial decision-making processes.

We developed a stochastic inventory model that reflects business as usual (BAU). Based on this model we designed a SCF model, where a reverse factoring mechanism is introduced with the aim of improving performance, in a way to measure the potential value creation that a LLP could deliver through SCF.

BAU Model: The objective of this model is to imitate the behaviour of the operations of a supplier under a theoretical BAU setting. This model is of descriptive nature, which means that it aims at adequately describing the casual relationships that may exist in a theorised system, leading to more understanding of the internal processes.

SCF Model: The objective of this model is to develop policies, strategies and actions to improve performance vis-à-vis the BAU setting.

It may be very hard, or impossible, to empirically assess the changes in performance due to changes in specific actions or structure e.g. by controlling relevant variables. Also, very often conducting empirical experiments may deem too expensive or hard to execute. Likewise, due to the immense quantity of flows and complexity of the system under study, the problem cannot be approached analytically.

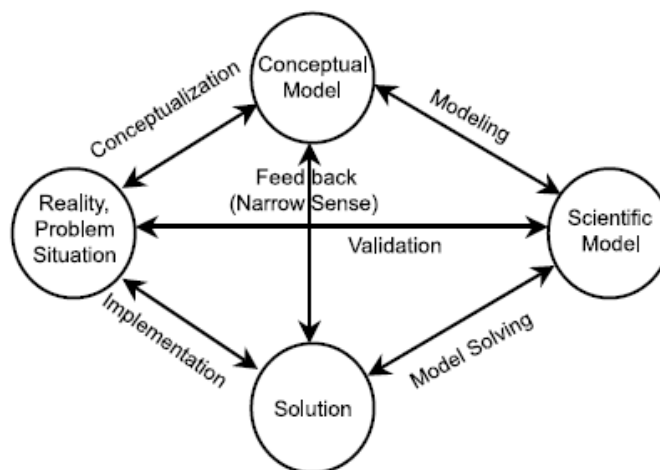
⁷ The original objective of this study was to develop a model with empiric data. Due to several complications, we were not able to follow this path, for which we opted for a design of experiments instead.

We have developed our models with discrete event simulation. We have tested performance improvement of SCF over BAU with DES, answering RQ1 and RQ2, which have a quantitative nature. To test RQ3 and RQ4, DES was also used. Additionally, to address RQ5, RQ6 and RQ7, our numerical findings served as input to a qualitative approach, which resulted in better understanding of the main drivers, causal relationships and structure of the system to better gauge impact on performance based on the roles of each party and the structure of the solution.

Based on Mitroff et al.'s (1974) model of the OR approach (see Figure 3-1), this research is classified as follows. The BAU setting follows the cycle of “conceptualisation – modelling – validation”. First, a conceptual model was built, which was later translated into a DES model. Once fed with data the model's behaviour and output was validated, mainly via face, concurrent and internal validity tests. The SCF setting, a normative model, follows a “conceptualisation – modelling – model solving – implementation” cycle. The SCF model was first conceptualised and translated into a DES model. The model was solved to get specific answers and insights to generate recommendations for its future implementation. This last step is limited to the generation of a list of recommendations and the actual implementation is set out of scope of this research project.

The structure of this document also corresponds to this procedure. Based on Chapter 2 and 3, Sections 4.1 and 5.1 **conceptualise** the problem for the BAU and SCF scenarios respectively. Sections 4.1 - 4.2 and 5.1 - 5.2 deal with formulating the system conceptually and **specifying** the scientific model in the simulation environment. Sections 4.3 and 5.3 cover the testing and **validation** of the model. Finally, Chapter 6 reviews the numerical results and Chapter 7 addresses the strategic considerations, policy formulation and guides towards the **implementation** of a SCF solution. The steps are discussed briefly in the next sections where an overview of the study is presented.

Figure 3-1: Mitroff et al.'s (1974) OR model approach



Source: Mitroff et al. (1974)

3.1.1 BAU Model

The BAU model aims at imitating the supply chain operations of a generic firm. The procedure to follow for this modelled is explained in detail below.

Conceptualisation

An initial literature review was conducted to gather understanding of the typical business model of logistics companies e.g. 3PLs, 4PLs and LLPs and the business environment within this industry. Also, information shared by DHL LLP via interviews, presentations and spreadsheets was used for better comprehension of the current business operations of DHL and of the supply chains they serve. Qualitative information about two specific customers was acquired to obtain better understanding of these companies' operations. When necessary, we also theorised about the inter-company flows i.e. information, material and cash. Based on this, a conceptual model was delineated (see Section 4.1).

Modelling

At this step, a DES model was developed based on the conceptual model. The model was later specified to a developed design of experiments.

Validation

DES offers great possibilities to model complex systems. However, as it deals with higher complexity, it becomes a challenge to formulate the relations between various parameters. For this reason, it is necessary to continuously test the model in order to verify its robustness and its validity i.e. whether the model exhibits the expected behaviour. Also, as the objective of this model is to imitate a real business setting, it is necessary to validate if it fulfils this purpose. For this end, robustness tests were undertaken. All these tests were done iteratively, which included parameter and structure validation, sensitivity analyses and carrying out face, concurrent and internal validity tests

3.1.2 SCF Model

The SCF model corresponds to a redesign and reengineering of the BAU model. The steps for the development of this model are outlined below.

Conceptualisation

The conducted literature review was directed towards exploring suggestions to address the outlined problem. The mechanism of SCF was studied to generate understanding of SCF solutions. The BAU model was thus reconceptualised to a SCF design (see Section 5.1).

Modelling

A DES model was developed based on the conceptual SCF model, and was built over the BAU model.

Model solving and validation

The model was run and adjusted until it performed according to expectations and specific functional requirements. To test model validity, reliability, we undertook the same tests as for the BAU model.

Implementation

With the results of several experiments, we have outlined strategic and tactical operations for logistics companies who aim at including SCF solutions to its portfolio of VAS.

3.2 Design of Experiments

We have made a design of experiments and provided it with material necessary to answer the research questions and create theories within OM. In order to make a good design, we conducted desk research and interviews with supply chain specialists to get a better sense of the critical relationships and causalities in supply chain operations and financial structures.

3.2.1 Desk research

Desk research provided a general understanding of the system under study. The following is a non-exhaustive list of the tasks that were undertaken:

- *Market analysis*: use of several surveys to obtain data for buyers and suppliers, especially average payment terms, interest rates, relative working capital, relative liquidity, etc.
- *Results of SCF implementations*: use of several sources to obtain numeric data on results of SCF implementation programmes.
- *Online databases*: used to obtain industry data e.g. margins

3.2.2 Interviews

Interviews with supply chain specialists also provided a general understanding of the operations and financial models at supply chains. Interviewees were primarily university staff or professionals at control towers within DHL, as well as SC managers working within the aerospace and automotive industries.

3.2.3 Model parameters and design of experiments

We have carefully chosen a set of model parameters to feed the simulation model. We based our selection on information obtained during our preliminary research. Simple parameters with a low scale were chosen in order to be able to better trace the model's behaviour. Based on literature, the scope of the conceptual models and the aforementioned research, we drafted a set of experiments to answer our research questions. Section 6.1 describes in detail the experiments that were carried out. The main focus of the experiments is to uncover the underlying structure of the system under study in order to be able to explain how SCF solutions create value. Also, the experiments aim at providing with key insights to generate better understanding of SCF solutions and to assist logistics companies in this process. Finally, our aim is as well to contribute to academic literature by filling the identified research gaps.

3.3 Discrete Event Simulation

Simulation denotes the process of building a physical or logical model that mimics the behaviour of a real-world system of interest at an arbitrary level of detail, with a high level of experiment control, on a short period of time and with a big amount of modelling flexibility. Therefore, it gives the modeller the possibility of conducting sensitivity and scenario analyses. Also, simulation permits to imitate key input variables that have high volatility and uncertainty, evaluating system under different variability levels.

DES was chosen as the simulation technique for this study. DES is a logical type of simulation, where systems are governed by logical and mathematical relationships. Reasons for choosing DES over other simulation techniques include its focus on mathematical and logical relationships and random components, the possibility it offers of making statistically valid inferences about system performance, its focus on processes, its suitability for decision and prediction making and its ability of keeping track of the state of system as time progresses. Finally, although DES does not offer the possibility of optimising, the flexibility of this modelling technique lets the modeller carry out sensitivity analyses to find near-optimal solutions, and to understand the internal structure of SCF

In DES, a computer generates numerical data that simulates the random elements of the system. This includes, but is not limited to, time-related elements (Hughes, et al., 2008). A DES model can thus be developed as a *decision support tool*. DES enables imitating a real business setting, where several scenarios, operating conditions, assumptions, policies, configuration choices, etc. are represented. Hence, DES can be used to simulate a BAU setting to be compared with a SCF mechanism with the certainty that changes on performance are a consequence of the followed interventions.

DES may prove more valid than the methodologies used in past literature as it lets consider more complex settings that better resemble reality. Elements such as the consideration of several financing periods, stochastic events, company policies, decision making processes and the effects of these decisions made on firm and supply chain performance, are integrated to the model, increasing its validity and reliability.

The Simulation model was made in Arena® Version 14.70.00007 from Rockwell Automation Technologies, Inc. with an Academic Licence. Arena is one of the leading software packages for DES. It uses a SIMAN processor and simulation language. Arena is one of the most advanced DES software packages. It has a very friendly user interface in the form of modules and connector lines to specify the flow of entities. Statistical data on experiments is easily recorded and outputted as reports. Furthermore, it has enhanced animation and a developed optimisation tool “OptQuest”. Likewise, there is a good and consolidated body of literature regarding modelling supply chains with Arena (e.g. Altioik & Melamed, 2007; Kelton, et al.; 2011). For these reasons, Arena was selected over other DES programs e.g. Enterprise Dynamics®, ProModel® and SAS Simulation Studio®.

4 BAU Model

This chapter presents the conceptual Business As Usual model, as well as information on its specification and validation.

4.1 Conceptual Model

This section gives a description of the conceptual model. This step produces a conceptual model that forms the basis of the qualitative and quantitative analysis of the BAU processes. The conceptual analysis presented in this chapter will append insights from the problem statement and the literature review (see Chapters 1 and 2) but is self-contained in order to understand the conceptual foundations of the simulation model and experiments in the subsequent chapters. We refer to Appendix 4 for a detailed view of the conceptual model and to Appendix 1 to Appendix 3 for the complete list of parameters and variables. The entire conceptual model is depicted schematically in Figure 4-1.

We developed a simulation of a continuous review stochastic inventory model for multiple echelons⁸. Specifically, the model covers the case of a set $i = \{1 \dots I\}$ of tier 1 suppliers (*T1S*), that sell set of products $k = \{1 \dots K\}$ over a set of periods $t = \{1 \dots T\}$, where one period represents $l \in \mathbb{R}^+$ years. Suppliers own a manufacturing plant (*P*) and a warehouse (*WH*), from which material is shipped to a single creditworthy buyer. Suppliers source raw material from a tier 2 supplier (*T2S*). The manufacturing plant interacts with two buffers: an input buffer (*IB*) storing incoming raw material, and an output buffer (*OB*) storing outgoing finished product. The system can be envisaged as a multiechelon supply chain. We focus mainly on echelons $e = [1,2,3]$, where the *WH* corresponds to echelon 1, the *OB* as echelon 2 and the *IB* as echelon 3. Echelons $e = 0$, the buyer and $e = 4$, the *T2S* are not subject to a deep analysis in this study.

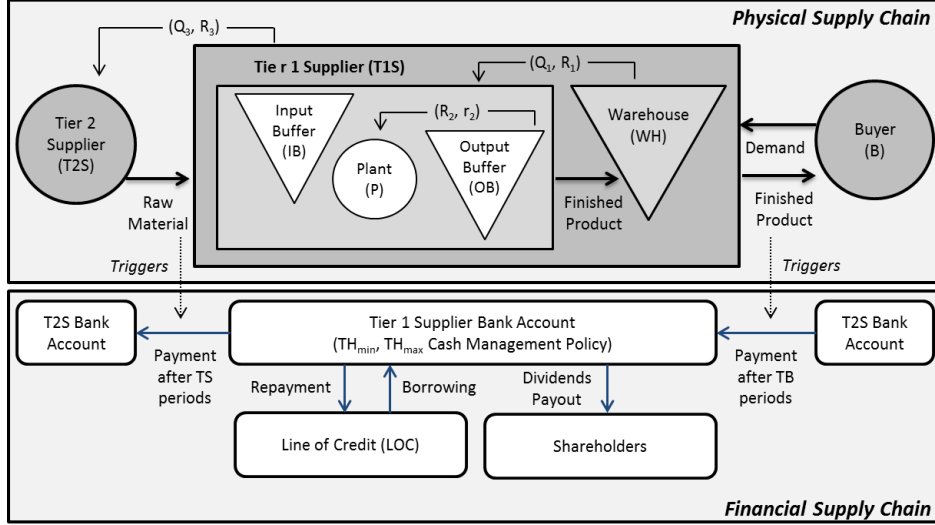
Tier 1 suppliers face a customer demand stream of $D_t^{i,k}$ units per period at the *WH* and use a continuous-review $(Q_1^{i,k}, R_1^{i,k})$ control policy, based only on information at the *WH*. If the warehouse has sufficient inventory, the order lead time consists only of transportation delay. Excess demand at the *WH* is backordered, and additional delays are experienced due to additional transportation delays and possible upstream stock-outs. The *WH* orders $Q_1^{i,k}$ units from the output buffer (*OB*) whenever the inventory position (inventory on-hand plus outstanding orders minus backorders) down-crosses $R_1^{i,k}$.

The plant's manufacturing policy is a continuous-review $(r_2^{i,k}, R_2^{i,k},)$ policy. The plant starts producing a batch size $bs^{i,k}$ once the *OB* inventory down-crosses level $r_2^{i,k}$. Production consumes one unit of raw material at the *IB* for each unit of *OB*. Production is stopped once inventory at the *OB* equals or exceeds $R_2^{i,k}$. Furthermore, shortages of raw material in the *IB* may lead to starvation, causing production to stop. The *IB* orders to the *T2S* with a continuous-review inventory control policy $(Q_3^{i,k}, R_3^{i,k})$. The *T2S* is

⁸ This model is an adaptation and extension of the Multiechelon Supply Chain example found in Altioik & Melamed (2007).

assumed to have unlimited capacity in such a way that lead time is limited to transportation delay and plant's orders are always fully satisfied.

Figure 4-1: Multiechelon supply chain



Each time that a $T1S$ supplier orders from the $T2S$, she pays $c^{i,k}$ per unit ordered plus a fixed price f^i . Specifically, upon arrival of raw material orders, suppliers book quantity $H_t^{i,k} = Q_3^{i,k} \times c^{i,k} + f^i$ into accounts payable, and after $TS^i \in \mathbb{N}^+$ periods transfer $H_t^{i,k}$ to the $T2S$ and simultaneously balance the AP account. At the Plant, once raw material is processed, it increases its value to $w^{i,k} > c^{i,k}$.

Every period, the $T1S$ supplier receives stochastic demand $D_t^{i,k}$ from a single buyer, and sells each unit at price $p^{i,k} > w^{i,k}$. Once the goods are picked up, ownership is transferred to the buyer. Upon arrival to the buyer's facility, the supplier books quantity $G_t^{i,k} = D_t^{i,k} \times p^{i,k}$ to accounts receivable. The supplier offers the buyer to pay after $TB^i \in \mathbb{N}^+$ periods. Hence, after TB^i periods, the buyer transfers $G_t^{i,k}$ to supplier, who balances the AR. We assume the buyer has a stronger bargaining position, and thus $TB^i \geq TS^i$ holds. Each backlogged unit at the warehouse entails a unit penalty cost per period $b^{i,k}$ and for each unsold unit, the supplier incurs a unit storage cost per period $h^{i,k,e}$. We assume that the holding cost at all echelons is less than the backorder cost at the WH i.e. $h^{i,k,e} < b^{i,k} \forall e$.

The cash management policy also follows a continuous review. The supplier meets periodic expenses with cash level C_t^i retained from previous periods or by borrowing from a bank, which is made via a line of credit (LOC). The supplier i requires a minimum cash threshold level $TH_{min}^i \geq 0$ and has a maximum cash threshold $TH_{max}^i > TH_{min}^i$. Whenever cash levels are below TH_{min}^i , or if the supplier is to pay an invoice that will make that her cash level below TH_{min}^i , she borrows from the LOC the quantity so that $C_t^i = TH_{min}^i$ holds after paying the invoice. In case of excess cash, the supplier uses the excess $TH_{max}^i - C_t^i$ to pay down debt, and in case the LOC balance is zero, it pays out the excess as dividends. Thus, period cash inflows comprise sales from previous periods as well as loans from the LOC. Period

cash outflows comprise periodic expenses PMT_t^i (holding costs and interest expenses), as well as debt repayments and dividend pay-outs.

The annualised interest rate for borrowing equals β^i per monetary unit per period. Also, as shareholders could have invested retained cash elsewhere, an annualised opportunity cost of α^i is assessed on each monetary unit retained. In perfect capital markets (Modigliani & Miller, 1958), we should expect $\alpha^i = \beta^i$, but we assume that capital market frictions may entail $\alpha^i < \beta^i$ or $\alpha^i > \beta^i$ (Myers & Majluf, 1984; van der Vliet, et al., 2015; van der Vliet, 2015). We assume an opportunity cost rate of η^i per year on each monetary unit of AR that result from the payment term. We also assume $\eta^i < \alpha^i$ as the risk of investing in an AR is lower than the one of investing in the firm itself. Van der Vliet, et al. (2015) argue that this occurs because contrary to the settlement of the AR, which are due after a known delay, the timing of cash dividends from the firm depends on demand and realised profits, making dividends more uncertain than a future customer payment.

We define a joint base stock and cash management policy as $Z^i(Q_1^{i,k}, R_1^{i,k}, R_2^{i,k}, r_2^{i,k}, Q_3^{i,k}, R_3^{i,k}, TH_{min}^i, TH_{max}^i)$. For a specific base stock and cash management policy, we define $GC^i(Z^i)$ as the average cost per period as follows:

$$GC_{BAU}^i(Z^i) = \frac{1}{T} \sum_{t=1}^T \left\{ e^{\beta_d^i} LOC_t^i + e^{\alpha_d^i} C_t^i + e^{\eta_d^i} AR_t^i + \sum_{k=1}^K \sum_{e=1}^3 h^{i,k,e} \cdot I_t^{i,k,e} + \sum_{k=1}^K b^{i,k} \cdot B_t^{i,k,3+} \right\} \quad (4-1)$$

where LOC_t^i refers to the line of credit balance at time t , C_t^i refers to the cash balance at time t , AR_t^i to the accounts receivable balance at time t , $I_t^{i,k,e}$ refers to inventory hold and $B_t^{i,k,3+}$ refers to backordered items at time t and T denotes total periods. Sub index d at α, β and η indicates the rate converted to the equivalent of the period length t assuming continuous compounding. Thus, the average cost per period includes holding and penalty costs, borrowing expenses, the opportunity cost of holding cash and the opportunity cost of holding AR.

With the defined model, we would like to make several remarks. Note that the cash management cost is linked to uncertainty in the match between incoming and outgoing cash flows. Similarly as it occurs with the material flow and safety stock, if demand were deterministic, suppliers would be able to match cash inflows and outflows and there would be no need to borrowing and/or retaining cash reserves. Also, there is an interaction between the inventory policies at the supplier and the cash retention level via thresholds TH_{min}^i and TH_{max}^i . Replenishment cost in period t depends on the demand of the previous periods and the cash level available to replenish inventory depends on TH_{min}^i and TH_{max}^i . Finally, even if the payment term comprises one period, a deficit could still arise. Supplier's backlogged demands are included in the replenishment cost but the actual payment from the buyer is delayed until the material arrives to the customer (van der Vliet, et al., 2015).

The system is subject to the following assumptions:

Material Flows

1. The warehouse faces customer demand that arrives each period with a demand quantity that follows a lognormal distribution.
2. At all echelons, the unsatisfied portions of demands are backordered. The order fulfilment i.e. the shipment takes place until the full order becomes available. Consequently, there is no shipping of partial backordered demands.
3. There is a delay in material transfer between all echelons denoted by LS_e^i . Between the input and output buffers there is specifically a manufacturing delay, and between all the other echelons there is a transport delay. Likewise, there is a transportation delay LB^i between the warehouse and the buyer. All delays follow an Erlang distribution, specifically $Erl(k = 2, \lambda = 1)$ periods for transportation delays and $Erl(k = 3, \lambda = 5)$ periods for the manufacturing delay.⁹
4. Material ownership is transferred from the suppliers to the buyer immediately when the goods are picked up at the warehouse.
5. There is an infinite transportation capacity. Once a transport request is sent, it will be fulfilled after a certain lead time. There is no probability of material being lost, stolen or damaged during transportation. Hence, the probability of shipment acceptance at the buyer equals 100%.
6. At all echelons, orders are received in the order they were placed i.e. there is no overtaking
7. Suppliers are dedicated to a single creditworthy buyer.
8. We do not theoretically demonstrate optimality of constant inventory policies.

Financial Flows

1. Payment terms are deterministic amounts and there are no payment defaults.
2. There is no lead time in the flow of cash.
3. Although the model could impose a limit to the line of credit, doing so may force our focus on default events instead of on suppliers' financing needs due to trade credit provision and the cost attached to it. Thus, we assume unlimited borrowing capacity from the LOC.
4. The buyer always has sufficient cash to pay for orders. There is no probability of default.
5. The costs related to adding value to raw materials at the production are assumed to be fixed, independent and/or uncorrelated to the operations, for which they are not considered.
6. The supplier only generates cash by direct sales. Other kind of income e.g. yields on short term investments like securities are not considered. Likewise, as the supplier does not make short term investments, there are no corresponding cash inflows of maturing securities.
7. Other kind of expenses e.g. taxes, or capital expenditures are not considered.
8. Dividend pay-outs do not consider future cash positions or requirements. Dividends are paid out based solely on the cash balance C_t^i at a certain point in time t . This is not the case in reality, where managers base their decision on future cash positions forecasts. For instance, if a manager expects important cash outflows in the following periods, she would rather keep the excess cash in order to use it for future payments rather than for dividend pay-outs.¹⁰

⁹ These Erlang distribution parameters were taken from Altiok & Melamed's (2007, p. 294) example of a multiechelon supply chain system.

¹⁰ For a cash model that relaxes this assumption, please refer to Stone's (1972) model.

9. We assume that suppliers have only one bank. The “cash allocation problem” referred by Stone (1972), which refers to the allocation of cash balances among several banks, is out of scope.
10. We do not theoretically demonstrate optimality of constant cash threshold policy.
11. Our proposed cash management policy is analogous to a s,S inventory policy, where α and β correspond to a holding and shortage costs of cash. In reality, cash management practices may be more complex. This policy is a simplification of the dual threshold model of Stone (1972).
12. Contextual factors that motivate cash policies are absent of model e.g. bank agreements that require a minimum average cash balance (Stone, 1972). When a minimum average cash balance is required, the opportunity cost of holding cash, unless cash is hold in excess of this amount, is zero because these balances must be met. We ignore this situation and assume an opportunity cost α^i for each monetary unit on the cash balance.

Information Flow

1. We assume full information visibility and transparency, which is updated on a real time basis.

4.2 Model Specification

This section discusses the translation from the conceptual model to a DES model. The model is based on the assumptions and theoretical structure described in the conceptual model and the literature review.

4.2.1 From Conceptual Model to Simulation Model

In order to translate the conceptual model into a DES model, initial parameters need to be defined. We define $i = 1$ as we consider the case of a single or a pool of suppliers. Similarly, we define $k = 1$, as we consider the case of a pool of products instead of several individual products. Consequently, the simulation model is based on average values of the pool of suppliers and products. It follows that, from these definitions indexes i and k are omitted from this point.

4.2.2 Model Structure

The Arena model is composed of eight segments, of which four comprise the inventory-holding buffer in a system echelon: the warehouse, IB, OB and the Tier 2 Supplier. Each buffer is subjected to the following events: order arrival, inventory updating, replenishment, order triggering, and shipment. Likewise, additional supply chain activities are modelled, such as order arrival at the downstream end i.e. the warehouse, product manufacturing at the plant, order backordering, among others. The other four segments comprise the cash management at the supplier: a) booking of accounts receivable and administration of excess cash: 2) booking of accounts payable and administrations of cash shortfalls, 3) payment of periodic expenses and 4) computation of periodic total costs. Appendix 7 offers a detailed description of the Arena simulation model.

4.2.3 Data and Parameters

We carefully selected a set of parameters for our experiments to feed the simulation model. The parameters related to the inventory and cash management policy Z were obtained via optimisation. An (near) optimal policy Z^* that minimises the average cost per period $GC(Z^*)$ was sought using the Arena's tool "OptQuest".¹¹ Given the complexity of the optimisation, we broke down in four parts the optimisation: first we optimised the inventory policy at the warehouse, then at the output buffer, then at the input buffer and at last the cash management policy. For the warehouse, we demanded a service level of at least 95% and for the other two echelons 90%. By having a high service level, the impact on operations cost can be considered to be negligible. Hence, we were able to minimise the impact of the cash policy on the inventory management policies. See Appendix 1 and 2 for the value of all parameters.

We use $Z^* = (Q_1^*, R_1^*, R_2^*, r_2^*, Q_3^*, R_3^*, TH_{min}^*, TH_{max}^*)$ to denote the optimal policy. We rewrite the objective function as GC_{BAU}^* suppressing the immediate dependence on Z^* . For a detailed review on the optimisation equations, consult Appendix 10.

4.2.4 Key Performance Indicators

We defined relevant key performance indicators (KPIs). All KPIs were computed per individual supplier and include average cost per period, operating margin, quick ratio, average earnings before taxes margin, net working capital, interest expenses, short-term debt to current assets ratio and cash conversion cycle. Consult Appendix 6 for a description of all the KPIs and the formulas to compute them

4.3 Model Validation

We have tested the validity and reliability of the simulation model. For a review on validity, we refer to Howit & Cramer (2011). We conducted face, concurrent and internal validity tests by conducting several sensitivity analyses and checking that model behaviour was as expected. Face validity measures if the items measure what they claim to measure. We have assessed this validity informally, by interpreting experiments results and analysing model behaviour. By analysing the form and behaviour of certain graphs, we confirmed validity. Concurrent validity refers whether scales correlate well with other measures of the same concept taken at a different setting. We made this by comparing scenarios with different coefficients of variation under the same conditions. We obtained consistent and coherent results for higher volatility. Finally, internal validity evaluates whether the experiment design closely follows the principle of cause and effect. Hence, by conducting sensitivity analyses and several scenarios we assured that changes in model inputs caused expected outcomes. All tests were successful and satisfactory and the model behaved as expected. Appendix 8 reviews these tests in detail.

¹¹ OptQuest uses internal heuristic algorithms by changing input controls to move toward an optimum configuration. Consequently, OptQuest may report near-optimal solutions.

5 SCF Model

This chapter presents the conceptual SCF model, as well as information on its specification and validation.

5.1 Conceptual Model

This section presents the conceptual design for the SCF mechanism at the SC under study. Under a SCF structure and specifically under RF there is a change of roles in supply chain partners. This model considers the situation in which suppliers discount receivables at a cheaper rate, provided by collaboration with the buyer and a FSP. Furthermore, since the supplier's opportunity cost of holding receivables η may influence its use of RF, we consider two possible scenarios: automatic discounting (AD) and manual discounting (MD). This model is built upon the BAU model with certain extra considerations and modifications. We define parameter $\gamma^i \in (0,1)$ as the annualised fraction of face value that suppliers should pay to discount a receivable. For example, if $\gamma^i = 4\%$ is applied to a receivable to be received within 3 months, the supplier could get immediately 99% of the face value ($= 100 - 4 \times 3/12 = 99$). This discount is applied at the moment the supplier requests a discounted receivable. Therefore, the discount cost increases with the remaining days to the payment term maturity, motivating suppliers to discount the receivables that are due sooner. We set $\gamma^i < \beta^i$ so cash from discounting is preferred to cash from borrowing. If the supplier discounts all receivables and still requires extra cash, she borrows via the LOC. Appendix 5 discusses the SCF conceptual model in detail.

5.1.1 Automatic discounting

Under automatic discounting, the supplier discounts the full value of any receivable as soon as it is possible to do so. We assume that a minimum of χ^i days need to pass after the arrival of the goods to the buyer before the supplier can discount the receivable. After this time, the supplier can discount the receivable booked χ^i periods ago. Consequently, holding costs for receivables are still incurred for the periods that the receivable is owned by the supplier i.e. χ^i .

We define a joint base stock and cash management policy as $Z^i(Q_1^{i,k}, R_1^{i,k}, R_2^{i,k}, r_2^{i,k}, Q_3^{i,k}, R_3^{i,k}, TH_{min}^i, TH_{max}^i)$. For a specific base stock and cash management policy, we define $GC_{AD}^i(Z^i)$ as the average cost per period as follows:

$$GC_{AD}^i(Z^i) = \frac{1}{T} \sum_{t=1}^T \left\{ e^{\beta_d^i} LOC_t^i + e^{\alpha_d^i} C_t^i + e^{\eta_d^i} AR_t^i + e^{\gamma_d^i} ARF_t^i + \sum_{k=1}^K [h^{i,k} [NI_t^{i,k}]^+ + b^{i,k} [-NI_t^{i,k}]^+] \right\} \quad (5-1)$$

where ARF_t^i refers to the amount per period that was discounted, γ_a^i represents the discounting cost per period assuming continuous discounting, j represents the time to maturity of the discounted invoice, and all other variables are as in the BAU model.

5.1.2 Manual discounting

Under manual discounting, the supplier prefers to discount receivables rather than borrowing to cover cash deficits, but does not discount receivables if enjoying a cash surplus i.e. if $C_t^i \geq T_{min}^i$. We also assume that a minimum of χ^i days has to pass after delivery for discounting receivables.

We define a joint base stock and cash management policy as $Z^i(Q_1^{i,k}, R_1^{i,k}, R_2^{i,k}, r_2^{i,k}, Q_3^{i,k}, R_3^{i,k}, TH_{min}^i, TH_{max}^i)$. For a specific base stock and cash management policy, we define $GC_{MD}^i(Z^i)$ as the average cost per period as follows:

$$GC_{MD}^i(Z^i) = \frac{1}{T} \sum_{t=1}^T \left\{ e^{\beta_a^i} LOC_t^i + e^{\alpha_a^i} C_t^i + e^{\eta_a^i} AR_t^i + e^{\gamma_a^i} MRF_t^i + \sum_{k=1}^K [h^{i,k} [NI_t^{i,k}]^+ + b^{i,k} [-NI_t^{i,k}]^+] \right\} \quad (5-2)$$

where MRF_t^i refers to the amount per period that was discounted, and all other variables as above.

We point out that in order to minimise costs, suppliers select the invoices that yield the lowest cost i.e. they discount specifically the invoices whose maturity is due the soonest.

5.2 Model Specification

The model was built based on the BAU model. Therefore, all the specifications made for the BAU hold except the changes related to the RF mechanism. Appendix 7 offers a detailed description of the Arena simulation model. Likewise, for every instance of the model we used OptQuest to find an optimal policy Z^* that minimises the average cost per period $GC(Z^*)$. Furthermore, we measured the same KPIs as for the BAU case.

5.3 Model Validation

We have tested the validity and reliability of the simulation model by following the same steps as for the BAU model. As in the BAU case, all tests were successful and satisfactory and the model behaved as expected. Appendix 9 reviews these tests in detail.

6 Experiments and Numerical Results

This chapter discusses the conducted experiments, presents the numerical results and provides an analysis of the model output that links the results to the research questions.

6.1 Design of Experiments

We designed two sets of experiments: Experiment 1 (a)-(f) and Experiment 2 (a)-(d). In all experiments one period corresponds to one day. Annual financing rates are converted to daily rates by assuming continuous compounding. Also, we defined two dimensions to identify supplier profiles: by categorising them according to industry profile with gross margin defined as $\omega = \frac{\text{revenue} - \text{cost of goods sold}}{\text{revenue}}$, which was calculated at the end of the simulation run, and with risk profile $\phi = \beta/\alpha$. Conventional finance literature argues that the main motivation for companies to retain and/or optimise cash is capital market frictions, which can cause that $\alpha \neq \beta$. We assume that companies with higher firm-specific risk have a higher borrowing cost β . Hence, we vary only parameter β under the assumption that the opportunity cost of holding cash α is the return shareholders could obtain by investing elsewhere e.g. securities in the capital markets¹². This return is less volatile than firm specific risk. Hence, ϕ represents firm riskiness¹³. Furthermore, since the firm's opportunity cost of holding receivables may influence its use of reverse factoring, we consider automatic and manual discounting. We consider two scenarios: when η , the cost of holding AR, is zero, and when η equals the cost of discounting through reverse factoring: $\gamma = 0.03$.^{14 15} On the former case, the firm employs manual discounting (MD) and on the latter automatic discounting (AD). Finally, we consider a periodic demand with a lognormal distribution with mean $\mu_D = 10$. To test effects of higher demand uncertainty on supplier's performance, we consider two scenarios, one with a coefficient of variation $c.v. = \frac{\sigma_D}{\mu_D} = 0.25$ and another with $c.v. = 1$. For the list of all parameters used at the experiments, consult Appendix 1.

We look for an optimal policy Z^* for every experimental instance to compare system performance across different scenarios. We use $Z^* = (Q_1^*, R_1^*, R_2^*, r_2^*, Q_3^*, R_3^*, TH_{min}^*, TH_{max}^*)$ to denote the optimal policy. We rewrite the objective function as $GC_{(\cdot)}^*$ suppressing the immediate dependence on Z^* . For a specific review on the optimisation equations, consult Appendix 10. Finally, we declare financial costs function $FC_{(\cdot)}^*$ as follows:

¹² From 1926 to 2008, the average market premium i.e. the return on top of the risk-free rate (r_f) in the US has been 7% (Metrick & Yasuda, 2011). Treasury yields are selected as a proxy for r_f . As these are at the moment close to zero, we assume $r_f = 1$, and we define $\alpha = r_f + 7\% = 8\%$.

¹³ We defined a range for ϕ between 0.5 and 2, implying a maximum $\beta = 16\%$. This may be conservative. According to literature, in the case of SMEs, their cost of financing may approach 20% or more (Gustin, 2006).

¹⁴ We selected $\gamma = 3\%$ assuming $r_f = 1$ and a spread of 2%. However, creditworthy buyers may currently have costs of financing equal or lower to 1%. Hence, $\gamma = 3\%$ is very conservative.

¹⁵ If $\eta > \gamma$ then the benefits of reverse factoring are bigger. Hence we limit our scenarios to $\eta = 0$ and $\eta = \gamma$ in order to measure the benefits for companies with a low cost of holding AR and that benefit less from RF.

$$FC_{(\cdot)}^* = \frac{1}{T} \sum_{t=1}^T \{e^{\beta_d} LOC_t + e^{\alpha_d} C_t + e^{\eta_d} AR_t + e^{\gamma_d} ARF_t\} \quad (6-1)$$

As seen, $FC_{(\cdot)}^*$ comprises only the financial costs i.e. cost of holding cash, cost of borrowing, cost of discounting receivables and cost of holding account receivables.

Experiment 1: Supplier direct benefits when introducing SCF.

- a) *Supplier financial ($FC_{(\cdot)}^*$) and total ($GC_{(\cdot)}^*$) cost savings for varying levels of risk profile ϕ and different gross margin ω , with a negligible cost of opportunity of holding AR $\eta = 0$.*
We explore the savings for different supplier risk and industry profiles by varying the borrowing cost and gross margin. The firm employs MD.
- b) *Average reduction in cash flow volatility for varying levels of ϕ and a different ω with $\eta = 0$.*
We aim at confirming previous studies that suggest that SCF reduces cash flow volatility. We do so by taking the average of standard deviation reduction for companies of several risk profiles and compare these with those of firms with different gross margins.
- c) *Financial and overall cost savings for different payment terms TB for a supplier with risk level ϕ and industry profile ω , with $\eta = 0$.*
- d) *Supplier financial and overall cost savings for varying levels of ϕ and different ω , where the cost of opportunity of holding AR equals the reverse factoring discounting cost, i.e. $\eta = \gamma$.*
As the cost of holding AR is equal to the cost if discounting, the firm employs AD.
- e) *Average reduction in cash flow volatility for varying levels of ϕ and varying ω , with $\eta = \gamma$.*
- f) *Financial and overall cost savings for different payment terms TB for a supplier with risk level ϕ and industry profile ω , with $\eta = \gamma$.*

Experiment 2: The impact of payment terms extension and the supplier indifference curve for the trade-off of payment term extension and price cut.

- a) *Total costs when extending payment terms under BAU and SCF with no opportunity cost rate for holding receivables.*
We explore the trade-off between cheaper credit and extended payment terms in RF when $\eta = 0$.
- b) *Necessary price cut to make a supplier indifferent between BAU and reverse factoring with payment term extension*
Here we look for price cut y to make supplier indifferent between BAU and SCF with a payment term extension and a price cut, for starting $TB = 30$, risk profiles $\phi = (1.0, 2.0)$ and $\eta = 0$.

In all experiments we let the system start with cash position equal to the maximum threshold TH_{max} . Likewise, starting inventories on hand at all echelons were set above the reorder point. Receivables, payables, the LOC Balance and accumulated dividends had a starting value of zero. We assess performance after 500 warm-up periods i.e. days. Also, at period $t = TB$ we reset back to zero the *LOC* balance to compensate for the extra borrowing the supplier had while not receiving cash inflows. We calculate 95 percent confidence intervals from 30 independent replications with a run-length of 4000 periods including the warm-up.

6.2 Numerical results

In this section we cover the results from each experiment. Section 6.2.1 covers the results from Experiment 1, while 6.2.2 from Experiment 2.

6.2.1 Results from Experiment 1

Here we discuss the results on the first block of experiments, which aims at answering RQ1 and RQ2.

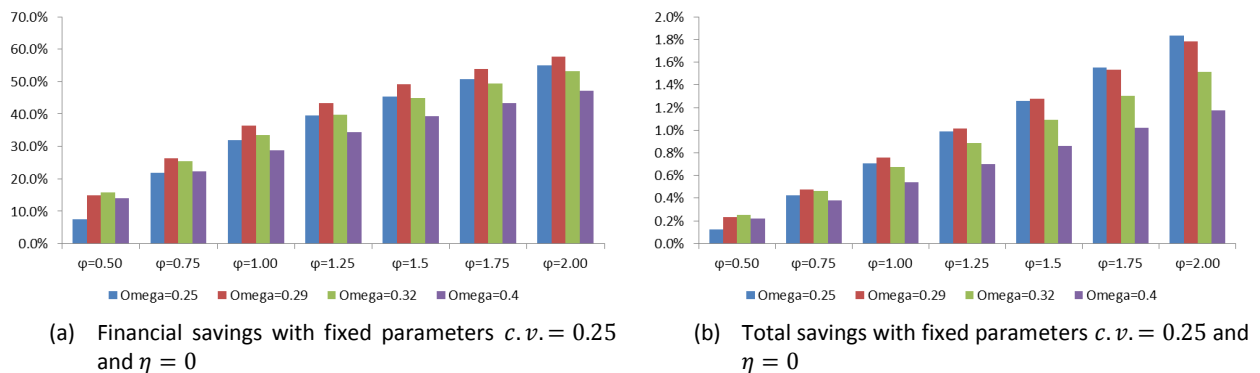
Experiment 1a: Supplier financial and cost savings for different risk and industrial profiles and a negligible cost of holding receivables

In all configurations of this experiment, we observe the following general relationship between cost savings, risk profile ϕ and gross margin and industry profile through gross margin ω :

The financial and total savings achieved through manual discounting with respect to the BAU setting increase monotonically with risk profile, and are higher for companies with lower gross margin.

Figure 6-1 illustrates this finding. We calculated financial savings by employing the formula $\frac{FC_{BAU}^* - FC_{MD}^*}{FC_{BAU}^*}$ and we followed the same procedure for total savings. We see that companies with a lower risk ϕ (and hence lower cost of borrowing) have smaller savings through reverse factoring. This is because they already have a cheap financing rate. However, companies with a high borrowing rate – typically SME suppliers – have a substantial amount of savings due to a bigger interest rate arbitrage $\beta - \gamma$. Likewise, companies with access to MD face less cash flow uncertainty due to shorter effective payment terms, meaning that they require less cash to hedge against uncertainty. Thus, they also have a lower opportunity cost of holding cash. On the other hand, firms with lower margins benefit more than companies with higher margins. The reason for this is because the former have lower liquidity levels, hence are in need of higher level of financing and as a result have higher financial costs.

Figure 6-1: Financial and total savings with $\eta = 0$



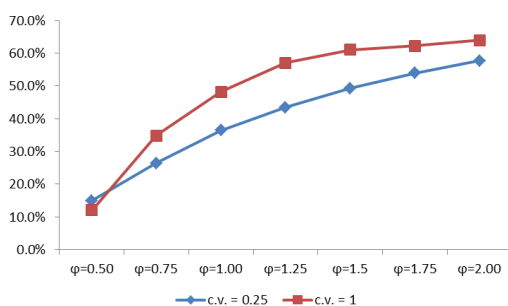
We also conducted this experiment with a higher coefficient of variation $c.v. = 1$ to measure the impact of higher demand volatility on financial and total savings and we arrived to this conclusion:

The financial savings are higher for firms with higher demand uncertainty, but total savings are expected to be lower compared to firms with lower demand uncertainty.

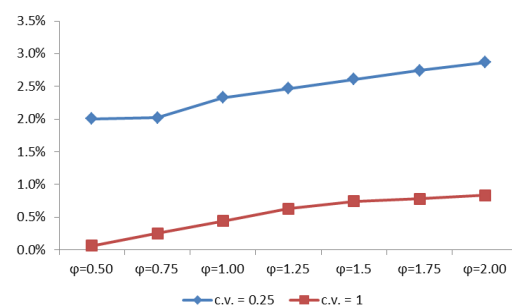
We conducted an experiment for two suppliers with margin $\omega = 0.29$, several ϕ and demand volatilities $c.v. = 0.25$ and $c.v. = 1$. We can see in Figure 6-2 (a) that financial savings are higher for the firm with higher demand volatility. When having higher demand uncertainty, firms need more liquidity to maintain operations with the same customer service levels. They achieve this by holding on to more cash when interest rates are high, or borrowing more when interest rates are low. When implementing SCF suppliers have access to quick cheap cash, decreasing dramatically their need for borrowing and/or holding on to extra cash. Financial savings are bigger for firms with higher demand volatility.

However, when looking at Figure 6-2 (b) we see that overall savings are less for firms with higher demand volatility, which may be misleading. The reason of lower savings is because higher demand volatility forces the supplier to also hold on to more inventory to satisfy the same customer service levels. Financial costs have a lower share of the overall costs than the operations costs, making the financial saving, albeit higher with $c.v. = 1$, to be smaller when considered as an overall saving. Therefore, savings through MD on firms with higher volatility have a lesser effect on total costs than firms with lower volatility because operations costs, which have a higher share, increase as well and as a result make financial savings, have a smaller effect on the total cost savings.

Figure 6-2: Comparison of Financial and total savings with $\eta = 0$ for $c.v. = 0.25$ and $c.v. = 1.0$



(a) Financial savings with fixed parameters $c.v. = 1$ and $\eta = 0$ for $\omega = 0.29$



(b) Total savings with fixed parameters $c.v. = 1$ and $\eta = 0$ for $\omega = 0.29$

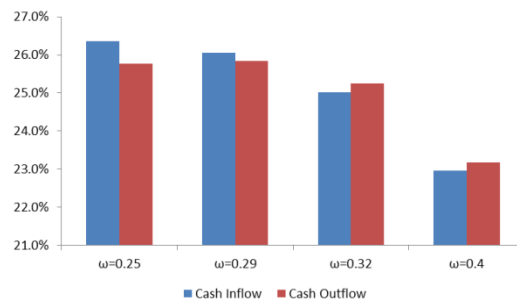
Experiment 1b: Average reduction in cash flow volatility for different industrial profiles

In this experiment, we measured cash inflow and outflow volatility and we always found significant reductions. This experiment yielded the following finding:

There is a substantial reduction in cash inflow and outflow volatility when adopting manual discounting, which is more pronounced for companies with lower gross margins.

In our model, cash inflows comprise sales of matured invoices, sales through MD and borrowing. Cash outflows include payment to the $T2S$ after payment term TS , periodic payments in the form of holding costs and borrowing expenses, debt repayments and dividends pay-outs. If companies have the possibility of discounting receivables whenever necessary, they can better align cash requirements with cash availability, for which cash flows smooth and volatility decreases. Also, our results point towards lower volatility reductions for companies with higher margins. This is understandable, because companies with higher margins have higher levels of liquidity and thus require less hedging via holding on to cash, less financing (through reverse factoring or the LOC) and can better match cash requirements with cash availability. On the other hand, firms with lower margins need more hedging and financing. Finally, we witnessed very similar reductions in cash flow volatility for companies across several risk profiles. Therefore, we took the average reduction for companies with the same margin across the several risk profiles in order to show a central effect.

Figure 6-3: Reduction in cash inflow and outflow volatility with $c.v. = 0.25$ and $\eta = 0$



Cash flow volatility reduction with $c.v. = 0.25$ and $\eta = 0$

Experiment 1c: Financial and overall cost savings for different payment terms TB for a supplier with risk level $\phi = (1.0, 1.5, 2.0)$ and industry profile $\omega = 0.29$ with $\eta = 0$.

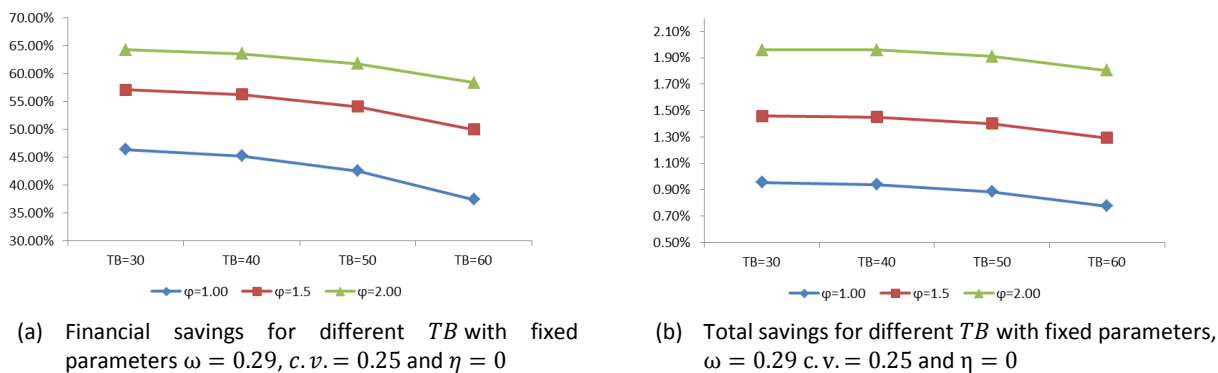
In this experiment, we show the case of a supplier with margin $\omega = 0.29$. We note that the findings of this experiment for other values of ω are similar, for which we only present this single case. We measured the financial and total cost savings for suppliers with this margin and three different risk profiles across different payment terms¹⁶. Our results converge on the following conclusion:

Benefits of manual discounting in the form of financial and total cost savings decrease monotonically when a supplier grants longer payment terms.

¹⁶ We note that the effect of having longer payment terms on the financial flows is the same as the one of having longer material lead times. When a supplier delivers material after a long lead time, they also delay further cash inflows because buyers typically begin counting payment terms after material has arrived at their facilities. Therefore, the ultimate effect on cash flow of having longer lead times and longer payment terms is the same.

When a firm discounts a receivable, the total financial cost it pays for doing so depends on the volume of the invoice, the interest rate and the time to maturity. Provided that invoice amount and interest rate are fixed, the longer the time to maturity is, the higher the financial cost will be. Hence, if payment terms are longer, the time to maturity will be higher too. For this reason, companies that already offer long payment terms to their customers benefit less from MD than firms who offer shorter terms. This can be seen in the figure below. Both financial and total cost savings decrease for suppliers with higher payment terms. Consistent with earlier experiments, we can also appreciate that companies with higher ϕ benefit more than companies with lower ϕ irrespective of the TB level.

Figure 6-4: Financial and total savings for several payment terms with $\eta = 0$



Experiment 1d: Supplier financial and cost savings for different risk and industrial profiles and with cost of holding receivables η equal to the cost of discounting γ .

In this experiment we also observe a general relationship between cost savings, ϕ and ω :

The financial and total savings achieved through automatic discounting with respect to the BAU setting increase monotonically with risk profile, and are higher for companies with higher gross margin.

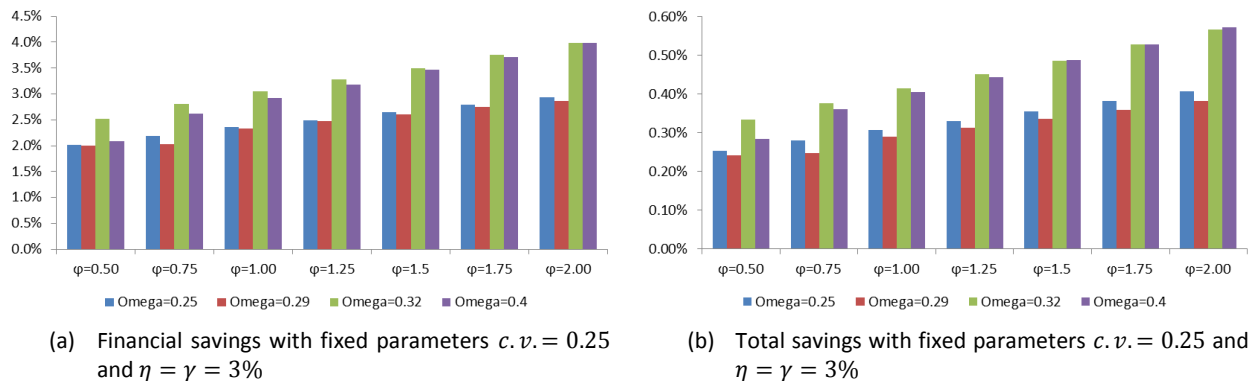
As in experiment 1a, financial and total cost savings increase for companies with a higher risk profile relative to companies with lower risk profile. This occurs due to the interest rate arbitrage $\beta - \gamma$. Contrary to experiment 1a, companies with higher margins benefit more than firms with lower margins.

As a first consideration, benefits from AD are considerably less than in experiment 1a. The reason for this is the following. When there is a cost of holding receivables equal to the cost of discounting, firms would rather cash in the receivables than leave them on their balance sheet. Consequently, there are considerable savings on the cost of holding receivables, which are however mostly offset by the cost of discounting as $\eta = \gamma$. Furthermore, the cash management model dictates that all excess cash $C_t - TH_{max}$ is paid out in the form of dividends. Consequently, most of the extra liquidity achieved through AD is lost as dividends and the supplier still has a similar borrowing behaviour, leading to only a small reduction in borrowing costs. Likewise, cash levels are slightly lower as in the BAU case due to quicker cash, which changes the cash policy. Therefore, financial and total savings in the form of AD are

much lower than in the MD case. However, we expect that if a firm values the cost of holding receivables to be higher than the cost of discounting, savings will be higher.

Also, we saw that under AD benefits are higher for companies with higher gross margin. As discussed, extra liquidity obtained through AD usually leaves the company early through expenses, debt repayments or dividends, meaning that suppliers still have significant borrowing costs. Companies with higher margins have higher liquidity than those with lower margins, meaning that they have a lower need of financing. Companies with lower margins still have similar borrowing and cash holding behaviour. As well, quicker cash and at a higher margin means that these firms need less amount of cash to hedge against uncertainty, from which it follows that they have a lower opportunity cost of holding cash relative to firms with lower margins. Thus, benefits from AD are higher for these suppliers. Our results are summarised in Figure 6-5.

Figure 6-5: Financial and total savings with $\eta = \gamma$



Experiment 1e: Average reduction in cash flow volatility for different industrial profiles with $\eta = \gamma$

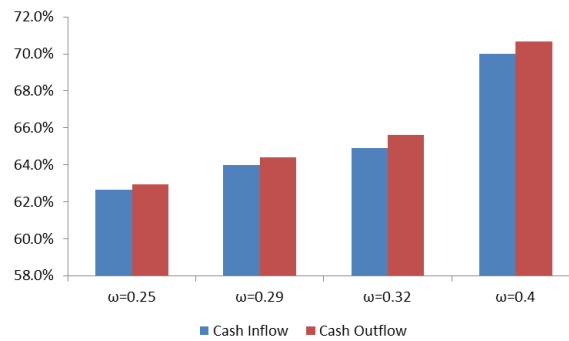
In this experiment we also measured cash inflow and outflow volatility. Although we also found reductions as in Experiment 1b, our results contrasted in the following way:

There is a substantial reduction in cash inflow and outflow volatility when adopting automatic discounting, which is more pronounced for companies with higher gross margins.

The reason for cash flow volatility reduction through AD is the same as in the case of MD. There are two differences: AD reduces volatility considerably more than MD, and suppliers with higher gross margins reduce cash flow volatility at a higher degree. When applying AD, there is no decision to discount, as all receivables are discounted χ days irrespective of the cash position. This smooths cash flow levels. We also know from literature that longer payment terms and lead times induce higher variance. Being able to reduce considerably payment delays and at an automatic manner makes cash flow volatility to be cut dramatically. The same rationale applies for cash outflows. Suppliers who have a constant stream of cash inflows are able to smooth their cash outflows, especially dividends and debt repayments.

With respect to higher variance reduction for suppliers with higher margins, we can apply the same line of thought as in Experiment 1d. As discussed, companies with higher margins require less financing and cash when applying AD relative to companies with lower margins. This enables a lower amount of and more predictable cash transactions, especially borrowing, repaying debt and paying out dividends. Hence, they enjoy a higher reduction in cash inflow variance relative to suppliers with lower margins.

Figure 6-6: Reduction in cash inflow and outflow volatility with $\eta = \gamma$



Financial savings with fixed parameters $c. v. = 0.25$ and $\eta = \gamma$

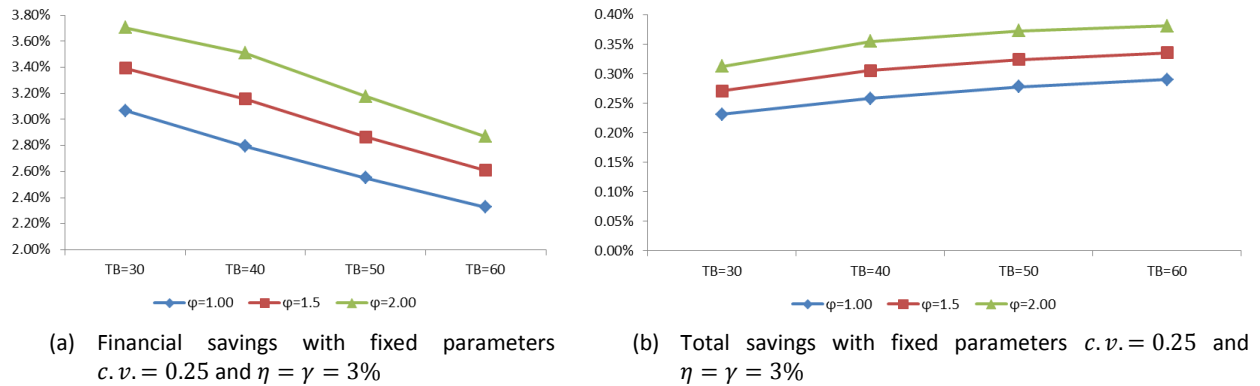
Experiment 1f: Financial and overall cost savings for different payment terms TB for a supplier with risk level $\phi = (1.0, 1.5, 2.0)$ and industry profile $\omega = 0.29$ with $\eta = \gamma$.

As in Experiment 1c we selected the case of a supplier with margin $\omega = 0.29$. We measured the financial and total cost savings for suppliers with this margin and three different risk profiles across different payment terms. Our results converge on the following conclusion:

Benefits of automatic discounting in the form of financial cost savings decrease monotonically when a supplier faces longer payment terms but increase slightly in the form of total cost savings.

The reason why reverse factoring becomes less attractive for companies with longer payment terms in terms of financing savings is the same as in the case of AD: longer payment terms entail a higher time to maturity and thus higher financing costs. Therefore, financial savings decrease to lower payment terms. We can also appreciate that the impact of longer payment terms on savings is much smaller when considering total costs, and we even see a small reverse in the trend. Whilst in the MD case benefits on total savings decrease with payment terms, in the AD case the opposite occurs. We have not found a clear explanation for this effect. However, we theorise that this is due to the cash policy design, which causes that extra liquidity via AD leaves the firm in the way of dividends, causes financial savings to be much smaller than in the MD case. Also, having in fraction $1 - GC_{AD}^*/GC_{BAU}^*$, financial costs less than 1 and operations costs bigger than 1, coupled with financially small savings and no operations savings, might be the cause for the change of trend.

Figure 6-7: Financial and total savings for several payment terms with $\eta = \gamma$



6.2.2 Results from Experiment 2

Here we discuss the results on the second block of experiments, which aims at answering RQ3 and RQ4.

Experiment 2a: Effect on total costs for supplier when extending payment terms for scenarios BAU and MD with no opportunity cost rate for holding receivables

In this experiment we explore the effect of extended payment terms on conventional financing i.e. BAU and on reverse factoring with MD and $\eta = 0$. Also, we study the trade-off between cheaper financing and extended payment terms through reverse factoring. These studies support the following assertion:

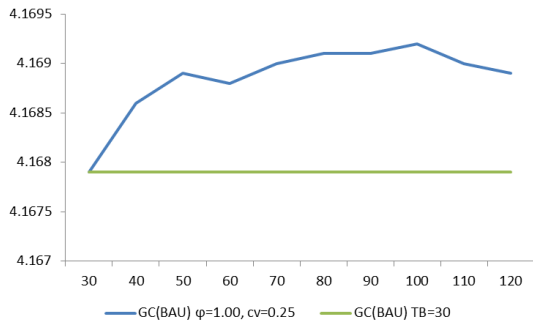
The extension of payment terms induces a non-linear effect on the total cost for the supplier.

This effect can be seen in Figure 6-8 (a), where we assumed an initial payment term of 30 days, and measured the total cost for the supplier by extending payment terms in steps of 10 days for the BAU case. Our findings are consistent with literature (cf. van der Vliet, et al., 2015). When extending payment terms, the overall effect on the total cost that the supplier incurs increases non-linearly.

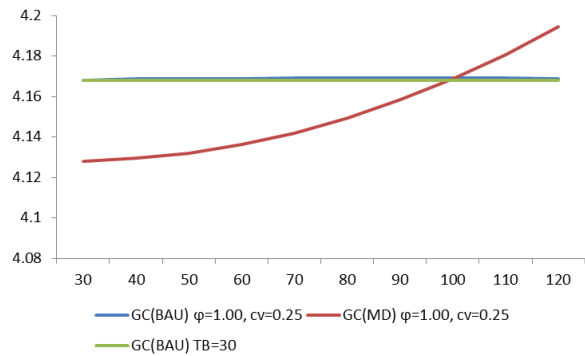
We have also measured the total cost a supplier faces when being offered reverse factoring with a credit term extension and also found a non-linearity. We depict this cost in Figure 6-8 (b). The blue line is the same as in Figure 6-8 (a) but due to the scale it looks linear. The red line is the total cost with MD. As seen, it has a curvilinear form and it grows at a much higher rate than the BAU blue line. The green line denotes GC_{BAU}^* with initial $TB = 30$. In this specific scenario, we even see that after an extension to 100 days the cost under MD is higher than both the BAU cost with the original and with the extended payment terms. Consequently, we conclude the following:

When extending payment terms, benefits for the supplier decrease relative to the equivalent BAU total cost with extended payment terms and also relative to the BAU scenario with the original payment terms.

Figure 6-8: Extended payment terms with $c.v. = 0.25$, $\phi = 1.0$ and $\eta = 0$



(a) Total BAU costs with $c.v. = 0.25$, $\phi = 1.0$, $\omega = 0.29$ and $\eta = 0\%$

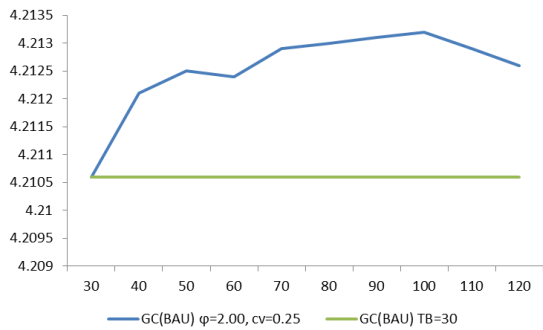


(b) Total BAU and MD costs with $c.v. = 0.25$, $\phi = 1.0$, $\omega = 0.29$ and $\eta = 0$

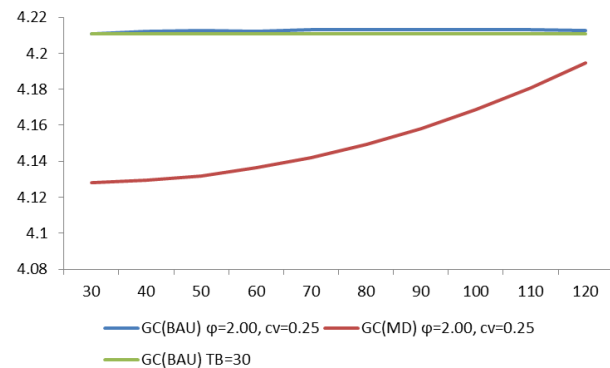
We made the same experiment for a supplier with a higher risk profile ϕ , which is depicted in Figure 6-9. We can observe the same effects as in Figure 6-8: non-linearity in total cost when payment terms extension and a decrease in benefits with the increase on payment terms. When comparing Figure 6-9 (b) with Figure 6-8 (b) we find that suppliers with a higher risk profile have higher benefits $GC_{BAU}^* - GC_{MD}^*$ when being offered reverse factoring with payment term extension $TB + x$ than suppliers with a lower risk profile. We assert the following:

The effect of a payment term extension on the supplier depends on the supplier's cost structure. Suppliers with higher risk profile ϕ have higher benefits when facing a payment term extension $TB + x$ than suppliers with lower risk profile when offered reverse factoring with extended payment terms.

Figure 6-9: Extended payment terms with $c.v. = 0.25$, $\phi = 2.0$ and $\eta = 0$



(a) Total BAU costs with $c.v. = 0.25$, $\phi = 2.0$, $\omega = 0.29$ and $\eta = 0\%$



(b) Total BAU and MD costs with $c.v. = 0.25$, $\phi = 2.0$, $\omega = 0.29$ and $\eta = 0$

In order to test the effects of demand volatility, we have repeated the experiment with a higher coefficient of variation. These results are summarised in Figure 6-10. From these, we suggest:

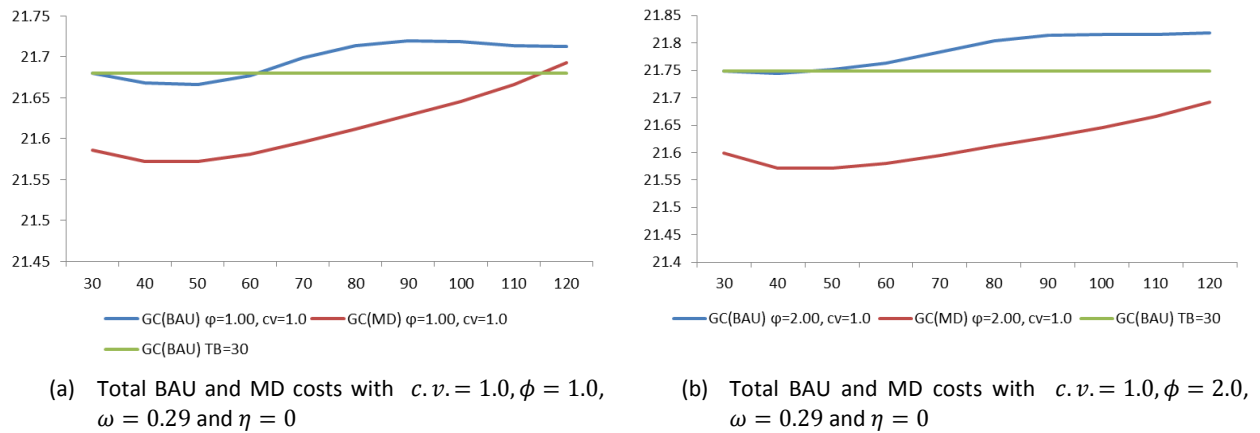
The effect of a payment term extension on the supplier also depends on demand volatility. Higher volatility induces a higher non-linearity effect on the total cost. Under higher demand volatility, suppliers with higher risk profile ϕ also have higher benefits when facing a payment term extension through reverse factoring than suppliers with lower risk profile.

Figure 6-10 shows a similar effect than in the previous two figures, with the difference that there is a higher non-linearity in the total cost curves. Thus, we also infer:

The higher the demand uncertainty is, the higher the non-linearity effect induced to the total cost of managing a cash and inventory system.

Likewise, we can see that unlike in Figure 6-8 (b), the cost of reverse factoring with payment terms extension becomes higher after a longer extension (120 days versus 100 days).

Figure 6-10: Extended payment terms with $c.v. = 1.0, \phi = (1.0, 2.0)$ and $\eta = 0$



Experiment 2b: Supplier indifference curve between BAU and reverse factoring with payment term extension and price reduction

In this experiment we looked for the supplier indifference curve between net profit at BAU and SCF. We specifically looked for MD with a price cut y and a payment term extension x that yields the same profit to the supplier as in the BAU case with $x = y = 0$. Payment term extensions impact the supplier's cost, but a price cut changes the supplier's revenue. Therefore, we need to consider net profit when drawing the supplier indifference curve. We calculate average net profit per period as follows:

$$\begin{aligned}
 & \text{Average net profit per period} \\
 & = \text{Average revenue per period} - \text{Average COGS per period} - GC_{(\cdot)}^* \\
 & = \frac{1}{T} \sum_{t=1}^T p \cdot D_t - \frac{1}{T} \sum_{t=1}^T y \cdot \{c \cdot Q_3 + f\} - GC_{(\cdot)}^*
 \end{aligned} \tag{6-2}$$

where the first term refers to average demand per period, the second term refers to the average expenses when ordering Q_3 from the $T2S$ and $y \in (0,1)$ is equal to 1 when the $T1S$ orders raw material at period t and is 0 when he does not order.

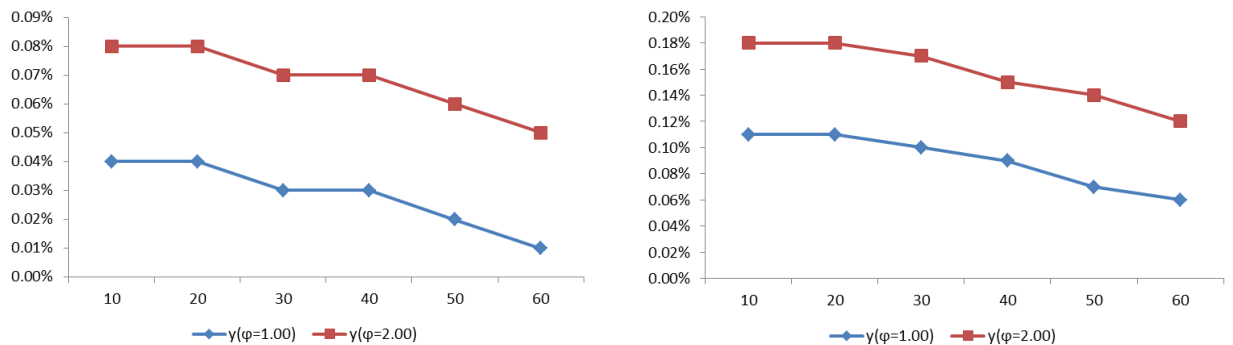
As reported by SC professionals and academics collaborating in this project, typically buyers want to extend payment terms that are currently low i.e. 30 days to 60 or 90 days, and it is less common that they demand extensions when payment terms are already high. Likewise, in many European countries average payment terms are around 30 days (EOS Group, 2014). We also know that benefits of SCF are lower for suppliers who have already long payment terms. Hence, our experiment considers the case of a supplier, who currently offers payment terms $TB = 30$, and measure the effect when TB is increased in steps of 10 days. Also, we consider risk profiles $\phi = (1.0, 2.0)$ and $\eta = 0$. We conclude the following:

The price cut y coupled with payment term extension x that leaves the supplier indifferent between BAU and SCF is too small to justify its implementation.

As seen in Figure 6-11, the price reductions necessary to leave the supplier indifferent are well below 0.3%. This is because the financial cost savings through SCF are very small with respect to the overall costs. Likewise, the impact of payment terms extension on total cost and net profit is minimal. In this sense, even though SCF has a big effect on financial and total costs, it does not affect much net profit. Hence, the necessary price cut to leave the supplier indifferent has to be very small. These findings are consistent with common supply chain practices, where price reductions are not conceded by suppliers when joining a SCF programme. In any case, suppliers with higher risk profile and with higher demand volatility are better positioned to concede higher price cuts. This is consistent with our earlier findings: suppliers with higher risk profiles and higher demand volatility benefit the most from SCF solutions.

Even though these findings suggest that price cuts are not sufficient to justify their implementation, we can expect that on a real setting, a company with a very high leverage, high financial costs and high demand volatility could concede a more significant price reduction to remain indifferent. Therefore, we suggest that the decision, if considered, should be studied carefully.

Figure 6-11: Supplier indifference curve for payment term extension and price cut



(a) Admissible cost reduction y for payment term extension x with $TB = 30$, $c.v. = 0.25$, $\phi = (1.0, 2.0)$, $\omega = 0.29$ and $\eta = 0$

(b) Admissible cost reduction y for payment term extension x with $TB = 30$, $c.v. = 1.0$, $\phi = (1.0, 2.0)$, $\omega = 0.29$ and $\eta = 0$

7 The potential role of a LLP

The experiments and numerical results have provided a better understanding of SCF solutions under complex systems. Based on our findings, we address the potential role of a LLP in SCF solutions. We also point out several managerial insights, strategic considerations and special recommendations. Therefore, this chapter answers research questions RQ5, RQ6 and RQ7.

7.1 The potential role of a logistics company

Logistics companies have been successful in the provision of transportation and logistics services to physical supply chains. LLPs have taken over the role of providing SCI services for the PSC in order to improve SC efficiency and operations performance. However, not much has been discussed about the role of these companies in the P/FSC integration. In the following paragraphs we study how logistics companies could tap their potential and direct their activities to also integrating the financial supply chain. We discuss three scenarios in which LLPs could operate: business as usual, SCF with no refinancing and SCF with refinancing.

7.1.1 *Business as usual*

In this section we describe the BAU model followed currently by certain LLPs. LLPs are firms that take over the transportation, logistics and supply chain management activities of their customers, typically material goods buyers. They are the party that serves as the interface between transportation providers or carriers and their buyer or receiver. By integrating information flows, they look for efficiencies and cost savings in the PSC in order to improve their customers' performance and bottom-line results.

Generally the BAU model operates as follows: the buyer sends purchase orders (POs) to material suppliers, who bundle them and send transportation requests (TRs) to LLPs.¹⁷ Based on contractual agreements, strategic considerations or operations convenience, LLPs select the most suitable transportation supplier i.e. a carrier, who will deliver the goods to the buyer. The buyer compensates the material supplier for the goods and the LLP for the transportation activities. On top of that, the LLP charges a (fixed) management fee to the buyer. The LLP subsequently compensates the carriers for the transportation services.¹⁸ In parallel, the material supplier goes to a FSP e.g. a bank to finance her working capital, albeit typically at a high cost. This model is represented schematically in Figure 7-1.

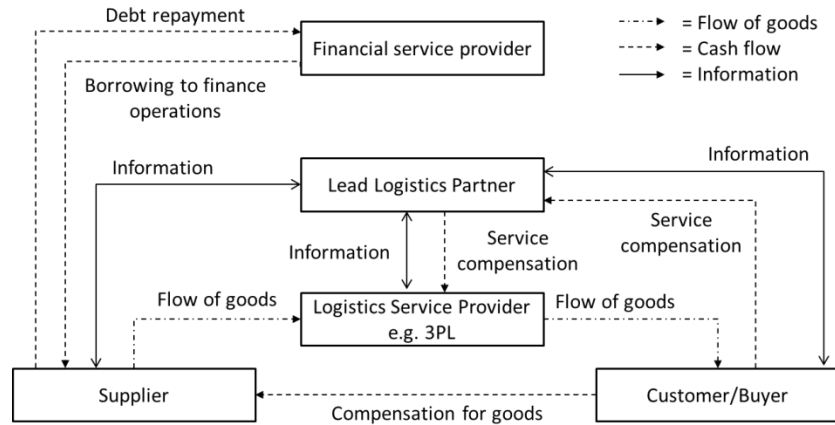
Under BAU the LLP serves as a PSC integrator: all information flows related to the PSC converge to the LLP, who increases visibility and commits to operational improvements. In this sense, by centralising

¹⁷ The LLP is also responsible for bundling i.e. consolidating POs and/or TRs into consolidated shipments. In many cases the LLP is dependent on the supplier to provide the actual ready to ship date, hence the supplier bundles POs ready at the same day. However the LLP checks, triggers and consolidates further if possible and necessary.

¹⁸ By collecting payments for transportation services on behalf of carriers, the LLP already integrates to some extent the FSC, although this does not purely represent a SCF solution.

information and the decision making process, the LLP improves the SC network design to achieve savings and efficiencies. In this scenario there is no integration of the FSC – there is no entity that actively aims at integrating it and look for efficiencies. Hence, each company independently manages its financial policy irrespective and very often at the expense of other firms. As shown in Figure 7-1, the supplier requests credit from a FSP independently of the financial activities of other SC partners.¹⁹

Figure 7-1: Conceptual framework – BAU



7.1.2 SCF with no refinancing

As reported in literature, typically when SCF is implemented, it is done independently of the LLPs: buyers approach a FSP, which provides financing via reverse factoring to the buyer’s material suppliers. Even though this has proven to be an effective way of decreasing working capital volume and its related cost, sometimes SCF implementations have failed (Seifert & Seifert, 2011), arguably either due to errors in implementation and execution and/or bad designs.

There are several conflicts of interests that permeate a supply chain. While buyers want to increase payment terms to reduce days payable outstanding (DPO) and reduce their cash conversion cycle (CCC), suppliers want to reduce payment terms to reduce days sales outstanding (DSO) and also reduce their CCC. This creates a conflict of interests, which is usually solved via negotiation. Even though SCF solutions help to (partly) resolve these conflicts of interests (Hofmann, 2009), very often suppliers – who have a lower bargaining power – are unsatisfied after SCF implementations. This is exemplified by Milne (2009), who has reported that certain corporations have introduced RF as a ‘sweetener’ to an unpopular decision to increase payment terms to suppliers. Several researchers and this study have concluded that this is an inefficient strategy since it induces a non-linear financing cost beyond the opportunity cost of carrying additional receivables (Tanrisever, et al., 2012; van der Vliet, et al., 2015), which may be difficult to predict under stochastic settings.

¹⁹ Although each company requests financing from FSPs, for simplicity we do not show this in our schematic model. Also, since supplier performance is the focus of this study, we only concentrate on the supplier financial activities.

Another conflict of interests emerges when a company borrows from a FSP, where the latter demands a risk-adjusted price for the provided debt capital in the form of interest. In order to calculate the price, the FSPs have an internal rating process to assess the creditworthiness of the borrower, which requires information provided by this company. As Hofmann (2009) discusses, the borrower (agent) knows his own creditworthiness very well but he does not wish to share this information to the full extent with the lender (principal), leading to problems of asymmetric information distribution, for which transaction costs arise (e.g. information costs, negotiation costs, monitoring costs).

These two conflicts pose a challenge to SCs. The possibility to design a solution to circumvent these may prove to be a valuable proposition for SC participants. We suggest that a good possibility to solve the described issues is to add an external company to the FSC that can proactively seek for a solution that mitigates the conflicts of interests and creates value for all the involved parties. This necessitates that this party has also sufficient knowledge and information about the SC, its operations and risk. Also, this entity needs to be an expert in implementations and executions. LLPs are recognised for being execution champions, which makes them a good candidate to fit this role. Also, LLPs are firms that already work close to the PSC of its customers and have sufficient knowledge of the supply chains they serve. Furthermore, LLPs are companies with experience on supply chain integration, possess a good IT infrastructure and analytical capabilities, and have sufficient data of the SCs they manage. They could leverage their position to design, plan and orchestrate the activities of the FSC and integrate the P/FSC.

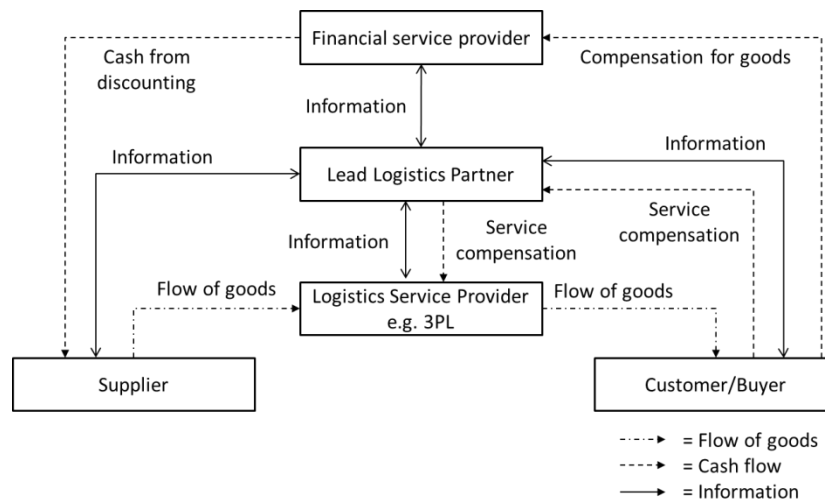
This new potential role does not represent a trivial challenge for the FSC integrator. Firstly, having to mediate between SC companies with conflicting interests is by itself a very hard task. Secondly, as buyers usually want to increase payment terms, the SC integrator would have to carefully gauge the non-linear effects on the total costs of the supplier and on overall SC performance. This task is made harder under a stochastic setting and long payment terms. Moreover, the overall impact on the supplier depends on the cost structure of these firms, especially under manual discounting (van der Vliet, et al., 2015). This causes that the analysis and design of an appropriate solution to be more complex and demanding, for which an experienced firm is required. Also, knowing well the SC and having the right experience to approach the lack of integration of the FSC is vital to engineer a good solution, which by no means is an easy undertaking. An LLP may prove to be the company with the necessary knowledge of the supply chain that also has good analytic means and experience to carry out this analysis and design. Finally, another advantage of having an LLP as the designer and orchestrator of SCF solutions is that this firm can use its position in order to look for the most competitive interest rate for the supply chain in the ways of providing better information visibility and transparency to the FSP. This will lessen the second conflict of interest pointed out hereinbefore: FSPs will have more and better access to the operations and financial activities of the supply chain, reducing thus the transaction costs and in this way the interest rate they charge.

Figure 7-2 proposes a conceptual framework of how a LLP could provide P/FSC services. Under this model, the LLP gathers information of the material and financial flows of the supply chain and designs an appropriate SCF solution in collaboration with the SC partners that guarantees that there is value creation for all partners, and that the proposed solution does not hurt (significantly) the interests of a particular partner. Also, the LLP pays special attention in reducing information asymmetries, and works

towards integration the material and the corresponding financial flows. For this end, an electronic platform is set for the exchange of information between the parties, and simultaneously orchestrates the operations and financial activities of the supply chain. By improving information visibility, several efficiencies are to be found, which will yield higher performance and savings. However, despite these benefits, the information asymmetry issue between capital providers and the supply chain may not be completely solved and asymmetries may always remain. Also, FSP participation and commitment is a critical success factor. The LLP also needs a very deep understanding of SCF, as well as analytic and IT capabilities to deliver sufficient value creation to supply chains. Finally, the LLP may be required to engage in certain costs e.g. by hiring financial specialists and investing in an (improved) electronic platform. However, the platform could be provided by the FSP.

A specific and deep business model for the LLP for this scenario is left out of scope of this dissertation. However, based on the current business model for the PSC integration, we infer that LLPs could charge a (fixed) management fee for their commitment to cost savings and higher performance. Also, a possibility where the LLPs can obtain a fraction of savings above expectations may further align SC interests.

Figure 7-2: Conceptual framework – SCF with no refinancing



7.1.3 SCF with refinancing

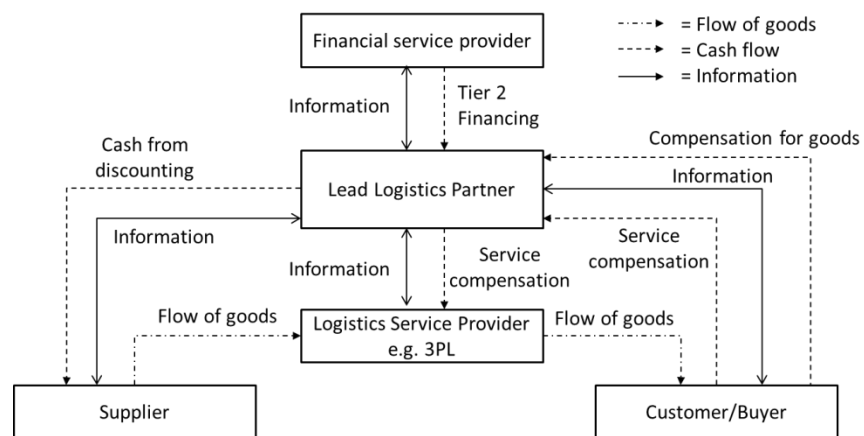
In the scenario without refinancing, the FSP is the only party that provides financing to the supply chain. There exists however another possibility, where the LLP provides direct financing to the supply chain and that she refinances with a FSP. Hence, the tier 1 financing is given by the LLP and the tier 2 by the FSP. This scenario is represented schematically in Figure 7-3. This new possibility brings in further benefits and challenges for the supply chain. These are discussed below.

The first and foremost advantage for the supply chain is that having the LLP directly financing the SC causes that there is a better alignment of interests between the LLP and the SC partners. Furthermore, being a party that better understands the SC risks, and by having a lower information asymmetry, the LLP could provide a more competitive rate than the one the FSP would offer. When the LLP also faces SC

risk, she will be inclined to be more selective when deciding which parties and invoices to finance²⁰. By taking over this risk (instead of the FSP), the interest charged by the FSP may be even lower, as the LLP will only take over manageable risks. Also, for the LLP this may represent a further opportunity of increasing revenues and increasing overall margins. Specifically, the new revenue stream will be the difference between the interest the LLP offers to the supply chain via RF and the interest that she pays to the FSP for refinancing this volume. Also, in case that the LLP is a creditworthy company, this could improve her profitability as it may be offered a lower refinancing interest.

There are certain disadvantages of this scenario. First, a potential conflict of interests between the LLP and the SC could take place. As the new revenue stream for the LLP improves with a higher interest charged to the supply chain, the LLP may be motivated to charge a higher interest to borrowers. This opportunistic behaviour can be contractually controlled by committing the LLP to deliver certain cost savings and efficiencies and setting good rewards in case performance is higher as expected. Another disadvantage of this scenario is that it necessitates that the LLP has a very high creditworthiness in order to (1) guarantee a low refinancing rate and (2) assure that its credit rating is not impacted considerably by increasing its risk exposure to payment defaults. The LLP needs to also understand very well all the risks that she is assuming e.g. country (political and economic), industry, firm specific risks, etc. Failure to understand them may prove to be highly dangerous. Finally, a final drawback is that the LLP may be required to engage in certain costs e.g. by hiring financial specialists and investing in an (improved) electronic platform, which otherwise would be provided by the FSP. However, Aberdeen Group (2007) notes an average investment of € 0.1-1.5 million in the electronic platform may be quickly recovered.

Figure 7-3: Conceptual framework – SCF with refinancing



In the table below, we present an overview of the advantages and concerns from each of the three possible scenarios that have been discussed hereinbefore.

²⁰ Nevertheless, the LLP has resources to significantly reduce this risk. A possibility is having a frame contract between the SC parties at place, and also having a payment guarantee contract with the buyer to assure that no default will take place.

Table 7-1: Advantages and Concerns of SCF Scenarios

Scenario	Advantages	Concerns
Business As Usual	<ul style="list-style-type: none"> – Every party is independent and flexible to decide its own cash management policy. – Convenient when supplier-buyer relationship is short term and/or not strategic. 	<ul style="list-style-type: none"> – Inefficient allocation of capital in supply chains. – Supplier weakening and higher disruption risk. – No party proactively integrates FSC. – No long-term value creation. – Lack of integration of P/FSC
SCF with No Refinancing	<ul style="list-style-type: none"> – LLP actively seeks to create value and find efficiencies. – FSP has better access to SC information and visibility, enabling lower borrowing cost. – Full participation of FSP may bring in better experience and know-how of SCF to supply chain. – LLP concentrates solely on solution orchestration. – No conflict of interests between LLP and supply chain. 	<ul style="list-style-type: none"> – Challenge to mediate between SC partners and between SC and FSP. – LLP requires deep financial understanding, as well as analytic and IT capabilities to create value. – FSP participation and commitment is critical success factor. – Information asymmetry (though lessened) between supply chain and capital provider remains. – LLP may require investing in resources to provide orchestration activities.
SCF with Refinancing	<ul style="list-style-type: none"> – LLP actively seeks to create value and find efficiencies while controlling for risk exposure. – Supply chain outsources transaction costs related to finding financing to the LLP. – Information asymmetry between capital provider i.e. LLP and supply chain is minimal. – LLP may offer lower interest rate than FSP due to better SC understanding. – SC and LLP interests are aligned thanks to LLP's risk exposure. – LLP has new source of income. – Convenient when LLP has better credit rating than buyer. 	<ul style="list-style-type: none"> – Challenge to mediate between SC partners and between SC – LLP requires deep financial understanding, as well as analytic and IT capabilities to create value. – LLP has to be a very creditworthy company. – LLP is exposed to new default risks, for which its credit rating and borrowing rate may be impacted. – LLP has motivation to charge higher rate to achieve higher profits (this behaviour can be minimised through contracts). – LLP may require investing in resources to provide orchestration and financing activities.

7.2 Strategic considerations

Having discussed the main takeaways of this study and the potential roles of a LLP in a SCF solution, we proceed now with strategic considerations, which are mostly based on the experiments. With these, we aim at pointing out managerial issues to be addressed to assure that the LLP can propose a value adding solution to its customers and their supply chains.

7.2.1 Customers to approach / target groups

Based on the experiments, suppliers with lower gross margins benefit the most from SCF solutions. Based on the research of Damodaran (2015), where he obtained the margins for several industries in the US, we propose certain manufacturing industries that could potentially benefit from SCF. In this study we used gross margin (revenue minus cost of goods sold) to define one of the dimensions of supplier profile. The closest indicator to our definition of gross margin in Damodaran's survey is $\frac{EBITDA+SG\&A}{Revenue}$.²¹

Based on the data published by Damodaran (2015), the average gross margin of all industries was 30.42%. As a rule of a thumb, we selected the industries that are below or slightly above this average. We found that Steel, Auto Parts and Trucking, Retail (Automotive, Grocery and Food, General and Online) Aerospace/Defence, Hospitals/Healthcare Facilities, Chemical, Construction and Building, Packaging & Container, Paper, Shipbuilding & Marine, Rubber & Tires, Electronics, Metals & Mining, Semiconductor Equipment and Machinery are good candidates for SCF, as all these have a margin between 14 and 35%. The complete list of industries and margins is found in Appendix 11.

It is also well known that industries begin after certain time to "commoditise", for which margins tend to become smaller and competition rougher. The LLP should pay attention to this trend and find commoditising industries, since they may become excellent recipients of SCF solutions.

It is also important to select the kind of companies that would be more interested in SCF as a VAS by the LLP. We recommend that the LLP addresses clients, with whom she already has a long relationship, rather than new customers. Having more trust, knowledge of the customer and her supply chain, and a story of successes may serve as arguments for the LLP to better persuade the customer to join a SCF programme. Nevertheless, we do not discard a possible scenario in which a new customer may be motivated to join a SCF programme.

Furthermore, depending on whether the approached LLP customer would act as a supplier or as a buyer, we recommend the LLP to specifically follow these points to assure higher success possibilities:

Suppliers – In case the party is a supplier, we consider an outbound supply chain, where the supplier sells his goods to several customers. We recommend the following buyer profile to approach:

- The supplier needs to have a moderate to high risk and hence a high cost of financing to maximise interest rate arbitrage and thus financial savings.
- SCF relies on coordination, cooperation and information sharing, for which the supplier needs to have a well-developed and long-term relationship with the buyer to assure buyer interest
- If a buyer wants to extend payment terms, SCF may prove to be a win-win solution for the companies. The role of the LLP may prove crucial to assure that the supplier obtains a good deal and does not lose too much value when extending payment terms.

²¹ EBITDA refers to Earnings before Interests, Taxes, Depreciation and Amortization. SG&A denotes Selling, General and Administrative Expenses. By summing these two amounts we arrive to Gross Revenue.

- If customer demand is uncertain, the supplier benefits more. The LLP should look for these kinds of suppliers to increase savings.
- If the supplier already grants long payment terms, SCF may let her have access to have cheap financing, despite benefits being lower to firms who grant shorter payment terms.
- Suppliers located in developing economies, and especially SMEs, have limited sources of financing, which are often expensive and require significant collateral. Suppliers in developing markets are very good candidates for SCF.

Buyers – In case the approached party is a buyer, we consider the case where a buyer offers SCF to a group of suppliers. We recommend the following buyer profile to approach:

- Buyers that are looking to improve the overall performance of their SC, reduce disruption risk and increase supply chain strength may find in SCF a good strategy to achieve these goals.
- Buyers that strongly rely on specific suppliers may feel more inclined to help these suppliers become (financially) stronger.
- Buyers that are interested in including a considerable amount of their supply base (at least 60%) in the first wave have better possibilities of success (Seifert & Seifert, 2009)
- Buyers that are interested to propose SCF to their suppliers but that are unsure about its consequences, how to design it, negotiate and implement it, may be also excellent candidates to hire the LLP to conduct the design and orchestration activities.
- Buyers dealing with suppliers located in developing countries may be even keener on exploring offering SCF to their suppliers.

7.2.2 Defining the role to follow

We have pointed out two roles that the LLP could follow. Now, we provide certain factors LLPS may consider when deciding which role to follow. Nevertheless, we emphasize that it is possible that the LLP follows both roles simultaneously, depending on several strategic considerations.

SCF with no refinancing: We recommend SCF with no refinancing if:

- The LLP does not have a competitive borrowing rate and good credit rating.
- The LLP has strong reasons to believe that financing the supply chain would have an impact in its creditworthiness and credit rating due to higher risk exposure.
- There are no sufficient resources to limit risk exposure for financing supply chain.
- The supplier in question is located in a geography with high perceived country risk (political and economic), currency risk (exchange rate, devaluation) and cultural risk (cultural patterns, honouring contractual obligations), for which selecting a (local) FSP may be more convenient.²²
- The supplier is located in a geography where the LLP cannot find a landscape to serve the needs of the LLP's customer

²² This represents an example in which the LLP may not provide financing to a specific supplier within the whole supplier base e.g. due to her higher geographic risk, but may simultaneously finance other suppliers.

SCF with refinancing: We recommend SCF with refinancing if:

- There is a considerable positive spread between the offered rate to the SC and the LLP borrowing rate, which would justify the new risk exposure.
- The new revenue flow has a considerable good impact on LLP margins and profitability.
- The internal due diligence has positive results and the LLP has good resources to limit risk exposure e.g. via a guarantee contract.
- The SC supports LLP financing in order to align the LLP interests (especially via risk exposure) with the ones of the SC.
- It is possible to set a good contractual structure in order to control conflict of interests where the LLP wants to maximise profit at the expense of the SC. This can be done by commitments of the LLP to deliver SC savings and increased performance.

7.2.3 Approach to the Financial Service Provider

Similar as in the case of the customer, we believe that the best FSPs to approach are the ones with whom the LLP or the buyer already has a long relationship and trust. This may enable that better knowledge facilitates the introduction of a SCF solution. However, a new FSP may also prove to be a good option if current or past FSPs have not been very successful. Also, we recommend LLPs to look for FSPs that already have experience in providing SCF and reverse factoring. Finally, Seifert & Seifert (2009) suggest that having a FSP with a good bank's geographic reach, legal expertise and its financial muscle is crucial for a successful SCF implementation.

Once a FSP has been selected, the LLP may approach her accompanied with the buyer, especially in the case of no refinancing, since the latter is the party that ultimately borrows from the FSP, even though the suppliers pay the financial cost. By committing to provide further visibility and information to the FSP, information asymmetries should decrease and with it transaction costs, leading to a more competitive interest rate offered to the SC. The LLP and the buyer should also make sure that the FSP is also considered a partner under the SCF mechanism and not a mere financial provider. As such, the FSP should also be provided with a win-win deal that satisfies her interests. Furthermore, it should be emphasised that the FSP gets access to new markets and new customers. Also, special attention needs to be given that the FSP has new sources of income at a low risk. And despite the interest rate is low, the transaction volume may prove to be a sufficient flow of income to justify the FSP participation. Another advantage for the FSP is that she can effectively build credit history of the borrowers (possibly for future commercial relations) and serve companies that were once inaccessible, especially SMEs. Also, in the case of suppliers located in emerging economies, whose access to conventional financing is low due to market frictions and lack of maturity of the financing industry, the FSP could educate them and facilitate future commercial relationships. Hence, this could prove to be a good chance for the financing sector to penetrate a new market without facing a significant risk.

If the FSP is approached for a refinancing deal, the risk does not lie anymore (or at least directly) with the buyer and the supply chain, but with the LLP. Therefore, the creditworthiness of the LLP will be

crucial to assure that the FSP wants to join the programme and that she offers a competitive interest rate. Consequently, the LLP should exhaust all resources to reduce her exposure to risk.

7.2.4 Other strategic considerations

LLPs also need to pay attention to van der Vliet's (2015, p. 18) typology of SCF practices. The author has defined two dimensions for SCF practices: strategic objectives and implementation tactics. These dimensions are considered strategic and tactical because they concern decisions on the aims of SCF and on the methods used to reach those aims respectively. As a first step, the LLP needs to identify and if necessary, guide the strategic objectives of the customer. This dimension has Transaction-oriented SCF on one extreme and Competence-oriented SCF on the other. Each one is defined as:

- Transaction-oriented SCF: focus on achieving transactional benefits through working capital benefits or savings in capital cost e.g. payment terms extension and/or price reduction.
- Competence-oriented SCF: enhance a supply chain competence, such as supply base agility. In order to realise supply chain competencies it is generally required that firms invest in resources.

As pointed out hereinbefore, the motivation of the buyer could be to improve her working capital position and achieve savings through SCF. On the other hand, the buyer may be seeking to improve the competencies of her supply chain, for which SCF may be adopted to demand supplier investments in performance. For instance, savings may be used by the material supplier to increase capacity, product quality and reduce lead times. As these two ends in this dimension are opposites, it is important that the LLP recognises the buyer's objectives, and possibly guides the supply chain (through his role as mediator) to a goal that brings value to each entity in the supply chain.

The second dimension, Implementation Tactics, has also two opposite dimensions:

- Uniform Implementations: the initiating firm follows roughly a single specification for all SCF arrangements with participating suppliers
- Customised Implementations: the initiating firm adjusts the type and terms of the agreement to fit the nature their supply relationship(s). Terms offered to each supplier are tailored to the size of the transactional benefits that SCF yields for each supplier

In the case of uniform implementations, the initiator (typically the buyer) aims at providing several suppliers roughly the same arrangement. It can be assumed that initiators follow uniform implementations to avoid the costs of customisation, very often at the expense of suppliers, who may face an arrangement that harms their performance.

Being execution champions, LLPs could bring supply chains a higher degree of customisation than the one they would achieve on their own. Van der Vliet (2015) reports that customisation measures may increase total return of an SCF arrangement, for which a great investment in technology and administration is necessitated. This investment could be accordingly done by the LLP, possibly with the cooperation of the FSP. Also, customisation may also entail a more prominent role for the FSP due to this party's specialization in financial analysis. Furthermore, for a competence-oriented SCF

arrangement, a customization tactic may even bring about further complexities. For instance, buyers may be exposed to agency and moral hazard problems. Suppliers may divert extra liquidity and funding for personal interests or to serve other investments other than the one agreed between the parties e.g. investment on performance. However, literature on customisation measures for ensuring effective supply chain investment from SCF arrangements is yet limited (van der Vliet, 2015).

Apart from the discussed strategic considerations, we present other success factors that LLPs should contemplate. The first and foremost is internal sponsorship. Seifert & Seifert (2009) have found that SCF implementations are twice as much successful when the CEO leads them rather than the CFO. Hence, LLPs need to assure a high degree of sponsorship from customers. Likewise, their study acknowledges that supplier involvement is vital success factor. Their study found out that implementations are most successful when they include at least 60% of the supply-base in the first wave. Finally, another important issue to consider is the degree of complexity existing at the SC. As mentioned in the literature review, SCF entails very often a clear IT challenge, with the risk of data being fragmented and the challenges of common sharing and interfacing (Steeman, 2014). Despite LLPs are parties that already deal with high complexity in the PSC, it may be advisable to ask for a more collaborative partnership of the FSP, especially regarding the IT Platform.

All in all, being an execution expert that serves as a mediator between SC partners, the LLP could provide a solution that yields better benefits for SC participants than the one they would have on their own. This can be achieved by delivering a solution that matches the interests of the supply chain (or convince the SC of a better objective), and by implementing a more customised solution that maximises total return of the SCF arrangement.

8 Conclusion

This chapter concludes this dissertation. We do so by pointing out the main takeaways from the experiments, by briefly discussing the potential role of LLPs in SCF solutions and by stating the limitations to this research, as well as further research opportunities.

8.1 Main takeaways from experiments

In order to provide LLPs with the necessary understanding about SCF solutions, this study built on previous academic efforts to create a more complex model in order to describe, explain and predict how SCF creates value in supply chains. For this goal we developed a continuous-time stochastic inventory and cash management model of a supplier firm that sells finished goods to a single buyer, sources raw material from a tier 2 supplier and manufactures the goods in an internal plant. In the BAU scenario, the supplier has a cash management policy that allows him to borrow money from a line of credit in case the cash level is below a certain threshold, and to repay the debt or pay out dividends in case the cash level is above a certain threshold. By assuming that the buyer is a creditworthy one, we modelled for the scenario in which the buyer offers SCF to the supplier in the way of reverse factoring, letting him obtain quicker cash at a cheaper rate. Specifically, the supplier has the option of discounting all receivables automatically i.e. as soon as it is possible to sell the receivable to the factor, or manually i.e. whenever he is required according to the cash management policy.

Our findings are consistent with previous literature that has employed more simplified models. SCF solutions also create value and improve performance at more complex systems. As this study acknowledges that a supply chain is as strong as its weakest link – typically suppliers – we have focused mainly on the performance of these firms. Our approach had its main focus on financial and total cost savings. When firms reduce their costs, their profitability and their bottom-line improves. Likewise, we have found that cash flow volatility is significantly reduced through SCF. When firms reduce cash flow volatility, they also reduce their risk perception and therefore improve their capital sourcing cost, or its weighted average cost of capital (Brealey, et al., 2011), which enables a higher enterprise value. Also, by having lower cash flow volatility, suppliers and supply chains can improve their analytic capabilities, enhance forecasts and make better decisions.

In order to test under which circumstances SCF solutions create (more) value, we have proposed two main supplier profiles: risk and gross margin. Also, we tested these profiles for suppliers with different demand uncertainty and with different payment terms. We have found that generally suppliers with a higher risk profile (and thus higher borrowing costs), lower gross margins, with higher demand uncertainty and with lower offered payment terms benefit the most. We argue that despite these kinds of firms are the better recipients of SCF solutions, other suppliers may benefit as well and the decision to implement SCF should be studied by every firm carefully.

With the purpose of testing company concerns regarding the decision to adopt SCF, we have found in literature that suppliers mostly are affected when their buyers condition the introduction of SCF with payment terms extension. Past studies have found out that when buyers extend payment terms, the total benefits for the supplier are reduced, making it an inefficient strategy (Tanrisever, et al., 2012; van der Vliet, et al., 2015). These studies have been made with the aid of simplified simulation models. We were able to validate previous findings on a more complex setting and we have found out that payment terms extension induces a non-linear effect to the total cost for the supplier, which may be hard to measure. The extension reduces the benefits that the supplier gains from a SCF solution, and this reduction depends on the supplier's cost structure and demand volatility. Hence, we argue that the decision to extend payment terms under a stochastic setting has to be very well studied by managers.

Finally, this dissertation addresses an uncovered topic in literature – the trade-off between payment terms extension and price cut. The main motivation for this study is the fact that suppliers typically transfer their working capital financing costs to their customers when these have aggressive cash management practices (He, et al., 2011). We looked for the price for a given payment term extension under reverse factoring that would yield the same profit to the supplier as the one under an initial BAU scenario with no payment term extension and price cut. Our findings suggest that the price cut required to leave the supplier indifferent between BAU and SCF with extended payment terms is too low to justify its implementation. This may explain why this possibility is not practiced in supply chains.

8.2 Final thoughts

In the first pages of this dissertation we have pointed out how the lack of integration in the FSC has led to a higher disruption risk, lower performance, higher costs, and above all, a structural weakness. When a supplier has no access to competitive sources to finance working capital, his performance may be impacted, which ultimately could lead to a disruption. Also, we have discussed that the financial side of the supply chain could be an area of further efficiencies. This has led to a higher firms' interest in managing the FSC with an equally integrated view similar to the applied to the PSC, where the financial flows can be integrated with the material and information flows. Particularly, opportunities to improve the efficiency of working capital by unlocking cash trapped in the FSC have been recognised as a potential area of improvement. We theorise that an LLP could be a good candidate to be the entity that directs efforts to achieve these objectives. In this sense, the LLP could drive and facilitate the introduction of SCF arrangements, which account for SC strategies and firm-specific interests.

In order to assist LLPs in generating better understanding of SCF solutions, we have explained how value can be created with reverse factoring in a complex system. We have provided the conditions, supply chain characteristics and situations under which SCF creates value. We accomplished this with the aid of a discrete event simulation model. By following a design of experiments, we have found that companies with lower margins, higher risk profiles, with higher demand uncertainty and low payment terms benefit the most from reverse factoring. Also, we have tested the effect on the total cost of extending payment terms. Our findings are consistent with previous literature. Extending payment terms induces a non-

linear effect on the total cost of managing an inventory and cash system and the benefits of SCF reduce with longer payment terms. Especially, the effect depends on the supplier cost structure and demand uncertainty. In our last experiment we also concluded that offering reverse factoring with payment terms extension and price cuts may not be a reasonable proposition, as the price cut to leave the supplier indifferent between BAU and reverse factoring with extended payment terms is too small to justify its implementation.

We have also discussed several strategic considerations such as target groups and supply chain characteristics that facilitate a more successful SCF adoption. Similarly, we proposed two roles that the LLP could follow: (1) solely as a designer and orchestrator; or (2) as designer, orchestrator and first provider of financing. Based on these, we discussed several considerations LLPs need to bear in mind for a successful programme. LLPs need to put special focus on which customers to seek, the role to follow and the approach to the FSP. All this also has to be done following several managerial considerations, such as the mentioned Strategic Objectives and Implementation Tactics.

All in all, SCF may prove to be a successful new path for LLPs. If LLPs succeed in meeting the demand for consolidating and innovative solutions to integrate the PSC with the FSC, they will not only aid their customers in becoming more competitive, but they will differentiate from other logistics firms in a commoditising industry and become more profitable. More than that, if LLPs take a more integral approach and shift their attention towards the FSC, they could integrate the FSC via SCF as a value added service and release their potential to become full supply chain integrators. Being execution champions, LLPs could bring in new possibilities for companies that are still unsure to embark on SCF implementations. Yet, this is not an easy task and it is still necessary that LLPs generate better understanding of SCF solutions. SCF implementations represent also an IT challenge, and only LLPs with good integration and analytical capabilities may provide positive results. Finally, there is a general consensus that the market is not yet fully mature to embark on SCF solutions. This poses a challenge to supply chains and LLPs, as it may be required to educate firms, especially suppliers, on financial and working capital management, to unleash the full potential of SCF solutions.

In any case, there is definitely a market for SCF solutions, but corporations and their CFOs have not yet found ways to integrate their P/FSCs successfully, or have not yet seen the need of integrating them. Bearing in mind that there is no more expensive money than the one a firm lacks, and that there is currently a structural weakness in supply chains, it is imperative to look for a new design to overcome the described difficulties that suppliers face. . In a world where competition is no longer between corporations but between value chains, LLPs may prove to be the entities that achieve a paradigm shift and bring SCF solutions to life.

8.3 Limitations and further research

Despite this study provided a good amount of insights, it is not exempt of limitations. First of all, due to certain constraints with the optimisation software, the optimisation procedure needed to be simplified and certain assumptions were made. With the described method, the impact of the financial

management on the operations was minimised. In reality, operations and finance are interconnected. There is evidence that inventory decisions can interact with the receipt and/or provision of trade credit (Protopappa-Sieke & Seifert, 2010). Also, the financial mechanism also impacts inventory decisions and performance (van der Vliet, 2015). A follow up study may be necessary, in which our assumptions are relaxed and the effect of cheaper credit through reverse factoring on operations is studied in depth.

Our study has assumed full and complete information availability, transmission and access. In a real setting this does not occur – there are always frictions and information imperfections that may hold. A study that measures the value creation of SCF on a system with imperfect information may be a fruitful research path.

Another limitation is the fact that our model was not tested on actual data. Bertrand and Fransoo (2002) state that Operations Research (OR) should study models that are closer to real-life processes, and that their analysis results should be tested in real life. Thus, theoretical quantitative research should be combined with empirical quantitative research. The original objective of this study was to conduct the simulation with empiric data. For several reasons, this path had to be abandoned. A follow-up study that models a stochastic inventory and cash management system of a SC based on a true case study with empiric data may support theory building within OM (Eisenhardt & Graebner, 2007; Meredith, 1998).

Furthermore, due to lack of information on the operations and cash management policy of an empiric case study, our model was rather generic. It would be of great interest to develop a model based on a specific supply chain to describe, explain and predict SCF value creation not only on a more complex system, but at a real setting.

Finally, we present several possible future investigation paths that we believe may prove fruitful. First, developing a model that has a more realistic cash management policy may deliver further insights into the effects of SCF. A policy that considers future cash outflows and position to its decision making process may better resemble reality, especially when applying automatic discounting. Also, a model that is expanded to include various products and suppliers, and thus more complexity, may be an interesting path for buyers interested in implementing SCF on a larger scale. As well, a study that investigates SCF with reversed roles, where the supplier – and not the buyer – is the party with the higher creditworthiness and bargaining power, may provide great insights for customers that are under such circumstances and that are in need of financing. Examples of these firms are retailers. Another possible research path is considering SCF for financing services e.g. transportation. Under this scenario, the LLP would be able to finance payments to its 3PLs and carriers. This research also mentioned that SCF could be used to improve SC agility and performance. A study that links SCF with improvements in performance may be of great value to SCF initiators. Finally, this study did not address specifically the subject of the electronic platform that the LLP would use in order to integrate the FSC.

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Appendix

Appendix 1. List of deterministic parameters

Table A-1: Deterministic parameters

Symbol	Name	Value	Unit
b	Supplier penalty cost	1	EUR/(unit*day)
bs	Production batch size	10	Units
c	Unit cost paid by supplier	See below	EUR/unit
e	Echelon number	(1,2,3)	Dimensionless
f	Fixed ordering cost paid by supplier	See below	EUR/order
h^e	Supplier holding cost	(0.04,0.05,0.05)	EUR/(unit*day)
l	Length of one period	1	Day
p	Supplier offered price to buyer	10	EUR/unit
w	Unit value after supplier processing	8	EUR/unit
y	Binary variable indicating when supplier i orders	(0,1)	Dimensionless
α	Opportunity cost of retaining cash for supplier i	0.08	%/year
β	Interest borrowing rate for supplier i	Depending on experiment	%/year
γ	Reverse factoring discount	0.03	%/year
η	Opportunity cost of holding AR for supplier i	Depending on experiment	%/year
χ	Minimum of periods to elapse before discounting is possible	10	Days
Q_e	Fixed order under R,Q inventory policy for $e = 1,3$	See below	Units
R_e	Reorder point under R,Q inventory policy for $e = 1,3$	See below	Units
r_2	Minimum inventory level at output buffer	See below	Units
R_2	Maximum inventory level at output buffer	See below	Units
TH_{max}	Maximum supplier cash threshold	See below	EUR
TH_{min}	Minimum supplier cash threshold	See below	EUR
TB	Payment term granted to buyer	Depending on experiment	Days
TS	Payment term granted to supplier	30	Days

Table A-2: Deterministic parameters for experiments with $c. v. = 0.25$

Parameters	$\omega = 0.25$	$\omega = 0.29$	$\omega = 0.32$	$\omega = 0.4$
c	6.65	6.3	5.6	4.9
f	28.5	27	24	21
R_1	43	44	45	41
Q_1	14	15	15	14
r_2	20	16	25	25
R_2	42	44	35	30
R_3	14	17	18	18
Q_3	35	32	20	20

Table A-3: Deterministic parameters for experiments with $c. v. = 1.0$

Parameters	$\omega = 0.29$
c	6.65
f	28.5
R_1	41
Q_1	195
r_2	200
R_2	400
R_3	20
Q_3	40

Table A-4: BAU Cash management policy, $c. v. = 0.25$ and $\eta = 0$

Scenario	$\phi = 0.50$	$\phi = 0.75$	$\phi = 1.00$	$\phi = 1.25$	$\phi = 1.5$	$\phi = 1.75$	$\phi = 2.00$
$\omega = 0.25$	TH_{max}	200.0	200.0	200.0	200.0	200.0	200.0
	TH_{min}	199.0	199.0	199.0	199.0	199.0	199.0
$\omega = 0.29$	TH_{max}	219.5	200.0	200.0	200.0	200.0	200.0
	TH_{min}	197.7	196.3	188.3	199.0	199.0	199.0
$\omega = 0.32$	TH_{max}	297.7	200.0	200.0	200.0	200.0	200.0
	TH_{min}	100.0	199.0	199.0	199.0	198.0	199.0
$\omega = 0.4$	TH_{max}	200.0	200.0	200.0	200.0	200.0	200.0
	TH_{min}	181.3	199.0	199.0	199.0	198.0	199.0

Table A-5: MD Cash management policy, $c. v. = 0.25$ and $\eta = 0$

Scenario	$\phi=0.50$	$\phi=0.75$	$\phi=1.00$	$\phi=1.25$	$\phi=1.5$	$\phi=1.75$	$\phi=2.00$
$\omega = 0.25$	TH_{max}	326.3	326.3	326.3	326.3	326.3	326.3
	TH_{min}	103.5	100.0	100.0	100.0	103.5	100.0
$\omega = 0.29$	TH_{max}	200.0	200.0	200.0	200.0	200.0	200.0
	TH_{min}	196.3	188.3	199.0	199.0	199.0	199.0
$\omega = 0.32$	TH_{max}	200.0	200.0	200.0	200.0	200.0	200.0
	TH_{min}	100.0	100.0	100.0	100.0	100.0	100.0
$\omega = 0.4$	TH_{max}	200.0	200.0	200.0	200.0	200.0	200.0
	TH_{min}	100.0	100.0	100.0	100.0	100.0	100.0

Table A-6: BAU Cash management policy, $c. v. = 1.0$ and $\eta = 0$

Scenario	$\phi=0.50$	$\phi=0.75$	$\phi=1.00$	$\phi=1.25$	$\phi=1.5$	$\phi=1.75$	$\phi=2.00$
$\omega = 0.29$	TH_{max}	200.0	200.0	200.0	200.0	912.3	1,459.8
	TH_{min}	100.0	100.0	100.0	100.0	100.0	103.6

Table A-7: MD Cash management policy, $c. v. = 1.0$ and $\eta = 0$

Scenario	$\phi=0.50$	$\phi=0.75$	$\phi=1.00$	$\phi=1.25$	$\phi=1.5$	$\phi=1.75$	$\phi=2.00$
$\omega = 0.29$	TH_{max}	200.0	200.0	200.0	200.0	200.0	200.0
	TH_{min}	100.0	100.0	100.0	100.0	100.0	100.0

Table A-8: BAU Cash management policy, $c. v. = 0.25$ and $\eta = \gamma$

Scenario	$\phi=0.50$	$\phi=0.75$	$\phi=1.00$	$\phi=1.25$	$\phi=1.5$	$\phi=1.75$	$\phi=2.00$
$\omega = 0.25$	TH_{max}	200.0	200.0	200.0	200.0	200.0	200.0
	TH_{min}	199.0	199.0	199.0	199.0	199.0	199.0
$\omega = 0.29$	TH_{max}	200.0	200.0	200.0	200.0	200.0	200.0
	TH_{min}	196.3	199.0	199.0	199.0	199.0	199.0
$\omega = 0.32$	TH_{max}	200.0	200.0	200.0	200.0	200.0	200.0
	TH_{min}	199.0	199.0	199.0	199.0	199.0	199.0
$\omega = 0.4$	TH_{max}	200.0	200.0	200.0	200.0	200.0	200.0
	TH_{min}	199.0	199.0	199.0	199.0	199.0	199.0

Table A-9: AD Cash management policy, $c. v. = 0.25$ and $\eta = \gamma$

Scenario	$\phi=0.50$	$\phi=0.75$	$\phi=1.00$	$\phi=1.25$	$\phi=1.5$	$\phi=1.75$	$\phi=2.00$
$\omega = 0.25$	TH_{max}	200.0	200.0	200.0	200.0	200.0	200.0
	TH_{min}	100.0	100.0	100.0	100.0	100.0	100.0
$\omega = 0.29$	TH_{max}	200.0	200.0	200.0	200.0	200.0	200.0
	TH_{min}	100.0	100.0	100.0	100.0	100.0	100.0
$\omega = 0.32$	TH_{max}	200.0	200.0	200.0	200.0	200.0	200.0
	TH_{min}	100.0	100.0	100.0	100.0	100.0	100.0
$\omega = 0.4$	TH_{max}	200.0	200.0	200.0	200.0	200.0	200.0
	TH_{min}	100.0	100.0	100.0	100.0	100.0	100.0

Appendix 2. List of stochastic parameters

Table A-10: Stochastic parameters

Symbol	Name	Parameters	Unit
μ_D	Mean demand per period	10	Units/Day
σ_D	Demand standard deviation	(2.5,10)	Units/Day
D_t	Customer demand for supplier i product k at time t	$LOGN \sim (\mu_D, \sigma_D)$	Units/Day
E	PO inter arrival time	1	Day
LB_0	Supplier incoming order processing time	1	Day
LB_1	LSP pick up delay	0	Days
LB_2	Time on transit	$Erl(k = 2, \lambda = 1)$	Days
LB_3	Logistics lead time	$1 + Erl(k = 2, \lambda = 1)$	Days
LB	Total delivery lead time to buyer	$1 + Erl(k = 2, \lambda = 1)$	Days
LS_2	Production lead time	$Erl(k = 3, \lambda = 5)$	
$LS_{1,3}$	Total delivery lead time to echelon e	$Erl(k = 2, \lambda = 1)$	Days

Appendix 3. List of variables

Table A-11: Variables

Symbol	Name	Unit
AP_t	Supplier accounts payable balance	EUR
AR_t	Supplier accounts receivable balance	EUR
B_t^e	Supplier backordered units	Units
C_t	Supplier cash balance	EUR
DIV_t	Supplier dividend pay-outs on period t	EUR
F_t	Supplier borrowing on period t	EUR
GC	Average cost per period	EUR/day
G_t	Invoiced amount for buyer purchase order $PO_t^{i,k}$	EUR
H_t	Invoiced amount for supplier order $IO_t^{i,k}$	EUR
I_t^e	Supplier inventory on hand	Units
IP_t^e	Supplier inventory position	Units
LOC_t	Supplier level of line of credit at time t	EUR
PMT_t	Supplier expenses on period t	EUR
PO_t	Buyer purchase order	Orders
RP_t	Supplier debt repayment on period t	EUR
Z	Joint base stock and cash management policy	-

Appendix 4. Conceptual Model: BAU

The system can be envisaged as a multiechelon supply chain of four echelons $e = [1,2,3]$, where the warehouse corresponds to echelon 1, the output buffer as echelon 2 and the input buffer as echelon 3. Tier 1 suppliers face a customer demand stream at the WH and use a continuous-review $(Q_1^{i,k}, R_1^{i,k})$ control policy, based only on information at the WH . If the warehouse has sufficient inventory, then the order lead time consists only of transportation delay. Excess demand at the warehouse is backordered, and additional delays are experienced due to additional transportation delays and possible upstream stock-outs. The warehouse replenishes its stocks from the output buffer (OB) whenever the inventory position (inventory on-hand plus outstanding orders minus backorders) down-crosses level $R_1^{i,k}$.

The plant's manufacturing policy is a continuous-review $(R_2^{i,k}, r_2^{i,k})$ policy. The plant starts producing a batch size $bs^{i,k}$ once the OB inventory down-crosses level $r_2^{i,k}$. Production consumes one unit of raw material at the IB for each unit of OB. Production is stopped once inventory at the OB equals or exceeds $R_2^{i,k}$. Furthermore, shortages in raw material in the IB may lead to starvation, causing production to stop. The IB orders from the $T2S$ with a continuous-review inventory control policy $(Q_3^{i,k}, R_3^{i,k})$, who is assumed to have unlimited capacity in such a way that lead time is limited to transportation delay and plant's orders are always fully satisfied.

The buyer sends stochastic purchase orders $PO_t^{i,k}$ to the warehouse of supplier i at time t that contain the demand for *one* specific product type k with a quantity $D_t^{i,k}$, which follows a lognormal distribution.

Inventory on hand units for each echelon e of supplier i , product k at time t is denoted as $I_t^{i,k,e}$. Once a demand arrives at echelon 1 and 3, if it cannot be fully met from inventory, the available inventory is committed immediately and the unmet portion is back-ordered until the total portion is available. The amount of backordered units of k for supplier i , at time t is denoted by $B_t^{i,k,e}$, where $e = 1,3$. Note that the input buffer does not have backorders. However, in case of not having enough raw material the production can be starved.

Echelons 1 and 3 review inventory position in a continuous way, which is calculated as $IP_t^{i,k,e} = IP_{t-1}^{i,k,e} - D_t^{i,k} + IO_t^{i,k,e}$. Thus, the inventory position is reduced each time a demand is committed (demands are allocated to inventory on-hand or backorder). Demands to the warehouse are denoted by $D_t^{i,k}$ and demands to the input buffer are denoted are production batch sizes, denoted by $bs^{i,k}$. When inventory position at echelons 1 and 3 get to a level lower than $R_e^{i,k}$, inventory $IO_t^{i,k,e}$ is ordered. Based on the inventory policies, it follows that $IO_t^{i,k,1} = Q_1^{i,k}$ and $IO_t^{i,k,2} = Q_2^{i,k}$.

Lead times of material ordered by echelon e is defined as LS_e^i , where LS_1^i and LS_3^i refer to transportation delays and LS_2^i refers to manufacturing delay. All delays follow a Gamma distribution.

Suppliers pay price $c^{i,k}$ per unit of raw material needed to produce a unit of product k and pay a fixed cost f^i per order. Upon delivery to the IB, suppliers pay after a payment term of $TS^i \in \mathbb{N}^+$ periods. This means that upon arrival of the ordered goods demanded LS_1^i periods ago, the supplier books a quantity

$H_t^{i,k} = IO_t^{i,k,1} \times c^{i,k} + f^i$ to the accounts payable account AP_t^i and after TS^i periods he transfers the amount $H_t^{i,k}$ and balances the AP.

Upon arrival of raw material, the supplier processes the goods, consequently adding value to them. The processing time is denoted by LS_2^i and due to the added value, the inventory unitary value increases to $w^{i,k} > c^{i,k}$. We assume that suppliers hold only raw and finished goods inventory and that work-in-process inventory is negligible. Suppliers sell finished goods from the warehouse at price $p^{i,k} > w^{i,k}$ per unit. Each backlogged unit at the warehouse entails a penalty cost $b^{i,k}$ and for each unsold unit, the supplier incurs a storage cost $h^{i,k,e} < b^{i,k}$, where $e = 1,2,3$, where both costs are per unit per period.

We assume that the supplier has a delay of processing incoming customer purchase orders denoted by LB_0^i . Once a supplier i processes an incoming demand, he orders a transport request (TR) to deliver a PO to the buyer, there is a delay until the LSP picks up the order from supplier i which is denoted by LB_1^i . The time that a product remains on transit is denoted as LB_2^i . Thus, the total logistics lead time since a transport request is sent until it goods arrive to the buyer equals $LB_3^i = LB_1^i + LB_2^i$ and the total lead time for the buyer to receive an order equals $LB^i = LB_0^i + LB_3^i$. We assume that there exists an unlimited transportation capacity and that the buyer covers the transportation costs.

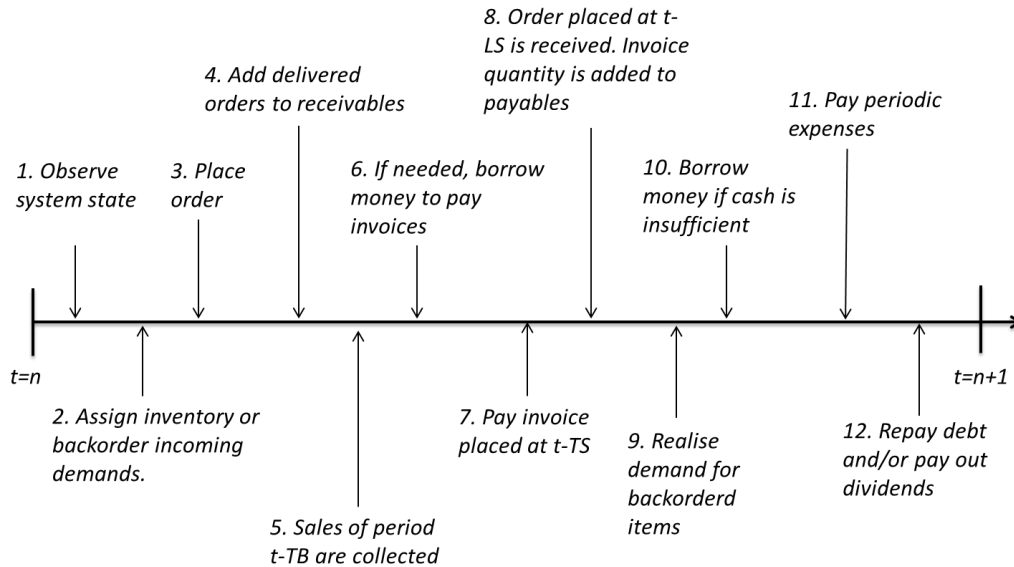
The supplier i grants the buyer a payment term of $TB^i \in \mathbb{N}^+$ periods. We assume that, as the buyer has a stronger bargaining position than the supplier, $TB^i \geq TS^i$ holds. The payment terms starts to count from the moment that a demanded order is delivered to the buyer. Upon arrival, the buyer accepts the order and commits to pay the monetary quantity of $G_t^{i,k} = D_t^{i,k} \times p^{i,k}$ after TB^i periods. The supplier books $G_t^{i,k}$ to the accounts receivable AR_t^i . At maturity i.e. at time $t + TB^i$ the buyer transfers a monetary quantity equal to $G_t^{i,k}$ and the supplier balances the AR to convert them into cash.

The supplier meets periodic expenses and maturing accounts payable with cash retained from previous periods or by borrowing from a bank. Borrowing is made via a line of credit (LOC), and only occurs whenever retained cash is insufficient. The supplier i requires a minimum cash threshold level $TH_{min}^i \geq 0$. At every moment, the cash level C_t^i is updated, which considers cash inflows from sales made TB^i periods ago and bank loans, and cash outflows from periodic payments PMT_t^i , which include fixed costs, variable expenses, holding and shortage costs and interest expenses. Other cash outflows include cash repayments to the LOC or dividend pay-outs. After each cash outflow, the supplier checks cash level, and if it is insufficient i.e. if $TH_{min}^i > C_t^i$, the supplier borrows from the line of credit the difference $F_t^i = TH_{min}^i - C_t^i$. Also, before each invoice payment to the T2S, the supplier checks what would be the cash level after paying the due invoice, and if cash level falls is expected below minimum threshold i.e. if $C_t^i - H_{t-TS^i}^{i,k} < TH_{min}^i$, the supplier borrows the quantity so that her cash level equals TH_{min}^i after the transaction by borrowing $F_t^i = TH_{min}^i - C_t^i + H_{t-TS^i}^{i,k}$.

If the cash level exceeds the maximum cash threshold $TH_{max}^i \geq TH_{min}^i$, the supplier balances the line of credit i.e. pays back to the FSP the surplus denoted by $RP_t^i = C_t^i - TH_{max}^i$. If at any moment t it occurs that $LOC_t^i = 0$ and $C_t^i > TH_{max}^i$, then the surplus is paid out as dividends to the shareholders for the amount of $DIV_t^i = C_t^i - TH_{max}^i$.

The annualised interest rate for borrowing equals β^i per unit per period. We assume unlimited borrowing capacity. Also, as shareholders could have invested retained cash elsewhere, an annualised opportunity cost of α^i is assessed on each monetary unit retained. In perfect capital markets (Modigliani & Miller, 1958), we should expect $\alpha^i = \beta^i$, but we assume that capital market frictions may entail $\alpha^i < \beta^i$ or $\alpha^i > \beta^i$ (Myers & Majluf, 1984; van der Vliet, et al., 2015; van der Vliet, 2015). We assume an opportunity cost rate of η^i per year on each monetary unit of AR that result from the payment term. We also assume $\eta^i < \alpha^i$ as the risk of investing in an account receivable is lower than the one of investing in the firm itself. Van der Vliet, et al. (2015) argue that this occurs because contrary to the settlement of the AR, which are due after a known delay, the timing of cash dividends from the firm depends on demand and realised profits, making dividends more uncertain than a future customer payment.

Figure A-1: Sequence of events at single period (BAU)



Based on the model description, Figure A-1 summarises the sequences of events in a period. At the start of the period, each echelon e at supplier i observes system state. At step (2), each echelon receives demands and assigns them by reducing inventory position $IP_t^{i,k,e}$ by the demanded quantity for $e = 1,3$. Also, each echelon reduces physical inventory by the demanded quantity and increases backorders in case demands are not fully met. At step (3) each echelon places orders quantity $Q_e^{i,k}$ if inventory position $IP_t^{i,k,e}$ is below reorder point $R_e^{i,k}$ for $e = 1,3$, and for $e = 2$ the plant begins manufacturing if inventory position is below $r_2^{i,k}$. At step (4) the delivered orders to the customer (after transportation delay) are added to accounts receivables. On step (5) the supplier collects sales from period $t - TB^i$. At step (6) the supplier computes how much the ending cash position would be after paying the maturing invoice and borrows if necessary to have a cash level equal to TH_{min}^i after the transaction. At step (7) the supplier transfers to the $T2S$. Incoming orders placed at $t - LS^i$ arrive at step (8) and the supplier

adds the invoiced amount to accounts payable. On step (9) the supplier uses the new inventory to realise pending backordered items. At step (10) supplier borrows from the LOC if necessary. On step (11) the supplier pays periodic expenses PMT_t^i i.e. interest expenses and holding costs. On step (12) the supplier repays debt and/or pays out dividends.

When suppliers finance their operations solely from internal cash and conventional borrowing, the transition equations for inventory, payables, receivables, cash level and LOC balance are as follows:

$$IP_{t+1}^{i,k,e} = IP_t^{i,k,e} - D_t^{i,k} + IO_t^{i,k,e} \quad (\text{A3-1})$$

$$AP_t^i = AP_{t-1}^i + \sum_{k=1}^K [H_t^{i,k} - H_{t-TS^i}^{i,k}] \quad (\text{A3-2})$$

$$AR_t^i = AR_{t-1}^i + \sum_{k=1}^K [G_t^{i,k} - G_{t-TB^i}^{i,k}] \quad (\text{A3-3})$$

$$C_{t+1}^i = C_t^i + \sum_{k=1}^K G_{t-TB^i}^{i,k} + F_t^i - PMT_t^i - RP_t^i - DIV_t^i \quad (\text{A3-4})$$

$$LOC_{t+1}^i = LOC_t^i + F_t^i - RP_t^i. \quad (\text{A3-5})$$

where

$$PMT_t^i = \sum_{k=1}^K \sum_{e=1}^3 h^{i,k,e} I_t^{i,k,e} + e^{\beta_d t} LOC_t^i \quad (\text{A3-6})$$

$$y = \begin{cases} 0 \\ 1 \end{cases} \quad \begin{array}{l} \text{if } IO_{t-TS^i} = 0 \\ \text{if } IO_{t-TS^i} > 0 \end{array} \quad (\text{A3-7})$$

$$F_t^i = [TH_{min}^i - C_t^i + H_{t-TS^i}^{i,k}]^+ \quad \text{if } C_t^i < TH_{min}^i \quad (\text{A3-8})$$

$$RP_t^i = \begin{cases} C_t^i - TH_{max}^i \\ LOC_t^i \\ 0 \end{cases} \quad \begin{array}{l} \text{if } C_t^i > TH_{max}^i; LOC_t^i \geq C_t^i - TH_{max}^i \\ \text{if } C_t^i > TH_{max}^i; LOC_t^i < C_t^i - TH_{max}^i \\ \text{Otherwise} \end{array} \quad (\text{A3-9})$$

$$DIV_t^i = \begin{cases} C_t^i - TH_{max}^i \\ C_t^i - TH_{max}^i - LOC_t^i \\ 0 \end{cases} \quad \begin{array}{l} \text{if } C_t^i > TH_{max}^i; LOC_t^i = 0 \\ \text{if } C_t^i > TH_{max}^i; LOC_t^i < C_t^i - TH_{max}^i \\ \text{Otherwise} \end{array} \quad (\text{A3-10})$$

Equation (4-1) computes net inventory position at the start of a period $t + 1$. Equation (4-2) reduces the AP by the amount paid to tier 2 supplier at period t i.e. the inventory received at period $t - TS^i$ and increases it by the monetary amount received at period t . Equation (4-3) reduces the AR by the amount of cash collected at period t i.e. the sales from period $t - TB^i$ and increases it by the amount of sales of

period t , where the moment of sales is considered at the arrival of goods. Equation (4-4) balances the amount of cash at period $t + 1$ and equation (4-5) balances the amount borrowed from the LOC at period $t + 1$. Equation (4-6) computes all the period expenses. Equation (4-7) sets y as a binary variable, which is equal to 1 when supplier makes a raw material order and equal to zero when the supplier does not order. Equation (4-8) computes the amount of cash borrowed from the LOC each period, Equation (4-9) calculates the amount that is repaid to the LOC per period, and equation (4-10) calculates the amount of cash that is paid out as dividend per period.

We define a joint base stock and cash management policy as $Z^i(Q_1^{i,k}, R_1^{i,k}, R_2^{i,k}, r_2^{i,k}, Q_3^{i,k}, R_3^{i,k}, TH_{min}^i, TH_{max}^i)$. For a specific base stock and cash management policy, we define $GC^i(Z^i)$ as the average cost per period as follows:

$$GC^i(Z^i) = \frac{1}{T} \sum_{t=1}^T \left\{ e^{\beta_d^i} LOC_t^i + e^{\alpha_d^i} C_t^i + e^{\eta_d^i} AR_t^i + \sum_{k=1}^K \sum_{e=1}^3 h^{i,k,e} \cdot I_t^{i,k,e} + \sum_{k=1}^K b^{i,k} \cdot B_t^{i,k,3+} \right\} \quad (A3-11)$$

where LOC_t^i refers to the line of credit balance at time t , C_t^i refers to the cash balance at time t , and AR_t^i to the accounts receivable balance at time t . Also, the index d at α, β and η indicates the rate converted to the equivalent of period length t assuming continuous compounded. Thus, the average cost per period include holding, penalty costs, interest expenses, the opportunity cost of holding cash and the opportunity cost of holding AR.

Appendix 5. Conceptual Model: SCF

The SCF model is built upon the BAU model with certain extra considerations and modifications. We define parameter $\gamma^i \in (0,1)$ as the annualised fraction of face value that suppliers should pay to discount a receivable. For example, if $\gamma^i = 4\%$ is applied to a receivable to be received within 3 months, the supplier could get immediately 99% of the face value ($= 100 - 4 \times 3/12 = 99$). This discount is applied at the moment the supplier requests a discounted receivable. Therefore, the discount increases with the remaining days to the payment term maturity, motivating suppliers to discount the receivables that are due sooner. To measure this, we set t_0 as the moment in which the buyer sends a purchase order; $t_1 = t_0 + LB^i$ as the time in which the goods of the corresponding PO arrive at the buyer; $t_2 = t_1 + TB^i$ as the date in which the buyer will make the payment for the PO; and $j = t_2 - t$ as the remaining time to payment maturity for of the specific PO, where $t_1 \leq t \leq t_2$.

We set $\gamma^i < \beta^i$ so cash from discounted is preferred to cash from borrowing. If the supplier discounts all receivables and still requires extra cash, he will borrow via the LOC. Consequently, the sequence of events is the same as in Figure A-1 with the sole exception that at step (4) the firm discounts receivables as required and according to availability before borrowing via the LOC. Also, we consider two ways in which suppliers can apply RF: automatic and MD. These are covered now in detail.

Automatic discounting

Under automatic discounting, the supplier discounts the full value of any receivable as soon as it is possible to do so. We assume that a minimum of χ^i days need to pass after the arrival of the goods to the buyer before the supplier can discount the receivable. After this time, the supplier can discount the receivable booked χ^i periods ago. Consequently, holding costs for receivables are still incurred for the periods that the receivable is owned by the supplier. We denote ARF_t^i as the monetary amount that has been discounted via automatic RF on period t and define it as follows:

$$ARF_t^i = \sum_{k=1}^K G_{t-\chi^i}^{i,k} \quad (0-12)$$

All these assumptions entail changes in equations 4-3 and 4-4 and 4-8.

$$AR_t^i = AR_{t-1}^i + \sum_{k=1}^K G_t^{i,k} - ARF_t^i \quad (0-13)$$

$$C_{t+1}^i = C_t^i + ARF_t^i + F_t^i - PMT_t^i - RP_t^i - DIV_t^i \quad (0-14)$$

$$F_t^i = \left[TH_{min}^i - C_t^i + H_{t-TS}^{i,k} \right]^+ \quad \text{if } C_t^i < TH_{min}^i; AR_t = 0 \quad (0-15)$$

We define a joint base stock and cash management policy as $Z^i(S_t^{i,k}, TH_{min}^i, TH_{max}^i)$. For a specific base stock and cash management policy, we define $GC_{AD}^i(Z^i)$ as the average cost per period as follows:

$$GC_{AD}^i(Z^i) = \frac{1}{T} \sum_{t=1}^T \left\{ e^{\beta_d^i} LOC_t^i + e^{\alpha_d^i} C_t^i + e^{\eta_d^i} AR_t^i + e^{\gamma_d^i j} ARF_t^i + \sum_{k=1}^K [h^{i,k} [NI_t^{i,k}]^+ + b^{i,k} [-NI_t^{i,k}]^+] \right\} \quad (0-16)$$

Manual discounting

Under manual discounting, the supplier prefers to discount receivables rather than borrowing to cover cash deficits, but does not discount receivables if enjoying a cash surplus i.e. if $C_t^i \geq T_{min}^i$. We also assume that a minimum of χ^i days has to pass after delivery for discounting receivables. Therefore, we define the monetary amount of discounted receivables per period t as follows:

$$MRF_t^i = \begin{cases} \sum_{\substack{k=1 \\ t_1 \leq t \leq t_2}}^K G_{t-\chi^i}^{i,k} & \text{if } C_t^i < T_{min}^i \\ 0 & \text{if } C_t^i \geq T_{min}^i \end{cases} \quad (0-17)$$

These considerations also entails changes in equations 4-3 and 4-4 and 4-8.

$$AR_t^i = AR_{t-1}^i + \sum_{k=1}^K [G_t^{i,k} - G_{t-TB^i}^{i,k}] - MRF_t^i \quad (0-18)$$

$$C_{t+1}^i = C_t^i + MRF_t^i + F_t^i - PMT_t^i - RP_t^i - DIV_t^i \quad (0-19)$$

$$F_t^i = [TH_{min}^i - C_t^i + H_{t-TS^i}^{i,k}]^+ \quad \text{if } C_t^i < TH_{min}^i; AR_t = 0 \quad (0-20)$$

We define a joint base stock and cash management policy as $Z^i(S_t^{i,k}, TH_{min}^i, TH_{max}^i)$. For a specific base stock and cash management policy, we define $GC_{MD}^i(Z^i)$ as the average cost per period as follows:

$$GC_{MD}^i(Z^i) = \frac{1}{T} \sum_{t=1}^T \left\{ e^{\beta_d^i} LOC_t^i + e^{\alpha_d^i} C_t^i + e^{\eta_d^i} AR_t^i + e^{\gamma_d^i j} MRF_t^i + \sum_{k=1}^K [h^{i,k} [NI_t^{i,k}]^+ + b^{i,k} [-NI_t^{i,k}]^+] \right\} \quad (0-21)$$

As a final remark, equation (5-6) points out that whenever the cash level is below the minimum threshold, suppliers discount the invoices before borrowing from the LOC. In order to minimise costs, they select the invoices that yield the lowest cost i.e. they discount specifically the invoices whose maturity is due the soonest i.e. the ones who have a smaller j .

Appendix 6. Key Performance Indicators

Average cost per period (G)

The first and foremost KPI is the average cost per period, denoted by $G^i(Z^i)$ in Equation 4-10. This is the main driver of this model as suppliers aim at minimising this quantity by choosing a certain base stock level and the cash thresholds. While we do not theoretically demonstrate optimality of this constant base stock policy, we present later in this document sensitivity analyses for certain parameters to guide managerial decision.

Total Inventory Value

The inventory value reflects the resources that the company has spent for the inventory at a certain moment in time. This is subdivided in the cost that the company spends on raw material, as well as the cost that the firm spends on adding value to it at the production e.g. labour. The Inventory Value IV_t^i for supplier i at time t is defined as follows:

$$IV_t^i = \sum_{k=1}^K \left\{ c^{i,k}, I_t^{i,k,1} + \sum_{e=2}^3 w^{i,k}, I_t^{i,k,e} \right\} \quad (0-22)$$

In order to compute the average inventory value, it is necessary to sum over all the periods and divide by the amount of periods as follows:

$$Avg IV^i = \frac{1}{T} \sum_{t=1}^T \sum_{k=1}^K \left\{ c^{i,k}, I_t^{i,k,1} + \sum_{e=2}^3 w^{i,k}, I_t^{i,k,e} \right\} \quad (0-23)$$

Operating margin (OPM)

This margin measures how much of every monetary unity of revenue is kept by the supplier i as earnings before other expenses e.g. interests and taxes. It is calculated as the difference of the sales minus all cost of goods sold (COGS) and Selling, General and Administrative (SG&A) Expenses. However, as our model ignores or leaves out of scope SG&A expenses, only COGS are taken into account for this KPI. The formula to obtain this margin is the following:

$$OPM^i = \frac{Sales - Operating Expenses}{Sales} \quad (0-24)$$

$$= \frac{1}{T} \cdot \frac{\sum_{t=1}^T \sum_{k=1}^K G_{t-TB}^{i,k} - \sum_{t=1}^T \sum_{k=1}^K [c^{i,k} IO_{t-TS}^{i,k} + \sum_{e=1}^3 h^{i,k,e} I_t^{i,k,e} + b^{i,k} B_t^{i,k,3}]}{\sum_{t=1}^T \sum_{k=1}^K G_{t-TB}^{i,k}}$$

Quick Ratio

The quick ratio is an indicator of a company's short-term liquidity by measuring a firm's ability of meeting its short-term obligations with its most liquid assets. Consequently, the ratio ignores inventories from current assets. It is calculated as follows:

$$QR^i = \frac{\text{cash} + \text{accounts receivable}}{\text{current liabilities}} = \frac{C_t^i + AR_t^i}{LOC_t^i} \quad (0-25)$$

The average quick ratio is calculated as follows:

$$Avg. QR^i = \frac{1}{T} \cdot \sum_{t=1}^T \frac{C_t^i + AR_t^i}{LOC_t^i} \quad (0-26)$$

Average Earnings Before Taxes margin (EBTM)

This margin measures how much of every monetary unity of revenue is kept by the supplier i as earnings before taxes. It is calculated as the difference of the sales minus all expenses, including interest expenses.

$$EBTM^i = \frac{\text{Sales} - \text{Expenses}}{\text{Sales}} = \frac{\sum_{t=1}^T \sum_{k=1}^K G_{t-TB}^{i,k} - \sum_{t=1}^T PMT_t^i}{\sum_{t=1}^T \sum_{k=1}^K G_{t-TB}^{i,k}} \quad (0-27)$$

Net Working Capital (NWC)

The net working capital is the aggregate amount of all assets and current liabilities. Firms use this figure to measure the short-term liquidity and their ability to utilise assets efficiently. Net working capital for a certain period t and a supplier i is calculated as follows:

$$\begin{aligned} NWC_t^i &= \text{Current assets} - \text{current liabilities} = \text{Cash} + \text{Inventory} + \text{AR} - \text{AP} \\ &= C_t^i + IV_t^i + AR_t^i - AP_t^i \end{aligned} \quad (0-28)$$

In order to compute the average net working capital, then the sum over a period T is taken divided by the amount of periods.

$$Avg. NWC^i = \frac{1}{T} \sum_{t=1}^T NWC_t^i = \frac{1}{T} \sum_{t=1}^T \{C_t^i + IV_t^i + AR_t^i - AP_t^i\} \quad (0-29)$$

*Interest Expenses (IE)

Interest expenses are costs incurred by firms for borrowed funds. They are non-operating expenses that represent interest payable on a borrowing e.g. bonds, loans, convertible debt or lines of credit. In this case, the latter borrowing applies. It is calculated as the multiplication of the interest rate times the outstanding principal amount of the debt.

$$IE_t^i = \text{interest rate} \times \text{outstanding principal} = e^{\beta^i t} LOC_t^i \quad (0-30)$$

The average interest expense over a period T is calculated as the sum of the interest payments accrued over a period divided by the number of periods.

$$Avg. IE^i = \frac{1}{T} \sum_{t=1}^T IE_t^i = \frac{1}{T} \sum_{t=1}^T e^{\beta^i t} LOC_t^i \quad (0-31)$$

Short-term Debt to Current Assets Ratio (DAR)

The short-term debt to current assets ratio is a leverage ratio that defines the current debt relative to current assets. The higher the ratio, the higher the degree of leverage, and consequently the higher the financial risk. It is calculated as follows:

$$DAR_t^i = \frac{\text{Short term debt}}{\text{Current Assets}} = \frac{\text{LOC balance}}{\text{Cash} + \text{Inventory} + A/R} = \frac{LOC_t^i}{C_t^i + IV_t^i + AR_t^i} \quad (0-32)$$

The average DAR ratio over a period T is calculated as the sum of the interest payments accrued over a period divided by the number of periods.

$$DAR^i = \frac{1}{T} \sum_{t=1}^T DAR_t^i = \frac{1}{T} \sum_{t=1}^T \frac{LOC_t^i}{C_t^i + IV_t^i + AR_t^i} \quad (0-33)$$

Cash Conversion Cycle (CCC)

The cash conversion cycle (CCC) cycle, also known as the cash-conversion cycle, is also an important figure to be examined. CCC was introduced by Richards and Laughlin (1980) and is a metric that expresses the length of time that a company needs to convert resource inputs into cash flows. It considers the amount of time the firms needs to sell inventory, the amount it needs to collect receivables and the length of time the company is afforded to pay its bills without incurring penalties (Brealey, et al., 2011). Companies aim at minimising the cycle length in order to improve their e.g.

liquidity and (re)investment opportunities and reduce working capital costs. This figure is therefore used to treat dynamically and holistically the net working capital performance.

$$CCC^i = DIH^i + DSO^i - DPO^i \quad (0-34)$$

where each element represents a working capital sub cycle. *DIH* refers to days inventory held or average days in inventory, *DSO* refers to days sales outstanding or average collection period, and *DPO* refers to days payable outstanding or average payment period. Figure A-2 shows the CCC cycle and its components in a more graphical manner.

In order to compute each of these elements, the following formulas are used for each supplier *i*.

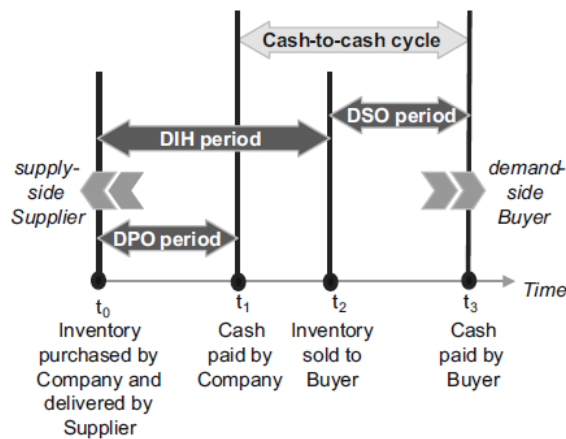
$$DIH^i = \frac{\text{Avg. Inventory}}{\text{Daily Cost of Goods Sold}} \times 365 = \frac{\text{Avg } IV^i}{\frac{1}{T} \cdot w^{i,k} \sum_{t=1}^T \sum_{k=1}^K D_t^{i,k}} \quad (0-35)$$

$$DSO^i = \frac{\text{Avg. Accounts Receivable}}{\text{Daily Net Sales}} \times 365 = \frac{\sum_{t=1}^T AR_t^i}{\frac{1}{T} \cdot p^{i,k} \sum_{t=1}^T \sum_{k=1}^K D_t^{i,k}} \quad (0-36)$$

$$DPO^i = \frac{\text{Avg. Accounts Payable}}{\text{Daily Cost of Goods Sold}} \times 365 = \frac{\sum_{t=1}^T AP_t^i}{\frac{1}{T} \cdot w^{i,k} \sum_{t=1}^T \sum_{k=1}^K D_t^{i,k}} \quad (0-37)$$

The Cash Conversion Cycle is then calculated using those three variables.

Figure A-2: The CCC and its components



Source: Hofmann & Belin (2011)

Appendix 7. Detailed Description of Simulation Model

In this section we describe each model segment in more detail, starting with the extreme downstream echelon and moving upstream the supply chain. Later, we describe the cash management segments. Our inventory Arena model was based in great part to Altiok & Melamed's (2007, p. 293) model of a Multiechelon Supply Chain, for which there will be certain modelling similarities. The cash management model was developed in its entirety by us.

Inventory Management Segment for Warehouse

Figure A-3 depicts the warehouse inventory management segment of the Arena model. This segment generates the demand stream, handles demand fulfilment, and triggers replenishment orders from the plant's output buffer. Every period, a single demand is generated by the Create module, called "Customer Demand Arrival at WH". Upon arrival, management needs one day to process demand, for which there is a Delay of 1 day. Each demand has a demand quantity, which following a Lognormal distribution $D_t \sim LOGN(\mu_D, \sigma_D)$. The demand quantity is determined within the Assign module "Assign Customer Demand" which assigns this demand as an entity attribute, which is followed by a Record module that tallies demand order quantities. Afterwards, the Assign module "Take Away From WH Inventory Position" deducts the demand quantity from the warehouse inventory position with the formula $IP_t^1 - D_t$. Afterwards, the customer entity proceeds to a Decide module, where it is tested whether the Warehouse Inventory Position is below the Warehouse Reorder Point i.e. $IP_t^1 < R_1$. In case affirmative, Assign Module "Order From Output Buffer And Update WH Inventory Position " changes variable "Order_Output" to 1, which would promptly release a pending order entity currently detained in the Hold module, called Shall We Release WH Order?, in the output inventory management segment (see Figure A-4). Also, within this Assign Module the ordered quantity Q^1 is summed to the Warehouse Inventory Position. In case negative, the entity skips this Assign module. The customer entity then proceeds to test whether the warehouse has sufficient inventory on hand by entering the Decide module, called "Check WH Inventory", where $I_t^1 \geq D_t$ is tested. The test has two possible outcomes. First, if the condition Inventory at the Warehouse equals or exceeds the customer demand, then the customer entity takes the True exit to the Assign module, called "Take Away From WH Inventory", where it decrements the on-hand inventory I_t^1 by the D_t . This is followed by a Record module, which tallies fully satisfied demands to later compute the customer service level. Second, if the condition Inventory at the warehouse is below customer demand, then the customer entity takes the False exit. In this case, the demand is not fully satisfied, and the unsatisfied portion is backordered from the manufacturing plant. To this end, the order entity proceeds to the Assign module, called "Increase Backorders", where two assignments take place:

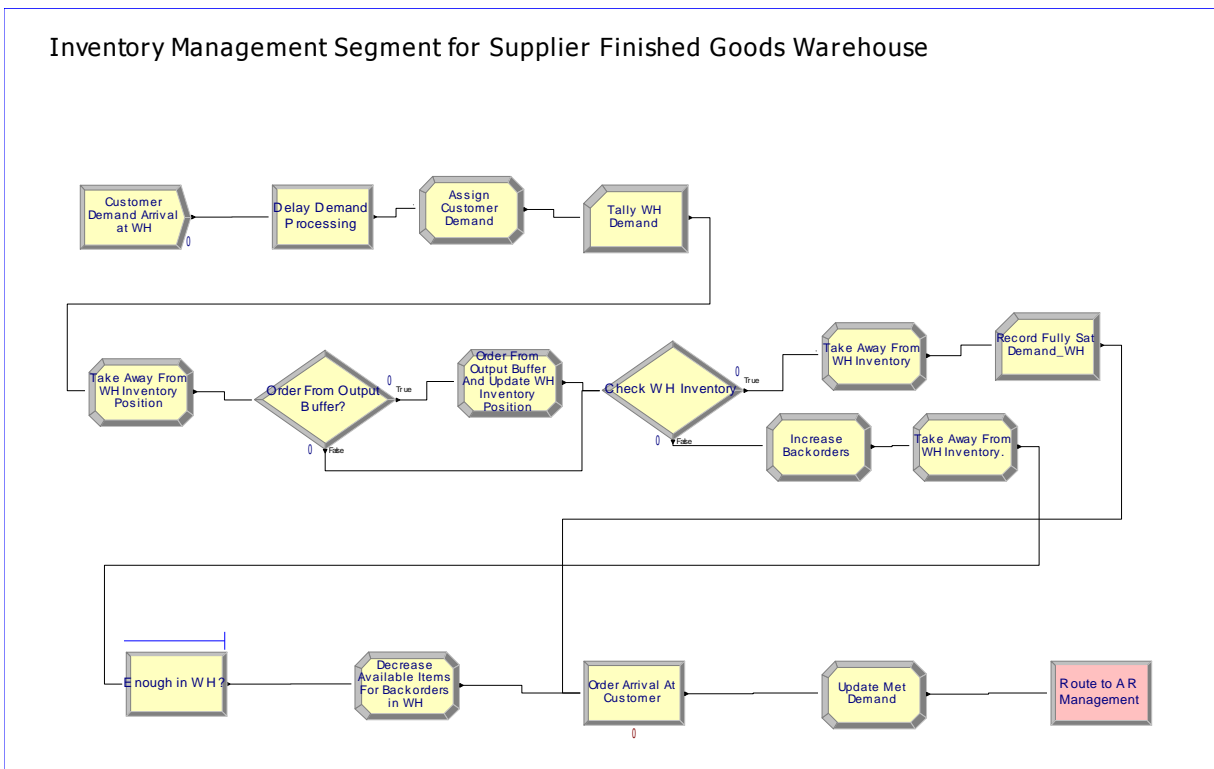
1. Attribute UnsatisfiedPortionDemand_WH is assigned value $D_t - I_t^1$
2. Variable B_t^1 is assigned value $B_t^1 + D_t - I_t^1$

The customer entity later enters a second Assign module, where variable I_t^1 is set to zero, and proceeds to Hold module "Enough in WH?", where it is detained until sufficient inventory accumulates in the

output buffer to satisfy the shortage. Specifically, the Hold module scans for condition AvailableForBackorders_WH >= UnsatisfiedPortionDemand_WH. The first variable is used to track the number of inventory product units on hand that are currently available to satisfy backorders during stock-out periods. Consequently, this entity is detained in this Hold module until sufficient inventory becomes available to satisfy the unsatisfied portion defined as an attribute. Note that multiple order entities may be simultaneously detained in this Hold module. We look that the orders are satisfied in their order of arrival at this module, for which we set the Hold module's queue discipline is FIFO. When the Hold module's condition is satisfied, then the order entity is released and proceeds to the Assign module called "Decrease Available Items For Backorders in WH", where the variable AvailableForBackorders_WH is decremented by the value of the variable UnsatisfiedPortionDemand_WH.

Afterwards, the two Decide module's paths join. At this point, the order entity is now ready for shipment to the customer. Recall that we assumed that product units are processed sequentially in the transportation system, so as to preclude overtaking. To enforce this rule, we use the Process module, called "Order Arrival At Customer", to model the transportation delay from the warehouse to the customer. The order entity next enters the Assign module, called "Update Met Demand", to update the warehouse met demand by making a cumulative sum of customer demand D_t . Finally, the order entity proceeds to be routed towards the financial management section via Route module "Route to AR Management".

Figure A-3: Arena model of the inventory management segment for the warehouse



Inventory Management Segment for Output Buffer

Figure A-4 depicts the output buffer inventory management segment of the Arena model. This model segment satisfies warehouse orders, generates OB orders, updates the OB inventory level, triggers resumption of suspended manufacturing as necessary, sends shipments to the warehouse, and updates the warehouse inventory level.

The Create module, called “Demand Arrival At Output Buffer” creates a single order entity at time 0, which later generates a pending order to be shipped from the WH. The order entity enters the Hold module called “Shall We Release WH Order?”, and is released once the variable Order_Output is set to 1, whereupon the order entity proceeds to the Assign module, called “Change Flag For Order From WH”, and sets Order_WH to 0. The order entity then proceeds to the Separate module, called Separate 1, where it duplicates itself. The order entity itself proceeds to enter the system as a WH order, while its duplicate loops back to the Hold module “Shall We Release WH Order?” to generate the next WH pending order.

The WH order entity is next tallied in the Record module, called Tally Output Buffer Demand, and then enters the Decide module called “Check Output Buffer Inventory”, where It then proceeds to the Decide module, called “Check Output Buffer Inventory”, to check whether the output buffer has sufficient inventory on hand to satisfy its demand. Two outcomes are possible. (1) If the condition $I_t^2 \geq Q^1$ holds, then the order entity takes the True exit to the Assign module called “Take Away from Output Inventory”, where it decrements the on-hand inventory by Q^1 . (2) If the condition $I_t^2 < Q^1$ holds, then the order entity takes the False exit. In this case, the demand is not fully satisfied and is backordered from the output buffer, and the order entity enters the Assign module, called “Increase OB Backorders”, to perform two assignments:

1. The UnsatisfiedPortionDemand_Output attribute of the order entity is assigned the unsatisfied portion of the demand $Q^1 - I_t^2$.
2. Variable B_t^2 is assigned value $B_t^2 + Q^1 - I_t^2$

This is followed by a second Assign module called Take Away From Output Inventory, where variable I_t^2 is set to zero. Consequently, the order entity enters Hold module “Enough In Output?”, which scans for condition AvailableForBackorders_Output \geq UnsatisfiedPortionDemand_Output. Noteworthy, the logic of this section is similar as in the previous segment. Once the condition is fulfilled, the order entity proceeds to module Assign module called “Decrease Available Items For Backorders In Output Buffer”, where variable AvailableForBackorders_Output is decreased by attribute UnsatisfiedPortionDemand_Output. After this, the two Decide paths merge in Decide module “Restart Production At Plant?”, where it is tested whether $I_t^2 < r_2$. In case it has, the entity proceeds to Assign module “Restart Production”, where variable “Production_Plant” is set to 1, which would promptly release the pending production entity currently detained in the Hold module, called Shall We Produce?, in the input-buffer inventory/production management segment (see Figure A-5), resuming the production process.

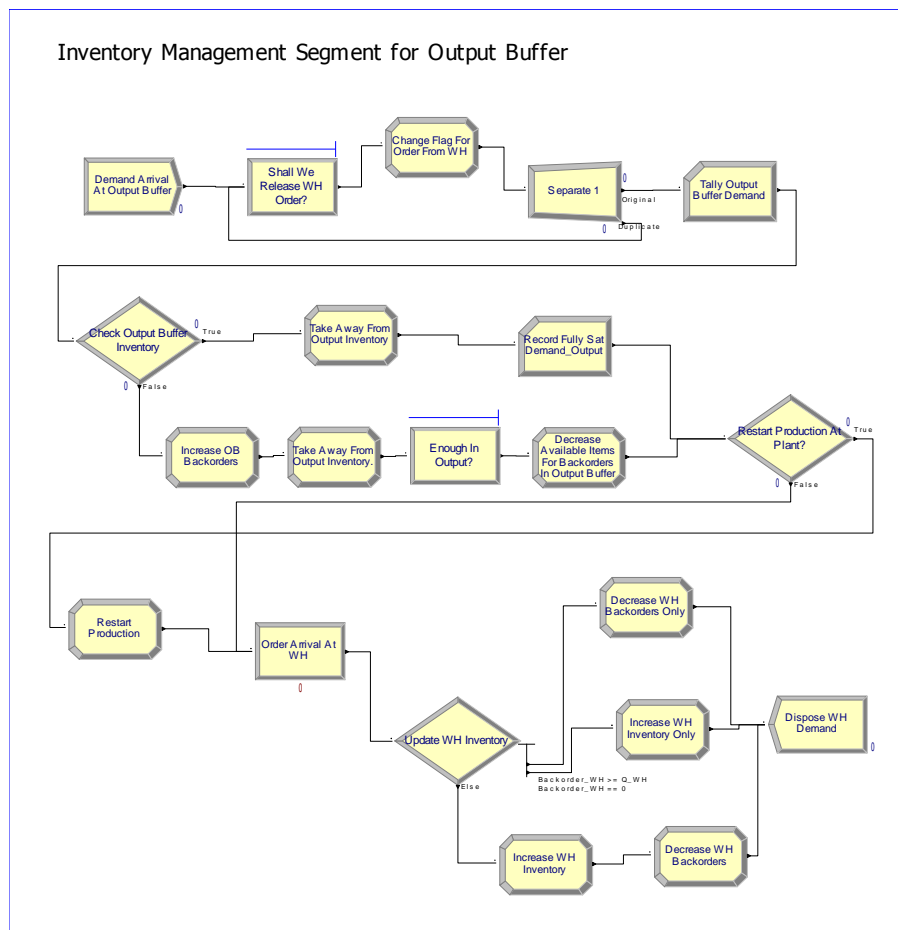
The order entity is now ready for shipment to the warehouse. To this end, it proceeds to the Process module, called Order Arrival At WH, to model the transportation delay from the output buffer to the

warehouse. The order entity next proceeds to the Decide module, called “Update WH Inventory”, where three outcomes are possible:

1. If the condition $B_t^1 \geq Q^1$ holds, then the order entity takes the exit for the Assign module, called “Decrease WH Backorders Only”, where it decrements B_t^1 by Q^1 and increments AvailableForBackorders_WH by Q^1 .
2. If the condition $B_t^1 = 0$ holds, then the order entity takes the exit for the Assign module, called “Increase WH Inventory Only”, where it increments I_t^1 by Q^1 .
3. If the condition $0 < B_t^1 < Q^1$ holds, then the order entity takes the exit for the Assign module, called “Increase WH Inventory”, where inventory is set to value $I_t^1 + Q^1 - B_t^1$ and variable AvailableForBackorders_WH is set to formula AvailableForBackorders_WH + B_t^1 . The entity proceeds to Assign module “Decrease WH Backorders”, where B_t^1 is set to zero.

Finally, the order entity proceeds to be disposed of in the Dispose module, called “Dispose WH Demand”.

Figure A-4: Arena model of the inventory management segment for the output buffer.



Inventory Management Segment for Input Buffer

Figure A-5 depicts the input-buffer production/inventory management segment of the Arena model. This model segment manages raw-material consumption and finished goods production by keeping track of a circulating control entity that modulates the suspension and resumption of production.

We recall that to manufacture a product unit, the plant removes one unit of raw material from the input buffer, processes it, and adds the resulting finished product to the output buffer inventory and updates its level. Since the Plant has an r_2, R_2 policy, once target level R_2 is reached, production is suspended. Production is re-started when the reorder point r_2 is down-crossed. Production may also be stopped due to starvation resulting from depletion of raw material in the input buffer, until it is replenished from the $T2S$ supplier.

This segment begins with Create module called “Production Process At Plant”, which generates a single control entity at time 0, which cycles in the segment such that each cycle represents a production cycle. The control entity first enters the Hold module, called “Shall We Produce?” and is detained there until the production is allowed to re-start i.e. when condition $Production_Plant = 1$, meaning that inventory level in the OB down-crosses the reorder level there. Once production is allowed to resume, the control entity enters the Record module, called “Tally Input Buffer Demand”, to tally the next product unit. The control entity then proceeds to the Decide module, called “Check Input Buffer Inventory”, where it is checked if there is enough raw material in the input buffer to produce a complete batch size bs . Recall that one unit of raw material generates one unit of finished goods. If true, it proceeds to the Assign module, called “Proceed to Production”, to update the number of satisfied demands. If false, starvation is in effect and the control entity takes the False exit to the Hold module, called “Wait For Inventory In Input Buffer”, until the condition $I_t^3 \geq bs$ becomes true. Once this condition is fulfilled, the control entity proceeds to the Seize module, called “Seize Plant”, where it seizes the single Plant resource. To model the consumption of bs units of raw material, the control entity enters the Assign module, called “Take Away From Input Buffer Inventory”, and decrements by bs both the inventory on-hand variable I_t^3 and the inventory position variable IP_t^3 .

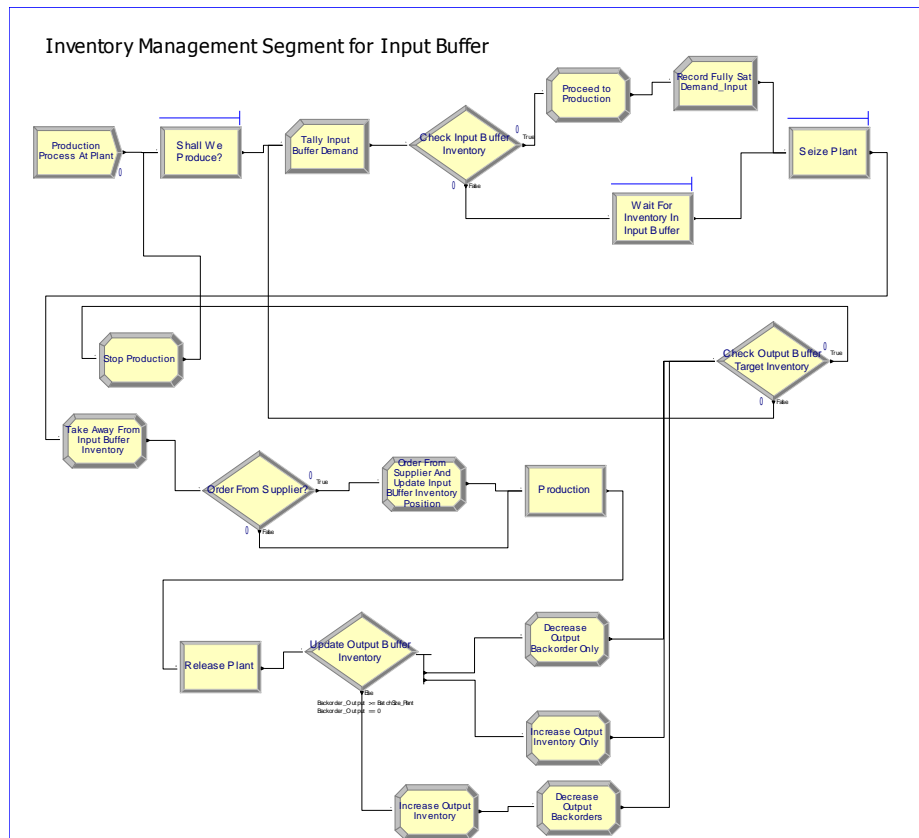
Similarly to the previous segments, the control entity next proceeds to the Decide module, called “Order From Supplier”, to check whether the reorder point at the input buffer has been down-crossed. If it has, a raw material replenishment is promptly triggered by releasing the order entity currently detained in the Hold module, called Shall We Release Plant Order?, in the supplier inventory management segment (see Figure A_6). The control entity next enters the Assign module, called “Order From Supplier And Update Input Buffer Inventory Position”, where it updates the input buffer inventory position IP_t^3 by adding Q^3 and triggers a supplier order by setting the variable $Order_Supplier$ to 1.

Afterwards, the two paths of the last Decide module converge in Decide module called “Production”, where the manufacturing time delay of a batch size is modelled. This module is followed by the “Release” module called “Release Plant”, where the Plant resource is released. In order to add inventory correctly, entity enters Decide module “Update Output Buffer Inventory” to check if there are any pending backorders in the output buffer. Three outcomes are possible:

1. If the condition $B_t^2 \geq bs$ holds, then the order entity takes the exit for the Assign module, called “Decrease Output Backorder Only”, where it decrements B_t^2 by bs and increments AvailableForBackorders_Output by bs .
2. If the condition $B_t^2 = 0$ holds, then the order entity takes the exit for the Assign module, called “Increase Output Inventory Only”, where it increments I_t^2 by Q^2 .
3. If the condition $0 < B_t^2 < bs$ holds, then the order entity takes the exit for the Assign module, called “Increase Output Inventory”, where inventory is set to value $I_t^2 + bs - B_t^2$ and variable AvailableForBackorders_Output is set to formula AvailableForBackorders_Output + B_t^2 . The entity proceeds to Assign module “Decrease Output Backorders”, where B_t^2 is set to zero.

The control entity then proceeds to the Decide module, called “Check Output Buffer Target Inventory”, to check whether the inventory level I_t^2 at the output buffer has reached its target level R_2 . If it has, then the control entity takes the True exit for the Assign module, called “Stop Production”, and sets Production_Plant to a value of zero to suspend production, after which it cycles back to the Hold module, called “Shall We Produce?”, to wait until the next production cycle triggered. Otherwise, the control entity takes the False exit and cycles back to the Record module, called “Tally Input Buffer Demand”, to start the next production cycle.

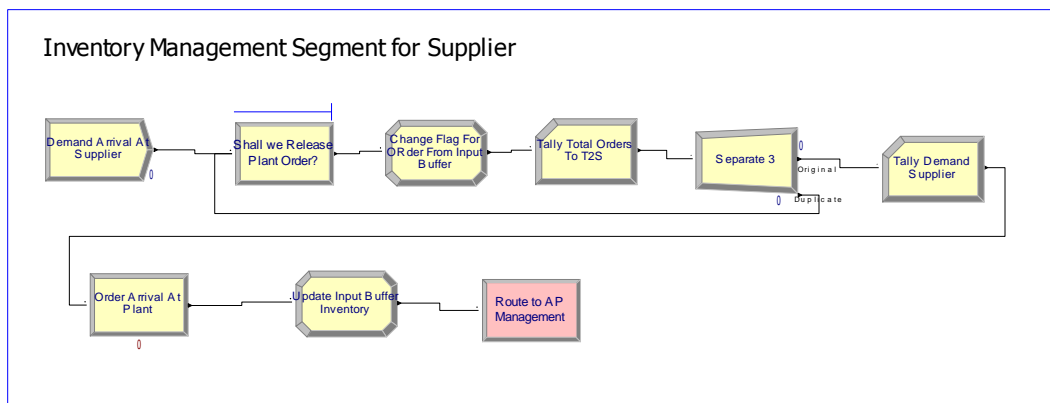
Figure A-5: Arena model of the production/inventory management segment for the input buffer



Inventory Management Segment for Tier 2 Supplier

Figure A-6 depicts the Tier 2 Supplier inventory management segment of the Arena model. This model segment generates input buffer orders, sends shipments from the T2S to the input buffer, and updates the input buffer inventory level. The logic of generating input buffer orders to the supplier is virtually identical to the generation logic used in the previous segments, and therefore will not be repeated. Noteworthy, this model segment is simpler than the previous because we assume that the T2S has infinite capacity and inventory on hand, for which replenishment delays reduce to transportation delays. At the end of this segment, the order entity goes to Route module called “Route to AP Management”.

Figure A-6: Arena model of the production/inventory management segment for the T2S



Cash Management: Accounts Receivable and Cash Outflows (Dividends, LOC Repayment)

Figure A-7 depicts the cash management system related to accounts receivable and cash outflows related to LOC repayment and dividends pay-out. This segment books the accounts receivable, records sales and cost of goods sold (COGS), decides whether to discount via reverse factoring, either by automatic discounting (AD) or manual discounting (MD) or to wait until maturity in the BAU case. Cash level is updated after inflow, and excess cash is either used to repay debt or pay-out dividends.

Entities entering this segment come from segment “Inventory Management Segment for Warehouse” (see Figure A-3), and proceed to Assign module “Increase AR. Plan Cash Inflow” where several assignments take place:

1. Attribute Invoice Price G_t , which is the amount invoiced to customers, is defined as customer demand D_t multiplied times the unit price p
2. Variable Accounts Receivable AR_t is defined as $AR_t + p \cdot D_t$
3. Attribute Invoice COGS is defined as $D_t \cdot COGS \text{ per Unit}$, where the latter equals $c + f/Q^3$
4. Variable CumNetSales is defined as the cumulative sum of attribute Invoice Price
5. Variable CumCOGS is defined as the cumulative sum of attribute Invoice COGS
6. Attribute InvoiceDate is defined as $TNOW$, which is the current time in the simulation run
7. Attribute InvoiceMaturity is defined as $TNOW + TB$

The entity proceeds to a Record module, where the attribute G_t is tallied to tally net sales. It proceeds to an Assign module called “Assign Avg Net Sales”, which divides cumulative sales over the current simulation run in order to compute average net sales per period. This amount is recorded in a Record module. The same steps are done to compute the average COGS per period. The entity proceeds to a Decide module called “Decide if Discounting”, which has three outcomes:

1. If variable *Automatic Discounting* = 1, the entity proceeds to Delay module “Delay to Autom Disc”. The variable Automatic Discounting is defined before the simulation is run. At the Delay module, the entity waits for a period of $\chi = 10$ days. After the delay, the entity proceeds to an Assign module called “Assign CF After Autom Discounting”, where the attribute cash flow amount CF_{AD} is defined as $G_t / e^{(InvoiceMaturity - TNOW) * \gamma_d}$, where γ_d represents the daily RF discounting rate assuming continuous computing. The entity proceeds to Assign module “AutomDiscount AR. Increase Cash”, where several assignments are done:
 - a. Variable AR_t is reduced by attribute G_t
 - b. Cash level variable C_t is augmented by attribute CF_{AD}
 - c. Control variable to measure total cash inflows *Cash Inflow* is augmented by CF_{AD}
 - d. Attribute Factoring Cost is defined as $G_t - CF_{AD}$
 - e. Variable CumFactoringCost, the cumulative cost of factoring, is defined as $CumFactoringCost + G_t - CF_{AD}$

The entity proceeds to a Record module, where Factoring cost is counted and later to an Assign module, where the average factoring cost is computed as $CumFactoringCost / TNOW$

2. If variable *Manual Discounting* = 1, the entity proceeds to Delay module “Delay to Manual Disc”. Like in the previous point, variable Manual Discounting is defined before the simulation is run. At the Delay module, the entity waits for a period of $\chi = 10$ days. The entity proceeds to Hold module “Hold Invoice”, where it waits for condition $TNOW \geq InvoiceMaturity$ to be fulfilled. At this hold module, invoices will be held and removed in following segments in case the supplier decides to discount non-matured invoices. Once the invoice matures and the condition is fulfilled, it proceeds to Assign module “Decrease AR. Increase Cash”, where the following assignments are made:
 - a. Variable AR_t is reduced by attribute G_t
 - b. Cash level variable C_t is augmented by attribute G_t
 - c. Control variable *Cash Inflow* is augmented by G_t
3. If *Automatic Discounting* = *Manual Discounting* = 0, then the entity proceeds to Delay module “Delay AR Payment Terms”, where it is held for TB days. Later, it proceeds to Assign module “Decrease AR. Increase Cash”, where the assignments shown above are made.

All decide paths converge in Decide module “Cash Level_s above THmax_s?”, where it is tested whether $C_t > TH_{max}$. In case the condition is not fulfilled, the entity is disposed. In case it is, then it continues to Design module “LOC Balance_s greater than zero?”, where three outcomes are possible:

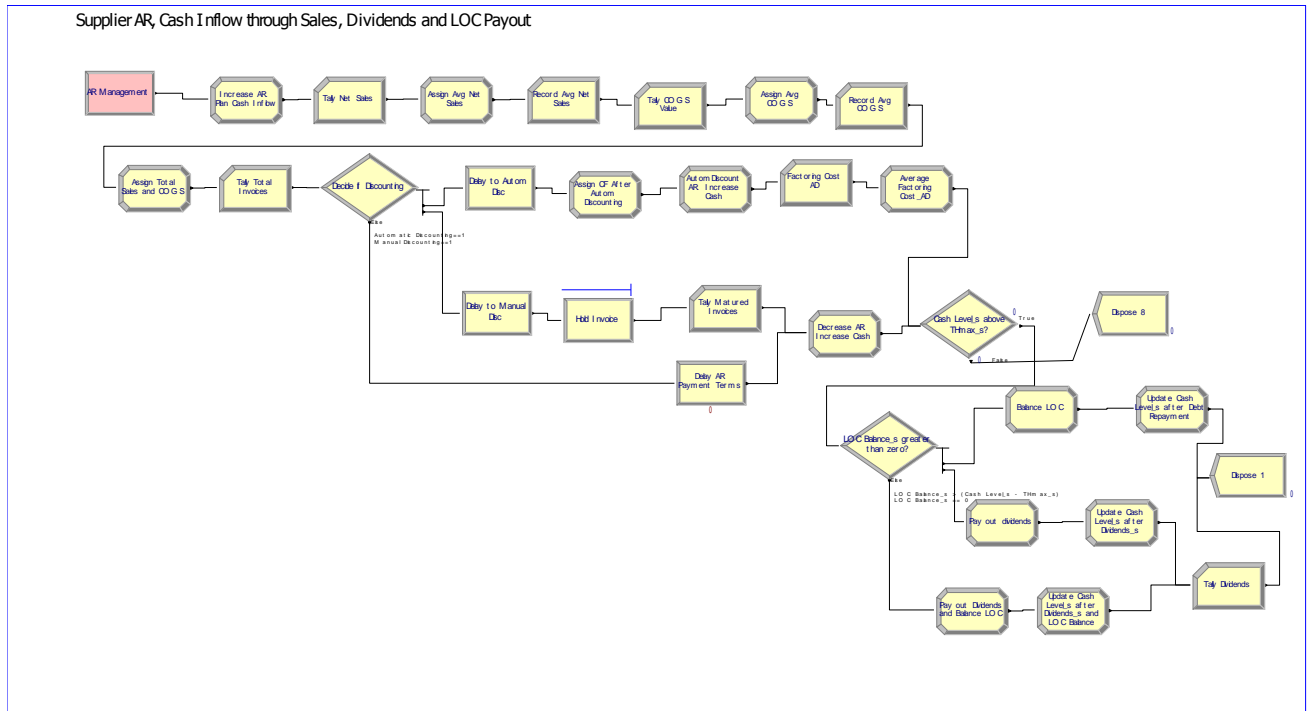
1. If $LOC_t > C_t - TH_{max}$ holds, the entity proceeds to Assign module “Balance LOC”, which deduces LOC_t by $C_t - TH_{max}$. Also, control variable Cash Outflow is augmented by quantity

$C_t - TH_{max}$. The entity proceeds to Assign module “Update Cash Level_s after Debt Repayment”, which sets $C_t = TH_{max}$.

2. If $LOC_t = 0$, the entity exits to Assign module “Pay out dividends”, where attribute Dividend is defined as $C_t - TH_{max}$, variable Accumulated Dividends is augmented by amount $C_t - TH_{max}$ and control variable Cash Outflow is augmented by quantity $C_t - TH_{max}$. Likewise, the entity proceeds to Assign module “Update Cash Level_s after Dividends_s”, which sets $C_t = TH_{max}$.
3. If $0 < LOC_t < C_t - TH_{max}$, the entity exits to Assign module “Pay out Dividends and Balance LOC”, where attribute Dividend is defined as $C_t - TH_{max} - LOC_t$, variable Accumulated Dividends is augmented by amount $C_t - TH_{max} - LOC_t$ and control variable Cash Outflow is augmented by quantity $C_t - TH_{max}$. Likewise, the entity proceeds to Assign module “Update Cash Level_s after Dividends_s and LOC Balance”, which sets $C_t = TH_{max}$ and $LOC_t = 0$.

The last two paths converge to Record module “Tally Dividends” and then all paths converge in a Dispose module.

Figure A-7: Accounts Receivable and Cash Outflows (Dividends, LOC Repayment)



Cash Management: Accounts Payable, cash Inflow through LOC

Figure A-8 depicts the cash management system related to accounts payable and cash inflows through LOC. This segment books the accounts payable, borrows from the LOC, triggers manual discounting and pays maturing invoices to the T2S.

Entities entering this segment come from segment “Inventory Management Segment for Tier 2 Supplier” (see Figure A-6), and proceed to Assign module “Increase AP. Plan Payment” where several assignments take place:

1. Attribute H_t is defined as $f + c \cdot Q^3$
2. Variable AP_t is augmented by amount $f + c \cdot Q^3$
3. Variable CumProcurement is augmented by amount $f + c \cdot Q^3$

The entity proceeds to Assign attribute Assign Avg Procurement, which computes average procurement cost per period as $CumProcurement/TNOW$, which is later recorded in a Record module. The entity proceeds to Delay module “Delay AP Payment Terms”, where entities are delayed by TS days. Entities proceed to Decide module “Cash Level_s after payment below THmin_s?”, where it is tested whether paying the current invoice would lead to a cash level below the minimum cash threshold. It does so by testing if $C_t - H_t < TH_{min}$. In case this occurs, the entity proceeds to Assign module “Amount to Finance”. In case it does not occur, then it proceeds to Decide module “Cash Level_s below THmin_s?”

If the condition is fulfilled, it proceeds to Assign module “Amount to Finance”, where variable $AmountToFinance$ is defined as $TH_{min} - C_t + H_t$, which is exactly the quantity needed to finance in order to have a cash level equal to the minimum threshold after paying the invoice. The entity proceeds to a Decide module, where it is tested if there are invoices waiting in the “Hold Invoice” Hold module (see Figure A-7). This is done with the formula $NQ(Hold Invoice.Queue) == 0$. In case there are no pending invoices, the entity leaves the True exit towards Assign module “Request Credit from LOC”, where the LOC_t is augmented by variable $AmountToFinance$ and to Assign module Increase Cash Level_s, where variables C_t and control variable $Cash Inflow$ are also augmented by $AmountToFinance$. The entity then proceeds to Assign module “Decrease AP. Decrease Cash”. If the condition is not fulfilled, then the entity proceeds to trigger manual discounting.

In manual discounting, the entity leaves through the False exit towards Remove module “Remove Invoice From Queue”, which removes the first entity in the Hold Invoice.Queue. The original entity i.e. the entity that triggered the removal of the entity proceeds to a Hold module “Wait to Update Cash”, which waits for a Signal sent from the row below, the one of the removed entity. This signal is sent via a predefined unique number e.g. 8. Once the signal is received, the entity proceeds to Decide module “Enough factored for THmin after payment?”, which checks whether $C_t \geq TH_{min} + AmountToFinance$ holds. In case it is fulfilled, the entity proceeds to Assign module “Decrease AP. Decrease Cash”. In case it is not, the entity flows back to Decide module “No Invoices Pending on Queue?”. The removed entity from the Remove module proceeds to Assign module “Assign CF After MD”, where variable CF_{MD} is defined as $G_t / e^{(InvoiceMaturity - TNOW) \cdot \gamma_d}$. In the next Assign module “MD AR. Increase Cash”, several assignments are made:

- Variable AR_t is reduced by attribute G_t
- Cash level variable C_t is augmented by attribute CF_{MD}
- Control variable to measure total cash inflows *Cash Inflow* is augmented by CF_{MD}
- Attribute Factoring Cost is defined as $G_t - CF_{MD}$
- Variable *CumFactoringCost*, the cumulative cost of factoring, is defined as $CumFactoringCost + G_t - CF_{MD}$

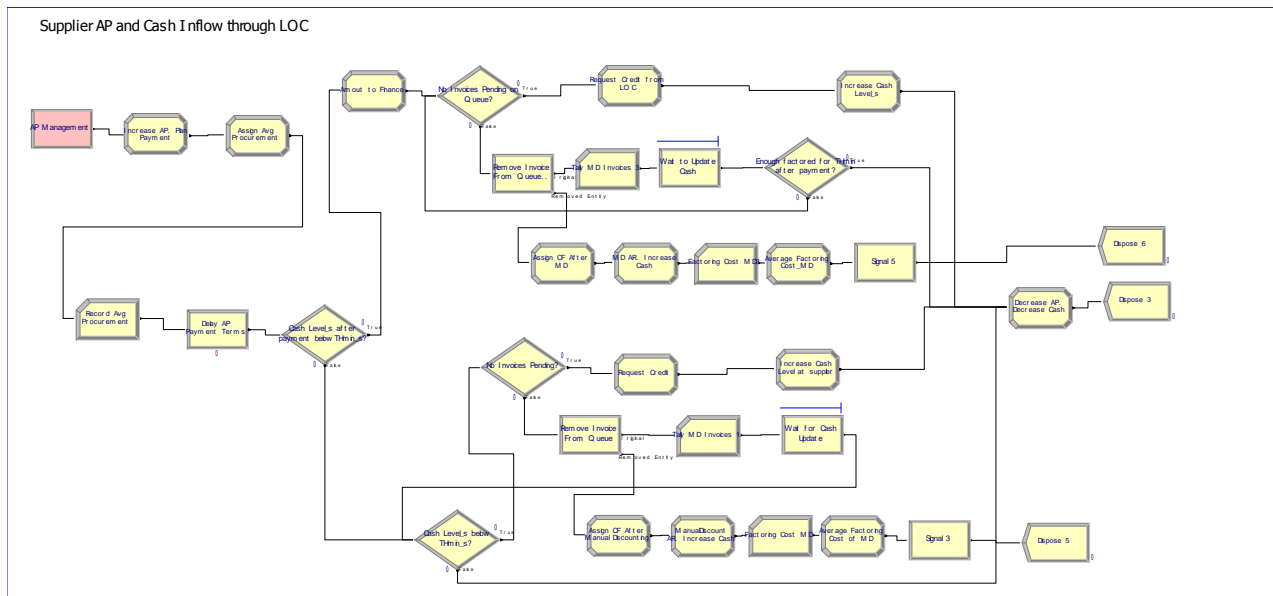
The entity proceeds to a Record module, that counts attribute Factoring Cost, and later by Assign module “Average Factoring Cost_MD”, where variable *AvgFactoringCost* is defined as $CumFactoringCost/TNOW$. The entity proceeds to Signal module, which sends a signal to the Hold module above by sending a unique value e.g. 8. The entity is later disposed.

If condition of Decide module “Cash Level_s below THmin_s?” is not fulfilled, it proceeds to a Decide module “Cash Level_s below THmin_s?”, where it is tested if $C_t < TH_{min}$. If the condition is fulfilled, then exactly the same manual discounting scheme as above is followed and the entity later proceeds to Assign module “Decrease AP. Decrease Cash”. In case this condition does not hold, the entity proceeds directly to the Assign module “Decrease AP. Decrease Cash”.

At Assign module “Decrease AP. Decrease Cash” three assignments take place:

- Variable AP_t is reduced by H_t
- Variable C_t is reduced by H_t
- Control variable *Cash Outflow* is augmented by H_t

Figure A-8: Accounts Payable, cash Inflow through LOC

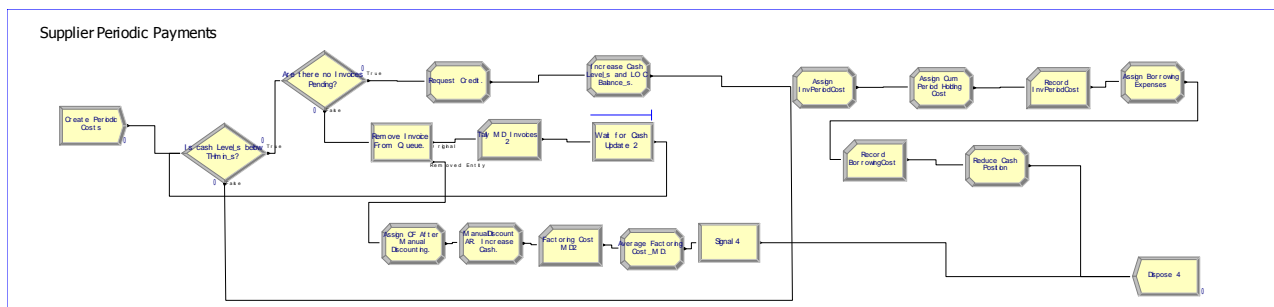


Cash Management: Periodic Payments

Figure A-9 depicts the cash management system related to periodic payments PMT_t . This segment requests credit and triggers manual discounting to assure sufficient cash is available before paying down periodic payments.

Single entities are generated every day at Create module “Create Periodic Costs” and proceed to Decide module “Is cash Level_s below THmin_s?”, where it is tested whether $C_t < TH_{min}$. In case the condition is fulfilled, the entity proceeds to a Decide module “Are there no Invoices Pending?”. From this point on, the structure is just the same as in Figure A-8, where the supplier borrows from the LOC in case there are no pending invoices available for discounting, or it triggers manual discounting. If the condition at the first Decide module does not hold, it proceeds directly to Assign module “Assign InvPeriodCost”, where variable *Period Inventory Cost* is defined as $I_t^1 * h^1 + I_t^2 * h^2 + I_t^3 * h^3$. In the next Assign module “Assign Cum Period Holding Cost”, the cumulative holding cost is computed, and this amount is recorded in the following module. Later, in Assign module “Assign Borrowing Expenses” the interests paid on the LOC are computed, where variable *BorrowingCost* is defined as $LOC_t \cdot \beta_d$. We recall that β_d is the interest rate converted to daily periods under the assumption of continuous compounding. The borrowing cost is recorded in the following module. Finally, in Assign module “Reduce Cash Position” variable C_t is reduced by *Period Inventory Cost* and *BorrowingCost*. Also, control variable *Cash Outflow* is augmented by *Period Inventory Cost* and *BorrowingCost*.

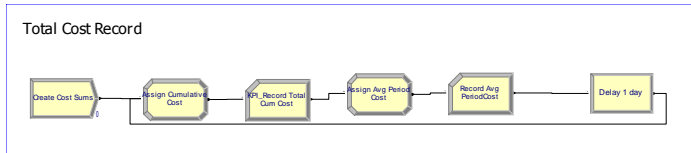
Figure A-9: Periodic Payments



Total Cost Computation

Figure A-10 depicts the cash management system related to total cost computation. This value was used for the optimisation at OptQuest. This segment calculates the total cost on each period and the cumulative cost. At time 1 Create module “Create Cost Sums” generates a single entity, which proceeds to Assign module “Assign Cumulative Cost”. Therein, attribute *PeriodCostVar* is defined as $GC_{(t)}$. And variable *CumTotalCost* is defined as $+GC_{(t)}$. An average period cost *AvgPeriodCost* is computed in the following Assign module as $CumTotalCost/TNOW$. The entity is delayed for 1 day and flows back to the first Assign module.

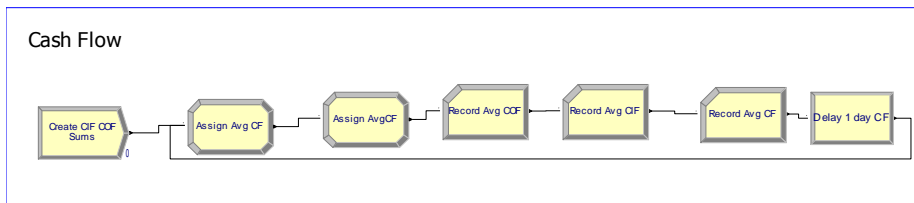
Figure A-10: Total Cost Computation



Cash Management: Cash Flow Variance Computation

Figure A-11 depicts the cash management system related to computation of cash flow variance. At time 1 the Create module “Create CIF COF Sums” generates a single entity, which proceeds to Assign module “Assign Avg CF”, which defines variable average reflecting cash outflow *AvgCOF* as the control variable *Cash Outflow/TNOW* and variable reflecting average cash inflow *AvgCIF* as the control variable *Cash Inflow/TNOW*. The following Assign module “Assign AvgCF” calculates the difference of the two previous variables. Three record modules record the three expressions and later the entity proceeds to Delay module “Delay 1 day CF”, where the entity is delayed for one day, after which it flows back to the first Assign module.

Figure A-11: Cash Flow Variance Computation



LOC Reset

Since the supplier begins receiving cash inflows and cash invoices only after *TB* periods, we see that during the first *TB* periods the supplier gets highly indebted. For this reason, as seen in Figure A-12, we generate a single entity at time *TB*, which proceeds to Assign module “Reset LOC”, which sets LOC_t to zero. This way, we erase all borrowing activity before the supplier begins receiving cash inflows.

Figure A-12: LOC Reset



Statistics Collection

Figure A-13 displays the spreadsheet view of the Statistics module. The spreadsheet includes Time-Persistent statistics of all inventory levels (stock, backorder, cash, LOC, etc). It also includes the Time-Persistent statistic of costs, several KPIs and of plant utilization, that is, the percentage of time the plant is busy producing. Finally, the Output statistics estimate customer service levels at each echelon in terms of the fill rate, namely, the probability (fraction) of orders that were satisfied from on-hand inventory, without experiencing backordering.

Figure A-13: Dialog spreadsheet of the Statistic module

Statistic - Advanced Process					
	Name	Type	Expression	Collection Period	Report Label
1	Avg_m WH Inventory	Time-Persistent	Inventory_WH	Entire Replication	Avg_m WH Inventory
2	Avg_m Output Inventory	Time-Persistent	Inventory_Output	Entire Replication	Avg_m Output Inventory
3	Avg_m Input Inventory	Time-Persistent	Inventory_Input	Entire Replication	Avg_m Input Inventory
4	Avg_m WH Backorder	Time-Persistent	Backorder_WH	Entire Replication	Avg_m WH Backorder
5	Avg_m Output Backorder	Time-Persistent	Backorder_Output	Entire Replication	Avg_m Output Backorder
6	Plant Utilization	Time-Persistent	Production_Plant == 1	Entire Replication	Plant Utilization
7	Avg_f AP_s Value	Time-Persistent	AP_s	Entire Replication	Avg_f AP_s Value
8	Avg_f Cash Level_s Value	Time-Persistent	Cash Level_s	Entire Replication	Avg_f Cash Level_s Value
9	Avg_f LOC_s Value	Time-Persistent	LOC Balance_s	Entire Replication	Avg_f LOC_s Value
10	Cm_WH Average Inventory Holding Cost	Time-Persistent	Inventory_WH * Holding Cost_WH	Entire Replication	Cm_WH Average Inventory Holding Cost
11	Cm_Output Average Inventory Holding Cost	Time-Persistent	Inventory_Output * Holding Cost_Output	Entire Replication	Cm_Output Average Inventory Holding Cost
12	Cm_Input Average Inventory Holding Cost	Time-Persistent	Inventory_Input * Holding Cost_Input	Entire Replication	Cm_Input Average Inventory Holding Cost
13	Cm_System Backorder Cost	Time-Persistent	Backorder_WH * Penalty Cost	Entire Replication	Cm_System Backorder Cost
14	CI_Cash Retention Cost	Time-Persistent	Alpha_Period Retaining Rate * Cash Level_s	Entire Replication	CI_Cash Retention Cost
15	CI_Interest Expenses	Time-Persistent	Beta_Period Borrowing Rate * LOC Balance_s	Entire Replication	CI_Interest Expenses
16	CI_Cost of Holding AR	Time-Persistent	Eta_Period AR Holdig Cost Rate * AR_s	Entire Replication	CI_Cost of Holding AR
17	Avg_m Total Inventory Value	Time-Persistent	Inventory Value	Entire Replication	Avg_m Total Inventory Value
18	KPI_Average Cost per Period	Time-Persistent	Period Cost_Expression	Entire Replication	KPI_Average Cost per Period
19	KPI_Average Net Working Capital	Time-Persistent	Net Working Capital	Entire Replication	KPI_Average Net Working Capital
20	KPI_Average Cost per Period_2	Time-Persistent	AvgPeriodCost	Entire Replication	KPI_Average Cost per Period_2
21	KPI_Total Cost	Time-Persistent	CumTotalCost	Entire Replication	KPI_Total Cost
22	KPI_Average Cost per Period_3	Time-Persistent	PeriodCostVar	Entire Replication	KPI_Average Cost per Period_3
23	CI_Cost of Discounting	Time-Persistent	Avg Factoring Cost	Entire Replication	CI_Cost of Discounting
24	KPI_WH Customer Service Level	Output	NC(Record Fully Sat Demand_WH) / MX(1, (NC(Tally WH Demand)))	Entire Replication	KPI_WH Customer Service Level
25	KPI_Output Buffer Customer Service Level	Output	NC(Record Fully Sat Demand_Output) / MX(1, (NC(Tally Output Buffer Demand)))	Entire Replication	KPI_Output Buffer Customer Service Level
26	KPI_Input Buffer Customer Service Level	Output	NC(Record Fully Sat Demand_Input) / MX(1, NC(Tally Input Buffer Demand))	Entire Replication	KPI_Input Buffer Customer Service Level
27	KPI_OPM	Output	(NC(Tally Net Sales) - NC(Tally COGS Value)) / MX(1, NC(Tally Net Sales))	Entire Replication	KPI_OPM
28	KPI_Average DAR	Time-Persistent	LOC Balance_s / MX(1, (Cash Level_s + Unit Cost * Inventory_Input + COGS per unit * (Inventory_Output + Inventory_WH) + AR_s))	Entire Replication	KPI_Average DAR
29	Avg_f AR_s Value	Time-Persistent	AR_s	Entire Replication	Avg_f AR_s Value
30	Avg_f CIF Value	Time-Persistent	AvgCIF	Entire Replication	Avg_f CIF Value
31	Avg_f COF Value	Time-Persistent	AvgCOF	Entire Replication	Avg_f COF Value
32	Avg_f CF Value	Time-Persistent	AvgCF	Entire Replication	Avg_f CF Value
33	StDev_f CF	Time-Persistent	TSTD(Record Avg CF)	Entire Replication	StDev_f CF
34	StDev_f CIF	Time-Persistent	TSTD(Record Avg CIF)	Entire Replication	StDev_f CIF
35	StDev_f COF	Time-Persistent	TSTD(Record Avg COF)	Entire Replication	StDev_f COF

Appendix 8. Model Validation: BAU

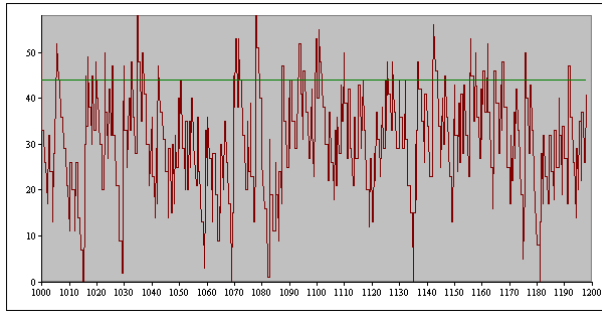
We have conducted face, concurrent and internal validity tests. For a review on validity, we refer to Howit & Cramer (2011). Face validity measures if the items measure what they claim to measure. We have assessed this validity informally, by interpreting experiments results and analysing model behaviour. By analysing the form and behaviour of certain graphs, we confirmed validity. Concurrent validity refers whether scales correlate well with other measures of the same concept taken at a different setting. We made this by comparing scenarios with different coefficients of variation under the same conditions. The graphs below also show this experiment. We obtained consistent and coherent results for higher volatility. Finally, internal validity evaluates whether the experiment design closely follows the principle of cause and effect. Hence, by conducting sensitivity analyses and several scenarios we assured that changes in model inputs caused expected outcomes. We confirmed this by selecting diverse levels of margins and risk profiles. This validity test can be seen in Section 6.2. Now, we present several tests we conducted in order to evaluate these three kind of validity.

The first test that we conducted was face validity. We have conducted these analyses for several scenarios. However, here we present the case of a supplier with margin $\omega = 0.29$, risk profile $\varphi = 2.0$ and coefficients of variation $c.v. = 0.25$ and $c.v. = 1.0$. We note that all the instances of this experiment yielded similar results.

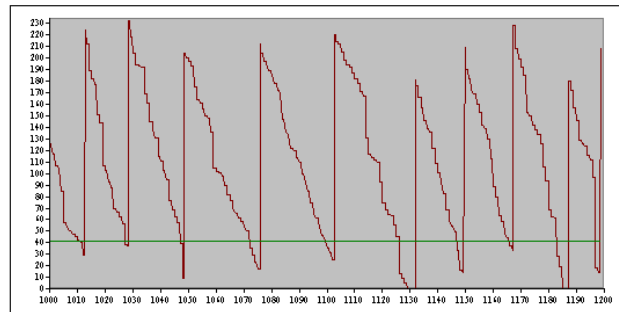
In all experiments we let the system start with cash position equal to the maximum threshold TH_{max} . Likewise, starting inventories on hand at all echelons were set above the reorder point. Receivables, payables, the LOC Balance and accumulated dividends had a starting value of zero. We assess performance after 500 warm-up periods i.e. days. Also, at period $t = TB$ we reset back to zero the *LOC* balance to compensate for the extra borrowing the supplier had while not receiving cash inflows. We calculate 95 percent confidence intervals from 30 independent replications with a run-length of 4000 periods including the warm-up.

First, we analyse inventory on hand at the warehouse, which is shown in the figure below. The graph on the left shows the case of $c.v. = 0.25$ and the one on the right $c.v. = 1.0$, both at times $t = (1000, 2000)$. According to theory, when facing higher volatility, the supplier has an inventory policy that requires him to hold on to more inventory to hedge against higher uncertainty, which is confirmed in our model. Furthermore, having less inventory requires that the supplier orders more often. Also, higher demand volatility also increases inventory volatility too, which can be seen in the graph as well. Finally, analysing the shape of the inventory, we realise that it resembles very well the shape of a typical Economic Order Quantity model.

Figure A-14: WH Inventory on Hand



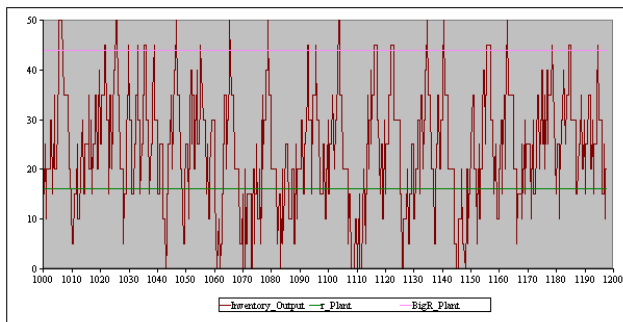
(a) WH inventory on hand and reorder point $c.v. = 0.25$



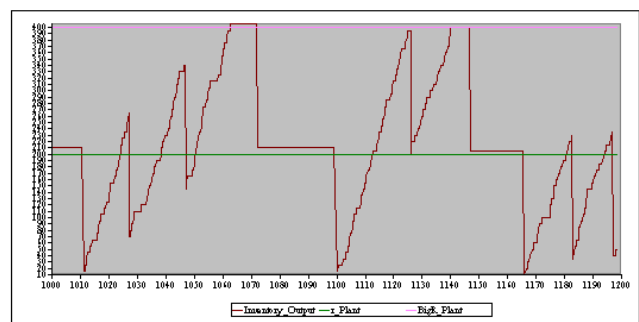
(b) WH inventory on hand and ROP $c.v. = 1.0$

We conducted the same test for the Output Buffer and we arrive at the same conclusions: the effects of higher uncertainty force the supplier to have higher inventory levels, and inevitably higher volatility. Likewise, the graph resembles very well the one of an Economic Production Quantity.

Figure A-15: OB Inventory on Hand



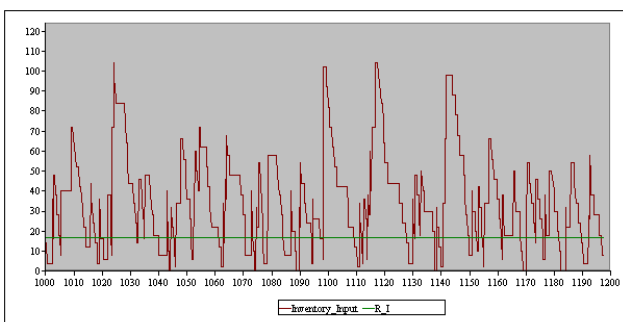
(a) OB inventory on hand and reorder point $c.v. = 0.25$



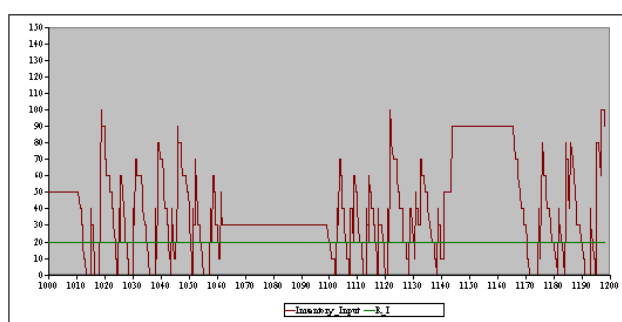
(b) OB inventory on hand and reorder point $c.v. = 1.0$

For the case of the Inventory at the Input Buffer, we have the same results. However, contrary to the other echelons, the inventory level is very similar on both scenarios. This occurs because higher demand volatility forces the first two echelons to hold on to more inventory, for which they absorb a higher part of the volatility.

Figure A-16: IB Inventory on Hand



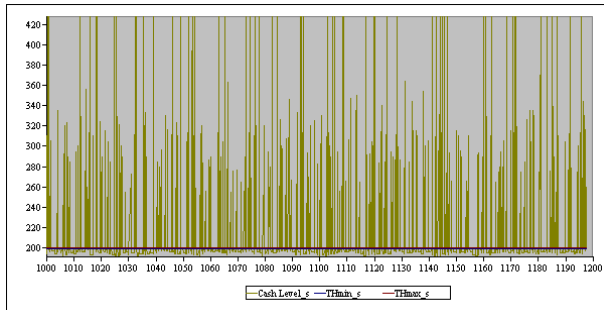
(a) IB inventory on hand and reorder point $c.v. = 0.25$



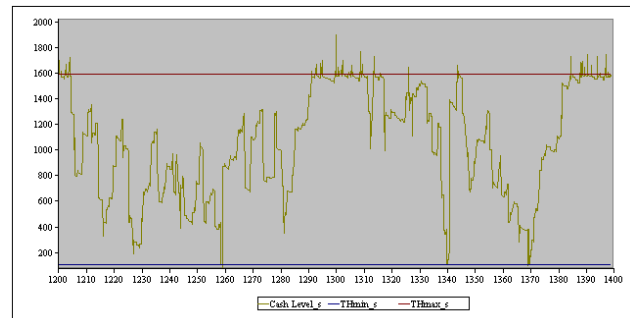
(b) IB inventory on hand and reorder point $c.v. = 1.0$

We have also tested cash level for both variability scenarios. With lower demand uncertainty, the optimised cash policy dictates a single threshold equal to 200. More volatility forces the supplier to hold on to much more cash, and the spread between the minimum and maximum threshold is much wider. This causes also more volatility and unpredictability in cash level amount.

Figure A-17: BAU cash Level



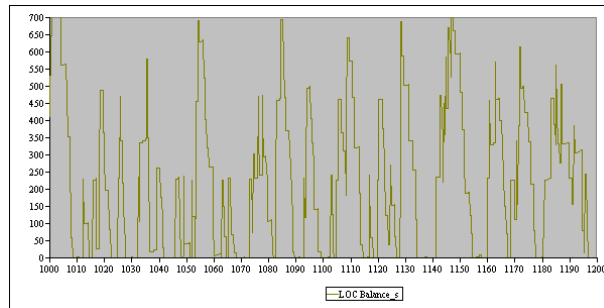
(a) Cash level and thresholds $c. v. = 0.25$



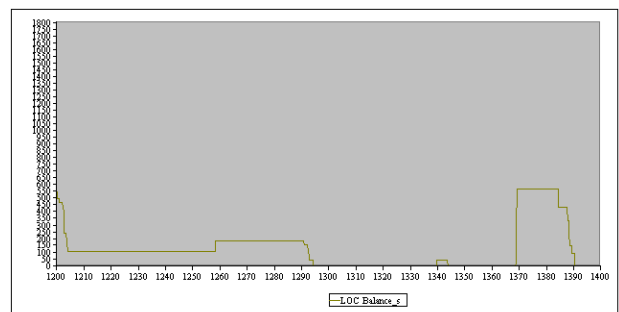
(b) Cash level and thresholds $c. v. = 1.0$

In the case of the LOC, we see also a less volatile balance for lower demand volatility. Also, we see that the supplier borrows much less often and smaller quantities from the LOC with $c. v. = 1.0$. This is consistent, because the borrowing rate is much higher than the cash holding cost. Hence, the supplier prefers to hold on to more cash. We also conducted this experiment for a lower level of ϕ and the result was the opposite: the supplier had a much higher borrowing activity and held a smaller amount of cash.

Figure A-18: BAU LOC Level



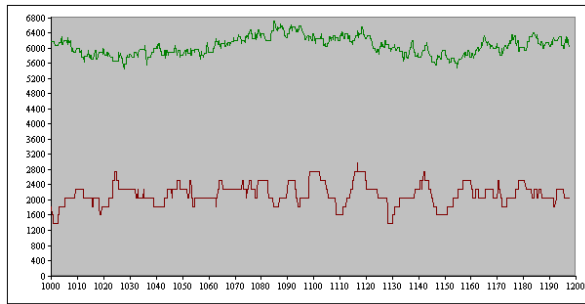
(a) LOC Balance $c. v. = 0.25$



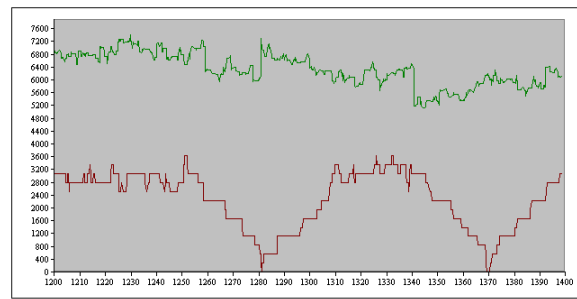
(b) LOC Balance $c. v. = 1.0$

Accounts Receivable and Payable also are impacted by volatility. Higher demand volatility directly causes higher volatility in AR. Also, demand uncertainty causes the supplier to have a much more irregular ordering activity, causing AP volatility to increase.

Figure A-19: BAU AP and AR



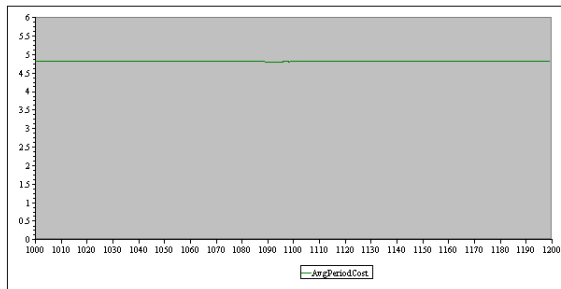
(a) Accounts Receivable and Payable $c. v. = 0.25$



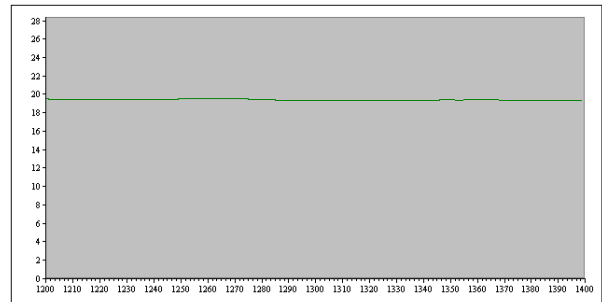
(b) Accounts Receivable and Payable $c. v. = 1.0$

Finally, we show the average cost per period. On both cases it is quite stable, but volatility causes a much higher cost for the supplier due to higher inventory, cash and credit levels.

Figure A-20: BAU average Cost per Period



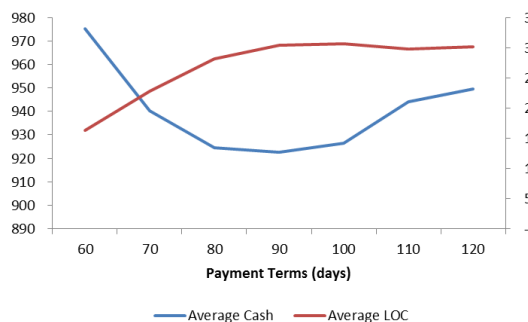
(a) Average Cost per Period $c. v. = 0.25$



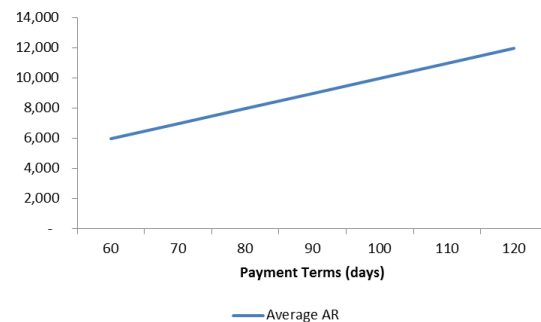
(b) Average Cost per Period $c. v. = 1.0$

We test cash, LOC and AR levels for different payment terms. First, we see in figure (a) that LOC level increases with payment terms. This makes sense as the firm needs more financing if there she has to wait longer for the cash inflow. Cash level decreases because the firm still has the same expenses to pay on the same frequency; hence cash on hand (either obtained by sales or by financing) is lower. Figure(b) shows that AR increases linearly with payment terms, which is reasonable as TB also increases linearly.

Figure A-21: BAU average cash, LOC and AR



(a) Average Cash (left y axis) and LOC (right y axis), with $\varphi = 2.0, \omega = 0.29, c. v. = 1.0$



(b) Average AR, with $\varphi = 2.0, \omega = 0.29, c. v. = 1.0$

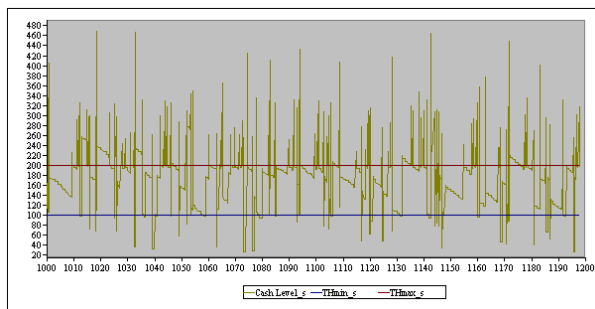
Appendix 9. Model Validation: SCF

We conducted the same experiments as in the BAU model to test validity of the SCF model. We now present the tests for manual and automatic discounting. However, since operations behaviour is the same as in the BAU case, we limit our analysis to financial flow measures.

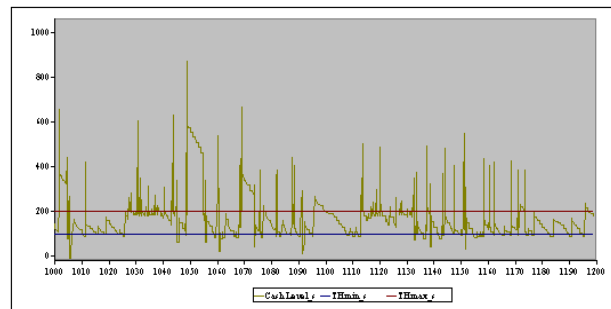
Manual Discounting

Looking at the graphs below we see that cash level under MD has a much higher volatility. Even though the policy is the same i.e. the optimisation yields the same values for the cash thresholds, we see that the figure on the right has much more variance.

Figure A-22: MD cash Level



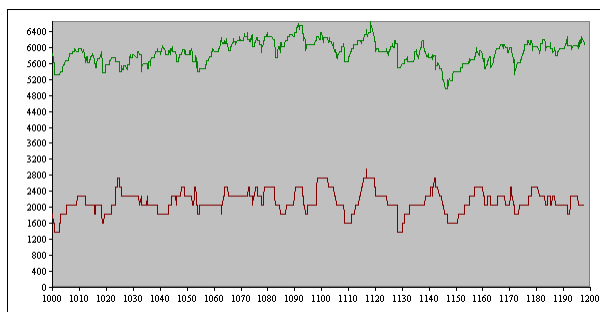
(a) Cash level and thresholds $c.v. = 0.25$



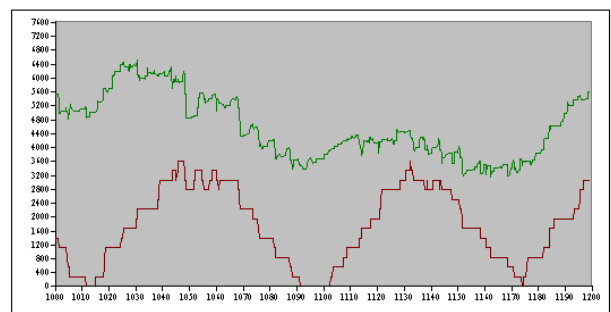
(b) Cash level and thresholds $c.v. = 1.0$

Accounts Receivable and Payable have a same behaviour as cash too. Also, compared to the BAU case we see that AR has a lower level due to discounting of several receivables, and AP has almost an identical behaviour.

Figure A-23: MD AR and AP



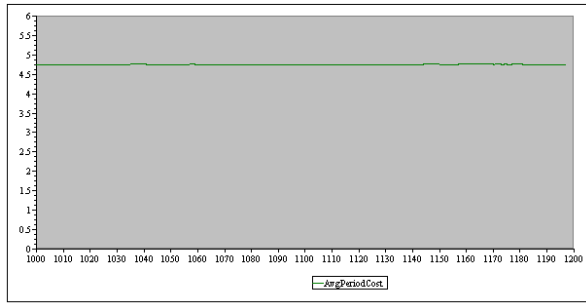
(a) Accounts Receivable and Payable $c.v. = 0.25$



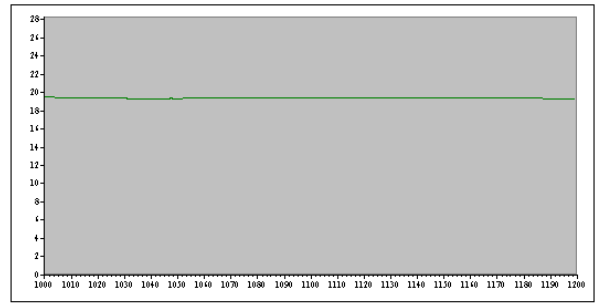
(b) Accounts Receivable and Payable $c.v. = 1.0$

Furthermore, as in the case of MD the supplier does not borrow anything from the LOC, we omit these graphs in this analysis. Finally, we show the average cost per period. We see again a quite stable amount. Also, higher volatility induces a higher cost for the supplier.

Figure A-24: MD average Cost per Period



(a) Average Cost per Period $c.v. = 0.25$

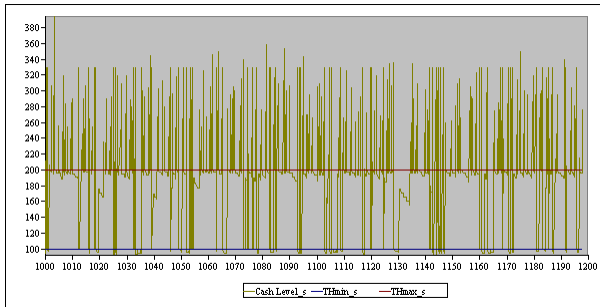


(b) Average Cost per Period $c.v. = 1.0$

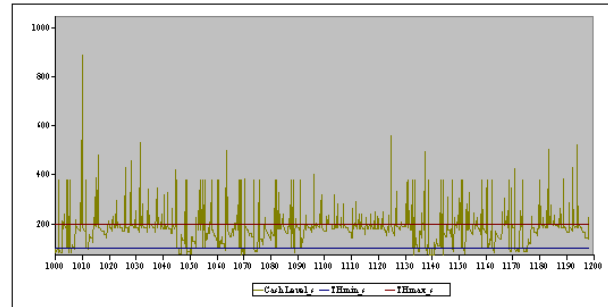
Automatic Discounting

The results under AD for cash level are very similar to the ones of manual discounting.

Figure A-25: AD cash level



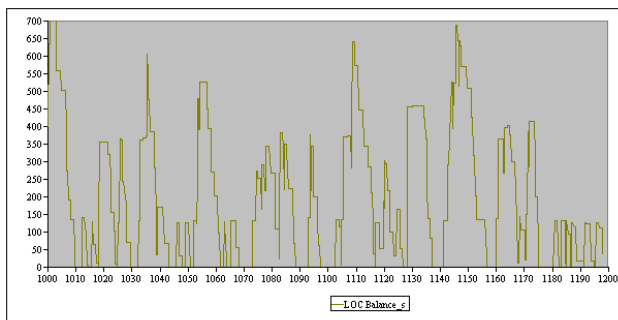
(a) Cash level and thresholds $c.v. = 0.25$



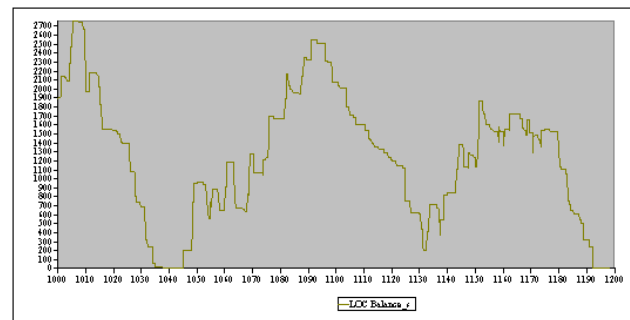
(b) Cash level and thresholds $c.v. = 1.0$

Analysing the behaviour of the LOC, we immediately see that borrowing activity is much higher and has a higher amount of variance for higher demand volatility. As we also pointed out in the main body of this dissertation, through AD most of the extra liquidity the supplier earns leaves the firm in the way of dividends. Therefore, borrowng activity does not decrease.

Figure A-26: AD LOC level



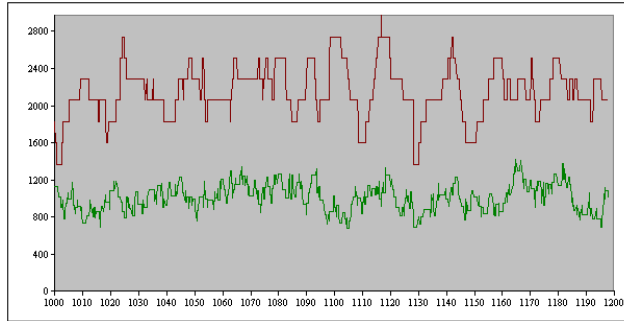
(a) Line of Credit $c.v. = 0.25$



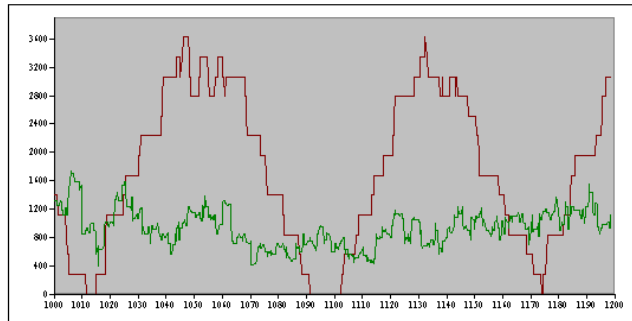
(b) Line of Credit $c.v. = 1.0$

Below we see that AR are much lower than in the BAU and MD scenarios because receivables are quickly discounted. AP behaviour remains constant because there is no change in payment terms to the T2S.

Figure A-27: AD AR and AP



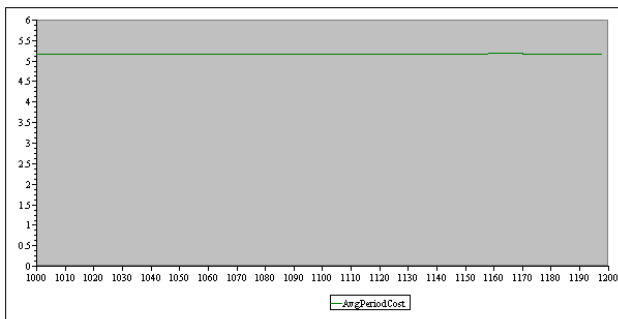
(a) Accounts Receivable and Payable $c. v. = 0.25$



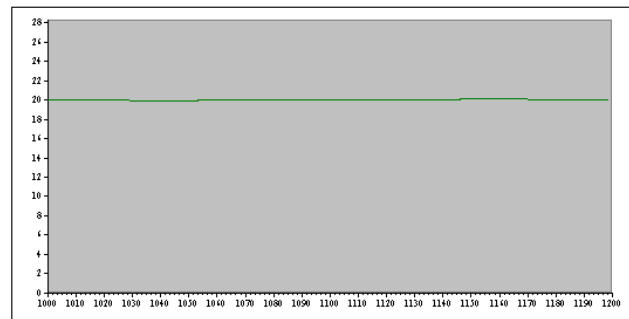
(b) Accounts Receivable and Payable $c. v. = 1.0$

We can draw the same conclusions with respect to the average cost per period.

Figure A-28: AD average Cost per Period



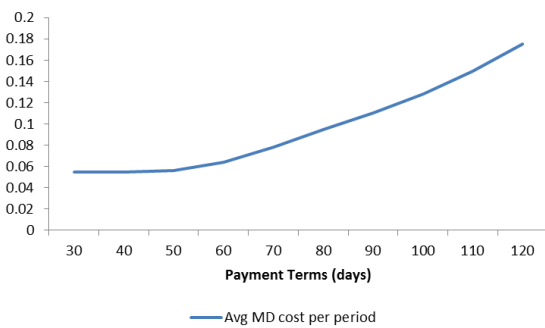
(a) Average Cost per Period $c. v. = 0.25$



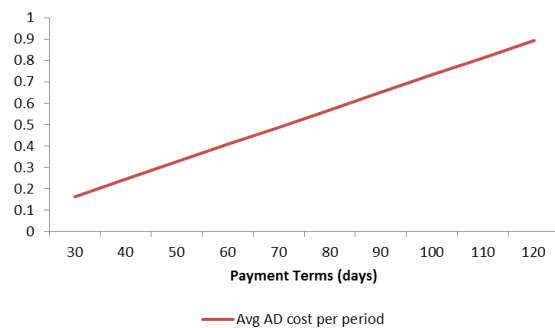
(b) Average Cost per Period $c. v. = 1.0$

Finally, we note that the AD discounting cost increases linearly with payment terms, while the MD cost does not increase in this manner. This is because under AD payment terms increase linearly and hence the time to maturity too. Under MD this does not occur because the supplier discounts only if needed.

Figure A-29: Average MD and AD cost per period



(a) Average MD cost per period, with $\varphi = 2.0, \omega = 0.29, c. v. = 1.0$



(b) Average AD cost per period, with $\varphi = 2.0, \omega = 0.29, c. v. = 1.0$

Appendix 10. Optimisation equations

Here we present the optimisation equations that were done for the scenarios $c.v. = 0.25$ and $c.v. = 1.0$. As pointed out hereinbefore, the approach towards the optimisation was made in four steps for each different instance of the model: first by optimising the inventory policy at the warehouse, then at the output buffer, then at the input buffer and at last the cash management policy.

OptQuest demands a starting suggested value. For all parameters, we defined this as the maximum amount as dictated in the constraints of each optimisation equation. Finally, the minimum amount for each constraint was set to the average demand per day i.e. 10 units for the inventory policies, and the monetary value of the average demand for the cash policy.

Case $c.v. = 0.25$

Warehouse

$$\begin{aligned} & \text{Min } GC_{(.)} \\ & \text{s. t.} \quad \text{Service level}_{WH} = \frac{\text{Fully satisfied orders}}{\text{Total orders}} \geq 0.95 \\ & \quad 10 \leq Q_1 \leq 50 \\ & \quad 10 \leq R_1 \leq 50 \\ & \quad Q_1, R_1 \in \mathbb{Z} \end{aligned}$$

Output Buffer

$$\begin{aligned} & \text{Min } GC_{(.)} \\ & \text{s. t.} \quad \text{Service level}_{OB} \geq 0.90 \\ & \quad \text{Service level}_{OB} \geq 0.90 \\ & \quad 10 \leq r_2 \leq 30 \\ & \quad 30 \leq R_2 \leq 50 \\ & \quad R_2 > r_2 \\ & \quad r_2, R_2 \in \mathbb{Z} \end{aligned}$$

Input Buffer

$$\begin{aligned} & \text{Min } GC_{(.)} \\ & \text{s. t.} \quad \text{Service level}_{WH} \geq 0.95 \\ & \quad \text{Service level}_{OB} \geq 0.90 \\ & \quad \text{Service level}_{IB} \geq 0.90 \\ & \quad 10 \leq Q_3 \leq 50 \\ & \quad 10 \leq R_3 \leq 50 \\ & \quad Q_3, R_3 \in \mathbb{Z} \end{aligned}$$

Cash Management

$$\begin{aligned} & \text{Min } GC_{()} \\ & \text{s. t. } TH_{max} > TH_{min} \\ & \quad 200 \leq TH_{max} \leq 500 \\ & \quad 100 \leq TH_{min} \leq 400 \end{aligned}$$

Case c. v. = 1.0

Here, we selected a much higher value for minimum amount of the constraints. We conducted at first experiments that assessed model behaviour, with which we selected the minimum values.

Warehouse

$$\begin{aligned} & \text{Min } GC_{()} \\ & \text{s. t. } \text{Service level}_{WH} \geq 0.95 \\ & \quad 20 \leq Q_1 \leq 500 \\ & \quad 20 \leq R_1 \leq 500 \\ & \quad Q_1, R_1 \in \mathbb{Z} \end{aligned}$$

Output Buffer

$$\begin{aligned} & \text{Min } GC_{()} \\ & \text{s. t. } \text{Service level}_{OB} \geq 0.90 \\ & \quad \text{Service level}_{OB} \geq 0.90 \\ & \quad 100 \leq r_2 \leq 300 \\ & \quad 301 \leq R_2 \leq 500 \\ & \quad R_2 > r_2 \\ & \quad r_2, R_2 \in \mathbb{Z} \end{aligned}$$

Input Buffer

$$\begin{aligned} & \text{Min } GC_{()} \\ & \text{s. t. } \text{Service level}_{WH} \geq 0.95 \\ & \quad \text{Service level}_{OB} \geq 0.90 \\ & \quad \text{Service level}_{IB} \geq 0.90 \\ & \quad 40 \leq Q_3 \leq 100 \\ & \quad 20 \leq R_3 \leq 100 \\ & \quad Q_3, R_3 \in \mathbb{Z} \end{aligned}$$

Cash Management

$$\begin{aligned} & \text{Min } GC_{()} \\ & \text{s. t. } TH_{max} > TH_{min} \\ & \quad 200 \leq TH_{max} \leq 3000 \\ & \quad 100 \leq TH_{min} \leq 1000 \end{aligned}$$

Appendix 11. List of industries and margins

The list below presents all the industries and their margins from the study of Damodaran (2015). The columns marked in grey represent the relevant industries that may prove to be good recipients of SCF from a LLP. Also, we show margins based on EBITDA. As discussed in the main body of this dissertation, the column EBITDA + SG&A / Sales is the closest indicator to gross margin.

Table A-12: List of industries and margins

Industry	Number of firms	Net Income Based	EBITDA Based		
		Net Margin	EBITDA/ Sales	EBITDA +SG&A/ Sales	EBITDA + R&D/ Sales
Oilfield Svcs/Equip.	161	3.81%	7.50%	10.44%	7.87%
Farming/Agriculture	37	3.33%	6.74%	11.29%	7.71%
Oil/Gas Distribution	85	3.04%	9.73%	12.37%	9.73%
Reinsurance	4	8.52%	12.10%	12.43%	12.10%
Engineering/Construction	56	1.56%	6.17%	13.00%	6.18%
Transportation	21	4.96%	12.31%	13.63%	12.33%
Healthcare Support Services	138	2.16%	5.27%	13.83%	5.35%
Steel	40	-4.33%	7.86%	14.34%	7.93%
Air Transport	22	9.32%	10.63%	14.57%	10.70%
Real Estate (General/Diversified)	11	34.38%	8.97%	15.62%	8.97%
Auto Parts	75	3.44%	8.80%	15.79%	11.47%
Auto & Truck	22	3.16%	8.23%	17.25%	12.71%
Food Wholesalers	14	1.79%	4.22%	17.50%	4.22%
Coal & Related Energy	42	-4.44%	14.63%	19.03%	15.42%
Retail (Automotive)	30	3.12%	6.09%	19.79%	6.09%
Trucking	30	3.78%	13.51%	19.84%	13.51%
Insurance (Life)	25	8.19%	10.74%	20.59%	10.74%
Homebuilding	35	6.82%	9.37%	20.70%	9.38%
Aerospace/Defense	93	7.64%	13.61%	21.13%	17.68%
Hospitals/Healthcare Facilities	56	4.50%	18.12%	21.56%	18.12%
Chemical (Diversified)	10	7.43%	14.42%	21.78%	17.96%
Construction Supplies	55	6.14%	12.61%	21.97%	15.16%
Chemical (Basic)	46	5.98%	15.93%	22.05%	16.50%
Insurance (General)	24	8.47%	18.13%	22.09%	18.15%
Oil/Gas (Integrated)	8	9.99%	18.98%	22.95%	19.26%
Packaging & Container	26	4.90%	13.34%	23.47%	13.98%

Retail (Grocery and Food)	21	2.71%	4.74%	23.56%	4.74%
Paper/Forest Products	22	2.58%	12.18%	23.85%	12.27%
Computer Services	119	5.56%	11.28%	24.78%	13.43%
Shipbuilding & Marine	14	13.96%	16.38%	24.79%	16.38%
Insurance (Prop/Cas.)	52	9.00%	16.15%	24.98%	16.15%
Rubber& Tires	4	3.16%	11.28%	25.00%	13.28%
Building Materials	39	4.09%	9.80%	25.78%	10.55%
Utility (General)	21	8.71%	25.72%	26.05%	25.76%
Furn/Home Furnishings	27	3.98%	10.75%	26.66%	12.47%
Retail (General)	23	2.67%	7.08%	26.74%	7.08%
Electronics (General)	189	6.18%	12.75%	26.86%	17.72%
Retail (Distributors)	90	4.23%	9.17%	27.59%	9.21%
Metals & Mining	124	1.63%	23.80%	28.22%	24.22%
Real Estate (Development)	18	1.26%	16.99%	28.79%	16.99%
Electronics (Consumer & Office)	28	3.56%	9.03%	29.78%	15.58%
Food Processing	96	6.87%	14.82%	29.83%	15.52%
Power	82	8.03%	27.09%	30.35%	27.20%
Total Market	7887	7.84%	15.18%	30.42%	17.21%
Semiconductor Equip	47	4.73%	16.53%	30.83%	29.76%
Environmental & Waste Services	103	3.08%	19.34%	31.01%	19.35%
Retail (Special Lines)	128	3.46%	8.79%	31.26%	8.83%
Business & Consumer Services	177	4.29%	12.93%	31.94%	13.18%
Diversified	23	10.12%	20.04%	32.18%	22.12%
Retail (Online)	46	2.34%	7.15%	32.55%	8.50%
Restaurant/Dining	79	9.40%	19.67%	32.74%	19.71%
Retail (Building Supply)	5	6.00%	12.04%	33.96%	12.04%
Machinery	137	8.54%	15.46%	34.42%	17.29%
Advertising	52	3.98%	15.08%	34.77%	15.29%
Computers/Peripherals	64	13.69%	23.66%	34.86%	28.59%
Electrical Equipment	126	5.64%	15.67%	35.02%	18.08%
Publishing & Newspapers	43	13.54%	14.43%	35.24%	15.60%
Financial Svcs. (Non-bank & Insurance)	288	34.14%	6.18%	35.25%	6.25%
Office Equipment & Services	25	4.47%	10.97%	35.68%	12.39%
Chemical (Specialty)	103	10.01%	18.63%	37.49%	21.49%
Transportation (Railroads)	10	18.29%	37.58%	37.70%	37.58%
Brokerage & Investment Banking	46	12.48%	0.45%	39.59%	0.50%
Semiconductor	100	13.70%	27.15%	40.07%	45.72%
Recreation	68	8.69%	18.64%	40.13%	21.12%
Hotel/Gaming	80	3.72%	23.93%	41.85%	24.25%
Entertainment	84	12.59%	23.84%	41.91%	23.87%

Telecom. Equipment	126	14.51%	22.86%	43.06%	37.59%
Drugs (Biotechnology)	400	11.18%	16.75%	44.16%	50.32%
Healthcare Information and Technology	127	6.72%	16.13%	44.45%	22.15%
Software (Entertainment)	20	10.11%	18.22%	45.10%	37.08%
Precious Metals	147	-13.91%	37.41%	45.18%	39.03%
Shoe	13	8.95%	13.71%	45.99%	13.82%
Information Services	67	13.78%	25.64%	46.17%	27.16%
Utility (Water)	19	15.03%	41.72%	46.30%	41.77%
Real Estate (Operations & Services)	52	4.96%	12.02%	47.62%	12.02%
Beverage (Alcoholic)	22	14.21%	22.27%	47.93%	22.29%
Investments & Asset Management	148	19.11%	17.67%	48.65%	17.95%
R.E.I.T.	213	19.01%	40.02%	48.75%	40.04%
Telecom (Wireless)	21	-2.93%	18.85%	49.13%	18.92%
Broadcasting	28	11.56%	28.72%	50.97%	28.73%
Education	42	1.99%	13.13%	51.14%	13.99%
Apparel	64	7.46%	14.77%	51.15%	15.34%
Banks (Regional)	676	22.23%	0.00%	51.35%	0.00%
Software (Internet)	327	15.57%	22.88%	51.41%	36.79%
Bank (Money Center)	13	18.90%	0.00%	51.56%	0.00%
Green & Renewable Energy	26	0.36%	34.77%	52.16%	34.80%
Oil/Gas (Production and Exploration)	392	7.52%	45.00%	52.43%	45.10%
Household Products	135	8.99%	19.79%	52.80%	21.59%
Healthcare Products	261	9.49%	22.26%	55.18%	30.03%
Cable TV	18	9.31%	28.90%	55.48%	28.96%
Software (System & Application)	259	17.34%	29.84%	56.67%	45.50%
Beverage (Soft)	46	12.66%	21.81%	57.96%	22.33%
Telecom. Services	77	11.47%	36.72%	58.62%	37.26%
Tobacco	20	22.42%	44.12%	61.21%	45.16%
Drugs (Pharmaceutical)	151	15.95%	32.81%	61.46%	47.69%
Unclassified	8	-43.05%	-10.84%	102.36%	-7.18%

Appendix 12. List of Abbreviations

Term	Meaning
4PL, 3PL	4th and 3rd-party logistics provider
AR	Accounts Receivable
AP	Accounts Payable
BAU	Business as Usual
BPO	Business Process Outsourcing
CDF	Cumulative Distribution Function
CLD	Causal Loop Diagram
COGS	Cost of Goods Sold
EBT	Earnings Before Taxes
EMEA	Europe, Middle East and Africa
FSP	Financial Supply Chain
FSP	Financial Service Provider
IT	Information Technology
KPI	Key Performance Indicators
LLP	Lead Logistics Provider
LOC	Line of Credit
LSP	Logistics Service Provider
OM	Operations Management
OR	Operations Research
PO	Purchase Order
P/FSC	Physical/Financial Supply Chain
PSC	Physical Supply Chain
RF	Reverse Factoring
SC	Supply Chain
SCF	Supply Chain Finance
SCI	Supply Chain Integration
SCM	Supply Chain Management
SG&A	Selling, General and Administrative (Expenses)
SME	Small and Medium-sized Enterprise
SO	Sales Order
VAS	Value Added Services
VMI	Vendor-managed Inventory
WACC	Weighted Average Cost of Capital
WC	Working Capital
WCM	Working Capital Management