A new technology paradigm for collaboration in the supply chain

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Abstract: ‘Just-in-case inventory’ is one of the traditional methods of reducing uncertainty in business. The unfortunate consequence of this approach is the bullwhip effect. An alternative approach is some form of collaborative scenario. Unfortunately, neither approach guarantees optimisation across the supply chain. The fundamental reason for this is found in the rational behaviour that participants in the process adhere to. As it is impossible to suppress rational behaviour, a solution for this problem is sought through orchestration and rigorous implementation of the Collaborative Planning, Forecasting and Replenishment (CPFR) process. A technology framework that promises to facilitate this objective is a Service Oriented Architecture (SOA) based on web services. However a new paradigm, more suited to collaborative business scenarios, is needed. Pi-calculus, coupled with business process modelling and web services, seem to offer a solution. This paper sketches the direction for future research.

Keywords: collaborative planning; forecasting and replenishment; CPFR; supply chain management; SCM; service-oriented architecture; SOA; web services; business process management; BPM; business process execution language; BPEL; pi-calculus.

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1 Introduction

Over the last decade and half, the world of business and industry witnessed numerous technology-based attempts to increase its competitiveness. Unlike the initiatives that preceded this phase, which were mainly concentrated on revenue generation, this particular phase was almost exclusively cost focused. Streamlining, downsizing, Business Process Re-engineering (BPR), core competence and other buzzwords became a part of everyday jargon. Most of these initiatives rely on some sort of enabling technology, designed to make businesses more competitive and more profitable. Unfortunately, despite major efforts, profitability remains a challenge. An alternative approach, focused on customers relationship management paradigm has been introduced, but also has failed to make a step change, at least in this domain.

In parallel with this latest effort, another paradigm started to emerge. Rather than trying to continue to focus on competitive pressures, which seem to provide diminishing returns, business started to see collaboration as a major differentiator. A realisation that value is created not only inside the boundaries of one organisation, but across the whole supply chain, has slowly, but surely begun to gain momentum. As always, technology is maturing and enabling this shift in philosophy, but some concerns and obstacles remain. The objective of this paper is to focus on several of these challenges and explore whether successful implementation of some of the collaborative scenarios in the supply chain is possible. A particular scenario examined is called Collaborative Planning, Forecasting and Replenishment (CPFR).

This paper will initially focus on behavioural issues causing supply chains to act inefficiently and will explore whether new collaborative paradigms have embedded solutions to address such issues automatically. Specifically, this paper will explore the phenomena known as the 'bullwhip effect' and the 'tragedy of the commons' as well as the reasons for their existence in the supply chain intimated. This paper then scrutinises some of the more recent initiatives, such as the latest Voluntary Inter-industry Commerce Standards (VICS) guidelines for CPFR implementation, in order to establish whether the above phenomena are addressed by such initiatives. The final section moves towards areas of future research. All current technologies, procedures and architectures for providing maximum efficiency and effectiveness were designed to work in a competitive environment. It is not necessarily easy to deduce what solutions are needed to improve efficiency and effectiveness in a collaborative environment. This paper intends to provide just preliminary glimpses and hints about the direction of future research in this domain.

2 Preliminary situation analysis

Supply chain issues are as old as the history of business venture. One particular, and not so new, phenomenon affecting every supply chain is inventory stockpiling. Whilst inventory minimisation is a known strategy for improving financial results, the reduction in inventory also yields an increase in exposure to uncertainty, which is difficult to manage. Uncertainty is one of the most undesirable attributes of any business and businesses usually endeavour to minimise it as much as possible. The solution, to many, is the adoption of a common sense, or 'just in case inventory' approach (deMin, 2004). However, this traditional 'just in case' inventory strategy, which reduces the level of uncertainty, has an unpleasant consequence on the supply chain, known as the *bullwhip effect* (Lee et al., 1997). The bullwhip effect can be seen as a result of the safety margins applied to inventory management by all the participants. Every member in the supply chain tries to handle uncertainty and the risk associated with it by adding a safety margin to their stock. However, moving up the supply chain, these safety margins get compounded, as everybody adds a safety margin on top of the existing safety margin. In other words, the further we go upstream, the greater the variance of orders, and consequently, the greater the relative increase in inventory levels.

In today's environment, the bullwhip effect is not only a result of uncertainty associated with lead times (due to order acceptance, manufacturing time, shipping time, etc.). It is also heavily influenced, and even more exaggerated, by some contemporary marketing tactics (promotions, two-for-one, new product enhancements and releases, etc.). Even if the perfect method of optimisation were invented to handle this problem, the bullwhip effect would remain one of the most difficult ones to eradicate. Why?

A simple reason is that the decisions that drive the bullwhip effect are a representation of the most rational behavioural pattern. Taking a safety margin into one's estimates is one of the most rational courses of action. Needless to say, we are only talking about rationality on an individual level. When this 'rationality' is compounded across the chain, the net effect is a complete breakdown of the objective function. Rational behaviour, when applied in isolation, can lead to chaos, just as irrational behaviour can.

The notion of rationality has been explored in a number of papers and some of the most elementary experiments go back almost couple of decades (Sterman, 1989). More recent sources (Sawaya, 2006), although they examine the bullwhip effects in the context of heterogeneous and stochastic demand, still refer to inexplicable findings attributed to behavioural issues, that is, rationality among others.

It has been indicated (Lee et al., 1997) that demand signal processing is considered to be the major contributor to the bullwhip effect and that this effect is a consequence of the players' rational behaviour within supply chain infrastructure. However, this is not the only cause. Most of the sources (Croson et al., 2005) quote the so called operational causes of the bullwhip effect, such as: order batching, gaming due to shortages, price fluctuations and demand signalling. This paper explores behavioural reasons, mainly in the domain of individual rationality, which is discordant with the notion of collaboration across the chain.

Even an experiment conducted to provide insight into behavioural dimension of cooperation in the supply chain (Croson and Donohue, 2006) indicates that certain barriers exist for the complete elimination of the bullwhip effect. Croson and Donohue have termed such a factor as the coordination risk, although one can hypothesise that the real reasons are due to individual rationality. We do not have experimental evidence to support such a hypothesis, but offer a logical exposition that requires further research in this domain.

The notion of individual rationality applied in isolation is not new, and it appeared in other disciplines under a somewhat different cloak. An alternative expression for, more or less, identical behaviour is known as *the tragedy of the commons* phenomenon. The notion of the tragedy of the commons goes back to Aristotle. It has been revamped during the mid 19th century by William Forster Lloyd and put into a contemporary context during the late 1960s by an ecologist (Hardin, 1968). The basic idea is built around an assumption that a number of herdsmen (sic!) keep their cattle on the commons. As a rational being, every herdsman is trying to maximise his gain. This means that each and every one of them is thinking of adding one more animal to his herd. From the individual point of view, this is just a maximisation of utility. The problem happens when they all follow this course of action and 'freedom in a commons brings ruin to all', as Hardin put it. The tragedy of the commons, just like its complement the bullwhip effect, implies that individual rational behaviour can have catastrophic consequences if applied in isolation.

The alternative to this approach, and the participants in the supply chain know this intuitively, is some form of collaboration with one another. Unfortunately, collaborative Supply Chain Management (SCM) also implies that overall inventory across the supply chain is a form of the *common good* and demands that all participants are acting in good faith with the common objective of reducing overall supply chain costs with particular emphasis, in this context, on overall inventory optimisation. It has been formally proven long time ago by von Neumann and Morgenstern (1947), that it is impossible to maximise, or minimise, two variables simultaneously. The only solution is some form of optimisation, subject to certain constraints. Unfortunately, this implies that because of this optimisation principle, we can never simultaneously minimise our own inventory and the total value of the inventory across the supply chain. If the objective function is the minimisation of the overall level of the supply chain inventory, then one person's individual inventory level is bound to be higher than it would be if they tried to minimise it in isolation from other participants in the supply chain. Effectively, individual inventory, although it plays an important role in the supply chain, is of a lesser importance than the overall inventory level across the chain. This is an unpalatable fact from individual point of view. The hopeful notion that follows from this fact is: if one person's inventory is going to go up for the sake of overall savings in the supply chain, then these overall savings must be greater than the costs associated with the increase in inventory. Or to put it differently, the rewards from participating in the collaborative supply chain scenario must be perceived to be higher than the potential reward (or loss) that comes from independent inventory optimisation strategy. The problem with this assumption is that nobody can guarantee it. So, how are individual participants likely to behave in this case?

Tentatively, the answer to this question can be found in Tversky and Kahneman's *Prospect Theory* (Kahneman et al., 1982). Kahneman et al. showed, in simple terms, that people tend to avoid risk when seeking gains and chose risk to avoid losses. The above two scenarios (individual inventory management and collective SCM scenario) do not seem to have congruent objectives. The individual inventory management strategy relying on the 'just in case inventory' philosophy is a prime example of the gain seeking principle. In other words, the businesses *seek to maximise sales* and will *avoid risks* that having a low level of inventory brings in this context. The collaborative SCM is primarily a loss avoidance strategy. In other words, the businesses are trying to *avoid losses* that high inventory level brings and are prepared to *take risks* associated with lower level of inventory. However, what do we actually mean by collaboration in the supply chain?

Collaboration related to inventory in the supply chain, in practise, often means an increase in visibility and some form of negotiation leading to a consensus. Increase in visibility alone can reduce the level of inventory, and the costs associated with it, without any increase in uncertainty. Already quoted paper by Lee et al. (1997) states that through the Vendor-Managed Inventory (VMI) strategy, various alliances (Nestle, Quaker Oats, P&G, etc.) are sharing the benefits of reducing inventory of up to 25%. Smith (2006) reports nearly 80% improvement in suppliers' on-time order fills and delivering 96% in-stocks during the peak season after the CPFR system has been implemented. This corresponds with theoretical findings. Carlsson and Fuller (2000) theorem proves that by increasing the visibility of demand statements through the supply chain, the variances of the suggested optimal orders will get smaller. Does that mean that the increase in visibility automatically neutralises individual rationality? Even more importantly, what happens with the negotiations part of collaborative behaviour and what are the consequences of seeking consensus in the supply chain?

Collaboration is more than a method of sharing information. It is a method of working together towards one single goal. However, although participating companies might have one goal, their circumstances, constraints and possibly even strategies how to achieve this common goal might differ. As they have no power to change the circumstances or constraints, the only element that is negotiable is the strategy of how to achieve the goals, that is, to seek the consensus. Seeking consensus through negotiations, therefore by definition, implies applying rational thinking. As there is no guarantee that the strategy will work, the most rational option is to protect oneself against potential losses. The individual rationality is back, and it will manifest itself through either the bullwhip effect or the tragedy of the commons. Clearly, the problem that potentially occurs in collaborative scenarios is exactly the same as the one that occurs in individual inventory management scenarios, that is: neither strategy eliminates uncertainties related to the final demand and the individual rationality will dominate and ruin the common good. The enabler for this rationality to resurface in collaborative scenarios is the negotiation part of the concept of collaboration. Astonishingly, whether we apply separate inventory management strategies or apply collaborative SCM strategies, we end up with the same problem. Both strategies, potentially, lead to inefficiencies and fail to deliver the expected results. Even more ironically, the reason for failure, in both cases, stems from highly rational behaviour. As it is illogical to expect that the participants will act irrationally, does it mean that we stand no chance of optimising inventory across the supply chain?

3 Collaborative planning, forecasting and replenishment

Historically, a number of management techniques were used to manage inventory successfully (Barratt and Oliveira, 2001). One of the more recent initiatives gaining significant momentum in industry is CPFR. In its simplest form, CPFR as a typical SCM strategy, seeks to reconcile production planning and associated inventories with customer demand. Demand management, as such, becomes a key issue. Besides the inventory reduction, CPFR is also expected to reduce out-of-stock items, improve asset utilisation and rationalise deployment of resources. However, the results have not always been encouraging (Stank et al., 1999).

VICS defines CPFR (VICS CPFR Overview, 2004) as a business practice that combines the intelligence of multiple trading partners in the planning and fulfilment of customer demand. As there is no single definition of CPFR, we offer a tentative alternative definition of CPFR as *a process and a business practise* relying on technology and procedures, aiming to produce one *unified statement of demand* and endeavouring to maintain optimum levels of inventory across the supply chain through *sharing and reconciling forecasts*. CPFR was first applied in 1995 when Wal-Mart formed a working group with Warner Lambert to pilot a new approach on collaborating in forecasting and replenishment of one of the products (Listerine).[1] It proved successful and it created many expectations. In addition to the primarily internal and cost focused drivers mentioned above, other external factors also drive the adoption of CPFR, such as: improvement in overall chain competitiveness, transparency and cost structure, ability to cope with fashion trends (or shortening of product life cycle), possibility to cope with moves to offshore production and a need to handle increasingly longer, global supply chains (Fliedner, 2003). Marginal CPFR benefits come from increases in sales, improvement in both trading partner relationships and communication and improvements in service level.

In order to 'regulate' and promote good practise in implementing CPFR, in 1998 the VICS Association launched one of the most comprehensive sets of guidelines in this domain. In an effort to globalise CPFR, in 2000 VICS teamed up with Efficient Consumer Response (ECR) Europe and created the nine step process model.[2]

Despite prescribing the procedure in great depth, the initial CPFR concept has not been too widely implemented. Why? A number of barriers (Barratt and Olveira, 2001) have been associated with the implementation of CPFR, such as:

- no shared targets
- difficulty to manage the forecast exception/review processes (in both sales and order forecasts)
- trading partner focuses on the traditional supply chain steps, not on the exception/review processes
- promotions and new items events are not jointly planned
- non-existence of an integrated decision support system to provide consumer, customer and market data
- no adequate information technology/expertise
- lack of discipline to execute preliminary (and preparatory) phases of the CPFR process (in particular, in the stages of issuing the front-end agreement and the joint business plan).

In addition to these, other issues (Fliedner, 2003) have been identified, such as:

- lack of trust in sharing sensitive information
- lack of internal forecast collaboration
- fragmented information sharing standards
- aggregation concerns (number of forecasts and frequency of generation)
- fear of collusion.

The latest revision of the CPFR framework (VICS CPFR Overview, 2004) changes nine steps into eight tasks, specifically:

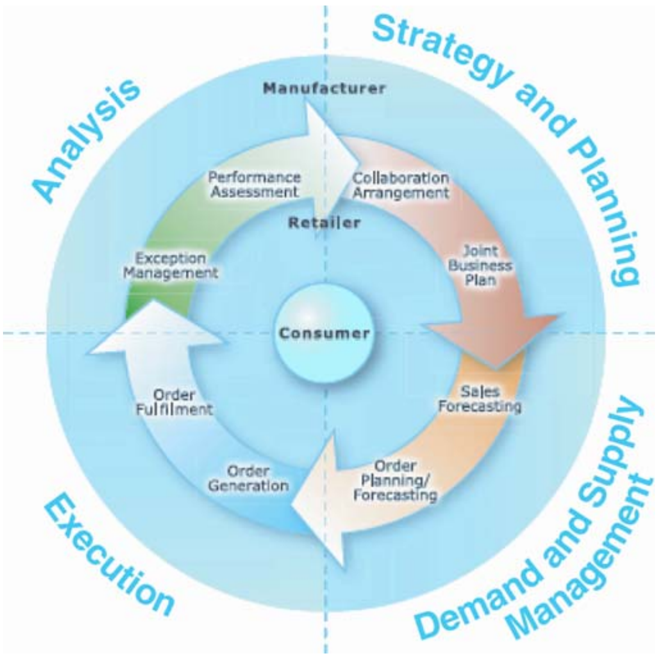
- collaboration arrangement
- joint business plan
- sales forecasting
- order planning/forecasting
- order generation
- order fulfilment
- exception management
- performance assessment.

The above tasks are integral part of four major Collaborative Activities intended to improve the performance of the participants in the chain. These four Collaborative Activities are:

- strategy and planning
- demand and supply management
- execution
- analysis.

The complete CPFR model can be visualised (VICS CPFR Overview, 2004) as follows (Figure 1).

Figure 1 CPFR model – collaborative activities and collaboration tasks



The CPFR reference model is designed to fit many scenarios. Four specific scenarios have been quoted as the most dominant in the large-scale CPFR deployments. They are:

- retail event collaboration
- Distribution Centre (DC) replenishment collaboration
- store replenishment collaboration
- collaborative assortment planning.

This is not an exhaustive list. However, from this paper's point of view, one of the most fundamental problems of the VICS CPFR process model is that it does not close the door to *individual rationality*. VICS CPFR Guidelines acknowledge that buyers and sellers have different views of the marketplace. The assumption that flows through all specific scenarios VICS quotes as examples of best practises are that by exchanging information and negotiating consensus, these differences can be overcome and the end result is a single shared forecast of both the order forecast and the sales forecast. This is the part that is particularly problematic. The notion that one party generates sales forecasts, communicates the results to the other party, collaborates upon and then uses the negotiated numbers as a baseline for the creation of an order forecast, does not make sense. Encouraging negotiations in order to eliminate exceptions and find consensus will not address the problem of rationality, as discussed in this paper.

Effectively the word 'collaboration' has been interpreted as a *method of reconciliation* of the forecasts between the participants in the chain. In a way, CPFR forecasts are almost treated as the *consensus forecasts*. The idea that through the negotiations, the participants will resolve exceptions and reduce the safety margins built into their individual forecasts, which will eventually eliminate potential risks of creating chaos in the system, cannot stand the scrutiny. If the CPFR forecasts are treated as consensus forecasts, then by definition this means that rationality is the foundation stone on which they were built. According to our premises, this foundation stone is crooked and the whole superstructure is likely to collapse. If this is the case, what is the solution?

4 Moving towards a solution

From the above exposition it is quite evident that the concept of individual rationality is a major stumbling block in an optimisation process and, therefore, the solution sought is the elimination of such rationality. As it is counterintuitive to expect that anyone will abandon rational behaviour, the fundamental question we need to resolve is: how do we eliminate individual rationality from the process?

The notion of rationality is implicit to human behaviour, so the only likely option is to remove the need for human intervention from the process. Unfortunately (or fortunately?) human intervention will never be completely eliminated. Even if the process is entirely governed by a set of rules implemented by systems, ultimately these rules were created by humans, and therefore, human intervention is intrinsic to the system. However, as drastic as the statement about eliminating human intervention sounds, it is not completely utopian, provided it is correctly implemented. The reasonable stand to take is to advocate that the amount of human intervention has to be selective and that it needs to be minimised. Generally speaking, people will intervene when there is a need to reconcile something. In our context, this means that the need to reconcile forecasts has to be eliminated. The solutions suggested further down in the text explicitly enable human interfaces, meaning that, when and where appropriate, it can be incorporated in the system.

From our definition of CPFR, the participants in the supply chain aim to produce one unified statement of demand. This means that there should be only *one perception* of the ultimate truth, that is, the final demand. As nobody knows what this demand will be, the only two things the participants have to agree upon (collaborate, reconcile, negotiate or seek consensus) are:

- What approach to (or method of) forecasting is to be used?
- How should the quality of demand forecasts be assessed?

These are the only elements where human intervention is appropriate. All the remaining issues can be converted into a straightforward optimisation problem, that is, calculation of individual levels of inventory defined by individual and collective constraints. The sharing and the reconciling part of our definition of CPFR "(… endeavouring to maintain optimum levels of stocks across the supply chain through sharing and reconciling forecasts)" applies to *sharing the constraints* whilst the part on reconciling the forecast, becomes more like a goal-seeking scenario from the world of optimisation.

The solution advocated in this paper is: *forecast (extrapolate) once and calculate (optimise) many times*. Essentially, by forecasting the final demand once and calculating individual replenishment levels as many times as necessary, we have eliminated a need to intervene at numerous points in this process and reintroduce the individual rationality. The word collaboration, in this case, does not mean seeking consensus forecasts, it means *collaborating on procedures* on how to implement this *process*.

Unfortunately, the final demand statement is a very dynamic and elusive category inclined to surprise everybody. Forecasting such a phenomenon is not easy, although a number of techniques produce satisfactory results. Some major advancements are needed in this domain too, but such an exploration would exceed the remit of this paper. We will assume that somehow it is possible to render acceptable demand forecasts. This paper, in the context of what has been said above, is interested in how to handle such forecasts, in a dynamic fashion, to optimise the supply chain. Clearly, a technology capable of handling dynamic variables in real time across disparate environments is needed. Only a few years ago such a technology did not exist, which effectively means that supply chain collaborative forecasting scenarios are only now slowly becoming a reality. What technologies do we have in mind? The suggested solution is a suite of technologies clustered around a Service-Oriented Architecture (SOA), primarily founded on web services; smart agents and real-time enterprise analytics.

5 Current technologies

One of the largest challenges for any supply chain is application integration. The variety of disparate systems makes integration impossible and traditional point-to-point integration methods (or even some more contemporary middleware-based techniques) are not sustainable. Some vendors hoped that making their Enterprise Resource Planning (ERP) systems more open would address this problem, but it remains a fact that only a new and revolutionary approach to this problem will enable supply chains to share their processes seamlessly through fully integrated applications. Some newer technologies (although not new in inception) such as SOA indicate that a road towards a solution is opening up. It has to be said that the precursors to SOA architecture (such as DCOM or CORBA), were too proprietary to achieve universal acceptance. The new, web services-based SOA, is truly an open architecture. We refer to software architecture as an abstraction of the run-time elements of a software system during some phase of its operation.

World Wide Web Consortium (W3C) describes *Web Service* as a software system identified by a Uniform Resource Identifier (URI), whose public interfaces and bindings are defined and described using XML.[3] Its functionality (definition) can be discovered by other software systems. These systems may then interact with the web service in a manner prescribed by its definition, using XML-based messages conveyed by internet protocols (such as SOAP). One can think about web services as software components that operate as either web objects or web applications. What is characteristic for them is that they are self-contained, self-describing and modular. They can be published, located and invoked across the web.

The above qualifies web services as prime candidates for implementing a variety of collaborative scenarios across the supply chain, including the CPFR. However, web services are in this case just a fundamental enabling technology, unable by itself to address more complex issues, such as the presence of the bullwhip effect. If web services-based SOA is good enough to bring disparate systems in the supply chain together and fully automate this process, why do we think that it is not good enough to resolve 'minor' technical issues, such as the bullwhip effect? The answer is, unfortunately, not so straight forward. It is certainly the right choice of the fundamental technology, but as such, it is not enough. A broader framework is needed. We need a major shift, from the focus on *individual applications* to the focus on *collaborative processes*. What kinds of technologies exist to enable such a shift?

One of the key web services technologies that emerged only recently is the so-called Business Process Management (BPM) (Smith and Fingar, 2003). BPM should not be confused with the notion of BPR, which is based on the principle that rather than just automating functions, processes need to be redefined, organisations changed accordingly and then mapped into a pan-enterprise application suite, such as an ERP system. These solutions were technology (data) driven. BPM advocates one single definition of a business process, rendering different views of this same process. BPM as a solution, unlike the previous ones, is business (process) driven, not data driven.[4]

A key element that makes BPM attractive and executable is a new language. Until recently several initiatives were competing for the market domination. The one, which seems to be winning, is called, Business Process Execution Language (BPEL), previously known as Business Process Execution Language for Web Services (BPEL4WS), promoted by the OASIS consortium.[5] BPEL is a subset of the previously promoted Business Process Modelling Language (BPML) language. The most important characteristic of BPEL is that the emphasis is no longer on automation, but on *orchestration*. Just as Unified Modelling Language (UML) creates components (objects) that can be used in executables (automation), BPEL create processes as the fundamental units-based on web services that can be shared between participants (orchestrated).

One of the reasons why BPEL fits well scenarios such as CPFR is its ability to incorporate and account for human intervention in the process. Although this paper advocates minimising the amount of human intervention (if not eliminating in certain places!), it also recognises a need for the use of human intervention. However, it has to be applied in the right places (or the right stages of the process). As BPEL business processes are defined as collections of activities that invoke services (Juric and Todd, 2006). This means that BPEL does not make a distinction between services provided by applications and other interactions, such as human interactions/interventions.

Several solutions available today (without quoting individual examples to avoid commercialisation) are intended to help create, deploy and manage cross-application processes with both automated and human workflow steps. Invariably they consist of some sort of BPEL-based development engine for composing services into business processes, a Business Activity Monitoring (BAM) supervisory solution based on business rules engine to gain visibility of business processes and an Enterprise Service Bus (ESB) to connect applications using the web services authentication and authorisation policies. However, although these technology solutions exist, they do not necessarily address the issues raised in this paper. Describing the reasons why their CPFR implementation was so successful, Smith (2006) stated: "… we had to look at, understand and fully embrace the spirit of collaboration…. It meant addressing cultural issues just as much as business processes". The cultural issues he is referring to can be partially interpreted as the philosophy issues as discussed in this paper. The challenge, therefore, is to identify a technology solution that could assist with the issues of collaboration in the supply chain.

6 Emerging technology solutions

Almost exclusively, all today's technologies and solutions were invented to support strategies-based on individual competitiveness. Regardless of the focus, that is, efficiency (cost) focus or effectiveness (customer) focus, they were all built around the notion that individual companies should somehow be able to differentiate themselves from their competitors and gain some sort of competitive advantage. To use the language from the beginning of this paper: they are all based on the premise of individual rationality. We have indicated that CPFR procedures, based on today's technology, will inevitably produce the same behavioural patterns as the previous competitive strategies. What we need, at least as the first step, is to find the technologies that will suppress the individual rationality instincts and enable a collaborative rationale.

We need to point out that the CPFR issues are just some of the issues that will surface as a result of collaborative efforts. There is no doubt that numerous other completely unique sets of issues, characteristic to various collaborative scenarios only, will emerge. We just do not have the exhaustive list of such issues, but it is reasonable to assume that they will be present. The fundamental question is, therefore, what kind of technology framework is likely to be able to tackle them adequately?

The example of the bullwhip effect is a good point in case. Past technological and conceptual paradigms are unable to eradicate it. This is because the current paradigm is based on the notion that improving one's competitiveness, often at the expense of one's suppliers or customers, is the most beneficial strategy. A fundamental shift of emphasis away from organisations' functional units and software application units is needed. These elements can no longer be building blocks of a solution. A new unit, which transcends an enterprise, as a single, self-contained entity, is needed. This new unit, supporting the whole supply chain and supporting the collaboration, as a winning strategy, is needed. What do we mean by a new unit and what new theoretical framework is capable of providing a foundation for this new *modus operandi*?

In the current paradigm, an *object* (a software object or a component) represents the most basic software unit that applications are built from/made of. These applications are designed to primarily support (automate) individual corporate functions. This philosophy has only been challenged in the last few years and the same application suites are being deployed to automate horizontal processes. However, a new unit that is needed is no longer an object, but a *process*. A process, in this case, provides a single view of a group of business activities undertaken by the supply chain in pursuit of a common goal. Individual applications, thanks to SOA, need to be converted into web services that will form a workflow transcending a single enterprise. Is such a framework emerging? Yes, it is.

The framework for this new paradigm is provided by the pi-calculus (Milner, 1999). Pi-calculus is simply an algebra for modelling systems of autonomous agents. These autonomous agents are called mobile systems. A mobile system is a form of communications network in which individual components interact with each other. The difference with the standard automation principles, where the component interaction is strictly prescribed, is that in the case of mobile systems the components are free and they interact spontaneously. This is the foundation of the *orchestration* principle, which replaces the principle of automation.

Participants in the supply chain are typical mobile systems. Mobility implies the notion of change, which is any modification of an existing relationship between two companies. A company can change its state by initiating an action (ship an order, pay a supplier, etc.). A company's partner in the supply chain interacts by attempting to change (or query) this state, which usually triggers some internal actions-based on business rules. These internal actions enable the company to ultimately be in a state which is consistent with one of its business partners. As actions are executed, they cause company to transition from one state to anoter. Interactions and actions, when assembled together, form the enterprise business processes.

Although the framework provided by the pi-calculus for this new paradigm has been known for some time, truly open architecture supporting this framework was missing. The emergence of the web services-based SOA is the first instance of a vendor agnostic architecture that can support this framework. The only missing link up until recently is an orchestration strategy that takes advantage of this framework and creates a new unit capable of supporting collaboration scenarios.

The reason why the pi-calculus is so important is a simple fact that it represents one of the most elementary foundation stones on which the philosophy of BPEL has been built. We mentioned that BPEL is a subset of a more generic specification called BPML. It is in fact the BPML specification that relies on the principles of the pi-calculus. The other underpinning theoretical foundation stone of BPEL are the so called Petri Nets. Several papers (Harvey, 2005) illustrate well how the relationship between various components and their theoretical roots are structured.

Up until recently various technologies that have been created with intention of achieving greater efficiency and effectiveness, were based on the principle that brutal competition and individual competitive advantage are winning strategies. All the solutions have had this principle implicitly embedded in their instances. The new world of supply chain optimisation makes an assumption that a winning strategy is based on collaboration, as much as it is based on competition. This automatically renders many current technologies inadequate. This paper advocates that a new paradigm is needed, although any attempt to define it will inevitably be somewhat fuzzy. A belief that pi-calculus, SOA, web services and BPEL, as manifestations of a new emerging technology, are capable of handling collaborative scenarios needs much more rigorous scrutiny. It also requires the world of academia to take the baton from industry and provide a new vision. Perhaps a new theoretical framework on how businesses should be run and integrated is also needed. Following an inductive approach, this paper attempted to look into CPFR as an example of a specific collaborative scenario, and concluded that current technologies will minimise some of the challenges identified, but will not eliminate them completely. A new paradigm is definitely needed.

The fact that using web services and BPEL it is possible to define a single process shared by the supply chain is a major step forward. The emergence of various choreography languages, primarily Web Services Choreography Description Language (WS-CDL), which by the way is also pi-calculus-based, means that nothing is standing in our way to make the paradigm shift. Usually a technology is an obstacle for implementing a particular methodology. This time around, perhaps for the first time in recent history, we have changes in technology that can drive changes in methodology. Clearly in this context, by methodology we mean collaborative processes in SCM, CPFR being just one of them. It is the time for academia to seize the initiative from industry and start putting together collaborative scenarios that might on the surface contradict the old competitive principles. Traditional methods of operating as a competitive unit in a complex environment are no longer optimal. New definitions of competitive processes are needed. Processes that span across individual and autonomous units, but united by a single objective that makes one supply chain more competitive than the other. The technologies based on the pi-calculus, SOA, web services, BPEL and WS-CDL, are here. All the enablers are present and ready to be applied. We now need a new 'methodology' to make it work properly in a new way.

In order to bring these challenges down to a practical level, we should offer a simple example, no matter how trivial it might seem. Rather than using a retail example, which would be the most obvious choice, let us look at a more complex supply management scenario from oil industry. An oil company uses an offshore production platform for processing oil and shipping it onshore. Many of these platforms are unmanned, which means that any stoppage can be very expensive. Companies plan outages and regular maintenance events to ensure that platforms do not encounter unplanned shutdowns. In order to execute regular planned outages, a lot of planning goes into it, which among other things, involves placing orders for numerous parts and components that need to be replaced during a shutdown. Effectively an oil company forecasts are translated into the component companies' demand and the component companies' demand is translated into, say, the foundries' capacity to satisfy this demand. Under the present regime, each and every one of the participants will create stocks that will maximise the return on investment and minimise the uncertainty.

The technologies we described above should suppress the individual rationality instincts and enable a collaborative rationale. What is a collaborative rationale in this case? To start with, it should be a single business process shared by all the participants in this supply chain. Business process becomes this new unit, rather than an application or an object as indicated earlier, that they all share. A process, in this case, provides a single view of a group of business activities undertaken by the supply chain in pursuit of a common goal, as we already defined. The goal is to prolong the time between the outages and to minimise the time that an outage will take. If this one platform, in our simple example, can stay in the production mode longer than any other platform and be turned around more quickly during the planned maintenance stoppage, then we have created a supply chain that is outperforming a competitive platform. An example here is very much analogous to the Formula 1 car race.

As we can see, the technology must support the formation of a new joint objective: make the unit stay in production longer than any other and shorten the planned outage. If sub suppliers cannot support this new objective and persist with their individual objectives, they will make themselves redundant in this particular supply chain. Ultimately, we all as consumers benefit from such a supply chain as the supply of such a valuable commodity (oil or gas) has not been interrupted and, ultimately, it has been delivered to us at a lower cost. In order to deliver such benefits, a new 'methodology' based on the technologies described above is needed.

7 Conclusion

Individual rationality, manifesting itself through the bullwhip effect, or as the tragedy of the commons, stands in the way of optimising inventory across the supply chain. A solution is some form of collaboration. As collaboration is founded on the principles of negotiations and consensus, this means that individual rationality inevitably creeps back into the process again. This paper advocates that a way to optimise the SCM and apply collaborative forecasting is to eliminate (minimise) human intervention and put more emphasis on shared processes. Experiments conducted in this spirit (Croson and Donohue, 2006) indicate that automating some of the functions and assigning to automatic agents various optimal behavioural models, indeed reduces the bullwhip effect. Admittedly it does not eliminate it, which definitely places this phenomenon in the proximity of the behavioural, rather than operational domain. However, if we wanted to apply the findings of such an experiment on a broader industrial scale, we would need to address the automation issues.

The challenge for automation in today's environment is that it must bridge disparate systems (islands of automation) and enable dynamic and real-time execution in order to optimise the system. This paper concludes that, unfortunately, this is not enough. A new paradigm is needed. A paradigm that will enable *orchestration* of independent services in the supply chain, defined as a single process. This new paradigm (or paradigms) should be founded on a new *framework*, new *architecture*, new *technology* and new *execution languages*. Indications are that the framework is provided by the pi-calculus, the new architecture by SOA, the new technology by web services, the new languages by BPEL and the new orchestration principles by WS-CDL. More research in this domain is needed to create new paradigms and see how these new paradigms can resolve some of the supply chain issues and, in particular, if they can even stimulate the emergence of new business models.

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Notes

[1]For details see http://www.gmabrands.com/industryaffairs/docs/cpfr.pdf. Accessed on March 2007.

[2]For details see http://www.cpfr.org/documents/pdf/CPFR_Tab_2.pdf. Accessed on March 2007.

[3]For details see http://www.w3.org/TR/wsa-reqs/. Accessed on March 2007.

[4]For a good overview of issues, see http://www.delphigroup.com/research/whitepapers.htm. Accessed on March 2007.

[5]For links see http://www.bpmi.org/ and http://www.oasis-open.org/home/index.php. Accessed on March 2007.