Business processes inter-operation for supply network co-ordination

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ARTICLE INFO

Available online 31 May 2009

Keywords:
Supply network co-ordination
Production planning and control
Co-ordination processes
Information systems

ABSTRACT

In a global supply network, the overall improvement of operational efficiency and customer satisfaction can only be achieved through greater co-ordination and collaboration of all the network members. However, full benefits of close co-operation within a global supply network can only be achieved when the business processes of the individual companies can inter-operate. Currently available commercial solutions are inadequate in supporting full network co-ordination in terms of business process changes and technical arrangements. This paper proposes a system that aims to improve the co-ordination of production planning and control activities across the supply network. To achieve this, it is important to develop new business processes and principles for company collaboration and corresponding information systems. This process starts from the identification of business and system requirements, which underlie the general business solutions for network co-ordination, developing the guiding design principles and subsequent process design and system implementation.

1. Introduction

Characterised by the growing trend of global outsourcing and competition (e.g. in computer, automotive and aerospace industries) (Williams et al., 2002; Ghiassi and Spera, 2003; Yusuf et al., 2004), the past decade has seen a transition from an enterprise integration paradigm towards an international supply chain integration paradigm (e.g. Clark and Hammond, 1997; Christopher, 1998, 2000; Christiaanse and Kumar, 2000). This new paradigm requires close partnership between supply chain members based on trust and co-operation (Lancioni, 2000) and emphasises enhanced information sharing and better co-ordination to improve cost-effectiveness and customer service (Maloni and Benton, 1997; Anussornmitisarn et al., 2005; Koh et al., 2008). Thus, it is widely accepted that inventory can be significantly reduced through enhanced supply chain relationships and more frequent communication of accurate, timely information on demand and inventories (Vickery et al., 2003; Droge et al., 2004; Grey et al., 2005; Bayraktar et al., 2008; Caloiero et al., 2008). However, full benefits of close co-ordination and collaboration within an international supply network can only be achieved when the business processes of the individual companies can inter-operate.

Currently available enterprise information systems such as enterprise resources planning (ERP) systems, advanced planning and scheduling (APS), supply chain management (SCM) and business-to-business (B2B) systems (e.g. EDI, e-hub) do not provide a full support for the integration and co-ordination of production planning and control activities in global supply networks (Xu et al., 2003; Puschmann and Alt, 2005; Koh et al., 2008). ERP was mainly focused internally and thus did not contribute much to the elimination of the barriers between business partners (Kelle and Akbulut, 2005; Loh et al., 2006). The recently emerged concept ERP II claims to support the idea of an extended enterprise (Kelle and Akbulut, 2005; Loh et al., 2006). The recently emerged concept ERP II claims to support the idea of an extended enterprise (Loh et al., 2006). However, industry analysts are cautiously optimistic in their reviews and perceptions of ERP II as there are some concerns related to failures of old ERP concepts (Koh et al., 2008). Similarly, most of current APS and SCM systems do not manage the supply chain outside
an organisation due to the centralistic view of hierarchical planning which underlies these systems (Stadtler, 2005). On the other hand, systems such as EDI, ERP, APS or SCM incur significant setup and operating costs (Boyle et al., 2008) and are normally beyond what most small and medium-sized enterprises (SMEs) can afford (Zheng et al., 2000).

The Internet-enabled B2B systems such as B2B marketplaces (or e-hubs) and B2B portals have the potential to promote co-operation between business partners. However, most of these tools are still in their early stages in relation to supply chain co-ordination (Sodhi, 2001; Skjøtt-Larsen et al., 2003; Puschmann and Alt, 2005). For example, it is still not clear how e-marketplaces can be used to achieve the goal of full network co-ordination in terms of business process changes and technical arrangements. Recent developments of process portals are mainly focused on the development of an integration architecture for inter-organisational information systems (Puschmann and Alt, 2005). Therefore, it is highly desirable to develop an innovative framework that captures key business processes that promote close collaboration and co-ordination in the supply network.

Currently, most companies communicate with their customers and suppliers by using communication tools such as telephone, fax or e-mail. Information is often delayed and can become distorted, creating the bullwhip effect and unreliable supply chains (Lee et al., 1997; Metters, 1997; Miragliotta, 2006). In contrast, the Internet has some compelling characteristics, such as low operating cost and multi-type data support (e.g. pictures, hyperlinks). It has provided a real opportunity for achieving effective co-ordination for participating firms with different levels of co-operation. However, to achieve the full benefits of Web-based network co-ordination, appropriate business processes and principles have to be developed, and supporting information systems implemented to meet business and information requirements.

This paper contributes to the development of new business processes and principles for promoting co-operation between network companies as well as the supporting Web-based systems for improving network co-ordination. They have formed a basis for further research in global network co-ordination and can be exploited for commercial software development. Particularly, the paper identifies major business and system requirements for supply network co-ordination, which lead to a set of inter-firm co-ordination processes. Guiding design principles and the decentralised system architecture serve as the overall business logic for reducing the complexity and achieving efficiency in relation to network co-ordination. Finally, the business processes and principles are implemented as prototype systems and evaluated in the context of the IST project Co-OPERATE.

2. Requirements and solutions

2.1. Background information of the project

As mentioned above, the proposed co-ordination processes and principles were implemented and evaluated in the European IST project Co-OPEAETE, the full title of which is 'Co-operation in dynamic networked organisations'. The project was focused on developing a set of new concepts, business processes and methodologies, and Web-based communication tools for improved co-ordination of production planning and control activities in the supply network. To achieve this, it is essential to analyse business and systems requirements for supply network co-ordination and to develop appropriate methodologies and co-ordination processes. The developed methodologies and processes were implemented in the form of two prototypes: concept and final. These prototypes were evaluated by the industrial partners in the project.

The Co-OPEAETE project targeted two capital-intensive industries: the semiconductor and the automotive supply industries, which are representative of globally distributed, cross-industry supply networks (So and Zheng, 2003). There are six main partners in the project and five SMEs affiliated to it. The six main partners include Imperial College London (UK), INESC (Portugal), Xansa (UK), Siemens VDO Automotive (Germany), Alcatel Microelectronics (Belgium), and MEMC Electronic Materials (Italy). The project covered the period of the beginning of 2000 to the middle of 2002, and was undertaken by a dedicated research team working on a full-time basis, of which the first author was a team member.

2.2. Business and systems requirements

Despite their differences in structure and technologies, the fundamental operational problem of today’s supply networks is the lack of synchronisation between demand and supply (Vokurka and Lumnus, 2000). On the demand side, the most detrimental factor that can create excesses or shortages of inventories is the ‘bullwhip effect’, which incurs high costs, waste of resources and a loss of market share (Wright and Yuan, 2008). On the supply side, unreliable execution processes, which often incur late deliveries (So and Zheng, 2003), can be the primary cause of inventory shortages and can also be another reason for holding excessive inventories. However, demand and supply variations are inevitable in today’s ever-changing industrial environment, which requires that the supply network must be flexible and responsive.

The analysis of business and system requirements was based on an extensive literature review and the results of in-company interviews with managers and operational staff of six companies in the automotive and semiconductor industries covering first, second and third-tier suppliers and SMEs, which were conducted for the Co-OPERATE project (Co-OPERATE deliverable D3, 2000). The major business requirements for a supply network co-ordination system are in three areas: (1) reducing the bullwhip effect, (2) enhancing supply chain reliability, and (3) improving supply chain responsiveness.

The major common features for most industries’ supply networks have structural and organisational requirements, which must be met by network co-ordination systems. Particularly, (1) the system architecture must be compatible with the heterogeneous and distributed industrial
environment in terms of different local legacy systems and geographically separated manufacturing locations, (2) the system needs to be scalable and quickly re-configurable to cater for the growth and changes of the network structure, and (3) the system should provide decision-support information especially in unexpected or exceptional situations.

2.3. Solutions: seven co-ordination processes

The above business and system requirements are first translated into seven interrelated business processes, which have the potential to improve network co-operation. These co-ordination processes can be briefly described as follows:

1. **Long-term business planning:** aims to generate a reliable and feasible long-term plan for the network through feedback from upstream companies regarding the feasibility of capacity and early communication of changes.

2. **Operational ordering and planning:** supports the short- and medium-term operational planning process by making orders and consumptions visible to the upstream companies and buffer levels and delivery schedules in the opposite direction. It also promotes the detection and resolution of planning problems early through feedback loops in the standard operational planning process.

3. **Request and feasibility study:** assists medium- to long-term network planning through a fast check for capacity and material availability across the supply network when new orders or large order changes are expected.

4. **Exception handling:** mainly focuses on dealing with short-term demand changes and short- to medium-term delivery problems through fast and effective negotiation processes.

5. **Multi-sourcing co-ordination:** is actually a building block of business processes 1–4, which helps to optimise the allocation of work to different suppliers based on a set of criteria (e.g. capacity, price), business rules and fast negotiation processes.

6. **Visibility of order progress:** closes information flow loops by feeding back order status information and providing early warning of delivery problems to the downstream companies.

7. **Network performance management:** includes a common set of network performance indicators (e.g. forecast accuracy, delivery reliability), evaluation and analysis of these indicators and suggestions for improvement programs.

To achieve maximum possible results with available resources, the seven co-ordination processes were prioritised by all project partners against the five strategic objectives proposed for the project (see Appendix A for details). Four co-ordination processes were chosen for further development and implementation. The four focused co-ordination processes were: operational order- ing and planning, request and feasibility study, visibility of order progress and exception handling.

3. Guiding principles for process design

As with engineering design, logically the first step is to translate business and system requirements as described in Section 2 into major functionalities that a network co-ordination system should have. The results of this conception form a number of overall guiding principles for the design of the co-ordination processes.

3.1. Demand and supply information visibility

Traditionally, companies try to optimise their manufacturing processes with inaccurate demand and supply information, resulting in long lead-times (Stalk, 1988). On the other hand, they tend to keep high inventory levels to protect themselves against demand variations and supply uncertainties. Demand and supply information visibility aims to reduce lead-times and inventory levels across the supply chain.

On the demand side, the supplier needs to get access to accurate, up-to-date customer demand (e.g. daily consumption or orders) so that they can make precise production plans, ensure the availability of goods in demand and minimise inventories at all levels (Kelle and Akbulut, 2005). On the supply side, the customer wants to view online the status of their orders (e.g. on schedule or delayed). Such information is critical for operational decision making. For instance, a customer is expecting the full quantity of goods ordered to make a production run. However, they are informed in advance by the supplier that the order can only be partly filled. In this case, the customer can take actions proactively to prevent production from disruption.

3.2. Exception-focused supply chain planning and execution

Making information visible across the supply chain is only one step forward, but not enough. The next logical step is using information to improve the supply chain efficiency. However, companies cannot handle every piece of information with equal management attentions simply because there is too much information in the supply chain and each piece of information has different implications for different management units. Thus, management should focus on unforeseen events or exceptions in the supply chain (e.g. rush orders and lost shipment) (Anussornmitisarn et al., 2005; Loh et al., 2006), which usually have a greater impact on the supply chain than do normal activities such as regular order placements and transferring of regular delivery schedules.

Exceptions can occur in both the supply chain planning process (before orders are placed) and the supply chain execution process (after orders have been confirmed), and come in the short to medium term (mainly reactive to exceptions especially in the short term) or the medium to long term (proactive to exceptions) as illustrated in Fig. 1. In the short to medium term, suppliers need to be
informed of any demand changes immediately so that they can have enough time to respond to customers’ new requirements. On the other hand, customers want to know any delivery problems of critical components sufficiently early so that they can take actions to prevent production from disruption. In the medium to long term, it is very important for suppliers to know of new orders or large order changes at the earliest time, and it may also be valuable to get the customer informed of capacity or material shortage or other order fulfilment problems.

To achieve responsiveness and efficiency in the supply chain, it requires not only focusing on exceptions, but also identifying and reporting them early enough so that they can be addressed in a timely manner and contained at the lowest level, minimising their knock-on effects. When exceptions are detected through business rules, expeditors or production planners in the affected companies need to be alerted immediately and supported by the most relevant information and standard business processes to achieve the optimal result during the exception handling process.

3.3. Rule-based supplier/customer co-operation

While exception-focused supply chain planning and execution aims to achieve simplicity in supply chain management, too many demand exceptions will keep suppliers constantly fire fighting and result in poor delivery performance, and too many supply exceptions will reduce the customer service level. It is thus practically necessary for the customer and the supplier to pre-negotiate their individual responsibilities based on certain business rules. This is especially important for supply chain partnerships, where contracts are typically negotiated for a given price and total quantity over a certain period (Wei and Krajewski, 2000).

In practice, customers usually provide their suppliers with a schedule of requirements (e.g. order schedules) that includes a fixation horizon. For example, the schedule for week 1 is fixed, week 2 may be changed by a small amount (e.g. up to 5%), week 3 may allow up to 10% quantity variation for an automotive electronic supplier with a lead-time of one week. This has formed a funnel for allowed demand variation. It is the supplier’s responsibility to follow the demand variation within the hatched area as illustrated in Fig. 2. Outside the hatched area, the responsibility is with the customer. For critical parts or components, it is the supplier’s responsibility to send an early warning to the customer on delivery problems in advance (e.g. at least one week).

In case of exceptions (e.g. late deliveries), however, the customer and the supplier should collaboratively resolve problems through fast, effective negotiations by using buffer stocks or flexibility in production. This mutual commitment and collaborative problem solving approach will certainly promote closer customer/supplier partnership.

3.4. Consumption-driven ‘pull’ model of inventory control

Traditionally, the production planning process in a supplier company is usually driven by batched customer orders and forecasts transmitted by EDI, fax or email, which is primarily a push process from the material flow
perspective (Welker et al., 2008). This push model has many drawbacks including the bullwhip effect (Geary et al., 2006). While the unwanted parts are overstocked, urgently needed components are often out of stock bringing the whole production line to a halt. The main reason for the problems is that the supplier does not have the immediate visibility of true customer demand. The solution lies in the move towards a pull model as illustrated in Fig. 3.

Fundamental to the pull model is the immediate visibility of planned consumption, which includes exact consumption quantities in the short term (e.g. 3 weeks) and planned consumption in the medium term (e.g. 2 months). While the short-term consumption information is ideally on a daily basis, time bucket for the medium term is normally a week. The supplier can then generate their production plan with the weekly consumption quantities, whereas they can fine-tune their short-term production and delivery schedules based on the actual daily demand of the customer.

Currently, most companies have their own buffer stocks to accommodate any short-term demand or supply variations. This kind of double buffering does not make sense in the pull model as it incurs more wasted inventory space, associated costs and management attentions. Preferably, the management of buffer stock should be assigned to the supplier so that they can optimise their internal production and delivery schedules while meeting the customer’s consumption requirements and maintaining the buffer stock at practically the lowest level. In practice, the buffer stock should be located at or near the customer site. However, both the customer and the supplier should have up-to-date information on the current stock level for operational decision support.

3.5. Leverage of local systems without central optimisation

As a typical supply network for just one product usually involves at least 10 critical companies, central optimisation
of such a supply network is infeasible both from business and information perspectives (Anussornnitisarn et al., 2005). From the business perspective, different companies may have incommensurable decision variables such as cost and delivery lead-times. On the other hand, central optimisation would jeopardise local decision autonomy of individual network companies. From the information perspective, central optimisation algorithm makes it difficult to incorporate the differential specifics of local planning systems. Meanwhile, the complexity involved in calculation and heavy network loading for data exchange during run times would make central optimisation technically impractical.

Generally, local legacy systems and processes are extremely heterogeneous among network companies and are adapted to local business and system requirements and the levels of investment. Therefore, there is no business and financial justification to replace these local legacy systems. On the other hand, as each company in a supply network usually has to participate in several supply networks, it requires that local systems within a company should be interoperable with the different supply networks, which means that the network co-ordination system should be adaptable to different local systems. As a result, the principle of leverage of local systems without central optimisation has an important implication for the design of system architecture as described below.

4. System architecture and process design

4.1. System architecture

The main purpose of system architecture design is to configure how co-ordination can be technically organised in a globally distributed network environment. Currently, there are three system architectures for network co-ordination in commercial software packages and research projects: (1) centralised co-ordination system with local data access (e.g. SAP’s R/3), (2) hybrid co-ordination system with some distributed local functionality and a central co-ordination module (e.g. SAP’s advanced planner and optimiser (APO), European project X-CITTIC (Rupp and Ristic, 2000)), and (3) fully decentralised co-ordination system without central co-ordination (e.g. i2’s Tradematrix Open Commerce Network (OCN), European project PRODNET II (Camarinha-matos et al., 1998)).

The centralised system architecture is inherently unsuitable for the development of a network co-ordination system simply because it does not maintain the decision making autonomy of individual companies within the network (Anussornnitisarn et al., 2005). The hybrid co-ordination architecture divides the whole task of co-ordination into two levels, i.e. the global level and the local level. Therefore, it overcomes some problems of the centralised co-ordination architecture, such as data privacy and system flexibility. However, it still poses some difficult problems, such as the ownership of the central module and delay of information flow due to heavy network loading. Therefore, the hybrid architecture was also considered to be unsuitable for manufacturing co-ordination in complex supply networks such as the automotive supply network.

In the completely decentralised model, each company in the supply network has its own local planning system, which performs local planning for the company while connecting through a unit co-ordination module to other network members, as shown in Fig. 4. Clearly, this decentralised system architecture has two important privileges over the other two in terms of network co-ordination: (1) to the highest extent, it maintains the local decision autonomy of individual companies in the supply network as there is no central optimisation for the total

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**Fig. 4.** The decentralised model for network co-ordination.
network (Anussornitisarn et al., 2005; Hulsmann et al., 2008), and (2) it supports heterogeneity of their existing local planning systems, particularly ERP systems for large companies and other forms of local planning systems for SMEs (e.g. PC-based applications). Therefore, it was considered to be most suitable for manufacturing coordination in global supply networks.

4.2. Process design

The overall guiding principles as described in Section 3 outline the major functionalities the coordination processes aim to realise and set the business rules for manufacturing co-ordination in the supply network. These overall guiding principles direct the high-level design of each co-ordination process, which include vision and objectives, key performance indicators and process-specific guiding principles. Each co-ordination process is modelled with integration definition for function modelling (IDEFO). In alignment with the top-down design approach, the IDEFO modelling technique uses a hierarchical approach for functional decomposition (Rensberg and Zwemstra, 1995).

While function modelling using IDEFO provides a detailed process view of the system through functional decomposition, scenario analysis tries to describe what the system should achieve from the user’s point of view, which bridges the gap between business process design and software development (Berg and Simons, 1999). The scenarios for each co-ordination process have been extensively discussed with expeditors and production planners from industrial partners of the Co-OPERATE project. The result of scenario analysis is sequence diagrams that show interactions between systems (e.g. ERP systems) and company users (e.g. expeditors) in a time sequence.

5. System implementation

5.1. Implementation approach

Based on the results of functional modelling and scenario analysis of the focused co-ordination processes as mentioned in Section 2.3, the network co-ordination system was implemented in the form of two prototypes: concept and final. The concept prototype helped to demonstrate the concepts and basic process functions and was implemented by using rapid Web application development platform, called EQOS. While this platform facilitated quick and easy development and testing of the concept prototype, it had less flexibility than programming languages (e.g. C++) in terms of implementation of the co-ordination processes and access of databases.

After the implementation of the concept prototype, the most popular implementation tools for Web application development were re-evaluated. An agent framework called FIPA (Foundation for intelligent physical agents)-OS (open source) was employed to implement the request and feasibility study process which provides fast intelligent decision support for individual network companies. Meanwhile, Microsoft’s active server pages (ASP) was chosen for implementing the final prototype of the other three focused co-ordination processes, which is called the pilot system afterwards. A three-tier client–server architecture was adopted to run the pilot system as illustrated in Fig. 5.

The Web browser and the Web server comprise the first tier (the presentation layer). For the pilot implementation, Microsoft’s Internet Explorer was the preferred Web browser. Microsoft’s Internet information server (IIS) was chosen to implement the Web server. The application server consists of the second tier (the application layer) and represents the business logic of the application. The main responsibilities of the application server include the access to the relational data base management system (RDBMS) and the execution of server-side business logic. Microsoft’s IIS and ASP engine implement this functionality and the integration between the Web server and the application server. Microsoft SQL server 7.0 was the chosen product for the provision of RDBMS services. Data exchanges between the RDBMS and ERP systems or local legacy systems can be achieved via XML files.

5.2. Database structure

Database design is logically an initial stage towards the implementation of business logic of a Web application as performing any system functionality usually involves interactions with databases. An integrated pilot system database was designed for managing all essential data.

Fig. 5. Technical architecture for the pilot system.
required for network co-ordination. To manage the supply chain by exceptions, only relevant data essential for manufacturing co-ordination are extracted from local legacy systems and transferred into the pilot system database. These data can be classified into five different sources:

1. **Administration data**: includes some basic information about each company in the network, e.g., company ID, name, and address. For each company, it also includes some key information about each user, e.g., user name, password, contact information.
2. **Product data**: contains key attribute information for both supplied and purchased products in a company, e.g., part ID, description, unit of measure.
3. **Order data**: provides some essential information on each of three types of orders (i.e., order schedule, consumption schedule and single order), e.g., order ID, order type, due date and quantity.
4. **Stock data**: supplies some aggregate information on both inbound and outbound stock in a company, e.g., on-hand stock, allocated stock, control limits.
5. **Manufacturing data**: is mainly about information on the shop floor. Key information includes production order ID, current milestone, produced quantity and planned due date.

The above data can be stored in a large enterprise database (e.g., an ERP database) or more often in multiple databases for different enterprise applications, such as warehouse management systems, and manufacturing execution systems. At SMEs, these data may be contained in files (e.g., spreadsheets and text files) or in other forms of databases. When network co-ordination activities take place, some derived data will be generated, e.g., delivery schedules, customer order status, revised delivery solutions from suppliers, minimum delivery request from customers. Fig. 6 illustrates the overall structure of the pilot system database.

6. **System evaluation and discussion**

   6.1. Evaluation of the proposed processes and approaches

   To evaluate the pilot system, a progressive, multi-phase evaluation strategy was carried out. Before the actual implementation process, the proposed co-ordination
processes had been validated from a conceptual perspective through multiple communications with the industrial partners and verified by the evaluation of the concept prototype. On the other hand, a simulation study was conducted to provide a quantitative assessment of the potential benefits of the proposed consumption-based planning approach in comparison with the conventional transactional-order-based planning approach.

The transactional order model represents the conventional planning approach, which does not send frequent and small orders to the suppliers due to higher costs in order placement and thus use reorder point systems. Meanwhile, the consumption schedule model represents the proposed planning approach, which communicates the daily consumption information for the coming week(s) to the upstream suppliers. The simulation studies involved three tiers of suppliers and the simulation programme was designed by using discrete event simulation techniques and the Visual C++ environment (Pradoux, 2001). The two models were assessed using five typical scenarios, which include response to a change in demand (sudden or forecasted), response to a series of changes in demand (gradual increase or cyclical) and the influence of lead-time.

The results of the simulation experiments for the above scenarios indicate that the consumption schedule model performs significantly better than the transactional order model in all the situations which are measured against a predefined set of criteria (e.g. deviations of stock level and time for response to changes in demand). For example, using a cyclical demand profile, the simulation results are presented in Fig. 7(a) and (b), which indicate that for all companies in the supply chain, the consumption schedule model for the pilot system copes with a changing demand much better than the transactional order model in terms of deviations of stock level and time for response. Table 1 presents the statistics of the average deviations for the five experiments mentioned above. The statistics indicates

Fig. 7. (a) The order-based system response to a cyclical demand profile (Xu et al., 2005). (b) The pilot system response to a cyclical demand profile (Xu et al., 2005).
that the stock level can be reduced significantly when using the proposed consumption-schedule-based planning approach.

### 6.2. Evaluation of the pilot system

The evaluation of the pilot system involves experts from industrial partners who are highly experienced with the existing methods and procedures. Company users were trained with user manuals and scenario scripts. After the user trial and verification phase, project members participated in an evaluation workshop to make sample runs of real-world business scenarios and to judge the system’s performance under these conditions. The results of the scenario-based testing and evaluation were captured by using detailed questionnaires. The main strengths of this system evaluation approach include analysing workflow in relation to existing working practices and IT tools.

As the evaluation work was carried out by the company users in the project, it may be argued that objectivity of their evaluation was compromised. However, the project team was fully aware of such potential criticisms. They were counteracted by basing the evaluation on real, historical data, such that the proposed processes can be analysed in comparison with the existing ones. Meanwhile, attention was paid to engage staff who are highly experienced with the existing methods and procedures, who can therefore be regarded as qualified experts.

The feedback from the business experts verified that the pilot system fulfilled all business and system requirements proposed in Section 2. From the business perspective, the evaluation results showed that the pilot system could improve demand and supply information visibility, provide early warning of disturbances and enhance the capability of collaborative problem-solving. Particularly on the demand side, accurate demand information can be communicated in near real time through streamlined business processes across the supply network, reducing the bullwhip effect (Geary et al., 2006). On the supply side, delivery performance in network companies is expected to be significantly improved through early identification and handling of delivery problems, reducing inventory levels and material shortages.

From the system perspective, first, the pilot system could be scaled to cater for the growth of the supply network, or easily re-configured to reflect the changes of the network structure due to its open and flexible system architecture. Second, the integrated database of the pilot system ensures data consistency and minimises data redundancies, making it a very stable and reliable system. Third, the pilot system features user-friendly interfaces and secure access by virtue of data ownership and user authorisation on different levels (e.g. system administrators, expeditors and production planners). Finally, though it may be argued that the local connection to the Internet influences the speed in accessing and navigating the system, by focusing on the key network co-ordination processes and minimising client–server transactions, the speed of the pilot system was enhanced and was satisfactory from the users’ perspective.

### 6.3. Limitations and suggestions

In Section 2, it is mentioned that the co-ordination processes were developed on the basis of an extensive literature review and the results of in-company interviews with managers and operational staff of six companies in the automotive and semiconductor industries. Actually, these processes have formed a research framework for manufacturing network co-ordination. On the other hand, as the framework presents only the most important processes for improved co-ordination of production planning and control activities in the supply network, it may be argued that the proposed framework has some limitations in terms of specificity and scope from the process perspective. First, it may be necessary to customise the functionalities of the co-ordination processes to meet the specific business requirements of individual network members. Second, new co-ordination processes may need to be identified and integrated into the existing framework to cover the special business requirements of a given industry.

As indicated in Section 5.1, Microsoft’s ASP was chosen for implementing the pilot system. To some extent, the ASP approach combines the advantages of the rapid Web application development platform (i.e. short system implementation cycle) and the object-oriented approach (i.e. flexible system infrastructure). On the other hand, in comparison with the Java-based system development method, the ASP approach has limitations in terms of system portability. Therefore, it is suggested that the Java-based, object-oriented approach be employed if the network co-ordination system is to be implemented for development of commercial software systems.
7. Conclusions and future research directions

This work represents an important step towards better co-ordination of production planning and control activities in global supply networks, which is supported by collaborative business processes and corresponding Web-based systems. By focusing on the key inter-company planning and execution co-ordination processes, it is expected to significantly reduce the cost of ownership of the Web-based system so that SMEs can be involved in the network co-ordination process without incurring high adoption costs (Arshinder et al., 2008). On the other hand, the developed co-ordination processes, the guiding principles for process design, the decentralised system architecture and the database structure are generally applicable to the co-ordination of production planning and control activities in a manufacturing network environment.

From the managerial perspective, the pilot system can be extended as a demonstrator to show how best practices in SCM can be achieved through enhanced information sharing and integration with business partners and to illustrate the expected benefits of improved co-ordination to all the parties involved. For example, the missed delivery handling process will get more and more responsive to delivery problems when information sharing migrates from the modest level, e.g. only the supplier has the visibility of inventories on the customer side, to the high level, e.g. the supplier has full control of inventories and clear visibility of the customer’s short-term production schedule.

From the technical viewpoint, it can be argued that the pilot system could be implemented in a different way. However, the presented research work has formed a fertile ground for future research in the area of network co-ordination. Specifically, future work can be undertaken along three research lines. First of all, to get the system up and running in a real industrial environment with the maximum possible cost-benefits in a reasonable period, it is essential to address the issue of the integration of the network co-ordination system with local legacy systems.

The functionality of the pilot system can be enriched by relevant decision support information such as specific reports through its integration with local legacy systems. For example, as the exception handling process interacts with the shop floor on the supply side, a comprehensive report on current production status on the shop floor, such as backlogs, WIP and bottlenecks, will be helpful in supporting the production planner for more advisable decision making.

Finally, as the pilot system was focused on the four co-ordination processes (i.e. operational ordering and planning, request and feasibility study, visibility of order progress and exception handling), the research work can be extended to include the detailed design and implementation of the other three co-ordination processes (i.e. long-term business planning, multi-sourcing co-ordination and network performance management) and their integration with the pilot system.

Acknowledgements

The author would like to acknowledge his gratitude and appreciation to all the colleagues in the Co-OPERATE project for their collaboration, valuable comments and contributions made during the project. He is indebted to Emeritus professor Colin Besant and Dr. Mike Ristic at Imperial College London for their encouragement, support and guidance. Particular thanks are due to Ms. Christine Pradoux for her simulation work used to evaluate the proposed planning method. The authors would also like to thank the anonymous reviewers for their helpful comments.

Appendix A. Strategic objectives for prioritisation of the seven co-ordination processes

1. Higher responsiveness with information and production in the supply network.
2. Lead-time reduction throughout the supply network.
3. Improved flexibility in the supply network.
4. Reduce inventory levels.
5. Increase the ability to solve problems in the supply network.

References
