THE WORKFLOW-ENABLED SUPPLY CHAIN, THE CIVIL CONSTRUCTION ENTERPRISE CASE STUDY

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This paper presents on-going research in the supply-chain management area. With this effort, we aim at bridging the gap between business process modelling in the supply chain and business process co-ordination by means of innovative workflow management tools. In this context we present the Supply Chain Operation Reference Model (SCOR) and illustrate its usage in a Civil Construction Enterprise case study. The civil construction enterprise presents, usually, a distributed organisational structure (strategic enterprise, construction sites, warehouses, head-offices, etc.), and operates in a transient and variable environment, according to the collection of works in progress. A common scenario is the construction process that involves the interaction with several suppliers and the co-ordination of many smaller firms (subcontractors), normally coordinated by one contractor. The relationship with the enterprise suppliers as well as between contractor and sub-contractor features a clear Source-Make-Deliver and Return pattern, demanding co-ordination and interoperability along those processes that cross the enterprise boundaries. The SCOR model process-orientation greatly facilitates supply chain business process decomposition, fostering therefore greater effectiveness process integration along the supply chain. The paper concludes with a proposal of new business process management concepts to be supported by novel distributed workflow management tools.

1. THE SCOR MODEL

The SCOR model has been developed to describe the business activities associated with all phases of satisfying a customer's demand. The model itself contains several sections and is organized around the five primary management process of Plan, Source, Make, Deliver, and Return, as shown in figure 1 (SCOR, 2000).

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Figure 1 - SCOR conceptual structure (SCOR, 2000)

By describing supply chains using these process building blocks, the Model can be used to describe both very simple and very complex chains, using a common set of definitions. So, SCOR model enables that distinct industries can be linked to describe the business processes supply chain, in an extended enterprise. The scope of the model is to describe and provide a basis for supply chain improvement, covering several complexity levels and bridging multiple industries. It also covers all customer interactions, all physical material transactions (supplier's supplier to customer's customer, including equipment, supplies, spare parts, bulk product, software, etc.) and all market interactions (for the understanding of aggregate demand to the fulfilment of each order). With the introduction of Return element, the model has been extended into the area of post-delivery customer support.

SCOR is a hierarchical model structured in four levels (SCOR, 2000):

1. The Top Level defines the scope and content for the Supply Chain Operations Reference-model. Process types are defined here.
2. At the configuration level, the company's supply chain can be "configured-to-order". Companies' implement their operations strategy through the configuration they choose for their supply chain.
3. Level 3 defines a company's ability to compete successfully in its chosen markets, and consists of: Process element definitions; Process element information inputs, and outputs; Process performance metrics; Best practices, where applicable; System capabilities required to support best practices; Systems/tools. Companies "fine tune" their Operations Strategy at level 3
4. Companies implement specific supply-chain management practices at this level. Level 4 defines practices to achieve competitive advantage and to adapt to changing business conditions.

The SCOR Model links therefore process elements, metrics, best practices, and all the features associated with the execution of a supply chain in a unique format. The uniqueness and power of the model, and its successful implementation is chiefly derived from the combined usage of the "Plan", "Source", "Make", "Deliver" and "Return" elements.

2. THE CIVIL CONSTRUCTION ENTERPRISE CASE STUDY

The construction enterprise presents, usually, a distributed organisational structure (strategic enterprise, construction sites, warehouses, head-offices, etc.), and operates in a transient and variable environment, comprising the concurrent management of far-apart construction sites. Construction industry uses a very unstable and transient workforce. The result of a construction project is usually a custom-built product from numerous raw materials and components, drawn from several sources. Unlike advanced manufacturing industries, concepts such as controlled working conditions, parallel working, standardisation, and innovation, are not embedded in the construction industry.

Another familiar scenario to civil construction is the widespread usage of subcontracting, transferring to those enterprises the responsibility to execute some specific construction activities. To this end, the construction process typically involves the co-ordination of many smaller firms (subcontractors) controlled and monitored by the contractor. The effective co-ordination and communication of these smaller firms by the principal contractor is essential to the success of any project. This clearly demands the usage of adequate decentralised business process co-ordination infrastructures, allowing firms to contribute to common process integration (Vernadat).

Basic functions and interactions in the civil construction enterprise are illustrated in figure 2 (derived from – V. Rembold). Information, material, management and financial flows are also illustrated. This description further includes all the extended enterprise participants (main contractor, subcontractors and suppliers) as well as locations (construction sites, warehouses and had offices).

A construction enterprise is, typically, structured in the following organisational areas:

- Management enterprise, including the strategic planning and the administrative area;
- Technologic planning, with activities related by engineering like I&D, projects, works budgeting;
- Works planning, responsible to determine the needs of materials, workmanship and equipments, supported by MRP ("material requirements planning) and CRP (Capability requirements planning) tools; Works control, in the three following aspects:
 - Costs, schedule and quality standards; Construction sites, with the production development, material and quality control, and measurement of works realised;
 - Parks of equipment (and head-offices), responsible to management and maintenance of machines;
 - Warehouses, responsible to material management, and so to the materials flows to the construction sites.

These organisational areas are responsible for the execution of an extensive number of business functions (Pinto, 2000). These functions (and organisational areas) are in fact replicated in several nodes of the extended enterprise. In this context, we would highlight examples such as construction sites, parks of equipment and warehouses. The number and location of these functional units is in fact variable in time, and depends on the actual work in progress.

Figure 2 - Interactions between basic functions in a civil construction enterprise

The organisational structure of a construction company comprises, usually, numerous construction sites and warehouses. Materials flow from suppliers to construction sites and/or warehouses. For each involved entity we identified Source, Make, and Deliver processes illustrated in figure 3:

- The construction site receives materials from suppliers or from the warehouse (Source Process). Inventory management rules such as the call-off strategy is also handled in S1. The actual production process is covered by the Make process. The Delivery process (D1) covers the interaction with the final customer.
- The Warehouse receives the order requests from construction site through its delivery process D1. Warehouse can also generate its own orders triggered by inventory management rules performed within the source process S1. The products are received from suppliers and delivered at the warehouse, however, the warehouse source process can order delivery at a particular construction site (link *a*)).
- Suppliers receive purchasing orders, Delivery process D1, and trigger their order fulfilment processes to ensure material delivery either at the warehouse or at particular construction site (link *a*)).

Figure 3 - Supply Chain Score Model

- Return processes were omitted but are definitely imbedded in the above picture, covering customer feedback, such as request for replacement of rejected materials.

The SCOR model could be further applied to the relationship between contractor and subcontractor. The relationships between contractors and sub-contractors are contract based and its interaction, features a complex and dynamic relationship (Ferreira, 1999):

- The need for the contract emerges and is driven by the actual production plan
- The contract manager handles the detailed contract elaboration: it includes legal issues, detailed work description, costs and payments, quality standards, penalties, safety requirements, timings, etc.
- The contract acceptance starts the process. The sub-contractor executes a detailed work plan, certificated by the contractor.
- From the moment the sub-contractor starts its own activity, the contractor starts the regular monitoring of the work in progress. This monitoring activity is a corner stone to feeding back information both for accounting and for construction management.

The relationship between contractor and sub-contractor works in both directions featuring a clear Source-Make-Deliver and Return pattern, demanding co-ordination and interoperability along those processes, keeping in mind that this could work along several subcontracting levels.

3. WORKFLOW-ENABLED SUPPLY CHAIN

The SCOR model process-orientation greatly facilitates supply chain business process decomposition, fostering greater effectiveness in the process integration along the supply chain. Figure 4 illustrates this flexibility by making a parallel between the enterprise engineering lifecycle derived from the Purdue enterprise Reference Architecture on the right (Pinto Ferreira, 1999), and the SCOR model levels on the left (SCOR, 2000).

Figure 4 – SCOR model and the Enterprise Engineering lifecycle

Figure 4 further illustrates the emergence of the Business-to-business paradigm, by putting the focus on the actual supply chain relationships both within and across enterprise borders. The evolution from traditional business practices to e-business (the usage of Internet technologies to improve and transform key business process) is definitely an opportunity to introduce innovation, efficiency and transparency in the business processes (Ferreira, 2001). In this context, workflow technology is becoming the cornerstone technology to support the so-called B2B e-business. Creating e-business process without a vision for workflow is dangerous and expensive. Workflow addresses e-business needs, streamlining transactions and being the glue for process co-ordination and consistency.

Innovative aspects could emerge from the future business models that B2B commerce will take. This will be based on new workflow technology developed to produce three crucial innovations (B-MAN, 2001):

- *Just-in-place Business Process Execution*: ensuring that the required knowledge and functionality for the right process is in the right enterprise location at the right time
- *Trust-based B2B Integration*: new models for process authentication and ownership across enterprise boundaries; these new models enables an higher level of interoperability between organizations
- *Transparent Enterprises*: seamless access to network business process information regardless of point of access, give rise to new methods of working.

B2B enterprise integration is enabled by business process co-ordination across enterprise boundaries. This objective could be achieved through the development of an innovative agent-enhanced workflow-based infrastructure. This infrastructure could use agents to encapsulate knowledge and functionality required to execute a business process. Co-ordination is achieved by ensuring that the right components

are instantiated and executed in the right order, in the right location in the enterprise network and at the right time. This will be achieved through a number of mechanisms, for example mobile agents, platform independence, and consistent user interface.

Interoperability between business process is currently achieved by using predefined standards for conventional software components. To this end, new formal models for process authentication and ownership across enterprise boundaries could be defined. These models will be used to describe relationships between organizations, for example, trust, privacy and rights. Once an inter-organisational trust relationship is created, business process can be dynamically launched and executed. Once a business process crosses an organisation boundary current systems make them invisible to other participant organisations. The scope is to make inter-organisational boundaries transparent, subject to previous definition of trust, privacy and access rights.

4. CONCLUSIONS

Supply chain management in the construction industry seems to be a critical area to driving innovation and to sustaining incremental and continuous improvement. As demonstrated, the SCOR model could be used in the different steps towards enterprise integration in the supply chain engineering lifecycle. Effective implementation of supply chain integration leads to performance improvement in the shape of reduced costs and better quality. In this context, workflow technology could become a key to support business process integration providing management tools and interoperability across a network of enterprises. The new extended enterprise integration will not only live from its integration with suppliers and customers, but will have to enable the so-called Just-In-Place / Just-In-Time paradigm (Ferreira1, 2001). Enterprise integration will have not only to cope with business process co-ordination across enterprise boundaries but will have enable enterprise transparency as well, supported by state-of-the-art trust-based protocols. Moreover, new technologies are driving us to a new scenario where processing and information mobility and availability will be a de facto business standard. The Just-In-Time / Just-In-Place clearly demands innovative approaches and research efforts to achieve what we anticipate as the future B2B commerce business models. These paradigms clearly demand a lighter and distributed workflow infrastructure to be developed in the course of the B-MAN project (IST-2001-32285).

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