Co-operation Formation in Non-hierarchical Production Networks

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Abstract: In this paper we introduce a concept of project-driven co-operation formation between SMEs (small and medium-sized enterprises). In contrast to conventional, more static supply networks, which are often dominated by a large-scale enterprise as main contractor, our model facilitates the dynamic co-operation formation between equal partners. The co-operation lasts for the duration of single projects and is therefore more suited for single piece and small batch production. Co-operation formation is supported by service brokering via electronic market places. The SMEs are very loosely coupled to the market place, having to provide only a company profile in order to be included in any selection process. A multi-objective selection mechanism helps to choose the most suitable partner for every task in the co-operation. This enables SMEs to accept and successfully fulfill customer requests for complex products, which they could otherwise not handle. Supply chain management within the co-operation bases on the new Extended Value Chain Management approach. It allows a probability assessment of delivery time and quantity assurances in tenders exchanged during the co-operation formation. Thus the risk of failure due to lacking information about likelihood of delivery in a supply point is drastically reduced.

1. Introduction

Non-hierarchical, regional production networks are the vision of a virtual enterprise model followed in a collaborative research project at the Chemnitz University of Technology [5]. The centre of interest is the evolution of a virtual enterprise model, which is based on small production units, so called competence cells. The general intention of our model is to improve the competitiveness of small and medium-sized enterprises (SMEs).

Our research pursues a path off the beaten track. The objective of already existing models is to restructure the co-operation between large-scale enterprises and dependent partners. The primary objectives of our model are, of course, the same ones as in existing models: reduction of production costs, improved flexibility, higher quality, reduction of the administrative overhead and the bullwhip effect. Already existing approaches dissect organisations into smaller units. These units possess only few and very specific key competences. The rationale behind this top-down strategy is to connect particular units in order to form a network. These networks should improve the companies' performance in complex production tasks [4].

By following the bottom-up principle the concept of Virtual Enterprises (VE) can also be applied to small and medium-sized enterprises. Their business is, as a rule, already concentrated on a small number of key competences. That means, they fulfill a particular function very well. However co-operation could enable the SMEs to accomplish comparable tasks as large-scale enterprises do. Today these co-operation are often built up hierarchically, because smaller enterprises are only involved as subcontractors of large-

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scale enterprises. A prominent example of this pattern, and coincidentally the essential driving force of innovation in Supply Chain Management (SCM), is the automotive industry.

Supply Chain Management is a major prerequisite for controlled co-operative

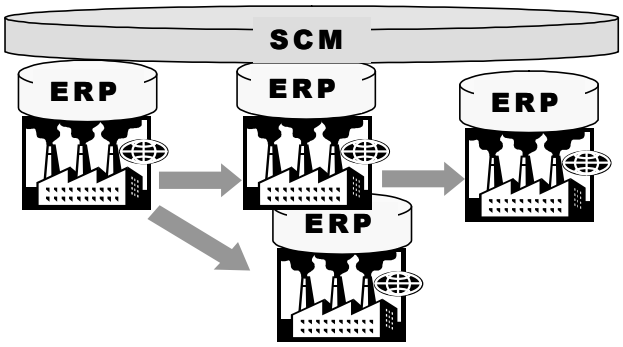

Figure 1: Supply Chain Network

production. Supply Chain Management is the integrated, customer-oriented view on business processes beginning with the initial supplier up to the end consumer. It comprises all strategic and functional measures for the efficient and effective coordination of inter- and intra-organisational material and product flows (figure 1). SCM shifts the focus of planning from the enterprise level towards the objective level [8].

SCM typically treats suppliers as “black boxes”, which means they receive inquiries as input and are expected to produce tenders as output. Their internal situation, such as their current capacity, is hidden to the client. Therefore the client has to delay further plannings until he receives the tender and, more critically, he has to rely on the assurances in the supplier’s tender without beeing able to check their likelihood. In reality however, delivery time and quantity statements are often only the supplier’s estimations. This degree of vagueness is not visible to the client and often turns out to be a pitfall in the co-operation.

2. Extended Value Chain Management

Extended Value Chain Management (EVCM) supports the quantization of delivery time and quantity assurances. The EVCM software is connected to the ERP system and can directly assess the likelihood for the fulfillment of a contract. This means, suppliers can be seen as “white boxes”. A product to be delivered can either be in stock – it is avalaible to promise and the likelihood is hundred percent. Or, the product has to be manufactured first. The ERP system provides the information if the manufacturing is possible within the given time frame. In this case the product is capable to promise. However the likelihood now depends on the supplier’s internal situation and reliability of the next level suppliers. This yields a chain of conditional probabilities for supply promises. In contrast to SCM, EVCM allows a more realistic planning on account of the probability chain. Moreover, the automatic processing of inquiries by EVCM software allows for an instant generation of tenders. The client receives an immediate response, which drastically decreases the delay in his further plannings. By combining the concept of EVCM with electronic market places, the advantage of fast and realistic tender generation is complemented by the option to have a flexible supplier network. The principle concept works as outlined in figure 3.

The left side of the figure shows a customer issuing an inquiry to a market place. The inquiry can also be automatically generated by an SCM-system [6]. Via the market place

potential first level suppliers for the final product are identified. Each supplier disassembles the value adding chain only in the part he has the technological or manufacturing competences for. Inquiries for the other parts are passed on to a market place again. In case a supplier does not need to further disassemble the value adding chain, the roll out process in this branch stops and the supplier returns a tender. Subsequently, in the roll back phase, the tender is returned to the inquiring instance. A supplier receiving tenders for out-sourced parts has to calculate his own tender. The selection of the most suitable supplier according to a set of recieved tenders requires advanced planning and scheduling tools [2]. The roll back phase is sketched on the right hand side of figure 3. At the end the customer receives tenders for the final product from the first level suppliers.

Finally the technique of decentralized disassembly likely yields a similar network to what a centralized SCM planning procedure would generate. The difference is that a centralized approach can theoretically guarantee a global optimum, if the complexity of the entire task can be managed. A decentralized approach cannot guarantee a global optimum. Nevertheless the striking advantage of decentralized disassembly is the greatly reduced complexity. The fast generation of realistic tenders offsets the lack of a guaranteed optimum. Furthermore the decentralized approach in connection with electronic market places allows flexible, project-driven co-operation formation. The SME's are not tied in a fixed supply network. Instead they can autonomously choose the most suitable partners for every project.

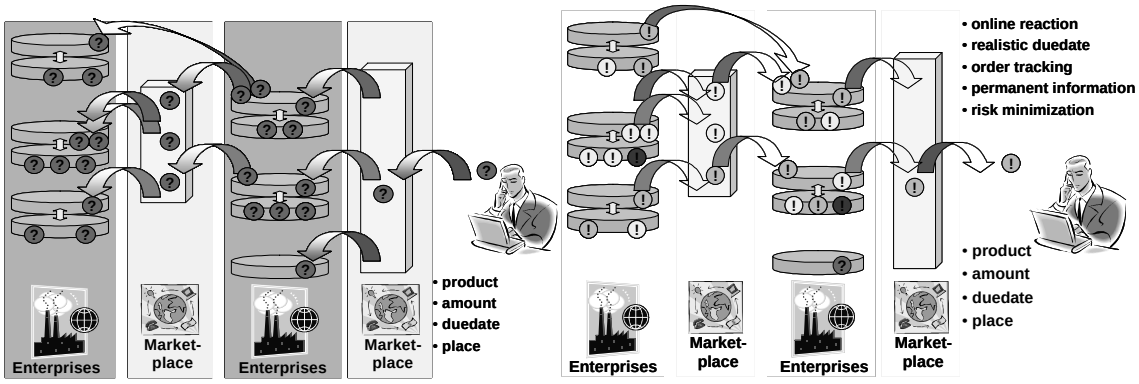

Figure 3: Extended Value Chain Management

The implementation of the described approach comprises two main areas. The functionality of the EVCM business logic as Add On to an existing ERP-system is hosted as application service. The objective of this ASP (application service providing) strategy is to provide the SMEs economically feasible access to EVCM tools [7]. Traditionally, SCM-solutions are only affordable for a limited number of users. For SMEs the costs are prohibitive. Our model of production networks offers the opportunity to overcome this exclusivity by integrating the e-business technologies and the enterprises' system environments of ERP or even SCM. Figure 4 illustrates this.

Hosting of EVCM systems can be accomplished by extending the market place functionality. The second area is the installation of a sophisticated mediation on market places. The mediator has to preselect only suitable suppliers for a given inquiry in order to avoid information flooding. It passes on the inquiry to the selected suppliers and routes their tenders back to the inquiring instance.

3. Mediation on EVCM Market places

In the EVCM model the market place acts as a broker for services and products supplied by independent SMEs. The broker selects suitable suppliers for a given inquiry. Suitable here means that the supplier is capable to fulfill the technological requirements stated in the inquiry. Therefore the market place needs two components to act as a broker. The market

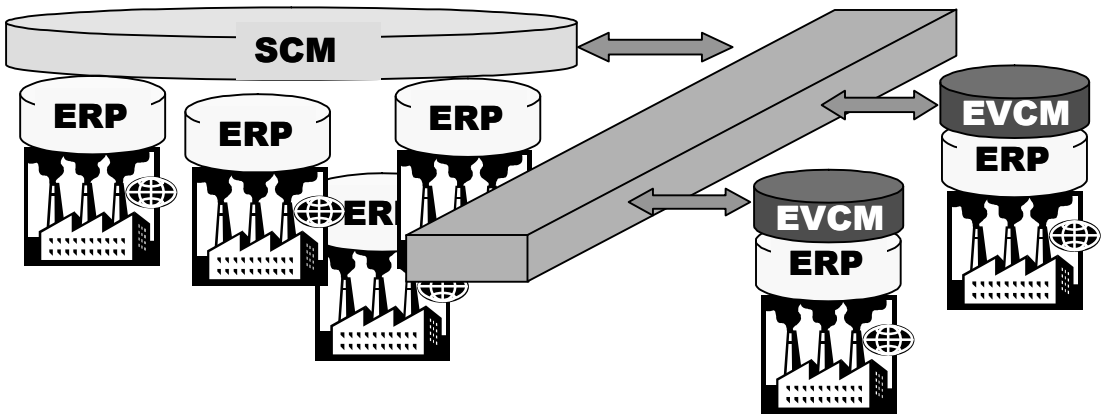

Figure 4: EVCM as basis technology of non-hierarchical production networks

place has to maintain a product and service catalogue describing the product ranges and technological capabilities that can be exchanged on it. This in turn requires that the SMEs register on the market place and describe themselves in compliance with the market place's domain ontology. The domain ontology, the market place's second required component, governs the formulation of catalogue entries as well as the inquiries. Each enterprise has to describe itself and its products or services in a profile by using the terminology maintained in the ontology. This establishes a common view on the product catalogue. The formulation of the inquiries in the same terminology enforces the semantic compatibility to the product catalogue and thus allows the identification of potential suppliers. It must be noted however that neither the product catalogue, the profiles nor the ontology contain static information. For example new products or services might be offered, which requires not only the insertion of another product but also the addition of concepts to the ontology. This in turn requires an extensible ontology and the efficient management of an arbitrarily large product inventory in a knowledge base at the market place.

For the efficient storage and retrieval of company profiles, we use the ICIx technology, which organises objects according to a content-based similarity measure [3]. The measure takes into account describing features and creates a multidimensional arrangement of the objects in form of similarity groups. Thus ICIx groups together providers of similar services or products [1]. To the resulting similarity groups links are established in the product catalogue. This mechanism allows the broker to retrieve quickly all suitable suppliers for a given inquiry once it has identified the appropriate entry in the product catalogue. The broker's search can either be conducted as exact match queries or approximate queries. Exact match returns only those providers whose profile contains exactly the product or service in question and all specified features. Due to the configuration variety of complex products an exact match is not always guaranteed. The approximate match however returns all members of the similarity group. In the first case, the inquiry can be passed on to the respective suppliers. The adherence to the concept ontology on both sides guarantees that these suppliers can manufacture the desired product. Therefore exhaustive and up-to-date description of their product range is of economic interest for the suppliers. In case of an approximate match the market place can either react

in the same way or require the client's decision. The supplier receiving an inquiry resulting from an approximate match has to decide whether it is technological feasible and he returns a tender, or it is infeasible and he rejects the inquiry. Figure 5 shows the components our model embeds in the market place.

While the selection of suitable suppliers for a product in the roll-out phase is based on content criteria, ie. technology, features and functions of products, the choice which tender to accept in the roll-back phase, and consequently which supplier to include in the co-operation, is based on economic criteria. A multi-objective decision has to be made with respect to the quantity to be delivered, delivery time, price and other conditions. The

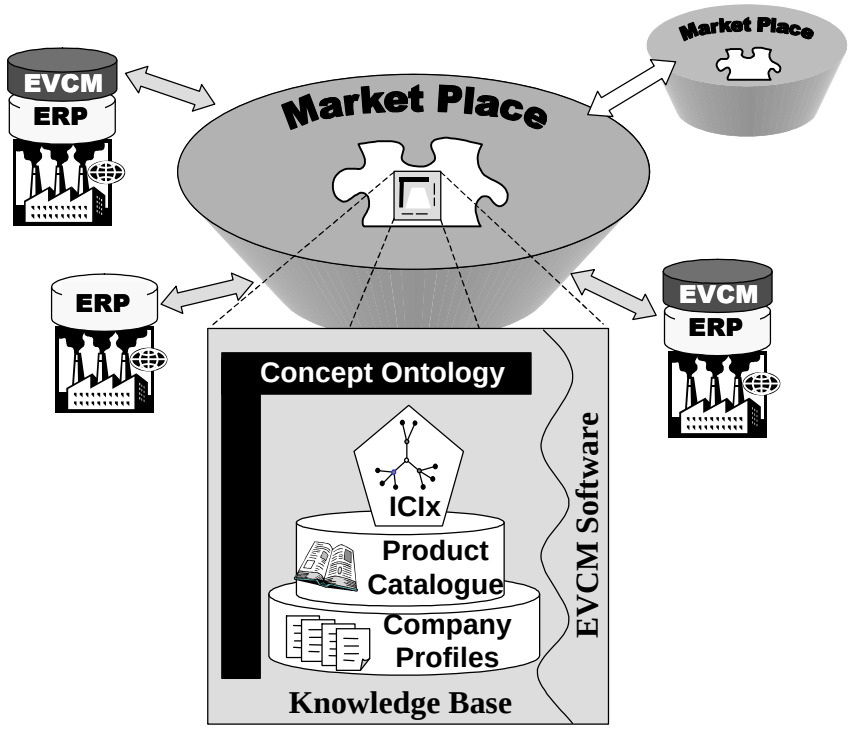

Figure 5: Embedding co-operation mediation in electronic market places

EVCM system has qualified each tender with a particular likelihood and thus the decision process is more detailed but also more complex. The risk of failure in a supply point, which was hidden in the SCM world, is now visible and can be included in the utility function of the optimization. This decreases the structural risk in the co-operation formation and operation. Moreover, the likelihood can be aggregated over all nodes of the supply chain and becomes part of the final tender the customer receives from the production network. The increased transparency of the tender represents an additional benefit for the customer and is likely to improve the customer's trust in the production network.

4. Summary

In this article we have proposed a concept for flexible co-operation formation. The co-operation formation is project driven. For a complex product to manufacture a network of most suitable participants is created under economic considerations. The partners are identified by a product causal approach, which means they are identified by offered products rather than their competences and capabilities. The product causal approach was chosen, because current research results do not allow an in-depth competence description, sufficient for the match-making purpose. As a consequence, the system includes at the

moment only manufacturers. Service providers can only be handled if the description of their services is very specific, for instance transport services. The description of more general services, for instance logistics, is a current research topic.

The core of the business logic in the co-operation formation is the electronic market place in conjunction with an Extended Value Chain Management system. We propose EVCM as new generation of Supply Chain Management systems. EVCM works on top of the companies' ERP system. Thus it allows insight into the companies' current capacities. On this basis realistic tenders as response to inquiries can be created rapidly. In combination with the communication speed in electronic commerce, this can dramatically accelerate the co-operation formation. Hosting EVCM as application service makes sophisticated supply chain management affordable for SMEs. This could turn supply chain management software into a fast growing mass market.

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