A toolset for building the Virtual Enterprise

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Abstract

Much research has been conducted to define what a virtual enterprise actually is and how it should work. This paper addresses the more specific question, how a virtual enterprise can be designed to be agile and to so best support short-term business opportunities. A framework is presented for the organisational design and the changing business roles of the 'business architect' who constructs the various phases of the virtual enterprise's lifecycle. This infrastructure for creating virtual enterprises is referred to as the 'Value System Designer'; a set of methods and tools to select partners, reengineer business- and logistic processes and to set up an information and communication platform for the virtual enterprise. The methods and tools have been developed in two longitutial research projects 'TELEflow' and the 'Virtuelle Fabrik' between 1995 and 1999. Focusing on the experiences gained from numerous cases, a summary on crucial success factors for designing virtual enterprises shall be presented. Thus, this paper gives insights and applicable know-how for companies and managing engineers in their role as virtual enterprise architects, for example leaders of project consortia or joint ventures or as first-tier suppliers co-ordinating supplier (sub-) nets.

1. Introduction and Research Method

The term 'Virtual Enterprise' has become a buzzword used in a multitude of contexts and all promising business success (Mowshowitz, 1997, Pulli et al., 1999, Goldman et al., 1995, Byrne, 1993). However, the virtue of virtuality (Chesbrough and Teece, 1996) is clearly confined to adapted applications in specific business environments. This research is undertaken with a double objective, to firstly identify the conditions under

which virtual enterprises can succeed and to secondly develop a normative approach to actually create virtual enterprises. The latter is referred to as the Value System Designer.

The findings consulted are taken from socio-technical research (Wollnik, 1977). This research method seems appropriate as the distinction and boundary between the intelligent manufacturing system and the organisational setting is becoming ever more blurred (Lau, 1997). Even though the research was iterative with many feedback-loops over a time span of three years (Susman and Evered, 1978), the findings presented are concurrent with the principal structure of research design. Based on available knowledge in business literature the hypothesis was formed that virtual enterprises perform best in turbulent business environments. Derived from this sociological finding, the technical design of the Value System Designer as an intelligent manufacturing system was constructed. In the technical phase of the research the Value System Designer was developed and a prototype implemented. In the second sociological phase of the research, the Value System Designer was applied in various business cases to so evaluate its performance. The outcome of these cases was then related to conclusions found in literature to so gain a deeper understanding of our research question; Under which conditions do virtual enterprises succeed?

For the academic community, this research intends to contribute to an improved understanding of the conditions under which virtual enterprise concepts can be applied. In turn, by creating a better understanding of the user scenario, more accurate technical requirement specifications can be distilled and thus providing the means to develop future methods, tools and intelligent manufacturing systems. For practitioners this research gives an explanation and forms the criteria on deciding to choose the virtual organisational design. Additionally, it will provide guidelines and best practices for the implementation issues of intelligent manufacturing systems.

The remainder of the paper is structured as follows. The stance on the contingencies of virtual enterprises will be clarified, which will allow managers to anticipate success and failure within their own context. This research is literature based. In the proceeding chapter the Value System Designer will be defined. This approach was designed during a four-year co-operative R&D project (Schuh, 1997) and was then engineered as a set of methods and tools later integrated in a life-cycle framework spanning the entire duration of a virtual enterprise. The third chapter reports the findings of the Value System Designer application in a number of business cases. These findings are distilled into lessons-learned and refined conditions defining when virtual enterprises can be successful is presented. Finally, future research is proposed from the lessons learned.

2. Theoretical Background – The structure of virtual Enterprises

It is generally acknowledged that firms today face a dynamic environment, changing at an increasingly rapid pace (Volberda, 1996, d´Aveni, 1994). Market opportunities in particular can arise and disappear again within a short timeframe. However, the ability of traditional Enterprises to adapt to these changes remains limited. This predicament, where the environment changes more rapidly than Enterprises can adapt to is referred to, as a turbulent environment.

Virtual enterprises are designed to behave in an agile manner towards market opportunities (Goldman et al., 1995, Goranson, 1999). This is achieved by stimulating organisational flexibility, particularly the competence to concurrently design a customer's product or service and the processes to produce or deliver it. The flexibility is supported by (but should not be confused with) the structure of a virtual enterprise.

Three basic elements, the customer value, the value system and the network describe the virtual enterprise for our purposes (Figure 1) and allow us to formulate answers for the following questions:

- Why was the virtual enterprise created?

  The virtual enterprise is designed to create value of a business opportunity. The value is the force that drives continuous restructuring of the virtual enterprise.

- How can the value be created?

  Value is created with the virtual enterprise, as business processes are adapted to the requirements of the short-term business opportunity.

- Who are the potential partners?

  The potentially participating partners of the network will in most cases be related parties; independent companies, but also decentralized profit centers or strategic business units of a global holding.

Insert Figure 1 about here

Competition in the information age is expected to take place less among single companies, but increasingly among clusters (Laubacher and Malone, 1997) of companies that work together to exploit the value of a business opportunity.

With the emerging information society, co-operation on a global scale can be expected to intensify thus increasing strategic relevance as distance no longer forms a limiting issue (Jaikumar and Upton, 1993). This shift might become a competitive advantage for large multinationals that already have a global structure. European companies, however, are smaller in size compared to their US and Asian counterparts. To reap the benefits of the information society, it is therefore often necessary for the European firms to engage in co-operative strategies to so create global presence.

Lacking the power of the large multinationals, smaller companies will have to seize the opportunity to substantially improve their competitiveness by creating, leading and sharing win-win constellations with their partners. In our cases we observed that this requires new management competencies, or will at least call for managers to broaden their interest domain. They shall have to leave their turf and actively re-engineer inter-company processes. In short, at the core of the virtual enterprise we found an incessant process of creating new and disbanding outdated temporary project configuration, which leads to agile behaviour (Figure 2).

Insert Figure 2 about here

The structure of virtual enterprises is a useful model to describe any configuration at given point in time. This paper however, will focus on the set of organisational routines and tools that produce the agile behaviour of a virtual enterprise; organised actions and interactions bringing processes together from different companies, different sites, suppliers, OEMs, distributors, service providers, etc. co-operating to provide customer services.

In other words it is our opinion that virtual organisations will excel in dynamically changing global markets on condition that new business opportunities can be identified and addressed using a new design of the virtual enterprise. The Value System Design approach supports the competence to engineer and re-engineer virtual enterprises in a systematic and professional way. The cases in Table 1 illustrate that this competence of concurrent engineering is a source of sustainable competitive advantage.

Insert Table 1 about here

3. The Value System Designer

3.1 A lifecycle based framework for designing virtual enterprises

The Value System lifecycle forms a framework for all enterprise engineering activities to design a virtual enterprise (Figure 3). In the pre-phase the business concept is defined,

which is then outlined in the architecture of the product. Our observation suggests, that co-operation is a significant element of the configuration phase to identify the best set of partners. In the next step virtual enterprise processes are engineered during the design phase and consecutively operation procedures follow. All virtual enterprises are by definition temporary, thus de-briefing and wind-up of the co-operation requires special attention in the disbanding phase.

Insert Figure 3 about here

The above mentioned phases can be supported by a number of off-the-shelf methods and tools. The following list is a mere illustration:

- Product specification methods to be applied in the pre-phase
- Competence database to identify the best partners for the virtual enterprise in the configuration phase (e.g. business-to-business e-commerce platforms).
- Modeling tool for network processes and logistics in the design phase
- Performance measuring systems to be used in the operations- and disbanding phase.

The cases on virtual enterprises studied in this longitudinal research suggest that in order to adequately respond to a temporary window of opportunity in the market, engineering and implementation competencies cannot be created for the occasion but need to be pre-installed and on standby. The network of partners can serve as the platform for these modular competencies and can so be accessed and applied to each individual business case. Contrary to the viewpoint of Miles & Snow (1986) who predict encompassing Information Systems to replace long standing trust relationships, our observation in numerous cases point to a co-operative culture as a complementary success factor to effectively access these competencies. In other words the critical success factor proved to be the co-operative culture within the network.

Furthermore, we found business-engineering activities in the virtual enterprise to occur more concurrent than sequential. With this we found that central electronic control, which is suggested by Upton and McAfee (1996) was refused by the peer network partners as an attempt to install hierarchical chains of command and control. Instead, after about two years of co-operating in the network distinct roles and specialisation of expertise of the individual partners were observed to emerge, each essential in a certain phase of the Value System's lifecycle. For the individual firm this was found to translate in a shift in strategic positioning. The traditional enterprise where a strategy was based

on the product or service with the enterprise supporting all phases of its lifecycle had changed. Firms that got more deeply involved in the network were found to increasingly define business strategies around their competencies (e.g. the design of new products, the engineering of processes, management of operations, supply of technologies) and to use the virtual enterprise to complement missing competencies from the network. In many cases the product was even passed on from network partner to network partner when maturing from concept design to prototype and further series production thus revealing that each phase of the virtual enterprise's lifecycle has distinct dominant competencies. Concurrent with the observed co-specialisation of partner firms in the network (Teece, 1986), more specific competencies for the co-ordination of the virtual enterprise developed in the network.

3.2 Roles and design tasks in the Virtual Enterprise

Based on observations, six roles can be distinguished to serve as an aid to determine strategic positions for any partner in a virtual enterprise (Figure 4). The roles were also used to analyse the requirement specifications for the development of more specific methods and tools to design virtual enterprises to become part of the Value System Designer. These role have been defined as follows:

The *broker's responsibility* is to market the network and retail the competencies of potential virtual factories. This person is an entrepreneur working predominantly in the early phase of a virtual enterprise, procuring new projects for the network. Thus, the broker acts as a facilitator between customers and production.

The competence manager provides engineering knowledge on available technologies and competencies of the network and gives application support to customers. During the configuration of the virtual enterprise this manager will concurrently engineer the processes and select the best partners. The project manager supervises the operations of the virtual enterprise offering time, project management, and budget control. Additionally the project manager will supervise the re-engineering process, e.g. replacing partners who do not perform satisfactorily.

Insert Figure 4 about here

The in/outsourcing managers of each network partner develop a dedicated interface with the network and interact with network partners. They offer technological know how, resources and personal technological expertise to the network. While operating a virtual enterprise the in/outsourcing manager is responsible for a step in the value chain of the system and represents the interest of his firm. The auditor serves the network as a neutral financial auditor providing financial solidity due to his independent status. The latter

becomes especially important in those cases where a track record for a customised on-demand engineered Value System is not available.

The network-coach is not related to a business opportunity but constantly serves as a coach for the members of the network. This coaching is necessary to create the indispensable co-operative culture of the network and can be achieved by governance of the network, setting business rules and routines for co-operation, providing technological infrastructures in the network and managing relationships (and conflicts).

3.3 Value System Designer Components

The Value System Designer is a direct result of converting the sociological research findings into specifications for a method to engineer and support tools (Brinkkemper et al., 1996). The objective was to integrate existing and develop new methods and tools for Value System Design. Four facets were developed for the 'Value System Designer' demonstrator. First an overall Value System Designer methodology as a framework, second, the value system re-engineering tool NetMovals which combines an enhanced process modeling tool for an inter-enterpriseal application with the new business network modeling tool. Third, a logistics management solution repository (LMSR) providing a strategic controlling tool based on the balanced score card and detailed criteria to measure the performance of the virtual enterprise. Finally the TELEflow Information Infrastructure was designed to provide services to swiftly set-up project specific IT infrastructures. The following chapter will introduce NetMovals, briefly indicating its integration with LMSR.

3.4 NetMovals: modeling the networks of partners, resources and processes

The case findings suggest that business strategies can be particularly successful, when existing industrial structures and networks are reconfigured to serve new business opportunities. Pre-existing resources and tested processes reduce the specific investment for capturing the new market opportunity. Consequently networks of partners, resources and processes each need to be modelled (Figure 5). Most important, however, are their interrelationships, which sum up strategic importance.

Insert Figure 5 about here

Equally important is the effect of the sub-network interrelationships on time-to market. Setting-up resources and processes from scratch were found to be a limiting factor for market penetration. The value system is a network of partners each providing the required competencies to supply a network of processes for the period of time needed to actualise the value of a business opportunity, regardless of individual geographic

distribution or ownership by partners. NetMovals thus was designed to additionally provide a process-modelling tool with a number of features, which are motivated by this field of application where existing industrial structures are reconfigured to serve new business opportunities. NetMovals therefore combines sub-network models as 'views' to allow for the redesign of the value system with an 'icon drag-and-drop' facility (Figure 6). This allows the different timeframes of the network evolution, which may take years of trust building to be integrated with the rapid re-configuration of new business processes.

Insert Figure 6 about here

Specific requirements from the network setting mould the design of the network. A predominant feature is that the partners are regarded as independent peers in the competitive scenario and thus the tool aims to support negotiations based on equality. NetMovals provides user-friendly interfaces and graphical functions as well as multi-user capability; important features to support negotiation. Each user can for example control what information can be publicly accessed in shared editing sessions and what is kept private as sensitive information that may affect the negotiation position. The amount of information given in the model has been limited in order to concur with the restricted human information processing capacity. However the possibility to hyperlink extensions has been included as an aid for fast Value System Design decisions.

3.5 Integration of Tools and Services

Once the network and process models have been established integration with other tools shall be executed, where necessary. The scenario of this integration draws on the fast configuration of Value System Designer services, which are needed for certain phases and tasks in the virtual enterprise lifecycle. For such a scenario the objective on the user side will be an on-demand integration of services and tools with simple browser technology and widespread business applications. NetMovals as an application, therefore, is delivered as a download and provides OLE interfaces for the integration with other off-the-shelf applications such as MS-Access or MS-Excel. The logistics management repository LMSR on the other hand will require expert consulting and shall therefore only be installed exceptionally for users. More often NetMovals models will be transferred to the logistics service provider to be run by computer application and/or executed by human experts. Redesign options from a logistics perspective, however, will then be returned as NetMovals models to the user.

4 Lessons learned from business practice cases in designing virtual enterprises

The Value System Designer is the result of more than four years of co-operative research and development. Today, the 'Value System Designer' is a modular package of business solutions combining concepts, methods and tools to support the design of virtual enterprises. Table 1 gives an overview of business practice cases, which have been undertaken to validate 'Value System Designer' solutions.

4.1 Lessons learned for the broker in virtual enterprises

The below mentioned three lessons concern the pro-active role of brokers that lead to a more agile behaviour of the virtual enterprise.

The projects created value for member firms by identifying market opportunities outside their core-business. This directs to the conditions of turbulent environments, where market opportunities emerge unpredictably and markets change their order of magnitude faster than Enterprises can adapt. Clearly, this case of making business in non-related industries is not covered by traditional marketing analysis, where a firm's conduct and the requirements for products are derived from the structure of the related industry (Bain, 1959). Similarly, in turbulent environments the identification of dominant players, suppliers, customers, or competitors becomes difficult. As we have seen, firms change the roles they play to the extent that they simultaneously assume multiple roles in parallel virtual enterprises. Consequently, with increasing turbulence it becomes more difficult to identify the competitive forces (Porter, 1979) that these players create in the industry, rendering this framework a less valuable basis for marketing decisions.

Concurrent Engineering with the customer has gained importance in the virtual enterprise. Initially pure market access was recognised as an important element of net-works, where only specific companies were equally situated in terms of access to profitable opportunities. In the industrial Italian region 'Prato', for example, many of the small textile-manufacturing firms are not in a position to reach customers world-wide. However, merchants "impannatores", provide access to market opportunities for the entire district (Kumar et al., 1996). The impannatore brings "an overview of external markets" and markets the services of other firms to "compete on the basis of price, innovation and service" (p. 207). In the construction industry market access is actualised by specialised project managers (hiring crafts required for a custom-designed building). In fact, the construction industry was discussed as a possible model for virtual enterprises. However in virtual enterprises there is an active search for opportunities rather than simple market access. In the construction, project managers organise the response to a customer request and do not actively encourage or seek new work. As a

matter of fact, this competence for pro-active behaviour was the motivation for a project launched by the Swiss construction industry to adapt the virtual enterprise concept.

Market opportunities do not present themselves neatly labelled as such. Instead, it is necessary for the broker to be able and willing to create opportunities and to stretch competencies beyond their primary business. Pümpin, (1992) refers to the concept of value potential, which he defines as value that is embodied—but not yet exploited—in constellations of the environment. He states that it is the active role of a promoter to develop and multiply a market opportunity through interaction with involved stakeholders. Unfortunately, not much is known about the process by which promoters develop new market opportunities. Innovation models, such as Abernathy & Utterbeck's (1978) concept of dominant design, focus on describing the lifecycle of an industry, which is powerful in retrospect description but has only limited predictive value towards the work of a broker.

To summarise, identification of market opportunities provides members of a virtual enterprise with access to applications that will fit their competencies in businesses beyond their traditional industrial boundaries. Membership in a network exposes the firms to ideas and demands that would otherwise have not been apparent. In a reservoir of market opportunities the network is specifically adapted to turbulent environments. Market opportunities have been illustrated as short-term windows, opening and then closing in an order of magnitude and so fast that the enterprise can simply not follow suit. Making a business opportunity selection requires more than simply picking things off a shelf. Instead, to accommodate short-term market opportunities requires extensive concurrent engineering activities by the individual member firms as well as on the network level.

4.2 Lessons learned for the competence manager

The lessons below relate to the role of the competence manager, as a core element towards a more agile behaviour of the virtual enterprise.

The conception of resources has gradually evolved and expanded in the Value System. Initially, we followed Jaikumar and Upton (1993) assuming that machining is a global commodity: resources were machines. Descriptions of these machines across the industries were based on the generally accepted classification scheme and terminology from the DIN 8580 standard, which defines all possible machining operations. The manufacturing resources available in different companies were identified in this way and listed in the "technology capacity bourse" database. Similarly, in Prato, Italy the functions performed by each of the small textile companies are well defined based on the required steps for the production of clothing. Thus the functions, dying, weaving, cutting

or sewing scheduled in a particular order can be allocated to a firm by taking individual properties into account.

The experience gained working with virtual enterprises revealed engineering services to be independent competencies that were not linked to machine tools but which were equally important for successful projects. These engineering capabilities were needed to back the network's competency to design and engineer complete customer solutions. Examples in the business practice cases included assembly competency, quality inspection and testing capabilities, project management or certification for ISO conformity. These capabilities required complex combinations of information technology (for CAD, CAE), testing devices, skilled engineers or accreditation. Chiesa and Barbeschi (1994) similarly deliberate that resources are not simple factors, but rather represent complex combinations of factors giving them a distinct and unique character.

Competencies were developed within the individual member companies as well as at the level of the network as a whole. Valuable competencies could include factors from multiple partner companies, enabling the network as a whole to respond to demands from the turbulent environment. Experiences gained from Value Systems show that more stable sub-networks of partners emerged, which as a group proved to have competencies for applications, for example, in medical technology or precision machinery. Similar empirical evidence of developing competencies is reported from Norway, where a learning cycle was implemented in a regional learning network. As network competencies were even more complex to describe. The 'competency manager' became essential as someone who knew what competencies were available among the various partner companies and could decide which might be applied to a particular customer's problem.

5 Conclusions and Future Research

Observation of cases and experiences in applying the concepts, methods and tools of the 'Value System Designer' have led to three critical factors to successfully design virtual enterprises:

First, a virtual enterprise design is preferred when 80% customer-specified requests allow for 20% engineering improvements to so optimise the network's competencies. Fully specified products often create rigid constraints when engineering processes, whilst vague customer requirements create no guidelines for an effective concurrent engineering process. Further research on innovation processes in virtual networks is therefore necessary.

Secondly for virtual enterprises to succeed it may be necessary for firms to fundamentally change their culture with regards to co-operation. Individual co-operation

and teamwork are essential pre-requisites for a successful virtual enterprise. Even more difficult to change are the decision and planning systems (e.g. MRP, ERP, Accounting, Strategic Planning). Although efficient in a stable business, in a virtual enterprise these systems can prevent fast reactions in the decision making process on a local level. Future research should therefore address the adaptation of innovative technologies in industrial networks.

Finally, the success of a virtual enterprise depends on a balanced provision of all management competencies or co-ordination roles. Virtual enterprises are constrained in their performance by the 'weakest link in the chain', the weakest role or phase in the virtual enterprise. Again, the advantage of the virtual enterprise is its ability to link the most suitable supplier to each individual service to so deliver a customer specific solution. The development of new business models that reflect industry specifics can be identified as the third field for future research.

In conclusion, support has been found for the hypothesis that in turbulent environments where the configuration of Value Systems rapidly change as the brief window of opportunity in the market opens and closes, virtual enterprises can be expected to outdo traditional firms.

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Tables:

Manufacturing Project	Description of Product	Description of virtual enterprise design process
Mechanism to electrically retract a car steering wheel	The mechanism targets a market of less than 10.000 items a year and is therefore not interesting to auto-suppliers used to lot sizes of hundreds of thousands. It is technically challenging, as it has to meet safety standards of auto industry at competitive manufacturing cost.	The network was prepared to face such opportunities, responding within two days to the customer request To engineer the process from the best competencies, ten potential technologies were identified. In a co-operative effort with the customer engineering changes of the product were implemented and prototypes manufactured.
Large precision base for tool machine	The base was a 20-mm sheet metal, roughly 1m x 1.5-m in size. More than 300 holes were needed for the assembly of all mechanisms of the tool machine. Placement of the holes de-fined the tool machine's precision. The piece was too big for most machines.	Alternative technologies such as drilling, laser drilling, and water drilling were identified and compared. During process engineering a large dimension tool machine was identified, on which the piece could be machined in one fixing. Value created was quality improvement (because of one fixing), and 75 % cost reduction.
Module for a letter sorting machine	The manufacturing of a module of an industrial postal letter sorting machines that was fully engineered. To meet short delivery deadlines, the manufacturer needed additional manufacturing capacity. The module was structured in mechanical and electrical subassemblies, and painted sheet metal as the cover and stand.	Competencies from the network. E.g. controller manufacturing for textile machines, and sheet metal manufacturing and painting from furniture industry were brought together to engineer the specific process for the customer project.
Air-conditioning unit	The concept of an air-conditioning unit, fitting a demand pocket in the upper range of the market was engineered and manufactured as a project lasting about two years.	During a presentation of the project 'Virtuelle Fabrik' an engineer in the audience revealed having a product concept and asked the necessary competencies to engineer the production process from the network. On stage, project members analysed the idea and proposed an initial architecture of contributions form three partners. Business was agreed, in a co-operative effort with the customer the unit was engineered, prototyped and 50 copies manufactured after 18 month, further orders are pending.
Re-engineering stability of a large sun-umbrella	Finite element simulation competency of an engineering firm in the network was used to improve wind stability of large restaurant umbrellas marketed by a textile manufacturer.	The network was prepared to face market opportunities from outside its companies' core-businesses. The network's brokers channelled a customer request from textile industry to highly specialised competencies available in a firm from the mechanical industry.

Table 1: Business practice case of designing virtual enterprises

Figures:

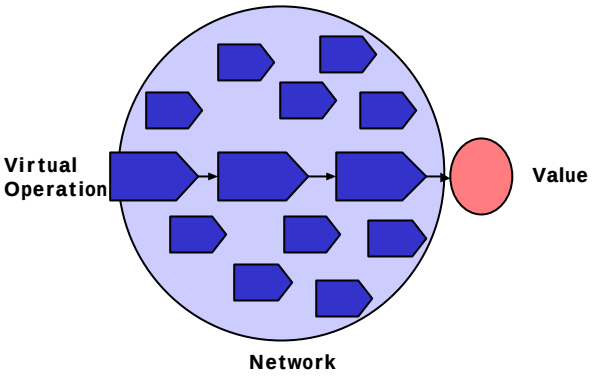

Figure 1: The Structure of Virtual Enterprises (Katzy and Schuh, 1998)

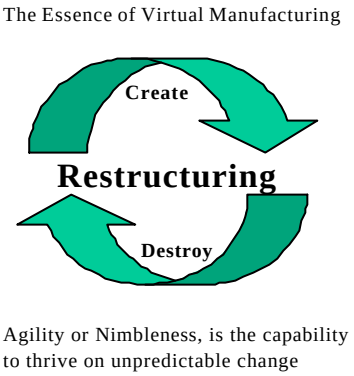

Figure 2: Dynamic Restructuring is the essence of virtual enterprises

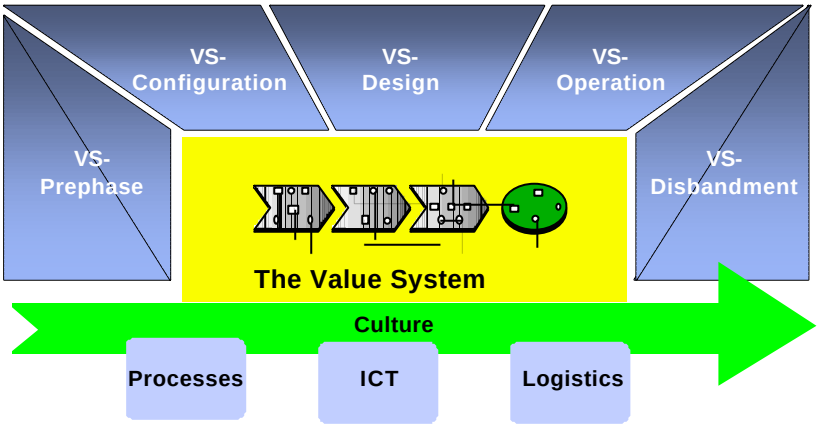

Figure 3: The Life Cycle Approach of the Value System (N.N., 1998)

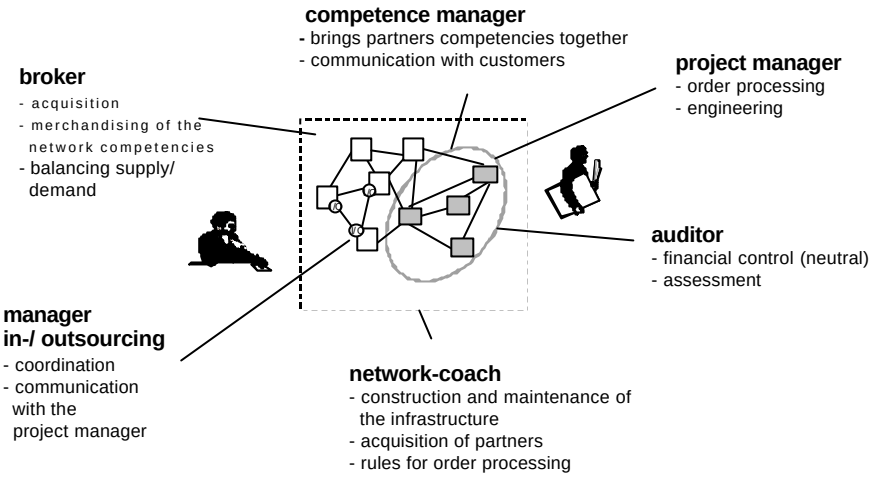

Figure 4: Roles in the Virtual Factory (Katzy et al., 1996)

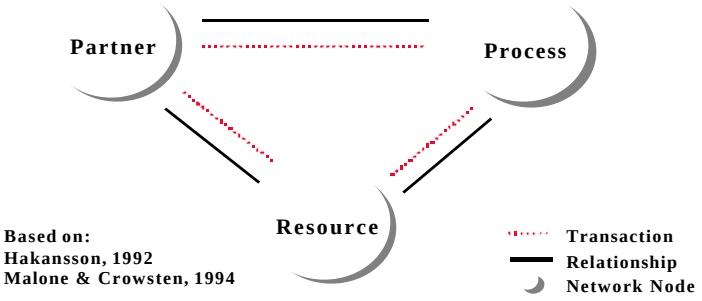

Figure 5: The Network Model

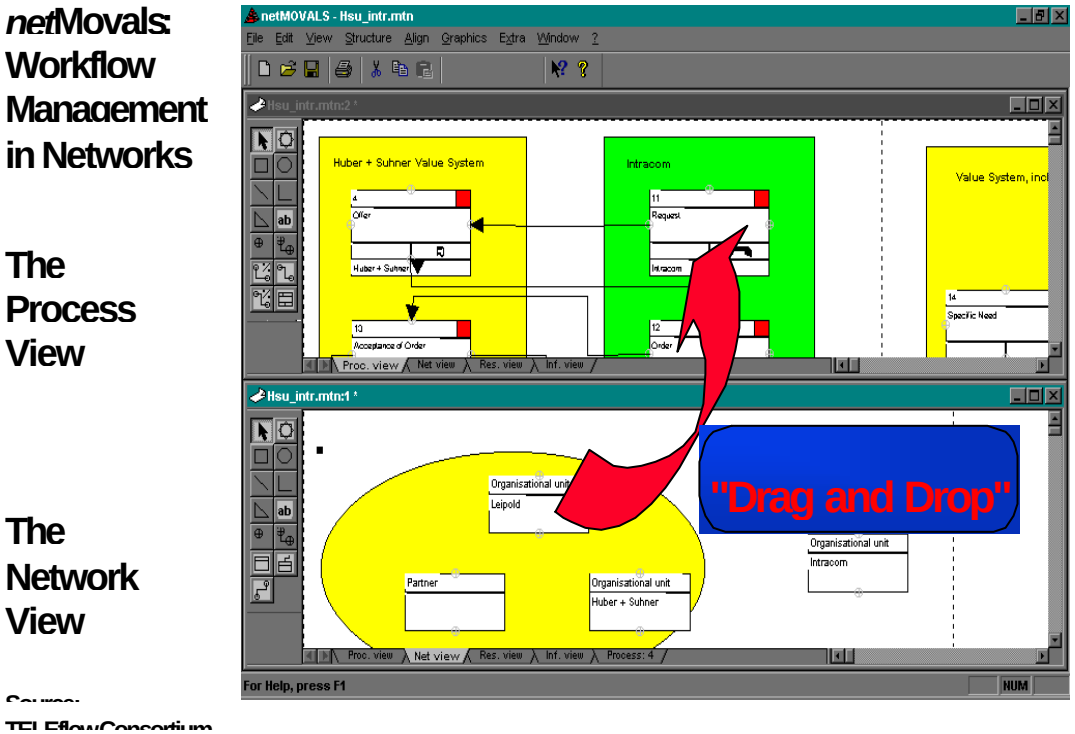

Figure 6: Screen from the NetMovals Tool