MODELLING THE LEARNING ENVIRONMENT OF VIRTUAL KNOWLEDGE NETWORKS: SOME EMPIRICAL EVIDENCE

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Abstract

This paper will report the results of empirical, web-based, research on the knowledge processes that take place in a virtual environment which has been created by the convergence between the telecommunication and information technologies. The analysis of some Virtual Knowledge Networks (VKNs) is presented; the 34 analyses focus on the network properties of both nodes and links. These properties inform a new general model of VKNs that describes the multilevel structure of virtual networks. An interpretation of VKNs is proposed, which makes use of complexity theory.

Keywords: virtual communities, learning, complex systems, knowledge, networks, extranets

1 Introduction

> *This is the cyberspace equivalent of the fairytale about stone soup, in which two men set up a big pot full of water over a fire in a town square, drop in a stone, and start stirring. The first curious passer-by asks what it is, and is told it will be a delicious stone soup; all it lacks is a few carrots. The passer-by fetches some carrots and drops them in. Other passers-by add potatoes, onions and so on until the soup really is delicious, and is served to all. Amazon has set up the pot and dropped in the stone; the Internet's townfolk are contributing most of what makes it perfect*
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> *A River Runs Through It – A Survey on Electronic Commerce The Economist 10 May 1997, p. 9*

In 1997 eBay was the busiest web site in the world[1]. It was founded in September 1995 by Pierre Omidyar as a one person company working from home and using as enabling infrastructure the web and two Pentium servers (Ticoll, Lowy, Kalakota 1998, p. 27). Conceived as an experiment in electronic commerce, eBay's vision was to replicate in the cyberspace the typical markets that take place on Sundays in so many squares around the world. The focus of the business was on the one to one formula, which meant providing a virtual space, made of a platform of enabling technology and business information, that made person to person trading a reality. eBay was immediately a success: 84,000 auctions were hosted on the site in December 1996 against 1,000 ten months earlier. US$ 6 million worth of transactions were carried out in the same year (www.ebay.com).

eBay is only one of the success stories that characterise the new world of business, not an isolated exception: the development of Linux (Raymond, 1999; Malone, Laubacher, 1998), Java (www.java.sun.com), Amazon (www.Amazon.com), indicate that a new model of business is at work, a cybercommunity model that posits networks, communities of individuals and decentralised mindset as the core elements of a new frame of reference. Some scholars (Harreld 1998; Ticoll, Lowy, Kalakota 1998) also describe Cybercommunities as "e-business communities": a set of distinct "Internetworked" enterprises, which use digital networks to co-operate and compete with other e-business community partners, by exchanging knowledge and information across trans-national borders.

Two trends seem to characterise the cybercommunities digital/global scenario:

[1] The measure is based on the amount of time that users spend on the site and on customer retention. See Media Metrix, PC Meter, June 1997

- The emergence of a new “Internetworked Organisation” paradigm: organisations are internally connected via Intranet, with suppliers and customers via business-to-business networks (Extranets), and with other organisations, business homes and consumers via public Internet. Flatter hierarchy and team based work organisation characterise this new enterprise, so as to respond more quickly to changes in the business environment and customer demands (Bahrami, 1992). Because Internet has the power and capacity to open channels of human communications and collaboration dramatically within an office, across space, and across time, collaborative work increasingly takes place in teams, on high capacity networks (Tapscott 1996).
- The development of virtual knowledge network (VKN) is related to the supply chain virtualisation process: the increase of the intangible elements in products, the telecommunication and information revolutions and the process of digitisation are increasing the climate of uncertainty in which companies operate (Rayport & Sviokla, 1995). Companies are adapting to the new environment, by focusing on a limited set of core competencies and by outsourcing most of the other functions (Hoskisson et Al., 1995; Ticoll, Lowy and Kalakota, 1998). In this way, new VKNs are emerging: we define a VKN as a network of distinct organisations connected via intranet/extranet/internet, where each organisation adds one or more distinct aspects of product/service package to the value of the network, by exchanging digital knowledge with other members. The changes in supply chain management are related to the opportunity for business and industries to capitalise on the convergence of commercial interchange, consumer market, distribution channel and production unit. The main virtual supply chain behaviours may be identified as:
  - horizontal collaboration[2] among independent team-based structures, which is replacing traditional vertical hierarchies (Zenger and Hestley, 1997): teams behave as suppliers and customers toward other teams that are both internal and external to the organisation (Bartlett and Goshal, 1995);

[2] A recent report by Collaborative Strategies has detailed the rising use of collaboration technologies in network settings (Collaborative Strategies, 2000: "The dataconferencing and real time collaboration market in the new millenium" Ed. Computer Currents Publishing Corp., San Francisco). According to this report, between 1998 and 2002 the average annual growth rate for data sharing will be 64%, for audioconferencing 19%, and for videoconferencing (counting both room-based and desktop figures) 25% . The majority of user organisations that implemented collaboration technologies (41%) used them to improve communication among distributed employees or for training. The next biggest use of collaboration tools (31%) was to support Web-based sales and marketing efforts. Individual distance learning weighed in next at 11%, and technical support and help desk functions were used by 7% of the companies surveyed.

- production and transaction organisation based on intermodality and complementarity instead of substitution, based on the assumption that the best way to handle risk is to share it by leveraging capabilities and resources of many players.

These processes have a twofold effect: first, they are increasing transaction and co-ordination costs, by increasing the number of activities (pushed out into the supply chains) that are not subjected to hierarchical control (Williamson, 1985) and second, they are transforming supply chains into supply networks. This process is well known in economic geography (Storper, 1997): geographic networks of small firms are formed when the process of vertical disintegration is met by a parallel process of agglomeration in a limited territory, that counterbalance the increase in transaction costs and allows the co-ordination of a supply network (Piore and Sabel, 1984). In a similar fashion the formation of a VKN takes place as a reaction to the increase in transaction costs, co-ordination costs and to the complexity of their value chain, by exploiting the power of self-organising networks, provided by ICTs cyberspace. The geographic proximity of the traditional industrial cluster is transformed into the spatially independent proximity of VKN.

VKNs are dominated by the forces of digitisation of knowledge and globalisation of competencies and production (Cronin 1996; Martin 1996; Boyer 1996; Hagel III, Armstrong 1997; Mandelli 1998; Benjamin 1998; Szuprowicz 1998; Hagel III, Singer 1999). These assets are related to the Information and Communication Technologies (ICT) development, and more specifically to the two processes of codification and exchange of knowledge. In the ICT world codification becomes "knowledge digitisation", the process by which human communication, business transactions and explicit knowledge become based on the binary code. Exchange becomes digital knowledge exchange, which happens through instantaneous communication.

What are the enabling factors of this new world of business? We think that the convergence between the ongoing revolutions in telecommunication and information technologies provides four distinctive features in this new world of business:

i. Agents: radical increase in the number of agents that form a community.
ii. Connections: virtually unlimited increase in the number of connections and therefore in the potential size of the community.
iii. Space: delocalisation of transactions which become space independent.
iv. Time: information transmission takes place at the speed of electronic communication.

Multiplication of agents and connections, and time and space independence constitute the four key features of the new network operating systems. As face to face communication is the enabling factor in the formation of geographic communities, the distinctive factor of the new world of communication is the formation of VKNs. To be successful VKNs need to transform the space provided by the new technology into a 'place' defined by a shared set of values, language, experiences and purposes (Benjamin, 1998)[3]. This is a crucial point, for it shows that the convergence of the new information and communication technologies (ICTs) constitute only the necessary infrastructural condition within which a virtual business community is created.

Starting from the enabling factors identified above, this paper will examine some of the characteristics of this new web-based world of business. The authors have carried out a series of web based analyses, exploring the issues posed by the emergence of VKNs (consisting of a central firm, suppliers, customers, partners) out of the repeated interactions and transactions made possible by the ICT platform. At the level of platform the Extranet stands out as the crucial enabling technology of the VKN. The paper examines the main features and benefits of the extranets based VKNs. Extranet mediated information exchange and transactions constitute the second level of analysis. This is focussed on the analysis of VKNs, and on the characteristics of the learning space in which knowledge is created, transformed, exchanged and diffused.

2 The Empirical Research Laboratory

Using VKNs as the units of analysis, requires a specific methodological approach that encompasses the virtual character of these networks. In this paper an Internet based research has been used to gather the primary and secondary data useful for this research. VKN analysis has started by identifying, via Internet browsers and search engines, the Web site of the main VKN partner, and has then followed two phases:

- identification and analysis of the main partners' Extranet architecture, in terms of applications, and links, characterised by using the information/documents available on the main partner Web sites;

[3] For a critical discussion of the dynamic relation between space and place see: Massey p.51-53

- identification and analysis of all other partners' Extranet architectures and links, singled out by scanning the Web sites of the other partners. Information has been verified and integrated with primary data obtained via e-mail, participation to discussion lists and virtual communities.

Benefits of this method of research concern:

- the speed of the information search: by moving around ("navigating") the Internet it is possible to dramatically compress information acquisition time;
- the quality and the updating of information, because of the online content control by VKNs partners;
- the easy accessibility of data without regard to geography, thanks to the universality of the World Wide Web standards.

Among the disadvantages, there are:

- the bias of information provided by VKN partners, that cannot easily be verified;
- the fragmentation and overload of information available on the web, which need a wide selection and integration.

The target of this exploratory research is to schematise the structure, the dynamics and the benefits of the VKNs, and to frame their learning environment. In this context the main research objectives are:

- to identify the different communication platform solutions adopted in the value chain by VKN partners;
- to frame the structure of the VKN that originates from the combined use of platform solutions by VKN partners;
- to evaluate the benefits obtained by VKN partners.

We have considered 34 analyses, that have been identified through some specialised information sources[4], integrated with some Internet-based analyses[5]. Analyses have been selected according to the following purposes:

- to explore their diffusion among the different sectors. Our analysis has included:
  - 18 analyses in the manufacturing sectors[6]:

[4] Szuprowicz, B. (1998) "Extranets and Intranets: E-commerce business strategies for the future" Ed. Charleston: Computer Technology Research Corporation

[5] http://www.actnet.com/Research_And_Analysis/index.html

  - n. 3 analyses of "specialised suppliers";
  - n. 9 analyses of "science based" firms;
  - n. 3 analyses of "scale intensive" firms;
  - n. 3 analyses of "supplier dominated" firms.
- 16 analyses in the tertiary: analyses have concerned both innovative services, as Info Test, engaged in the evaluation of Extranet solutions, and traditional services, such as accounting and tax consulting.

- to evaluate the geographic dimension of the markets involved. Our analysis has included VKNs which operate in a single city, as AMP Inc. (Chicago city), in a Country, as Dofasco Steel (Canada), or at a global level, as Amazon, CISCO, JAVA.

The following section will introduce the common patterns and features resulting from the analyses. A note of caution is useful here: our research captures a snapshot of the state of the communication platform of the VKNs with the objective of identifying its crucial features and of using those features to model its learning environment. We have not attempted in this article a longitudinal study of the evolution of VKNs, although such an approach could give an indication about the rate of change in the VKN environment. On the other hand, the novelty of the VKN authorises, we believe, an exploratory type of research based on a snapshot approach. A further limitation of a web-based method of research consists in the fact that non web-based communication and interaction are excluded from the research. However, this may not constitute a dramatic limitation as the example of Lynux (section 5.2.1) will show.

3 Results and Discussion

Tables 1-5 illustrate the results of the analyses and give some information about:

- the name of the more significant Organisation in the network;
- the main industrial sector of the VKN partners;
- the (strategic, planning and operational) knowledge exchanged among partners; knowledge is considered to be:
  - strategic if it is shared in order to define business, alter course, reset priorities;
  - planning, if it is shared in order to adaptively schedule and manage work more effectively;
  - operational, if it is shared in order to efficiently and accurately maintain work processes;
- the partners geographic distribution.

[6] the classification taxonomy is borrowed by Pavitt (1984)

Table 1: "Specialised suppliers" VKNs characteristics

Name	Type of Organisation	Knowledge shared	Geographic Distribution	Benefits
AMP Inc.	Leading connector products manufacturer	Operational knowledge: order placing automation Forum for communicating with wholesalers, distributors, reseller and customer, which is going to become a transactional system	World-wide	Communication with 15,000 customers 80,000 different products World-wide
Herve Thermique	Heating and air conditioning	Operational knowledge: TCP/IP Extranet to co-ordinate 23 offices and 8,000 business suppliers	France	Increasing efficiency and standardisation
Trane Corporation	Heating, ventilating and air conditioning	Operational knowledge: TCP/IP Extranet supports 300 independent wholesale vendors for purchasing, selling, and accessing information about its products	Wisconsin	Increased functionality

Source: adapted from B. Szuprowicz, "Extranets and Intranets: E-commerce business strategies for the future" and http://www.actnet.com/Research_And_Analysis/index.html

Table 2: "Science based" VKNs characteristics

Name	Type of Organisation	Knowledge shared	Geographic Distribution	Benefits
Adaptec Inc.	Microchip manufacturing	Planning and strategic knowledge to co-ordinate design and production with business partners Supply chain integration trough software that incorporates automated workflow and e-commerce tools	Hong Kong Japan Taiwan	Reduction of the chip production cycle time Shortening of the order-to-product delivery time
Boeing Aeroplane Co.	Aircraft manufacturer	Operational knowledge: TCP/IP Extranet that: • allows commercial customers to place and track part orders on the Web • supplies information regarding 410,000 parts in stock to 700 customers World-wide	World-wide	Substantial increase in efficiency for the company and its customers
Cisco Systems	Internet-working systems manufacturer	Planning knowledge: TCP/IP Extranet for optimisation of supply chain key processes	World-wide	Cost savings Substantial increase in efficiency for the company and its customers
General Electric	Multinational manufacturer	Operational knowledge: special trading system for handling commercial contracts between 1,400 suppliers and business partners. Two systems handle: The purchasing of materials required for the manufacturing processes The ready-made product and services required for running GE business units	World-wide	A more competitive bidding environment and lower costs
Java	Information technology	Strategic knowledge: TCP/IP Extranet joins together hardware and software firms, venture capitalists, and MIS managers	World-wide	Sustaining Java as the platform for application development
Lockeed Martin	Aerospace manufacturer	Strategic knowledge: TCP/IP Extranet for collaborative projects, meetings, baseline documents, contracts and schedules	California	Improvement in productivity
Marshall industries	Electronic equipment distributors	Operational knowledge: 200,000 Web pages of information, using a TCP/IP Extranet for competitive World-wide marketing to customers. Qualified users can interact with the system to obtain status reports of transaction profile, check order status, design registration and monitor sales activity	World-wide	Easy expansion to global market Customer intimacy
Microsoft	Leading software supplier	Planning knowledge: TCP/IP Extranet for supply chain management	World-wide	Cost savings
VHA Inc.	Healthcare Organisations alliance	Operational towards strategic knowledge: TCP/IP Extranet for collaborating and accessing an electronic catalogue of products for approximately 22,000 dial-up users. In the future VHA members will buy and sell merchandise and offer a wide range of medical, legal and pharmaceutical research capabilities	Texas	Better information exchange, through ubiquitous, secure environment

Source: adapted from B. Szuprowicz, "Extranets and Intranets: E-commerce business strategies for the future" and http://www.actnet.com/Research_And_Analysis/index.html

Table 3: "Scale intensive" VKNs characteristics

Name	Type of Organisation	Knowledge shared	Geographic Distribution	Benefits
Caterpillar Inc	Heavy equipment manufacturer	Operational knowledge: TCP/IP Extranet that connects Caterpillar engineering and manufacturing divisions with active suppliers, distributors, overseas factories and customers Customer can retrieve and modify detailed order information while the vehicle remains in the assembly line	World-wide	Shorter production cycle between design, suppliers and customers
Dofasco Steel	Steel manufacturer	Planning knowledge: TCP/IP Extranet for real-time collaborative computing, whiteboard applications and desktop videoconferencing Web based applications to provide interactive access to company databases for selected suppliers	Canada	Cost savings in communication Shorter delivery time Improved product design
General Motors	Auto and track manufacturer	Operational knowledge: System for marketing automotive products, through dealers and directly to consumers. Customers can get access to kiosks and personal digital assistants	Michigan	Instantaneous updating of changes in configuration or price of a car in all the company information services

Source: adapted from B. Szuprowicz, "Extranets and Intranets: E-commerce business strategies for the future" and http://www.actnet.com/Research_And_Analysis/index.html

Table 4: "Supplier dominated" VKNs characteristics

Name	Type of Organisation	Knowledge shared	Geographic Distribution	Benefits
Fruit of the Loom Activewear Online	Manufacturer	Operational knowledge: TCP/IP Extranet for online catalogue and sales ordering infrastructure for all its key distributors	USA	Supply chain integration, distribution and marketing
Kinko's Inc.	World-wide photocopy chain	Operational knowledge: TCP/IP Extranet links 850 stores and 23,000 employees, and offers: Internet access and rental of PC computer time to Kinko's customers Access to confidential data, such as credit information, sales reports and company policies and procedures	World-wide	Better co-ordination of stores and employees
Power AG	Agricultural products association	Operational knowledge: TCP/IP Extranet for linking manufacturers, distributors and retailers. Member companies are developing applications for order management, container tracking, regulatory compliance and financial information	Washington DC	Reduction in inventories

Source: adapted from B. Szuprowicz, "Extranets and Intranets: E-commerce business strategies for the future" and http://www.actnet.com/Research_And_Analysis/index.html

Table 5: Tertiary VKNs characteristics

Name	Type of Organisation	Knowledge shared	Geographic Distribution	Benefits
24 Hours in Cyberspace	Publisher	Planning knowledge: TCP/IP Extranet for organising 150 photojournalists, leading editors and over 50 hardware, TLC and software companies	World-wide	Supply chain integration, time to market, quality
Amazon	Books and CD ROM on-line seller	Operational knowledge: TCP/IP Extranet to sell products and to offer services	World-wide	E-commerce revenues Enhancing customers relations and customers loyalty
America On Line	Multimedia on line services	Operational knowledge: TCP/IP Extranet to offer shows, bundled services, entertainment	World-wide	Enhancing customers relations and customers loyalty
Aon Group Inc.	Insurer broker Organisation	Strategic knowledge: Subscription-based information service and research tool for high-end risk management customers Assistance to corporate directors of risk management in developing company policy manuals on political and health hazards	Chicago	Enhancing customers relations and customers loyalty
Booz, Allen and Hamilton	Managing consultants	Operational knowledge: TCP/IP Extranet that links offices and 2,000 remote consultants	22 countries	Cost savings
Coopers and Lybrand	Accounting and tax consulting	Operational knowledge: Corporate tax information for 75,000 employees Web site for public users at various levels and prices, including free access to some tax information	Washington DC	Up-to-date information on the constantly changing tax laws and regulations
CSX Corporation	Railroad Transportation	Planning knowledge: TCP/IP Extranet for managing shipping, which includes the largest suppliers of transportation services, such as railroads, trucks, container ships and barges. TCP/IP Extranet allows customers to trace shipment, initiate work orders and discover pricing data	World-wide	Tracking of the shipments to the line-item level, simplifying identification of bottlenecks and problems
EBay	Retail	Operational knowledge: TCP/IP Extranet for buying and selling, that is an Internet-enabled auction	World-wide	Improvement in customer services and reduction in transaction costs
J.B. Hunt Inc.	Truck transport services	Operational and planning knowledge: Internet-based applications designed to streamline the shipping to North American customers. The new application suite accomplishes order entry tasks, shipment tracking, and real time access to logistic data. The goal is to provide business-to-business applications that integrate the entire company supply chain.	North America	Improvement in customer services and reduction in transportation costs
Info Test	Largest manufacturing technology Extranet trial	Planning and strategic knowledge: Collaborative applications among major vendors	World-wide	Demonstration of Internet-based collaborative applications, among manufacturers, components and materials suppliers, distributors and customers
The link	Players directory	Operational knowledge: TCP/IP Extranet handles 16,000 biographies and photos of actors for agents	World-wide	A new way for agents to immediately forward vital statistics of actors to casting directors
Linkage Inc.	Human resources consulting	Operational knowledge: TCP/IP Extranet provides service to mobile clients nation-wide, who can access local and shared files, databases and e-mail from anywhere on the Internet	Massachusetts	Improvement in client services
Linux	Information technology	Strategic knowledge: TCP/IP Extranet joins together hardware and software firms, software developers	World-wide	Sustaining Linux as operating system
Reynolds & Reynolds	Business forms supplier	Operational knowledge: TCP/IP Extranet allows clients to obtain customised supplies, often a whole day earlier that previous procedures allowed.	Ohio	Increase in company's market share
Schwab and Partners	Investment services	Operational knowledge: TCP/IP Extranet for brokerage activities	World-wide	Participants receive access to an aggregated community of products, services and customers that is difficult to find elsewhere
UPS	Logistic and distribution services	Operational knowledge for supply chain management	World-wide	Minimising delivery times and inventory

Source: adapted from B. Szuprowicz, "Extranets and Intranets: E-commerce business strategies for the future" and http://www.actnet.com/Research_And_Analysis/index.html

The most frequently identified Extranet applications (ranked in order of importance) are shown in Table 6. Extranet applications are concerned with all the main activities of the Internetworked Organisations' value chain, such as supply chain management, user services, marketing, product development and human resource management.

Table 6: Main Areas of Application

Activities	**Applications**	**Frequency of application (%)**
– supply chain management	Communication with wholesalers, distributors, reseller and customer Co-ordination of suppliers Supply chain integration	44
– user services	Order automation	23
– marketing	Purchasing, selling, and accessing information about its products	17
– product development	Co-ordination of design and production with business partners	11
– Human Resources Management	Corporate information for employees	5

3.1 Mapping the VKN structure

According to our analysis results, the structure of all the VKNs is similar to an "hub and spoke" configuration, like the one shown in Figure 1, concerning the "Java Alliance" analysis.
"Java Alliance" is a loosely organised alliance, centred around Javasoft, a spin-off from Sun. Sun competence is shared with some main partners (IBM, Netscape, Oracle) and a lot of small actors. IBM provides, in addition to its corporate leadership in hardware manufacturing, a wide spectrum of Java solutions. Netscape supplies Internet software technologies with Java support. Oracle supplies the corporate database market and its competence in network computing architecture. Among other main partners are Intel, which is building Java chips, and Microsoft that furnishes programming tools for developers. A strong role is also played by customers:

- software vendors, that is, small firms which have built their companies around Java opportunities;
- corporate technology buyers, which have incorporated Java technology in their applications;
- user technology customers, which acquire technology and training and produce a rich amount of Java applications and knowledge/information feedback.

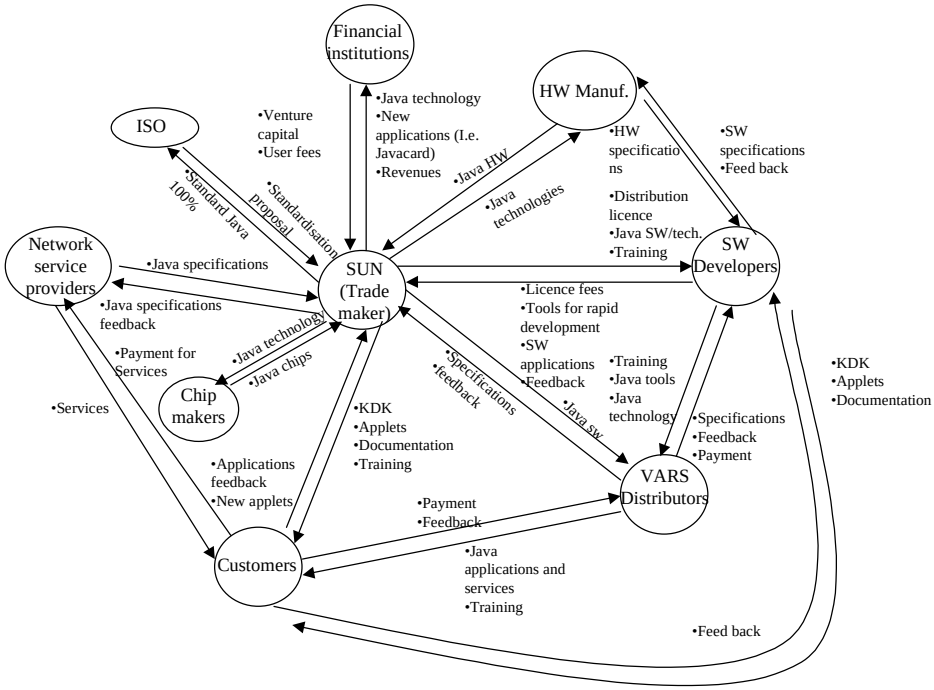

Figure 1 Typical structure of VKNs (Source: elaboration from www.actnet.com and www.java.sun.com)

As it is possible to see in the "Java Alliance" example, a VKN consists of many different nodes, interconnected by a web of linkages (transactions/relationships).

According to our analysis, VKN nodes may then be identified with the different "Internetworked Organisations": in "Java Alliance" nodes are Chip makers (Intel), Financial Institutions (Softbank), Software developers (Oracle, Corel, Microsoft), Hardware manufacturers (IBM), Customers (banks, firms, individual developers).

3.1.1 VKNs nodes

VKN nodes may be identified with "Internetworked Organisations", internally connected via Intranet, with suppliers and customers via business-to-business networks and with other organisations, business homes and consumers via public Internet (73% of the analyses use Extranets based only on TCP/IP protocol, while 27% use also different technologies, such as EDI and leased lines for inter-enterprise connectivity). Flatter hierarchy and team based work organisation seem to characterise this new Organisation, so as to respond more quickly to changes in the competitive environment and customer demands. Because Internet has the power and capacity to dramatically expand channels of human communications and collaboration from within an office, across space, and across time, "Internetworked Organisations" collaborative work increasingly takes place in teams, on high capacity networks (Tapscott 1996)

3.1.2 VKNs links

From our analysis it emerges that partners use Extranet architectures to develop a wide variety of links, including:

- upstream transactions with their suppliers (44% of the analyses), using Extranet solutions for: managing contracts as in General Motors, coordinating suppliers as in 24 Hours in Cyberspace, or managing the supply chain as in Microsoft;
- downstream transactions with distributors and clients (37% of the analyses), allowing users to access information about credits, sell reports, products/services, as in Linkage Inc, or to monitor transactions and orders, as in Marshall Industries, or to get financial information, as in Power PG;
- horizontal transactions with competitors or other institutions (18% of the analyses), as in "Java Alliance", where the target is co-ordinating hardware/software manufacturers, venture capitalist and marketing information systems to support Java language.

3.2 VKN Benefits

The main benefits of the VKN partners may be synthesised as:

- automation and optimisation of the supply chain, in order to improve the efficiency of its key processes. The ultimate objective, as it is possible to see in CISCO, is a high level of value integration among partners, thereby integrating all contributions in a single offer;
- integration of contents and services, in order to increase clients' benefits at lower prices, as in Aon Group Inc., for the delivery of financial services. The integration of specialised operators and service providers allows users to grasp many opportunities, at lower prices, compared to the offerings of specialised suppliers;
- co-ordination of suppliers, for partnering and outsourcing, permits integrated billing, less paperwork and decentralisation of decision making. Suppliers aggregation and processes optimisation allow also production cycle time reductions, because design and productions may be co-ordinated with business partners, as happens in Adapetc Inc. or in Caterpillar;
- involvement of clients, which carry out both a role of information producers and users (prosumer). As information producers, clients have a strategic role in providing feedback which allows the VKN partners to offer better post-sale services, to improve demand forecasts, to reduce delivery time and to offer a more sophisticated customisation service. For example

"Amazon" has many e-mail addresses to stimulate clients to ask for information, to make personalised requests, to judge products/services; the feedback are then used to modify its products/services according to these suggestions and feedback. "America On Line" also supports news groups, chat groups and bulletin boards, in order to improve its personalisation and "mass customisation" processes. As information users, clients access directly databases or "smart" manuals, as happens in the CSX Corporation, where Extranet allows them to trace shipments on-line, simplifying the identification of bottlenecks. In this way clients reduce the VKN partners' transaction costs, as in the AMP Inc., where information about order placement/execution is placed on line in an accessible format, reducing costs for giving product information and for supporting products' selection process;

- development of a VKN common brand, to face users' decreased inclination to spend time in searching unconnected Web pages. The ability to communicate a quality image becomes then a strategic source of clients' fidelity. For example, because of the good reputation of the "Fruit of the Loom" brand among its clients, all its VKN partners benefits from its good quality image, improving their competitive advantage with respect to isolated competitors.

4 An Interpretative Framework

VKNs are generating a new competitive space: competing in this environment requires new models to frame the features and dynamics of VKN's.

In this article we argue that models based on complexity theory may help us to frame and analyse VKN's phenomena. VKNs may be considered as complex adaptive systems (C.A.S.)[7], with an internal dynamic of self-sustaining cycles of knowledge exchanges among their Internetworked Organisations. In other terms, a VKN is characterised by positive self-sustaining knowledge mechanism among its Internetworked Organisations, which develop highly interconnected web of relations among them, generating the degree of "complexity" of the network.

Like a neural network, in a VKN the process of learning corresponds to the modification of the patterns of connections among the nodes. Unlike a neural network, individual nodes in VKNs exhibit a complex structure and are able of internal modification; indeed, by exchanging knowledge

[7] According to Holland (1995), "complex adaptive systems (CAS) are made up of large numbers of interactive adaptive elements that are diverse in form and capability. The complexity results from the adaptive behaviour of the agents".

among them, and by modifying their single behaviours according to the knowledge they receive, nodes allow the network to self-organise and develop new macro-configurations in order to face their environmental challenges.

A VKN, from a macro point of view, appears then as a flexible organisation, an "open system" which adapts continuously to its changing environment, by starting new strategic alliances (such as "Java Alliance" with VISA), by changing interactions among its actors (as in Power AG, where the network, used for e-mail communications, is evolving toward applications for order management, container tracking, regulatory compliance and financial information) or by offering new products and services to its clients (as in Amazon, which now sells also CD ROMs). This is the result of the dense web of interactions among partners, each of them reacts to local information/knowledge, without being aware of the global behaviour of the network. Self-organisation is then not the result of a deliberate strategy of a leader, but simply the result of the level of coherence that takes place between single actors in pursuing their own goals: indeed the set of all the agents' micro-behaviours results in the network macro-behaviour, showing the phenomenon known as "emergence[8]".

At a macro level, agents' micro-interactions determine some of the VKN's characteristics that are typical of a CAS. VKNs in fact seem to be:

- coevolutionary systems: the term coevolution refers to "*reciprocal evolutionary change*" (Thompson, 1994), whereby the evolutionary trajectories of the species (organisations) in a system become interdependent over time. The action of an actor determines a series of cascading effects on the other actors that are interconnected. Connections can also feed back, creating a loop. In some situations, they may generate a destabilising positive feedback, that is, a mutual reinforcement of cause and effect, which, as in the chain reaction, can create the right environment for radical innovations (Stacey, 1995). Some innovations are for example related to actors' high quality products, which increase their customers' competencies, generating in turn new feedback for improving products' performances (Arthur, 1996). On the other side, networks may show stabilising negative feedback: a mutual attenuation between cause and effect, which leaves the network stable, not innovative, and exposed to the competitiveness risks. In both cases, the resulting effect is the almost impossibility of isolated changes, the

[8] Emergence occurs when interactions among agents, at one level, give rise give rise to different types of CASs at the upper level. In this case CAS requires new categories to describe it, which are not required to describe the behaviours of their agents.

transformation of an actor without a simultaneous process of adaptation in the rest of the network. Coevolution can be, to an extent, managed: in a VKN this means managing the context of collaborative relationships in order to facilitate the emergence and operation of synergies (Eisenhardt & Galunic, 2000). This role in 'hub & spoke' structure is assumed by the central organisation.

- non-linear systems, according to three aspects. The first concerns the cause-effect relationship: there is no direct proportionality between input and output, due to the presence of feedback mechanism in the system. An emblematic example is "e-Bay", the Internet based auction system, which was created in 1995 by only one person working at home. Even if eBay was reasonably successful during its first months of activities, the real business explosion took place with the introduction of a simple software application that generated a non linear positive feedback in the community of users. The application enabled buyers and sellers to rate each other, by publishing comments on their experiences. Surprisingly the system, with a minimal investment, became used as much to criticise as to praise, and the number of hosted auctions grew from 1,000 in January 1996 to 84,000 in December 1996. The second aspect concerns the value generated by the network, which cannot be deduced by summing the performances of the single actors, because it is strictly related to the synergies created by the network links. In other words, it is the dynamic interaction among actors, which increases exponentially the innovation opportunities of the entire networks.
- self-catalytic systems. An useful example of self-catalytic reaction is given by Kauffman (1995), concerning chemical reactions which can be self-catalytic in the presence of a sufficient variety of molecules: the auto-catalysis occurs when a product of reaction (say, X) catalyses its own production through a positive feedback process. The amount of X formed at any instant depends on how much X was there in the first place. In an analogous way, in all case studies, a VKN presents a fundamental characteristic: the value of the network increases exponentially with the number of connections. In this way a VKN may generate positive feedback (Shapiro, Narvan, 1999), and a virtual cycle: the more popular the network, the more attractive it becomes for other users; on the other side, it can lose value as it is abandoned by users.
- path-dependent systems which have a history. There are no general laws that apply independently from the VKN specific evolution: luck or chance (or in Prigogine's (1989) terms fluctuations) often play relevant roles. The single actor's diversity (Allen, 1997) is also a necessary condition for their evolution. Actors' interdependence generates their co-evolution, as an evolutionary process that Kauffman describes as a rubber landscape where each step taken by an actor modifies the environment of all the others.

- dissipative systems: they need a constant flow of energy with the external environment to survive. As a CAS, a VKN is an "emergent" system, and emergence requires order and a negative flow of entropy to support this order (Nicolis & Progogine, 1989). In the VKNs, energy is necessary to maintain up-to-date Web sites, to encourage knowledge exchanges among partners, to recruit new partners, to motivate stakeholders, to shake up the network, and to provide new set of challenges that can not be faced by using the existing procedures. This energy is generally supplied by a node of the network, such as Sun Microsystem in the "Java Alliance", of "Fruit of The Loom" in "Fruit of The Loom Activewear".

A useful simulation model of a VKN macro-behaviour, as a CAS, is Kauffman's N-K Boolean network. Kauffman's network, like a neural network, is made up of nodes inter-linked with varying degree of connectivity: in the model, N is the number of the nodes, K the number of interconnections among nodes.
In an N-K Boolean network, as in a VKN, if K=1, the system is weakly connected; there are few feedback loops, and the system quickly settles down to a steady state with very little changes and innovative dynamics. On the opposite extreme (K=N), in a fully connected regime, when all agents are connected with one another, the network becomes chaotic, because any change determine a never ending series of cascading effects. Under these conditions of instability no macro patterns can emerge. Between these values, Boolean networks exhibit a transition phase, which is called "edge of chaos", where complex behaviours emerge, like VKNs ones.

According to our research results, about 80% of cybercommunities exhibit some of the characteristics of "edge of chaos" structures. Relevant properties include:

- ✓ self-organisation on a macroscale patterns based on repeated interactions on the microlevel;
- ✓ continuous dynamic change of the internal structure by means of modification of locus and density of connections, either as an adaptation to external constraints change or as a response to internal innovation;
- ✓ emergent macroscale correlation among the nodes of the network;
- ✓ emergent strategy.

5 A model of VKN Learning Environment

The results of the VKN analyses allow us to model a new learning environment (Figure 2), in terms of:

- VKN Cyberspace, that is the platform which represents the crucial enabling technology of the VKN;
- VKN Cyberplace, which represents the socially constructed environment, where the community of VKN actors transact and learn, using a shared language, common values and experiential base;
- VKN learning process outputs and performances.

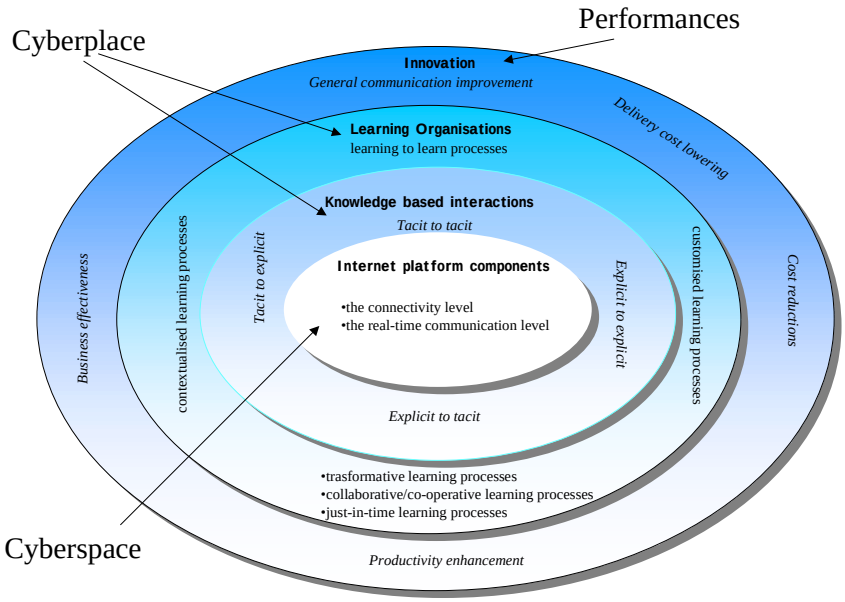

Figure 2: VKN learning environment model

5.1 VNK cyberspace

A VKN cyberspace may be configured in terms of Internet platform components.

Internet platform components support rich, relevant and productive individual and group on-line actions, and provides an infrastructure leading to a sustainable VKN (Benjamin 1998). These components, which allow Intranet and Extranet solutions, may be grouped in two levels:

- the connectivity level, made up by building blocks of basic universal connectivity and access, upon which communication, collaboration and content “provider value” can be built. This level includes network and protocol integration (gateways services), network management services and applications integration services;

- the real-time communication level, that mainly consists of software-based client and server tools to broadly facilitate two-way and broadcast communications, collaboration, entertainment, information search, delivery and analysis, and commerce.

5.2 VKN Cyberplace

A VKN cyberplace may be presented in terms of knowledge based interactions and VKNs actors.

5.2.1 Knowledge based interactions

The two levels of the virtual environment, defined in the introduction as cyberspace and cyberplace, are purposive to two functions: first, the offering of a platform for both the co-ordination of different types of knowledge and also the creation of shared meaning. Grant (1997:451) suggests that:

"If individuals must specialise in knowledge acquisition and if producing goods and services requires the application of many types of knowledge, production must be organised so as to assemble these many types of knowledge while preserving specialisation by individuals. The firm is an institution which exists to resolve this dilemma: it permits individuals to specialise in developing specialised expertise, while establishing mechanisms through which individuals coordinate to integrate their different knowledge bases in the transformation of inputs into outputs".

The firm is not the only place where co-ordination of specialist knowledge is achieved. In a network regime, where activities are widely decentralised outside the boundary of the single firms, the same co-ordination takes place at the level of the network, which becomes then the unit of analysis of economic activity. Unlike the traditional firm, where the co-ordination governance mechanism is explicit and ensured by an hierarchical structure, in a network type of organisation, the governance mechanism is more tacit and becomes dependent upon the non linear properties of a web of complementary agents.

According to Nonaka and Konno (1998) knowledge creation does not take place in a vacuum but requires a platform, described in the Japanese philosophy as 'ba':

"… ba is a context which harbours meaning. Thus, we consider "ba" to be shared space that serves as a foundation for knowledge creation."

Co-ordination and 'ba' in the virtual environment are based on specific knowledge interactions, which, at the information level, are provided by a nervous system made of specific software and hardware applications. These are the channels along which the knowledge conversion processes take place and upon which VKNs learning processes are based. More particularly, interactions generate a continuous and dynamic tacit-explicit knowledge conversion among individuals, groups and Organisations.

In order to explore the contribution of the Internet based platform to these interactions, it is suggested that the typical tacit-explicit dynamics of conversion processes take place in the cyberspace by means of the following applications options. Figure 3 (terminology is borrowed by Nonaka, 1995) synthesises the results of our analysis.

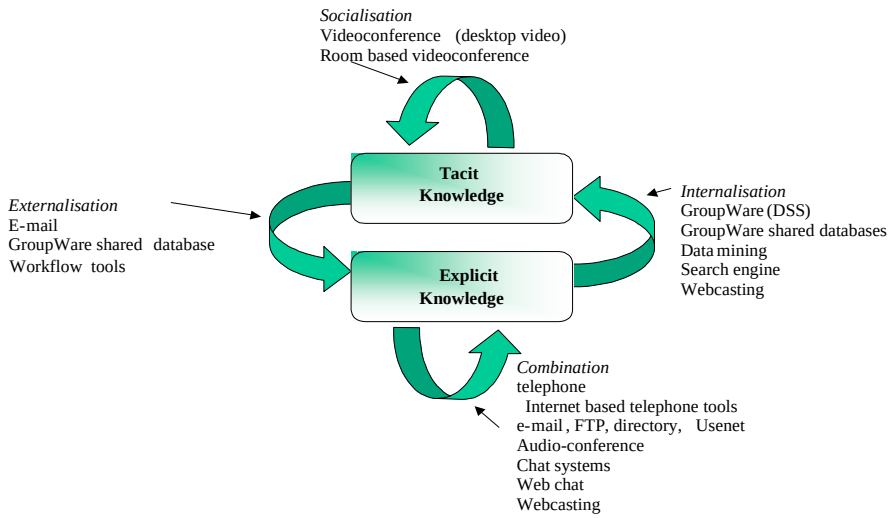

Figure 3: Applications and knowledge conversion processes

Applications like videoconferencing (desktop video) and room based videoconference enhance the learning mechanism related to the conversion from tacit to tacit knowledge (socialisation process). In fact videoconferencing facilitates brainstorming camps, informal meetings, detailed discussion, sharing experiences between product developers and customers, which can be realised also if people are not co-located.

E-mail, GroupWare shared databases, consulting, collaboration tools, workflow tools enhance the learning mechanisms related to the tacit knowledge articulation into explicit concepts (externalisation process).

Telephone, www based phone systems, e-mail, FTP, directory, Usenet, audio-conferencing, chat systems, web chat, computer conferences, webcasting, document archive, and workflow tools enhance the combination process, that represents the conversion from explicit knowledge to explicit knowledge: individuals exchange and combine knowledge through such media as documents, meetings, telephone conversations or computerised communication networks.

GroupWare (Decision Support Systems), GroupWare shared databases, data mining, search engine and webcasting enhance the internalisation process, that represents the embodying of explicit knowledge into tacit knowledge. This conversion is helped by knowledge verbalised or diagrammed into documents, manuals or oral stories.

The classification above is indicative, although based on some empirical observations. The authors support the view that virtual communication based on artificial channels of communication is different when compared to the richness of sensorial channels of communication (Weiser and Seely Brown, 1998). It is more limited if seen from the point of view of the amount of tacit knowledge that can be exchanged by means of ICT, although the increase in ICT bandwidth (proportional to information content) will make the virtual experience more and more similar to the 'real' one. Other virtual communication drawbacks concern the risks of useless connections among people, and of interaction/information overload, if there are not suitable mechanisms which filter incoming interactions/information, based on users' needs (Ljungberg, 2000).

At the same time the four factors identified in the introduction make virtual communication much more ubiquitous. Benjamin (1998, p. 300) expresses very well the implications of the above reasoning:
"In my mind, cybercommunities cannot and will not replace the "real world". Cybercommunities will supplement, not supplant existing communities. By allowing more people to interact in more ways and in more settings, cyberspace facilitates greater communication, more participation, deeper human connections, and, by extension, community".
At the same time, as is the case with radical innovation and the consequent paradigm shift, the ways in which the ICT tools will be used are yet to be fully discovered and their impact to be fully appreciated.

An interesting example of knowledge creation and diffusion in the cyberspace is the development of the operating system Lynux (Raymond, 1999; Malone and Laubacher, 1998). Lynux, widely regarded as the current biggest competitive threat to Microsoft Windows, was developed over a few years by a group of hackers[9], spread over the planet. They used only the cyberspace as their communication platform and formed a community where face to face interaction simply did not exist. The case of Lynux indicates that:

- ✓ Firstly, knowledge creation and knowledge sharing do not necessarily require physical co-location and face to face interaction;
- ✓ Secondly, development of communities based on trust and accepted ethical behaviour (internally defined) can take place in the cyberspace;
- ✓ Thirdly, if knowledge creation is largely a process of tacit to explicit conversion of individual knowledge (Nonaka, 1995; Boisot, 1998), then the virtual network's environment can be the locus of knowledge conversion processes that are conducive to innovation;

It may be argued that what was exchanged during the development of Lynux were bits of codified knowledge (lines of software code) and that therefore the process of tacit to explicit conversion took place at the individual level, before its diffusion in the hackers' community. The acceptance of this point of view would imply that the real issue in knowledge creation is not knowledge sharing but knowledge co-ordination (Grant, 1995). The example of Lynux indicates the feasibility of knowledge coordination in a self-organising VKN.

5.2.2 VKN actors

Each actor may be conceived as a Learning Organisations, that is a learning space without physical boundaries, where individuals can improve their capacities to create results, where there is potential to generate new mindsets, where people learn how to learn together (Senge,1990; Nonaka & Tackeuchi, 1995; Sabe, 1996; Foss, 1996; Argyris & Schön, 1978).

As "Learning Organisations", VKN actors are able to create visions, knowledge and mental models that are shared by their employees, and to prepare themselves to:

- test and apply new knowledge, as in "Java Alliance" or in "Info Test";
- learn from the past experiences and take benefits from past errors and successes, such as in "Adaptec Inc.";
- learn from others, as in "VHA Inc.";

[9] The history of Lynux is wonderfully narrated in Raymond (1999)

- amplify their learning spaces in the external environment as in “Coopers and Lybrand”;
- spread learning processes results, efficiently and effectively, to allow all the people inside the Organisation to use them, as in “Caterpillar Inc.”, or in “AMP Inc”.

As “Learning Organisations”, nodes are specialised in creating, acquiring, sharing knowledge, and in applying knowledge to define strategies. Indeed, they are able to identify new knowledge interconnections, to forecast the future evolution of the cognitive patterns, to understand a phenomenon in a systemic view, to set and apply corrective actions, through many different learning processes, which concern (Lipari, 1995):

- “learning to learn” processes, which allow individuals to plan, realise, and monitor their learning processes speed and directions, by efficiently selecting knowledge sources;
- “contextualised learning” processes, that is, knowledge applications in real contexts;
- “customised learning” processes, according to individuals’ preferences and culture;
- “trasformative learning” processes, which modify existing training systems, both in contents and in organisation, according to the environmental changes;
- “collaborative/co-operative learning” processes, which are strategic for the new organisational assets in the new pro-active firm, which is engaged in continuous improvements in the quality of products/services and in its key value chain processes;
- “just-in-time learning” processes, which exploit the learning opportunities offered by the global ‘supermarket’, where individuals can gain access to databases, multimedia resources and web sites, in order to develop flexible training process.

In this way nodes behave like open systems, that acquire information and knowledge from the external environment, and transform their knowledge into new products and new processes, that are in turn used by other Organisations.

6 Conclusions and Research Agenda

VKNs are a new type of organisation, based on a new type of communication, they are the product of the convergence between the revolutions in the telecommunication and information technologies. Four key factors are driving the evolution in the world of business: an increase in the number of players, an increase in the level of connectivity among players, transactions space independence and dramatic increases in the speed of transactions. The consequences and implications of the combined

actions of the factors will go well beyond the sectors more directly affected by the Internet, e-commerce and globalisation. These four factors, taken in isolation, are not new, but their combined effect represents a major discontinuity in the world of business. As in the theory of punctuated equilibrium (Jay Gould, 1982), long period of gradual, incremental adaptation are broken by short revolutionary periods of radical change. Much in the same way, the ICT revolution is acting so as to represent a watershed between the territorially bounded model of business and knowledge creation, and the virtual model.

In this article we present a description of virtual knowledge networks (VKNs), based on the distinction between the cyberspace (platform of technological opportunities provided by the new technologies) and the cyberplace (social environment built around the cyberspace). Cyberplace is inhabited by communities, the new unit of analysis of socio-economic activity, that are formed around a shared set of values, experiences, practices and purposes.

In the knowledge economy the ability to mobilise knowledge assets is central to survival and success. We present in the paper an empirical analysis of some VKNs, focussed on the network properties of nodes and links characteristics. These characteristics inform a general model of VKNs, that describes the multilevel structure of virtual networks.

It is suggested that VKNs may be considered as complex adaptive systems (CASs), with an internal dynamic of self-sustaining cycles of knowledge exchanges among their Internetworked Organisations. More specifically, we highlight some VKNs characteristics, which in complexity theory are associated to CASs structure and dynamics (Anderson 1999, Pascale 1999, Cilliers 1988, Holland 1995). To this end, classical theories of knowledge do not provide adequate supports. Recent studies suggest that “distributed” methods of modelling share some of the characteristics of complex systems (Cilliers, 1998). Neural networks[10] are considered particularly suitable, because of their great flexibility, and have been proposed as a basis for studying networks (Cilliers 1998, Heydebrand, 1989).

[10] "A neural network consists of large numbers of simple neurones that are richly interconnected. The weights associated with the connections between neurones determine the characteristics of the network. During the training period, the network adjusts the values of the interconnecting weights. The value of any specific weight has no significance; it is the pattern of weight values in the whole system that bears information. Since these patterns are complex, and are generated by the network itself, there is no abstract procedure available to describe the process used by the network to solve the problem" (Cilliers 1998)

Nodes and links manifest the same patterns at different ontological levels (individuals, groups, organisations, etc.), so that a network of relationships can be established between individuals, groups, organisations, showing the property known as "self-similarity". At each level, patterns of interactions show a similar topology, although the "size" of the nodes is different (Romano, Passiante, Elia 1999).

The analysis of VKNs opens a series of questions, such as:

- What is the relationship between the increase in transactions, made possible by the cyberspace, and the structure of VKN?
- Apart from the space independence, under what aspects will VKNs differ from territorially bounded networks of firms?
- What are the aggregation limits and the typical structures of VKNs?
- What is the meaning of coevolution in VKNs?

Our analysis is a qualitative field-based work which may be useful for identifying candidate parameters for a simulation aimed at exploring the variety of paths trough which a VKN may evolve, given its structure of connected, co-evolving partners. Simulation may be useful to see what emerges when VKN's agents interact with one another through a set of virtual connections. The results of the simulation will be used as a decision making tools to drive our future field research on VKNs.

In order to improve our understanding of the question highlighted above we are developing an agent based simulation of a distributed system of production and innovation. The simulation includes three blocks: a set of agents (and related services) distributed on a grid, an external market of demand and an external supply of technologies. In our simulation the mechanisms for change are local and based on local information (no central authority). The effects of these interactions are examined to discover the emergent properties of the system. Agents' behaviour is adaptive rather than rational (Axelrod, 1997)

In summary, in the last ten years the world of business networks has been transformed by the convergence of the technological innovations in computing and telecommunications. A new transactional space, the Cyberspace, has given rise to a new world of business, the Cyberplace, inhabited by distributed communities of organisations and individuals, whose learning processes are described in our model of VKNs and whose behaviour is resonant with that of complex systems.

References

Allen, P. (1997) *Cities and regions as self-organising systems*. Amsterdam: Gordon and Breach Science Publisher

Anderson, P. (1999) Complexity Theory and Organization Science. *Organization Science*, **10** (3), 216-232

Argyris, C. & Schön, D.A. (1978) *Organisational Learning: a Theory of Action Perspective.* Reading, MA: Addison Wesley

Arthur, W.B. (1996) Increasing returns and the new world of business. *Harvard Business Review*, July-August

Axelrod, R. **(**1997) *The Complexity of co-operation.* Princeton: Princeton University Press

Bahrami, H. (1992) The emergent flexible Organisation: Perspective fromSilicon Valley. *California Management Review, Summer, 35-52*

Bartlett, C. and Goshal S. (1995) *Managing beyond borders.* Boston: Harvard Business School

Benjamin, R. (1998) Cybercommunities: better than being there?, in *Blueprint to the digital economy* ed. D. Tapscott., A. Lowy & D. Ticoll, pp. 298-316. New York: McGraw Hill

Boisot, M. **(**1998) *"Knowledge Assets: securing competitive advantage in the information economy"*. Oxford: Oxford University Press

Boyer, M.C. (1999) *Cybercities*, New York: Princeton Architectural Press

Cilliers, P. (1998) *Complexity and Postmodernism*. London: Routledge

Cronin, M. (1996) *Global advantage on the Internet*. New York: Van Nostrand Reinhold

Eisenhard, K.M & Galunic, D.C. (2000) Coevolving At Last: a Way to Make Synergies Work. *Harvard Business Review*, Jan-Feb

Foss, N.J. (1996) *Firms, Incomplete Contracts and Organizational Learning*. DRUID Working Papers No. 96-2

Gould, S.J. (1982) The Meaning of Punctuated Equilibrium and its Role in Validating a Hierarchical Approach to Macroevolution. In *Perspective on Evolution*, ed R. Milkman, pp. 83-104, Sunderland, MA: Sinauer Publishing Co.

Grant, R.M. (1997) The Knowledge Based View of the Firm: Implications for Management Practice. *Long Range Planning*, p. 451, June 1997.

Hagel, III J. & Armstrong, A.G. (1997) *Net gain*. Boston: Harvard Business School Press

Hagel, III J. & Singer, M. (1999) *Net worth.* Boston: Harvard Business School Press

Harreld, J.B. (1998) Building smarter, faster Organisations. in *Blueprint to the digital economy* ed. D. Tapscott., A. Lowy & D. Ticoll. New York: McGraw Hill

Heydebrand, W.V. (1989) New Organizational Forms. in *Work and Occupations* n.16 323-357

Holland, J.H. (1995) *Hidden order: how adaptation builds complexity*. Massachusetts: Addison Wesley

Hoskisson, R.E., Hill, C.W.L., and Kim, H. (1995) The Multidivisional Structure: Organisational Fossil or Source of Value. *Journal of Management,* 19, 2, 22-42

Kauffman, S. (1995) *At home in the universe*. Oxford: Oxford University Press

Lipari, B. (1995) *Education in the Information Society,* www.srl.rmit.edu.au/mindware/learning/edinfo.htm

Ljungberg, F. (1999) Exploring CSCW Mechanisms to Realize Constant Accessibility Without Inappropriate Interaction. *Scandinavian Journal of Information Systems* **11** (1)

Malone, T.M. & Laubacher, R.J. (1998) The Dawn of the E-Lance Economy. Harvard Business Review, September-October

Mandelli, A. (1998) *Internet marketing*. New York: McGraw-Hill

Martin, J. (1996) *Cybercorp*. New York: Amacom

Massey, D. (1984) *The social Division of Labour.* London: MacMillan, 51-53

Nicolis, G. & Prigogine, I. (1989) *Exploring complexity: an introduction*. New York: Freeman

Nonaka, I. & Konno, N. (1998) The Concept of 'ba': Building a Foundation for Knowledge Creation. *California Management Review* **40** (3), Spring 1998

Nonaka, I. & Tackeuchi, H. (1995) *The knowledge-creating company*. New York: Oxford University Press

Pascale, R. T. (1999) Surfing the Edge of the Chaos. *Sloan Management Review* **40** (3), 83-94

Pavitt, K. (1984) Sectorial patterns of technical change: towards a taxonomy and theory. *Research Policy* **13** (6), 343-374

Piore, M.J. & Sabel, C.F. (1984) *"The second industrial divide: possibilities for prosperity"*. New York**:** Basic Books,

Raymond, E.S. (1999) *The cathedral and the Bazaar: Musing on Lynux and Open Source by an accidental Revolutionary.* Sebastopol CA: O'Reilly

Rayport, J.F. & Sviokla, J.J. (1995) Exploting the Virtual Value Chain. *Harvard Business Review,* Nov-Dec, 75-85

Romano, A. & Passiante, G. & Elia, V. (1999) The Web Economy: towards a new spatial context for learning and innovation processes in the business environment. Proceedings of the Regional Science Association 39th European Congress proceedings, Dublin, august

Senge, P. A. (1990) *The Fifth Discipline: The Age and Practice of the "Learning Organization*. London: Century Books

Shapiro, C. & Varian H.R. (1999) *Information Rules - a strategic guide to the networked economy*, Boston: Harvard Business School Press

Stacey, R.D. **(**1995) The science of complexity: an alternative perspective for strategic change processes. *Strategic Management Journal*, Vol 16

Stewart, I. & Cohen, J. (1997) *Figments of Reality: the Evolution of the curious Mind.* Cambridge: Cambridge University Press

Storper, M. (1997), *The regional world.* New York: The Guildford Press

Szuprowicz, B. (1998) *Extranets and Intranets – e-commerce strategies for the future*. Charleston: Computer Technology Research Corporation

Tapscott, D. (1996) *The digital economy.* New York: McGraw Hill
The Economist (1997) Online Auctions: Going, Going, Going. The Economist, May 31, p.61

Thompson, J.N. (1984) *The Coevolutionary Process*. Chigago: University of Chigago Press

Ticoll, D. & Lowy, A. & Kalakota, R. (1998) Joined at the bit: the emergence of the e-business community. in *Blueprint to the digital economy* ed. D. Tapscott., A. Lowy & D. Ticoll, New York: McGraw Hill

Weiser, M. & Seely Brown, J. (1998) Center and Periphery: Balancing the Bias of Digital Technology. in *Blueprint to the digital economy* ed. D. Tapscott., A. Lowy & D. Ticoll, New York: McGraw Hill

Williamson, O. (1985) *The Economic Institutions of Capitalism*. Basic Books, New York

Zenger, T.R. and Hestley, W.S. (1997) The disaggregation of Corporations: selective Intervention, high-powered Incentives and molecular Units. *Organisation Science*, 8, 3, 209-222