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International Purchasing and Supply Education & Research Association

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THE PURCHASING FUNCTION: WALKING A TIGHTROPE

Complexity, management and purchasing: towards an integrated approach

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4th-7th April 2004
University of Catania
(Catania, Italy)

Complexity, management and purchasing

Towards an integrated approach

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SUMMARY

The purchasing function is harnessed in the web of complexity, in such a way that it is necessary to talk about the *supply network* as a complex adaptive system. Since the purchasing function is a *complex actor in a complex environment*, the aim of this working paper is to suggest a *theoretical framework* to understand the principles of the theory of complexity and to apply them to the management of complexity by organizations and the purchasing function in particular. The paper focuses on the principles required to face complexity, fundamental for supply network to accept and win the new challenges.

KEYWORDS: complexity, management, purchasing

Introduction

The purchasing function is harnessed in the web of complexity. Since the purchasing function is a complex actor in the complex environment of supply networks (Choi et al., 2001), it is necessary to understand how complex adaptive systems (CAS) behave to adapt and evolve by studying theory of complexity and apply its principles to the environment of supply networks.

Theory of complexity is a multidisciplinary science (Morin, 1990; De Angelis, 1996; Battram, 1999): it takes into consideration elements of very different disciplines, such as systems theory, cybernetics, meteorology, chaos theory, artificial intelligence (A.I.), artificial life, cognitive sciences, computer science, ecology, economy, evolution studies, genetics, games theory, immunology, linguistics, philosophy, social sciences, management. Complex systems are characterized by numerous and different elements and numerous and non-linear connections; moreover CAS, which are complex living systems, are characterized by capacity of adaptation (Holland, 2002). A CAS may be therefore described as an aggregate of agents and connections, organized to grant adaptation: according to Holland (1995), a CAS is a system that emerges over time into a coherent form, and adapts and organizes itself without any singular entity deliberately managing or controlling it. This capacity of adaptation is reached through elaboration of information and model building (Cerrato, 1996): the most important aim for the elements of the system is adaptation and to reach their aim they

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continuously look for new ways to do things and to learn. Thus, they create extremely dynamic systems, where small changes can generate unimaginable consequences (Axelrod and Cohen, 1999), that is, butterfly effect. They place themselves between simplicity – too close to the immobility of a mechanism – and uncheckability – too close to loss of control (Battram, 1999).

A supply network is a complex adaptive system too, characterized by material flow and knowledge flow (Choi et al., 2001): managers have struggled with the dynamic and complex nature of supply networks (SN) and the inevitable lack of prediction and control. They have to accept the challenge of complexity, which provides us with questions rather than answers (Bocchi and Ceruti, 1985) and tries to answer questions apparently without a possible answer.

Principles of the theory of complexity

Since theory of complexity is a multidisciplinary science, literary contributions are numerous and heterogeneous. In this first part of the paper, we try to rationalize this huge field by identifying seven principles of theory of complexity (table 1). Each following paragraph will take into consideration one of the seven principles of complexity.

Table 1 – Principles of theory of complexity

	PRINCIPLES OF THEORY OF COMPLEXITY
1	Auto-organization
2	Edge of chaos
3	Hologramatic principle
4	Impossibility to forecast
5	Power of connections
6	Circular causality
7	Try&learn

Auto-organization

Theory of complexity studies systems that are open by a thermodynamic point of view, and are in this sense opposed to the closed systems studied by the second principle of thermodynamics. In these open systems, opposed to the tendency to degradation – entropy – there's a tendency to organization – neghentropy (Prigogine and Stengers, 1979). Olson and Eoyang (2001, p.10) describe effectively auto-organization as "[…] the tendency of an open system to generate new structures and shapes starting from internal dynamics. The organizational design is not imposed top-down or from outside, but emerges from the interactions of the agents in the system". One of the best and most general characterizations of auto-organization is the one proposed by systems thinking expert Gharajedaghi (1999). In his opinion, in every field – natural, social, organizational – auto-organization can be considered as a process where extremely differentiated elements reach a great integration. Flocking birds and ants are classical examples of auto-organization.

Complexity scholars state that auto-organization is a process of emergence supported by positive feedback and cooperation and competition. Emergent phenomena seem to have a life of their own with their own rules, laws and possibilities. Chance, order and disorder, positive feedback are all elements that take part into emergence (Waldrop, 1992). To have auto-organization, single elements must at the same time cooperate and compete. Cooperate to join forces and compete to achieve the best results (Waldrop, 1992; Olson and Eoyang, 2001).

Nobel Prize winning Philip Anderson (Waldrop, 1992, p.84) declared: «Emergence, in all its infinite variety, is the most enchanting mystery in science.»

Edge of chaos

Evolution takes CAS to that area between order and disorder called by complexity scholars edge of chaos (Waldrop, 1992). It is the only place where life can take place. Too much order causes death by ossification, too much disorder causes death by disintegration. According to Cohen (1997, p.69): "At the edge of chaos, the borders of change continuously flow between a stagnant status quo and the anarchy of endless destruction". Thus, edge of chaos is a dangerous place to be visited. It isn't order nor disorder. It is between order and disorder. It is a place of creation, but it can be even a place of destruction. A mathematical demonstration to say if a system is at the edge of chaos is provided by "auto-organized criticity", introduced by Danish physicist Per Bak and his collaborators (Waldrop, 1992): taking into consideration a sand pile, there is a high number of small avalanches and a low number of big avalanches.

This principle invites us to accept the contemporary presence of contrasting concepts (Morin, 1990), such as order and disorder, creation and destruction, life and death. We should move from "or" culture to "and" culture (Amietta, 1991): things don't exclude themselves, annul each other, neutralize, but coexist, sum themselves, live together, integrate, recall, find a dynamic equilibrium between them. Moreover, we should accept disorder as necessary for creation (Morin, 1990). . Disorder is everywhere (Bohm, 1957): in all living systems (Morin, 1990), in our mind (De Angelis, 1996), in every organization (Quattrocchi, 1984), in history (Waldrop, 1992).

Hologramatic principle

System and environment are tightly linked. Complexity theory posits that a CAS both reacts to and creates its environment, because "there is feedback among the systems in terms of competition or co-operation and utilization of the same limited resources" (Goldstein, in Zimmerman et al., 1998). The borders between system and environment, therefore, thanks to theory of complexity, become faint, sometimes inexistent, arbitrary (Varela, 1979; Gharajedaghi, 1999). To describe this tight relationships, complexity scholars utilize hologramatic principle (Morin, 1990). The term "hologram" was coined in 1947 by Dennis Gábor, who put together the Greek words holos (whole) and gramma (transfer): thus, an hologram consists of the transfer of the whole into its parts. Gabor applied the hologramatic principle in physics: in a physical hologram, the smallest point of the image includes all the information of the represented object, as in fractals (Mandelbrot, 1977). The hologramatic principle takes into consideration this fundamental concept about physical hologram and maintains that in complex systems the part is in the whole, and the whole is in the part (Morin, 1990). Typical examples are staminal cells into our body. They are the parts and they are into the whole, that is the body, but at the same time include information about the whole body. Pribram (1985) uses hologramatic principle for the representation of the brain. Even memory and language are organized according to hologramatic principle (De Angelis, 1996). Moreover, "Santiago theory", developed by scientists from Chile Maturana and Varela between the end of the Eighties and the beginning of the Nineties, utilizes a hologramatic logic to represent the way in which we understand and give sense to reality outside us through mental schema.

Impossibility to forecast

Future is not predictable. In a complex system, it is often true that the only way to predict how the system will behave in the future is to wait literally for the future to unfold (Choi et al., 2001). Complex systems however are not totally unpredictable, as chaotic systems. Mathematician Ben Geoertzel (Lindberg et al., 1998) makes a difference between impossibility to forecast state and structure: complex systems are unpredictable in their state, but not in their structure. For example the specific state of the weather conditions is not predictable: it is impossible to predict what the weather will be like in the next weeks or months. Notwithstanding this, the structure is not unpredictable: in fact there are some regular patterns that make it possible to predict for example the average climate of the following months. One finds that systems will tend to be involved in certain prototypical ways and, thus, our predictive capacity, although limited to the exact prediction at a future point in time, can benefit from the knowledge of these patterns (Choi et al., 2001). Complexity theory takes into consideration, between spaces of predictability and unpredictability, the space of possibilities (Battram, 1999). In a complex environment, where there is space for unpredictability and possibilities, predicting and imagining how to behave in the future become dangerous activities and we have to take into consideration weak signals (Harris and Zeisler, 2002). We have to evolve in complex, "rugged landscapes" (Kauffman, 1995). Optimisation can be an illusion, as one sits on one of what appears to be a mountain peak, when, in fact, it may simply be a bunny hill. Additionally, everything is changing in a dynamic fashion, and so the landscape is dynamic. Therefore, landscapes can be both rugged and changing (Choi at al., 2001).

Power of connections

Italian philosopher Quattrocchi (1984, p.36) asserts that "What is raised as scientific object [by theory of complexity] is not the thing, but the set of relationships that complexity point of view finds out beyond the thing/element". Complexity scholars state that the whole is more than the sum of the parts (Waldrop, 1992), and the added value is given by connections. This fact has been demonstrated by different simulations (e.g. neural nets, classifying systems, Boolean networks, exc.). The basic idea of simulations that demonstrate the power of connections is to represent a population of interactive agents as a net of connected knots. With reference to these simulations, it is possible to talk about "connectionist models". Thanks to one of these simulations, American scientist Stuart Kauffman was able to demonstrate the results already reached by Prigogine (Waldrop, 1992). He demonstrated in fact that just by increasing the number of connections between knots, the system go through a transition phase, from order to edge of chaos and finally to disorder (Battram, 1999). This fact happens just by altering the number of connections, therefore it is right to adopt the slogan "power of connections". Moreover, it is possible to say that all things and individuals of the world are parts of a huge non-linear net made of incentives, constraints and connections. The smallest change of any part causes up-settings in the other ones. Capra refers to this phenomenon as the web of life (1996).

Circular causality

Linear causality is one of the most important philosophical concepts of occidental world. It was already considered by Aristotele, who identified efficient, material, formal and final cause. Classic science singled out a linear relationship between cause and effect: a particular fact causes a particular effect, proportional to the cause. The relationships between cause and effect have been taken into consideration by many other philosophers, e.g. David Hume

(1711-76) and Immanuel Kant (1724-1804). In general, we always would like to attribute a certain effect to a certain cause, but this is often vain, as the 20th century thinkers understood, generating the shift from linear causality to circular causality. The concept of circular causality has been firstly taken into consideration by scientific researchers thanks to cybernetics and in particular to the studies by Norbert Wiener. Circularity became then one of the fundamental concepts of theory of complexity. Cause acts on effect, which feedbacks on cause. Virtuous and vitious circles arise. These circles can even be linked together and give origin to the complex web of life.

Try & learn

The shift from classic Darwinian evolution to complex evolution caused a great shift in the way scholars have looked to the theme of learning. Evolution and learning, in fact, are tightly linked. "Living is knowing", maintained Maturana and Varela in 1985 (De Angelis, 1996, p.49). The previous statement bases itself on «Maturana-Varela-Bateson Theory». According to this theory, life and cognition follow the same kind of process and share therefore the same nature: a learning structure is a living structure and it is living until it learns. Learning in complex environments, according to Rullani (2002, pp.85-86), "removes […] free complexity from the environment and metabolizes it in the structures of the system as managed complexity". Learning in this sense means managing complexity of external environment. According to Holland (Waldrop, 1992), complex adaptive systems can evolve thanks to two kinds of learning. The first kind is *learning by exploitation*, and means improving and changing personal behaviour. The second kind, more radical, is *learning by exploration*, and consists of trials to improve and change mental models, the ways we think and look at the world. This second kind of learning is more risky too: you try, explore, and learn. Gharajedaghi (1999, p.87) refers to these two kinds of learning as *first-order learning* – and *second-order learning*. Bateson (1990) maintains that learning in complex systems is more effective if it comes from exploration, and introduces the idea of try&learn. It is pretty clear that learning doesn't come from calculations and plans (Piaget, 1967), but from action in rugged landscapes (Kauffman, 1995). Exploration, trial, action: these are the new key words necessary to learn.

Principles of the management of complexity

Is theory of complexity just an interesting science or could it be something of great importance for our conceptions about organizations and strategy (Pascale, 1999)?

Organizational theory has considered complexity as a structural variable of both organizations and their environments. In relation to organizations, Daft (1992) states that complexity is the number of activities or subsystems within organization, observing that it can be measured according to three dimensions (vertical complexity, horizontal complexity, spatial complexity). In relation to environment, complexity has been seen as the number of different elements that organization has at the same time to deal with (Scott, 1992). However, classic conception used to consider firms as simple systems in simple environments. According to Olson and Eoyang (2001), this conception comes from the great influence of newtonian science and economy of Adam Smith. There has been a shift of paradigm (Gharajedaghi, 1999) and it has taken place in two dimensions: nature of organization and nature of knowledge about organization. This new paradigm considers firms as complex systems in complex environments. Keene (2000) maintains that the principles of theory of complexity must permeate the vision of organization, since they are fitter for instability and turbulence. Many different scholars consider organizations as CAS, and everyone points out one or more than one principles of complex systems that apply to organizations. Therefore, the seven principles of complexity can be declined into management, to allow organizations, as complex adaptive systems, to evolve in complex environments. In this second part of the paper, we apply the identified seven principles of theory of complexity to management (table 2). Each following paragraph will take into consideration one of the seven principles of management of complexity.

Table 2 – Principles of theory of complexity and management of complexity

	PRINCIPLES OF THEORY OF COMPLEXITY	PRINCIPLES OF MANAGEMENT OF COMPLEXITY
1	Auto-organization	Auto-organization
2	Edge of chaos	Creative disorganization
3	Hologramatic principle	Management sharing
4	Impossibility to forecast	Strategic flexibility
5	Power of connections	Network organization
6	Circular causality	Management virtuous circles
7	Try&learn	Learning organization

Auto-organization

To have bottom-up auto-organization, a balanced equilibrium between cooperation and competition is necessary. Eisenhardt and Galunic (2000) apply biological idea of co-evolution to organizations: they should evolve together with other organizations and with the environment. Depending on the chosen level of detail, it is possible to apply principle of auto-organization to the firm – considering it as a system – or to the system of firms, when they form networks or clusters.

Applying auto-organization to a single firm means looking for distributed intelligence. According to principle of auto-organization, few rules are sufficient to generate complex behaviour through bottom-up emergence. Organizations, therefore, should encourage active participation of employees, as an instrument to «complexify» them (Ashmos et al., 2002). Intellectual contribution by anyone in the organization is fundamental (Hamel, 1997), to reach distributed intelligence (DI), which is a function of human and social assets strategically relevant (McKelvey, 2001). It represents a kind of network within organization, where knots are generated by intelligence of the individuals (H, human capital) and connections are generated by people which converse and interact (S, social capital).

Looking outside single firms, competition is increasingly competition between coalitions, not between single firms: it is necessary for organizations to open out to new forms of collaboration, not only to decrease competition against other organizations, share risks, put together complementary resources, but even to develop new knowledge. A particular case of auto-organization is represented by Italian districts, which seem to be one of the richest elements for analysis for researchers in the field of theory of complexity (Quadrio Curzio and Fortis, 2002). Districts are open CAS, generated and continually renewed by processes of auto-organization (Corò and Rullani, 1998; Normann, 2001; Rullani, 2002).

Creative disorganization

The edge of chaos is reached by firms through creative disorganization, a principle similar to the concept of innovation proposed by Schumpeter (1942), who defined "the agglomerates of explosion" generating change as "perpetual storms of creative destruction". In CAS, and therefore in organizations too, when a higher degree of autonomy is given to agents to make decisions locally, outcomes are then allowed to emerge in a deviation-amplifying way or through positive feedback (Dooley and Van de Ven, 1999). Many of the creative activities found in firms emerge in this fashion. Thus, it is necessary to forget the idea that success comes from stability and order: life and innovation are generated at the edge of chaos – between formal and informal structures (Pascale, 1990; Stacey, 1991, 1992). Dee Hock, one of the founder members of VISA, calls his organization «chaord organization», where chaord points out the right mix between chaos and order (Savage, 1996). Creative disorganization can be facilitated acting in three different directions: organizational structures, directional styles, and management. Looking at organizational structures, it is necessary to create flat structure (Peters, 1992; Savage, 1996), lateral roles of co-ordination (Foster and Kaplan, 2001) and decisional decentralization (Pascale, 1992; Peters, 1992). Looking at directional styles, it is necessary to develop intrapreneuring (Peters, 1992; Keene, 2000), not to fear mistakes (Pascale, 1992; Peters, 1992; Foster and Kaplan, 2001) and not to fear conflicts, but exploit them (Pascale, 1992; Ciappei and Poggi, 1997; Olson and Eoyang, 2001). Looking at management, it is important to use techniques to develop single and group creativity (Peters, 1992; Foster and Kaplan, 2001). It is important to take into consideration that human being feels necessity to create. The engine of creation is dream. Future belongs to those who can imagine it, because "creating is living twice" (Camus).

Management sharing

Hologramatic principle requires sharing. On a social level, it requires values sharing. Peters and Watermann (1982) write about excellent organizations as those which have "strong cultures" and people are driven more by shared values than by rules, orders and formal procedures. "Values are vectors: they express the force in a given direction" (Jaques, 1989, p.112). A useful method to transmit the most important values in organizations is to rely upon symbols, myths or stories (Olson and Eoyang, 2001).

On a strategical level, it requires sharing of vision. Senge (1990) and Savage (1996) use hologramatic principle and fractal forms to describe vision: it is inside the firm, and the firm is inside it. To be turned into something powerful, vision needs: words, since it has to be exciting (Foster and Kaplan, 2001); actions, since it has to be real, tangible (Bennis, 1997); relations, since it has to be approved and shared by everyone in organization, emerging after a bottom-up process (Ciappei and Poggi, 1997; Olson and Eoyang, 2001).

On an organizational level, it requires team and network relationships There is necessity of sharing, since uncertainty is risky: referring to the risk and uncertainty implicit in the innovation process, Hayes e Abernathy (1980) called it the choice of the gambler. Ohmae (1989) concludes that "in a complex and uncertain world it is better not to play it alone". Theory of complexity can teach something about team building too. Olson and Eoyang (2001) maintain that are auto-organized systems. Kelly (1999) identifies four simple rules for team building: the last one derives directly from theory of complexity, and is coordination of co-evolution. Moreover, diversity has to be embraced in teams, since it is source of innovation (Keene, 2000).

Strategic flexibility

Impossibility to forecast is a fact for organizations. Aragòn-Correa and Sharma (2003) identify three kinds of uncertainty that organizations have to face: *environmental uncertainty, organizational uncertainty, and decisional uncertainty*. Change is open, unpredictable and created by us and the interconnections with other subjects (Stacey, 1996): open and exploratory strategies are more useful than long-term forecast to grant development in a complex and changing environment, since late to market means philosophical, as well as commercial, failure. The need for quick responses requires *adaptability, readiness, and flexibility* (Rabey, 2001). Adaptability is reached through what-if scenarios building. Forecasting becomes building of different options, that is, scenarios. Readiness is reached through external world monitoring and constant attention to weak signals, since competition is becoming "competing to imagine future" (Hamel and Prahalad, 1995). Attention to weak signals must be searched: organizations have to behave like High Reliable Organizations as nuclear power stations, where weak signals are taken into consideration and generate strong responses (Weick and Sutcliffe, 2001). According to Harris and Zeisler (2002), reaching the edge of chaos is the best way to seize weak signals. In our opinion, it is important to build an active monitoring system, create an internal and external network for knowledge accumulation, and establish a spontaneous empathy with people and markets. Strategic flexibility has to be pursued by organizations. Strategic flexibility means adaptability, readiness, and much more.

Network organization

The power of connections requires network organization. Firms have to create network with suppliers, clients, firms, banks, research centers and universities, public administration, job category associations and trade unions, and socio-cultural associations. Starting from transaction cost theory, it is possible to consider networks as hybrid organisational forms which combine elements of the market coordination (price mechanism) with the hierarchy (planning mechanism). Thus, networks of companies represent an intermediary solution between the integrated manufacturer and the "market", that is, the complex of independent manufacturers with whom exclusively short term ("spot") transactions are established. Innovation derives from a complex network: Rothwell and Zegveld (1985) describe innovation as "a complex network of paths of communication, both inside and outside organizations, which link different internal functions and link the organization to scientific and technological community and to the market." Since the relationship with rapidly changing technologies requires continual updating, Granstand and Sjolander (1990) maintain that firms turn more and more towards external environment, to satisfy their technological demand and to maintain or reach the technological pre-eminence. Therefore, firms give origin to networks for innovation (De Bresson and Amesse, 1991). Experts of theory of complexity maintain that network organization is the practical translation on organizational level of what happens in nature (K.Kelly, 1997). Thus, there is a shift from industrial view (hierarchy, market) to eco-systemic view (network) and from "working for someone" (hierarchy) to "working with someone" (network) (Battram, 1999).

Management virtuous circles

Virtuous circles have not been considered as important economic and managerial themes, even if they were implicit in some models. For example, Freeman (1982, p.214) states: "In the model Schumpeter II there is a strong loop characterized by positive feedback from successful innovation to improvement of activities of research and development, which gives origin to a virtuous circle …". Hegel used to describe philosophy as "the circle of circles". In our opinion, "the circle of circles" regarding organizations is the one between innovation and development. Innovation generates development, which generates new innovation, and so on. Other virtuous circles are: *ideas-enterprise; creation-sharing*; *knowledge-relationships; local-global*. Circles are not so simple, since they are usually connected between them. Connected circles are defined in an effective way by Gharajedaghi (1999), which considers for example the circle *innovation-development-knowledge-relationhips.*

Learning organization

Garvin (2000, p.11) defines a learning organization as "an organization skilled at creating, acquiring, interpreting, transferring, and retaining knowledge, and at purposefully modifying its behaviour to reflect new knowledge and insights". It is possible to talk about learning organization if learning and innovation generate a virtuous circle (Ciappei and Poggi, 1997). Although global market about Knowledge Management in 2002 overtook 3 billions $ and will double in the following three years (Pancotti, 2003), learning organizations have been embraced in theory but are still surprisingly rare (Garvin, 2002). Numerous examples of practical learning organizations come from Japan, where there is an almost fanatic devotion for learning, both inside organization and outside (Imai et al., 1985; Senge, 1992; Nonaka and Takeuchi, 1995). Argyris (1982), Morgan (1991), and Senge (1992) distinguish between single loop learning and double loop learning within organizations, while Garvin (2000) identifies three modes of learning, that is intelligence, experience, experimentation. We prefer to talk about *linear learning* (similar to learning by exploitation) and *circular learning* (similar to learning by exploration). The first kind of learning requires behavioural change, while the second one requires cognitive change, and has to be looked for by organizations. Thus, it is necessary to create within firms a continuous learning culture, that tolerates mistakes (Gharajedaghi, 1999). Sometimes a failure can be productive, and a success unproductive (Nadler, 1989).

Principles of complex supply management

Supply Management refers to the process of how products are designed, sourced through an often-complex network, manufactured and distributed from raw material to the end customer (Smock, 2003). There are different elements of complexity (Romano, 2003): the actors of the supply network are in general autonomous or semi- autonomous, they carry out different activities and interact, the supply networks involve non-stop physical (materials/products), informative, financial flows, supply networks extend on one side until the raw materials and on the other side until the end consumers. Increased globalization and accelerated product development are adding complexity to the supply chain, making its effective management more critical. "Every manufacturer's supply chain is expanding and becoming increasingly complex", says Doug Engel, partner and one of Deloitte's national manufacturing industry leaders. "However, complexity is not the enemy to the supply chain, effectively managing complexity can be a manufacturer's greatest asset", he says (Chemical Market Reporter, 2003). The greatest challenge facing supply chain leaders today is complexity. Deloitte Touche Tohmatsu studied nearly 400 U.S. manufacturers in an attempt to understand the issue, and has produced a new study entitled "The Challenge of Complexity in Global Manufacturing." (Burnson, 2003). Wilding (1998) maintains that there is deterministic chaos in supply chains and Choi et al. (2001) maintain that a supply network is an emergent phenomenon and that a delicate balance between control and emergence has to be found. Since supply networks can be seen as CAS, it is possible to use the same instruments for their comprehension. Artificial "agents" are generally used to model complex systems and are now frequently used to model supply chain phenomena. In this third part of the paper, we apply the identified seven principles of theory of complexity and management of complexity to complex supply management (table 3). Each following paragraph will take into consideration one of the seven principles of complex supply management.

Table 3 – Principles of theory of complexity, management of complexity and complex supply management

	PRINCIPLES OF THEORY OF COMPLEXITY	PRINCIPLES OF MANAGEMENT OF COMPLEXITY	PRINCIPLES OF COMPLEX SUPPLY MANAGEMENT
1	Auto-organization	Auto-organization	Distributed intelligence
2	Edge of chaos	Creative disorganization	Creative new product development
3	Hologramatic principle	Management sharing	Partnership
4	Impossibility to forecast	Strategic flexibility	International manufacturing/sourcing
5	Power of connections	Network organization	Supply network
6	Circular causality	Management virtuous circles	Integration and continuous improvement
7	Try&learn	Learning organization	Learning supply network

Distributed intelligence

Relationships of contemporary collaboration and competition are important even in partnership relationships: lean supply emerges as a kind of business characterized by competition and dynamic collaboration among actors (Lamming, 1993). These relationships are reached through independence of knots, that is distributed intelligence): if one would like to see a more creative and adaptive response from the supply network, then one must give more autonomy to the firms in the supply network, essentially increasing dimensionality – the degrees of freedom available for potential response. The degree of innovation by suppliers is directly proportional to the amount of autonomy that suppliers receive in working with customers (Choi et al., 2001). A small circle of close friends has to be built, where suppliers can even become technological leaders, innovators, leading partners (Lamming, 1993). According to Jeff Bezos, CEO Amazon.com (Wired, July 2000, p.255): you can "build a more robust company if you give up a bit of control in this organic market place". Supply networks display non-linear behaviour that centralized planning can't regiment. There is necessity for bottom-up approach. Similarly, in adaptive supply networks, intelligence and control aren't hoarded in one single "hub" (OEM), but rather delegated to "spokes" (suppliers) that use their freedom of action to fix local issues (Radjou et al., 2002). Companies need to build the supply chain from the bottom up, not the top down as they have done in the past (Sherman, 2001).

Creative new product development

The capabilities which serve the innovative process are located within the supplier, within the purchaser, and emerge as a consequence of the interactions between the two parties.

Therefore, there is necessity to adopt creative techniques for collaborative new product development. In particular we suggest a methodology that is articulated into five steps to generate collaboration and new ideas: *external* and *internal mapping*, *predisposition*, *creative process* and *evaluation*. Regarding *external mapping*, enterprises select external stimuli interpreting them according to their knowledge. In order to collect external signals, it is essential for organizations to *take part to exhibitions and meetings*, to get in touch with suppliers and develop interesting ideas about the relationship between them and the enterprise itself. *Internal mapping* is concerned with valuing the inner cognitive capital in order to exploit its potential and aid new business ideas to rise up. A technique that can be used for internal mapping is *creative targets list,* proposed by E. De Bono (1992). This technique may be used both to search not yet evident internal problems and to point out some new focus. *Predisposition* is concerned with creating an internal environment that may favour new ideas and rapidly eliminate old-fashioned ones. We think that a preventive *creative training* can be very useful to make people comfortable with such an argument and in particular with some basic techniques and procedures. *Creative process* is the idea generation. In this phase it can be very useful to involve suppliers in order to realize a sort of "cross fertilization" (Koestler, 1975) and produce new ideas to improve purchasing process. A possible technique to be used is *context modifying*, suggested by Foster and Kaplan (2001). There are different ways to modify a meeting context: the first is to modify the social environment where the meeting takes place, the second is to modify the physical context, the third is to change the mental approach to problems by using reversed thinking. *Evaluation* consists in the selection of the best ideas according to the inner judgment criteria of the enterprise. The techniques we suggest for this phase is *six thinking hats,* invented by De Bono (1992). It allows to divide logic from emotions, creativity from information, idea generation from idea evaluation, and to consider ideas from different points of view.

Partnership

Sharing is reached through partnership and integration. Partnership is a "strong inter-company dependency relationship with long term planning horizons" (Stuart, 1993). The critical role of trust in the process has to be underlined (Lamming, 1993): mutuality, shared objectives and interests are of considerable interest. The "area of contact" between suppliers and customers is amplified: from firms independence to continuous integration in operational processes, new product development, and strategic planning. Integration occurs on three levels (Zanger, 1998). On an *organisational level* the problems of the individual partners are fixed on a contractual basis with view to mutual fulfilment of objectives. *Material integration* results from specialisation along the value chain or from reciprocal resource utilisation in the production process. *Informal integration* comprises know-how interchange and permeates the other two levels. Actors in the supply network have to be integrated with and able to accommodate decisions made elsewhere. Otherwise, they won't be part of the supply network of the future (Sherman, 2001). *Integrated supply networks* must become way of life: changing is fundamental to meet complex demands.

International manufacturing / sourcing

Constantly adapting to changing circumstances is now the norm (Radjou et al., 2002). Firms that adjust goals and infrastructure quickly, according to the changes in their customers, suppliers, and/or competitors, will survive longer in their supply networks than firms that adhere to predetermined, static goals and infrastructure and are slow to change (Choi et al., 2001). Efficient supply chain is still essential for functional products, but a flexible supply chain is fundamental for innovative products (Fisher, 1997). Flexibility can be reached through the right geographical choice of suppliers. Supply networks are moving towards a global supplying system (Lamming, 1993). Varaldo (1997) maintains that once globalization regarded commerce, now production. According to a survey by Osservatorio TeDIS in 2002, 90% of the interviewed Italian SMEs outsources at least part of their activities and the 56,6% of these firms turns to strategic suppliers, that is, suppliers linked to the customer through partnership relationships. With particular reference to North-Eastern Italy, a recent survey by Fondazione Nordest (Marini et al., 2003) pointed out that the 95% of the interviewed entrepreneurs expects positive aspects for firms which choose to internationalise, and for the 83% it is an obliged way to follow to gain competitive advantage. International trade is not a zero-sum game. Its benefits will be widespread over time.

Supply network

Network organization is created through supply networks generation. Therefore, it is necessary to migrate inflexible supply chains to adaptive supply networks: brittle supply chains risk collapsing like a house of cards under the disruptive influence of business drivers (Radjou et al., 2002). Individual capacities in the supply network have to be values (Clark, 1989): suppliers have to be involved even in the phase of design. Dynamic networks of suppliers, characterised by flexibility and experimentation capacity, are necessary. The management of supplier relationships is a central, yet complex, element of purchasing's strategic role. A complex adaptive supply network should be generated: that is a collection of firms that seek to maximize their individual profit and livelihood by exchanging information, products, and services with one another (Choi et al., 2001). Therefore we need a more holistic view towards supply networks. For example, supply strategy: it is the extension of operations strategy to inter-organizational supply networks: it is "an holistic approach to formulate and implement rational strategies to create, stimulate and satisfy end client demand through innovation of products, services, structures and infrastructures of the supply network, in a global and dynamic environment" (Harland et al., 1999). There is evidence from studies in strategic management that organizations including Benetton, Rank Xerox, Toyota, Nissan and Caterpillar have taken a more strategic, holistic approach to manage the entire network of supply (Jarillo, 1993). There is a need for knowledge networking too, seen as the process of combining and recombining one another's knowledge, experiences, talents, skills, capabilities, and aspirations in ever-changing, profitable patterns (Savage, 1996), to develop sinergy potential.

Partnership and continuous improvement

Virtuous circles are important to be found even by supply management. Graves (1987) underlines the difference between American and Japanese research and development regarding circularity: "American system of research and development is unidirectional, while Japanese process, with its internal feedback mechanisms, is circular and dynamic. [In Japanese system] relationships are more organic and persons in charge and managers maintain an informative flow through the whole system". Thus it is necessary a new development model, which utilizes innovation from suppliers' environments and allows its growth (Lamming, 1993). Commitment, trust and continuous improvement are tightly linked (Lamming, 1993). An important virtuous circle for supply management is the one between partnership and continuous improvement. Partnership causes continuous improvement, which generates partnership, and so on.

Learning supply network

A supply network is not effective if it is not a *learning supply network*. Joint ventures, alliances, networks are exercises for learning (Lamming, 1993). Dodgson (1991) and Doz and Shuen (1988) underline that in continuous collaborations there are three kinds of learning: learning about partners, learning about tasks to be carried out, and learning about results. Japanese networks can generally be considered as learning supply networks (Imai et al. (1985, p.372): "whoever participates to the development process is involved in learning, even suppliers. […] It is this kind of "enlarged learning" that supports the dynamic process of product development among Japanese firms …". Researches on learning within supply management are not so common. To date a notable exception within the supply chain field is Richard Hall (1997) who has used the social learning cycle, developed by Boisot, to explore the knowledge acquisition and diffusion processes required to create new capabilities within a supply context. It is hoped that an understanding of the organisational learning processes required to facilitate the creation of inter-organisational capabilities can be expanded to supply management too (Batchelor, 1998). Some attention has been given to the application of knowledge management to supply management, as witnessed by the concept of knowledge supply network (KSN). Being an extension of the conception of supply chain management familiar to operations managers, knowledge supply network provides a most natural framework for operations management to contribute to the issues of knowledge management and intellectual capital, while retaining its tradition of practicality (Mak and Ramaprasad, 2003).

Conclusions

In this paper we have provided at the beginning a theoretical framework to understand the principles that allow CAS to evolve in rugged landscapes. In this part we have identified seven principles of theory of complexity. Since many scholars consider firms as CAS, we have in the second part declined the seven principles of theory of complexity into seven principles of management of complexity. Firms, like living systems, have to evolve in rugged landscapes. In the last part we have focused our attention on supply management, identifying in particular seven principles for complex supply management. In conditions of high complexity, purchasing function has to adapt and create new opportunities, finding a dynamic equilibrium between control and emergence. Complexity is a source of opportunities and threats. Just by knowing the principles used by living systems to maximise their adaptation, the purchasing function can seize opportunities and reduce threats. In conclusion, which directions for purchasing function? All the potential ones. In the network, ready to seize the creative moment.

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