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The Dynamics of Knowledge Creation Within Innovation Process From Case Studies to Agent Based Modelling

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THE DYNAMICS OF KNOWLEDGE CREATION WITHIN INNOVATION PROCESSES

FROM CASE STUDIES TO AGENT-BASED MODELLING

La dynamique de la création de connaissance dans les processus d'innovation

Etudes de cas et modélisation multi-agents

Completed Research Paper

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Abstract

While it is a truism to underline that modern industrial development in high technology environment strongly relies on innovation, little is known about the innovation success factors. We argue that studying innovation process – defined as a knowledge creation process – from a complexity perspective enables us to better understand this emergent process and its characteristics. This research deals with the knowledge creation trajectory within innovation processes. The framework of the paper is built on a review of a knowledge based view of innovation and the theory of complex adaptive system (CAS). Departing from real-life case studies of innovation processes, the research aims to explore and to understand the knowledge creation trajectory with a focus on the dynamics of this process. The empirical studies refer to IT-based innovations. We use a case study methodology based on a combination of data collection methods: interviews with key actors, non-participant observations and analysis of internal documents explaining the project stakes. The results show that the four processes of innovation evolve in seven, separate but interdependent, knowledge creation stages. The interweaving of these stages allows us to analyze the trajectory dynamics. The research also provides some evidence about the internal and external parameters impacting the trajectory. In addition, we observe a complex dynamic of evolution – specific to each process – characterized mainly by adaptation loops and feedback processes. The results of case studies allow developing an agent-based model of knowledge creation within innovation process and offering a new view of innovation, based on an interactionnist social approach.

Key words: knowledge creation stages, knowledge trajectory, innovation, complex adaptive system, case studies, agent-based model

Résumé

Cette recherche explore la dynamique de la création de connaissances dans un processus d'innovation. Un cadre conceptuel est construit à partir des approches théoriques de la connaissance et des systèmes complexes adaptatifs. A travers l'analyse de quatre études de cas, nous essayons d'appréhender la trajectoire complexe des différentes phases de création de connaissances, sa dynamique et ses principales dimensions. Ces résultats exploratoires permettent la construction d'un modèle multi-agent.

Introduction

Innovation is one of the main strategic concerns for the new millennium (Hamel, 2000). Facing at an uncertain environment, organizations have to constantly propose new products, services or market conceptions. The innovative activities have low rates of return on investment that well illustrate the complex and uncertain nature of innovation. Prediction of success or failure is almost impossible. The innovative act is neither linear nor easy to manage. These considerations lead to the mobilization of two theoretical fields. First, the knowledge and learning theories in order to better apprehend the knowledge creation mechanisms and select a model adapted to our research object. On the other hand, complexity theory applied to organizational sciences with the aim of highlighting the dynamics inherent to innovation processes.
This paper explores the creation knowledge trajectory within innovation processes through four case studies and proposes a new view of innovation based on an interactionnist social approach through a multi-agent model. The case studies deals with IT- based innovations. They concern the sectors of the health and of the citizens' e-accessibility. Three innovations are developed in Public sector and one in private sector.
This research intends to improve the understanding of this emergent and dynamic process in order to develop more appropriated methods and tools of knowledge management.

The following question act as framework to our research:
What are the dynamics of the knowledge creation trajectory within an innovation processes?
This implies first to explore the different stages which constitute the knowledge creation trajectory as well as their interrelations and second to study the key dimensions which facilitate this trajectory.

1. Conceptual framework

1.1 The innovation process

The concept of innovation is the most often defined as a new idea or approach that challenges the present order of the organization (Van de Ven 1986). The innovation can concern the development of a new product, a new service or a new organizational view and can vary in degree of radicalism *vs* incrementalism. Nevertheless, innovation covers different aspects according to the discipline and the analysis level. In this paper, innovation is viewed as a learning interactive process in which the participants improve their knowledge and their know-how by exchange and experimentation (Baets 2006; Harkema and Browaeys 2003; Nonaka and Takeuchi 1995). The development of new thing is similar to a sense making process that takes place in a specific social and institutional context (Akrich, Callon and Latour 1988; Weick 1995) and brings about large structural relations between departments, services, work groups with different skills and their environment. The selected perspective is interested by the community of creation which transform the innovation idea into concrete realization. This approach contrasts with the innovation diffusion model (e.g. Roger, 1995), the stage-gate model (e.g. Cooper and Kleinschmidt 1986) or the technology acceptance model (e.g. Venkatesh and Davis 2000). Innovation process is viewed as an "interconnected chain" of actions that opens to external information and knowledge and implies an iterative (go and no-go's) and entangled development (Kline and Rosenberg 1986). The works of MIRP[1] confirm the interest of this perspective. On the whole of technological and managerial innovations studied by these researchers during more 20 years, none innovation followed a linear trajectory with cumulative stages of activities. On the contrary, they observe a complex and disorderly progress of events in the innovation development. The process evolves and diverges in multiple and interdependent stages of activities. The multiple interactions between agents and the collective learning intrinsic to innovation call for a complex and dynamic view. In this approach, many researchers underline that innovation must be understood as an uncertain, emergent and self-organized process and studied through the ideas from complexity paradigm (Baets 1998; Carlisle et McMillan 2006; Cartier 2003; Cheng and Van de Ven 1996; Harkema 2003; Kanter 1988; Quinn 1985).
Departing from this literature report, it seems appropriate to ask for a relevant entry to study innovation complex system. Gell-mann (1994) considers that to understand more about complex adaptive system a focus on information flows is essential because they determinate the system state : stability, edge of chaos and chaos. By analogy, in human complex adaptive system information flows become knowledge creation trajectory. We develop and explain this concept in the next section.

[1] Minnesota Innovation Research Program

1.2 Innovation as knowledge creation trajectory

Nonaka (1994) was among the first authors to emphasis the knowledge-based nature of innovation. He underlines that new knowledge in organizations, and consequently innovation, is created, shared, developed and justified by collaborative social process and by individual cognitive processes. In the same way, Ruggles and Little (1997) show that innovation is a knowledge-intensive process in which existing knowledge is rethought and new knowledge is created. Therefore, more and more works bring nearer innovation to knowledge management, to theory and model of knowledge flows or knowledge lifecycle.

In this paper, we speak voluntarily about knowledge trajectory because this last seems adequate to the specific context of innovation and to social knowledge view. The notion of trajectory is used in sociology to analyse non-sequential social phenomenon. Strauss (1897) develops "the concept of illness trajectory" defined as "the physiologic course of a patient's disease and the total organization of work to be done over that course" (Strauss, 1987, p. 224). The notion of trajectory describes the temporal dimension of actions and interactions and covers the idea of direction and a multiplicity of itineraries that it necessary to take into account to explore social phenomenon in all its complexity. Lave and Wenger (1991) develop the notion of learning trajectory to analyse different kinds of learning – individual or collective – and their complex overlapping in the long term. It reflects a learning social approach linked to practice and experience, implying an extended scale of time.

In this research, we adapt this concept to explore the dynamic of different stages of knowledge creation and their evolution in a specific organizational context: the innovation process. In other words, a knowledge trajectory combines several knowledge creation stages. Moreover, in transposing this notion, our analysis takes place in a social perspective which turns its attention to knowledge as action and practice. This view is embedded in concepts such as Knowing (Cook and Brown 1999) and Community of Practice (Wenger 1998). Knowledge is understood, here, as an act of building and creation interrelated with learning social, cultural and historic contexts into which it evolves (e.g. Gherardi and Nicolini 2000; Maturana and Varela 1994; Spender 1996; Von Krogh and al. 1994; Vygotsky 1962). This embedded and situated knowledge affiliated to enaction paradigm (Varela 1989; Weick 1995) does not grasp as a stock or a static resource. It is, on the contrary, a flow and dynamic process continually reproduced and recreated through the social processes of interaction and the professional practice. Interactions between actors and their environment as well as their own experiences allow by learning to modify their conceptual and functional knowledge (McElroy 2000). Using Strauss's concept of trajectory permits us to study at the same time the evolution of the knowledge creation activities and the organizational configuration associated.

1.3 From knowledge creation stages to knowledge trajectory dynamics

In order to explore the knowledge trajectory in real cases of innovation processes, it is advisable to select a conceptual framework which fits with the complex and non-linear view of innovation and with the knowledge perspective advocated in this research. The Boisot's Model (1995, 1998), named Information Space (I-Space) fulfils this condition. The I-Space Model shows how organizational knowledge is created, developed and justified through a social learning cycle and describes the different knowledge flows (or stages) within the organizational context. These flows form a cyclic movement within the 3 Dimensions of the I-Space materializing by three knowledge dichotomies: 1. Abstract – Concrete, 2. Undiffused – Diffused and 3. Uncodified – Codified, as depicted in figure 1

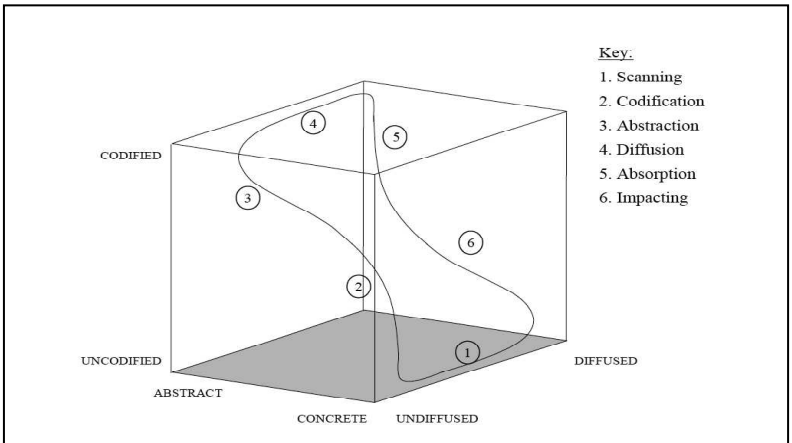

Figure 1: The social learning cycle, I-Space, Boisot (1995, 1998)

Boisot (1995, 1998) modelled the knowledge flows dynamics from external information to new diffused knowledge through six separate but interrelated stages of knowledge creation: 1.) Environment's **Scanning** and extraction of concrete information, considered interesting by organizational members. 2.) **Codification** is a response to what has been scanned. Extracted Information is, at this stage, selected and structured in order to reduce uncertainty and ambiguity. Selection generates often conflicts within the organizational groups. 3.) **Abstraction** is a move from specific and concrete knowledge to new general knowledge, applicable to diverse situations. The aim is to reduce the number of concepts and categories that one has to deal with. 4.) **Diffusion** of new knowledge – validated and codified – to the highest number of members or groups within and outside the organization. Knowledge is, in this step, de-contextualized. 5.) **Absorption** of newly diffused knowledge through a learning by doing process. In this phase, new knowledge provides an uncodified stock of practical and 'situated' experiences. 6.) **Impacting** is the final move from general and abstract knowledge to the specific and contextualized knowledge. New knowledge modifies practices, artefacts, belief schemes, behaviour rules…of members or groups. Like absorption, impacting is a diversity-generating process that allows resolving the conflicts generated through abstraction process. This appropriation trajectory depends mainly of concrete applications that new knowledge allows.
The I-Space holds mainly three advantages to analyse innovation processes. It combines, at first, the individual, collective and organizational levels of knowledge processes to different kinds of knowledge. It integrates, afterwards, the external environment's role in the knowledge creation process, that Nonaka's model (1991, 1994, 1995), for example, omits. At last, the dynamic nature of knowledge – the different stages do not evolve in a linear sequence – fits with our innovation theoretical conception. Therefore, our exploratory research retains the I-Space's six knowledge creation stages as conceptual framework to explore the dynamics of knowledge trajectory.

1.4 A Complex Adaptive perspective on knowledge creation in innovation process

The terms of "complexity theory" covers many fields and disciplines of scientific research (such as the chaos theory, as the dissipative structures theory, as the study of fractals, etc.) among which the CAS theory is dominant. Since some years in Management Science, the CAS theory knows a large echo by both researchers and practitioners (Burnes 2005). According to Dooley et al., (2003) the basic assumption within complexity theories is that organizations can be viewed as complex adaptive systems (e.g. Anderson 1999; Axelrod and Cohen 1999; Coleman 1999; Gell-Mann 1994; Houchin and MacLean 2005). Moreover, CAS is the more operational model of complexity theory. CAS can be defined as a complex, nonlinear and interactive system composed of numerous agents which has the ability to adapt to a changing environment (Sherman and Schultz 1998). Therefore, the CAS theory could be interesting to improve our understanding of emergence processes such as innovation and knowledge creation. The main characteristic of a CAS is its capacities to adapt and learn (Stacey 1995). Yet, learning is the main facilitating factors of innovation and knowledge. Additionally, complexity paradigm refers to ideas and concepts at a distance from the mechanistic view, its epistemological assumptions are based on the conception of emerging world view, holism, mutual causation (Dent 1999). This implies to study the relationships as unit of analysis and take into account the independencies within system in order to explore the emergent processes.
A CAS is made up of numerous heterogeneous agents – individual, groups or organizations – in interaction (Holland 1995). Each agent possesses its own cognitive maps, behaviour processes and rules, and environmental perceptions. Nothing indicates if all these aggregates converge or differ between agents of the same system. In fact, if agents are interrelated and interdependent in the system, they act locally in an autonomous way and according to their own action schemes (Anderson 1999; Stacey 1996). There is no global and fixed plan. The action processes evolve continually through learning, adaptation to internal and external variations, multiple and spontaneous interactions between agents as well as between agents and their environment. Agents draw from environment information that is diffused in system through repetitive interactions. Environment brings the requisite "energy" in order to self-regulate and self-organize the system. According to Simon (1974), a large part of inherent complexity in these systems comes from interactions between the internal and external configurations and can lead to stable or instable states.
The system, understood in a holistic perspective – "the whole is more than the sum of the parts" –, is non linear. In fact, different variations and adaptation capabilities make the system's behaviour unpredictable. CAS is governed by a self-organization principle (Anderson 1999; Stacey 1995) that authorizes emergence of new organizational patterns. Carlisle and MacMillan (2006) state that *"Their ability to learn and adapt is underpinned by key self-organizing behaviours including exploration and experimentation"*. Self-organization is facilitated through multiple interactions and when the system stands at the edge of chaos (Gell-mann 1994). This stage of moderated instability or "creative destruction" fosters the appearance of emergent processes like change, creativity or innovation. In this perspective, Stacey (1995) compares the creative and innovative acts to a process

that goes away from equilibrium, accepts disorder and uncertainty, self-organizes and adapts itself through learning.
This learning stage, allowing systems to self-organize, is encouraged by five factors (Andriani 2001; Eigen and Ingber 2000; Juarrero 1999; Kauffman 1993)
1) Multiple interactions between agents
2) Multiple interactions between agents and their external environment,
3) Numerous information flows
4) Large diversity of agents
5) Equilibrium between formal and informal systems (of exchange) within organization.

We try with the case studies to explore the influence of these factors on the dynamics of the knowledge trajectory.

Departing from these research aims, a methodology in two stages had been designed. First, a qualitative methodology based on the comparison of four case studies had been implemented in order to explore the dynamics of the knowledge trajectory within innovation processes as well as the key dimensions able to facilitate the success of a stage and the emergence of a another stage. Second, the results from these cases serve as empirical foundation to build a multi-agents model of simulation in order to evaluate more in depth the dynamic of knowledge creation and the key dimensions associated to the innovation configurations which encourage or block the evolution of trajectory.

2. Case- studies

2.1 Qualitative Methodology Research

The main objectives of the first qualitative step are to explore the knowledge trajectory with the help of Boisot's framework. The innovation processes, studied in depth, offer us the possibility to identify a radical change in the functioning of several organizations. Therefore, the case studies allow us better identifying the dimensions associated with the dynamics of knowledge creation. Our approach takes place in an exploratory logic where abduction (in the way of Koenig, 1993) has an important role in the final process of analysis. It is a hybrid exploration (Charreire 1995; Allard-Poesi and al. 1999), considering that we start neither entirely without a priori, nor without theoretical foundations. We tried to respect theses methodological principles in this case study methodology (Eisenhardt 1989; Yin 1990).
The data collection had been organized around:

- Primary data: centred interviews with the key actors of innovation processes (35 individual interviews[2], for the four cases, about more one hour for each) and non participant observations
- Secondary data (Weick 1993): through a set of internal and strategic documents explaining the project stakes, its implementation, the actors, etc…

This collection, based on a longitudinal and retrospective view provides a data triangulation (Eisenhardt 1989; Yin 1990) and a robust chain of evidence (Miles and Huberman 1991).
The data analysis is structured around two methods. First, we led an analysis of emergent sequences of knowledge creation stages with the methodology of the critical incidents (Flanagan, 1954). A critical incident is distinguished by an evident change in the activities of knowledge creation. For instance, the writing of Business plan characterizes the end of codification stage and the emergence of a new stage. Afterwards, a thematic content analysis (Krippendorff 1980) had been achieved with the assistance of Nvivo (qualitative data analysis software). For each stages of knowledge creation, we analyzed the evolution of seven dimensions (Van de Ven and Poole, 1995): actors, decision process, information flows, interaction spaces (formal *vs.* informal), management style (leadership and managerial culture), social relations (diversity, intensity of links, group's cohesion, conflict, and mobilisation) and knowledge mobilized (tacit *vs.* explicit, individual *vs.* collective).
It is advisable to clarify that we realized an intra-case analysis – summary of project and its trajectory, exploration of main dimensions, conclusion and synthesis of information provided by the case – as well as an

[2] For each case study, we have interviewed the main actors involved in the innovation process, who have a global and longitudinal view about the different stages of development. The profiles are varied: project managers, executive managers, consultants, suppliers, operational agents, users, elected members, public and private partners, etc. The data collection took place simultaneously for the four case studies from July 2006 to January 2008. The number of interviews by case study is the following: 11 interviews for IRIS case, 9 interviews for AP-HM TV case, 10 interviews for PIW case and 5 interviews for Peaceful-Assistance case. The interview guide is structured in two steps. First, we asked for the actors to retrace the innovation progress. This historic permits us, in a second time, to reorient the interview about knowledge creation stages and their key dimensions in terms of knowledge mobilised and configurations of work and interaction.

inter-case analysis in order to propose a comparative study of four processes. In this paper, we present only the inter-case analysis in focusing on the similarities of knowledge trajectory and key dimensions.

2.2 The Case-studies description

The analyzed innovations are Information & Communication Technologies centric: IT based innovation. They concern the sectors of health and of citizens' e-accessibility. Three innovations had been developed in the Public sector[3] (a French territorial civil service and a public Hospitals grouping) and one in the private sector (energetic enterprise). Yet, in all studied innovations there is a strong interweaving between public and private actors. These empirical studies refer to managerial or service relationship innovations and imply a major change for organizational members and/or users. They take place in broader rule-breaking strategies (Prahalad and Hamel 1989).

The IRIS Project – City of Issy-les-Moulineaux

The IRIS[4] project aims to implement an integrated contact center for citizens and a new system of citizen relationship management – which uses multi-channels communication (phone calls, physical visits, e-mails, mails, etc.). The idea of project has its origins in the difficulties met by the local authority in the processing and follow-up of users' requests (especially the request via e-mail) and in the important communication problems between the different services. The IRIS project aims to make it easier and to improve the follow-up of the requests through a high-performance first level of reception in order to avoid administrative redundancies. These two goals required the development and the implementation of two specific management tools: first, a database, called by agents "*the knowledge base*", common to civil services of the City and second, a web solution of "*citizen relationship management*". This last software allows keeping a traceability of relations between administration and users, dealing with an infinite diversity of requests and collecting in an exclusive database all exchanges with citizens[5]. Through this project, the local authority of Issy-les-Moulineaux wants to reorient its services towards the citizens needs, simplifying the administration access and improving the services' reactivity and the multi-orientation of reception functions. IRIS project led to the constitution of reception team, made up of 8 general and polyvalent agents. This team, supervised by the IRIS project manager, handles alternately physical and telephonic reception and e-mails processing. The project started in mars 2005 and IRIS service has been operational in February 2007.

The AP-HM TV Project – Public Assistance of Marseille Hospitals[6]

In January 2003, the Public Assistance of Marseille[7] Hospitals (in French AP-HM) decides to develop an innovative project in the field of health information: the launch of the first channel of hospital health in France, AP-HM TV. This project responds to the exponentially growing demand of the public opinion for health information and is directly linked with AP-HM's modernization strategy. Top management wanted through the launch of this internal TV channel to improve the institution's image and to accompany the change implied by the global approach of modernization. The AP-HM TV project aims at broadcasting free health programs in the rooms of hospitalised patients. The program schedule offers mainly information about hospitalisation, Institution news, Health advices, and broadcasts on sport, culture, and medicine history. In parallel, the project involves a Human Resources side: program design and broadcast of training and professional information. All staff programs could be viewed at chosen times. Besides, to be an information support for the non expert public and an internal communication tool for the AP-HM staff, the channel had to be a vector of valuing for all the hospitals actors. The project leads to the creation of an audiovisual service including nine professionals and connected with the AP-HM communication service. This ambitious project holds a high cost, estimated at 800 000 Euros by the project manager[8]. Therefore, for the key actors the main constraint was that the TV channel should rapidly generate revenues (financial partnerships, advertisements, broadcast selling…) in order to

[3] Increasingly, the public sector aims to improve the relationship management by developing electronic services (e-administration, e-government, e-proceedings ...). ICT seem to offer opportunities for the simplification and the personalization of public services through the creation of new interaction processes between the public organizations and their users.

[4] IRIS means Information and Reception Center for citizens of Issy-les-Moulineaux (City near to Paris)

[5] Even requests expressed orally (by phone calls or physical visits at town hall) are retranscribed in this knowledge base in order to be handled afterwards by the appropriate service.

[6] AP-HM is a regional grouping of hospitals.

[7] City in the south of the France.

[8] AP-HM TV caused multiple investments – for example: the recruitment of audiovisual professionals, the building and equipping of production studios, the buying of media equipments, etc.

foster its perennity. The AP-HM TV has been launched in June 2005. Several partnerships had been established following it to enlarge the broadcasting areas of the AP-HM programs.

The Protection of Isolated Workers (PIW) Project – Public Assistance of Marseille Hospitals

In 2004, in a French psychiatric Hospital two nurses had been killed by a patient. This event engages a national debate about the security and demobilization of the staff in this kind of sanitary structure. Following this debate, the AP-HM initiated a large review of the protection and surveillance of its isolated workers and decides to develop an innovative project based on GSM and geolocalization system. The PIW project, strongly supported by the civil service trade-unions, necessitated a global renovation of AP-HM's telephone network. After two years of project development, this led to the implementation of intelligent mobile phones which ensure the security of all isolated staff (more than 1000 agents). The PWI system includes two kinds of alarms. The first one is based on the lack of worker movement (potentially in the case of aggression) which induces the setting off of the alarm system. The second protection system is an alarm button which can transmit an alert on the request of the agent. In all case, the alarm sends a vocal message pointing out the number phone of attacked agent and the geographical positioning of the aggression. The stake of this innovation could be defined as the celerity of intervention and so, of prevention. The main difficulty to implement the system was to define the individuals to prevent in case of alarm and to detail the different areas of hospitals where isolated staffs work. If this kind of protection system is not unique for the AP-HM[9], the project originality consists essentially in its implementation within such a complex structure. Moreover, other innovations had been caused by this project. For instance the renovation of telephone network – with the change for Internet Protocol (IP) – allowed to fit up the most of staffs (nearly 15000 agents) with mobile phones, to create a central "call center" for all the hospitals and to develop a multimedia pass for patients.

The Peaceful-Assistance Project – EDELIA

This innovation project was developed by EDELIA a subsidiary of EDF[10] (Electricité de France). "Peaceful-assistance" is a system of teleassistance aiming to maintain the independence at home of seniors. It consists in a double security system for isolated people: a bracelet combining "hands free" portable telephone, intelligent alert system developed by Biotel and a control system at home of the water consumption. This last system is the real novelty of the service offer. Departing from the catastrophic diagnostic of the canicule in France in 2003, Edelia wanted to develop an adequate protection for the seniors isolated in the case of accident. Therefore, an innovation project allowing the control of water consumption has been developed. A system alert sets off when the isolated senior does not consume water during several hours. This mechanism has been experimented within the City of Laval[11]. Since 2007, it is now available everywhere in France with a monthly subscription. The medical platform which manages the alarm system is located in a hospital. The staffs are health professionals that knows how managing the emergencies.

2.3 The results of Case Studies

2.3.1 The stages of knowledge creation within innovation processes

The analysis reveals that if the almost of I-Space stages were clearly identified in the studied innovations, two I-Space stages remain overlapped and two others appeared. The located stages of I-space model concern scanning, codification, abstraction and diffusion. The overlapped stages of I-space model are the two last: absorption and impacting. Indeed in the four cases, these were not the subject of the two different processes but on contrary they seem strictly interrelated. At last, we observe that two supplementary stages appeared from the analysis of cases studies. They take place in the depths of the innovation progress – between the stages of codification and abstraction (figure 1). We have called these two emergent stages: *valorization* and *problem solving*. In order to facilitate the briefly statement of knowledge stages, we present them in their apparition order in the studied innovation processes (sequential presentation of the results)

1) ***Scanning*** is an essential stage in the four studied processes. Essential in terms of duration (on average one year for each project) and in terms of project conception. The innovation idea and the project principle appears

[9] At the time when the AP-HM develops this project, the system of PWI though GSM exists already in enterprise especially in factories.
[10] EDF is the historic operator of electricity in France
[11] City in the north-western of France

during this phase. For the IRIS project, the key actors practised a monitoring activity of innovative practices about citizen relationship management in public organizations and about customer relationship management in private organizations (integrated contact center, software of CRM, etc…). This scanning allowed actors to give a sense and a direction to the project, primarily initiated on the single idea to avoid the administrative redundancies. A key element of this trajectory is the detailed specification of the users' needs. If the identification need was at the origin of projects, this stage permitted to clarify its frame, nature and scale. The end of the scanning trajectory marks the real project launch – since the extracted information is linked with the objective and strategy of the structure – while it should be noted that this trajectory can be re-activated later in the process. Thus, in the AP-HM TV case, looking at the project scale and cost, the actors speak about a permanent monitoring activity: a continuous scanning.

Key dimensions – In this stage, the forms of knowledge mobilized are explicit collective (documentation, book, paper, etc.) and tacit individual (intuitive and relational knowledge). The confrontation of these two forms of knowledge allows the emergence of an abstract knowledge on the innovation idea and a shared belief about its legitimacy. The organizational configuration associated is flexible and informal. The innovation process does not require project structure and coordinator because of the number of involved actors is low. The information flows are fluid and emergent and mainly oriented towards external environment. The diversity between the key actors is moderated (but estimated as essential the by the interviewed actors to explore the external environment) and the intensity of links is strong (complicity and proximity between the key actors – voluntary mobilization).

2) ***Codification*** consists in the definition of the exact content of the project. *"What can we really make and how do we realize it?"*[12] During this stage the project team is really formed and extended. Key actors appeal to skills and specific expertise outside of the initial group. For instance in the PWI case, the key actors created an expert committee, regrouping a multitude of stakeholders – health professionals, lawyers, users, Information System experts, etc. in order to develop a viable security system for isolated workers. The codification stage leads to the writing of a formal strategic document: a call for tender for the IRIS and PWI projects and a business plan for the AP-HM TV and Peaceful-assistance projects. Contrary to the first stage, this one is relatively short – less than four months for each project. The project is, at the end of this stage, marked out and the necessary investments for its development can take place.

Key dimensions – To formalize the innovation concept, the forms of knowledge mobilized are explicit individual (expertise and declarative knowledge[13]) and tacit collective (a shared belief). This permits the emergence of a collective knowledge both explicit (works of group) and tacit (collective knowledge[14]). We observe, in the four case studies, that a project structure "ad-hoc" appears in this stage. It materializes by the informal and regular interactions between the involved actors. The interaction spaces and information flows concentrate at the level of "group project". If the project structure is still flexible, the roles and responsibilities become clearer. Moreover, with the participation of new actors the diversity increases and the intensity of links decreases. It seems to favour a rich exploration of possibilities concerning the innovation content.

3) ***Valorization*** ensures the legitimacy and merit of the project in order to mainly avoid potential resistance to change or blockings. In this stage, the key actors learned to sell the project at all levels and became Public Relation Agents. Internally, the aim is clearly to rally as much as possible around the project. It appears, in case studies, via the organization of work meetings and groups, idea boxes, brainstorming, etc. trying to associate as many actors and services as possible with the project objectives. In external, the main objectives are to facilitate the project external recognition, its future appropriation by users and to develop partnerships. The Key actors communicate on the project through information meetings, web site, municipal bulletins, specialist publications, conferences, etc. In public organizations, this stage seems particularly crucial. Indeed, with the complexity of their actors' gaming, the implication and commitment of stakeholders are requisite guarantee for the project pursuit.

Key dimensions – In this stage, the innovation perimeter spread with the multiplication of informal and formal meetings. The information flows intensify and diversify. The use of ITC is here particularly essential to diffuse the concept of innovation. The forms of knowledge mobilized are essentially explicit collective (codified knowledge about the project) and tacit individual (relational knowledge). The redundancy of information seems propitious both to the diffusion of explicit knowledge and to the circulation of tacit knowledge (Nonaka, 1994). In fact, the shared belief about the innovation legitimacy spread. Moreover, with the increasing of interactions

[12] Actor of the AP-HM TV project team
[13] In the sense of Argyris and Schön (1978)
[14] In the sense of Lave et Wenger (1991)

the key actors mention (directly or indirectly) a phenomenon of serendipity[15]. The research of adhesion allows to make lucky discoveries. In this stage, the project structure becomes more formal and planned. The interactions with internal[16] and external environment of the project require more of coordination. But paradoxically, the flexible and emergent project structure of previous stages does not disappear. It seems necessary to maintain these two kinds of structure to organize the work without harm to the creativity, initiative, and autonomy of initial group. The diversity between involved actors reaches its paroxysm (very strong). But it goes with the emergence of minor conflicts (of means or interests). In parallel, there is a coexistence of strong and weak links.

4) ***Problem Solving*** is really specific to innovation project where the development of a unique formula needs proceeding by experimentation. The four projects, in the development stage, encountered several difficulties and required continuous adaptations through an iterative learning. In the AP-HM TV case, for instance: the building of channel premises was delayed; the equipment was not adapted; etc. Thus, the stock of broadcastings necessary for the channel release could not been constituted and the technical breakdowns with the internal cable network was continuous. Related to all these issues, the first weeks of broadcasting were chaotic. In the analyzed cases, this problem solving stages is relatively long and delicate. The difficulties being linked together, it is crucial for the project final success, to operate unexpected arrangements: in other words, to manage the team's imagination. This stage appears in the projects throughout the development and deployment process of the innovation. It only ends with the work stabilization, in other words with the end of the creative process (during the diffusion stage)

Key dimensions – To transform the innovation concept into concrete achievement, numerous forms of knowledge are needed. First, explicit individual knowledge with expertise, declarative knowledge, personal works (...) of involved actors. Second, tacit knowledge both individual (practical and procedural knowledge) and collective (shared belief, collective knowledge, routines, collective improvisation). The tacit collective knowledge seems essential to develop innovation. A community of practice establishes, shares experiences by action and develops common language. Within the group of innovation, the cohesion is strong (common objectives, feeling of membership, permanent dialogue, etc.). The mobilization is realised by and for this community of creation. The cohesion and collective mobilization allow managing the diversity (professional, cognitive, cultural) by the development of strong links within the innovation group. Nevertheless, weak links are kept with external actors in order to favour the integration of new knowledge. In this stage, the most of analyzed dimensions evolve. The formalization of objectives, activities and control procedures, and the specialization of tasks, roles and responsibilities become requisite. The leadership is more and more directive to make progress the project. The information flows are more centralized and programmed. In spite of this movement of planning, the creativity, the flexibility, the polyvalence and the iteration culminate (i.e. whereas the project structure become more rigid). The innovation development can be viewed as a process of auto-organization in which innovation progresses between movement of stability and instability, between formal and informal structuring.

5) ***Abstraction*** is identified during the implementation of managerial innovation or the introduction on the market - for the Peaceful-assistance innovation. This stage is characterized by the emergence of new approaches linked to the project. Key actors attempt to grasp the opportunities connected with the project development itself or with its environment in order to increase its scale. In all cases, abstraction produces the addition of new parts of the projects. In the case of Peaceful-assistance project, abstraction allowed to add the "hands free" bracelet to the innovation. For the IRIS project, the implementation allowed to change from a unique centralized contact center – materialized by a unique place, a phone number and an e-mail – to multiple decentralized contact centers. The idea is the following: users can obtain reliable information whatever the contact point with the local authority. In addition, the applications of the CRM software that provides the requests traceability was broaden with the building of performance indicators on the services' activity. Yet, the studied abstraction stages exceeded widely some quoted examples.

Key dimensions – While the creation of new concrete knowledge and the development of new artefacts, the innovation process comes into an exploitation phase of existing capacities (March, 1991). The structure project takes a form definitively more formal. It is no more a question to create the innovation track but to manage its potentialities. The community of creation become here a community of work. The forms of knowledge mobilized in the abstraction stage are essentially explicit collective (scanning).

6) **Diffusion** is the logical result of the abstraction stage. When the new approaches of the project have been clarified, the new applications of the innovation should be diffused. But the project extension makes the diffusion difficult. Indeed, if the soundness of new applications is not fundamentally questioned, the lack of

[15] Creative exploitation of contingences.
[16] Internal environment refers to the organisation

preliminary communication can create some issues. In the IRIS case, the decentralized contact centers and the broader scope of the software applications produced internal resistances. And yet, the new parts of the managerial innovation have not reached an optimal operation. This stage is often similar to a perilous phase where the potential blockings are numerous.

Key dimensions – the innovation perimeter is extended (organization and its relations with users/consumers). The information flows are fragmented and the decision process is more centralized. The project structure evolves progressively towards an organizational structure (e.g. audiovisual department for AP-HM TV case, IRIS department for IRIS case) or disappears if the innovation is managed by external partners (PIW case or Peaceful-Assistance case). The mobilization is now more individual (i.e. interest for the work). The creativity gives way to routines and knowhow.

7) ***Absorption-Impacting*** is characterized by several dimensions. The first is similar to the appropriation of innovation by internal actors and/or users. Appropriation means here use and interiorization. In the studied case, the stage of absorption- impacting had been achieved without major strain. So, the innovations have been interiorized by stakeholders to become now an integrated part of the running structure or of the market solution. That had an impact on the internal operations of these organizations as well as on the structure of relationships with its users or customers. This absorption-impacting stage characterizes the innovation project success or failure. In the studied cases, the analyses allow us to qualify the innovation projects of success.

Key dimensions – This stage does not concern the innovation group but the users of innovation. Thus, the essential dimensions change here. Abstraction depends on the quality of the other stages: i.e. the identification of needs, the positioning on the market, the originality of product or service and the utility of innovation (Rogers, 1995). The technology acceptance is, in this stage, crucial. In the PIW case, the system is combined with mobile phone that makes easier the appropriation. Another instance with Peaceful-Assistance where the control system of the water consumption is not constraining.

If the stages of diffusion and abstraction are interesting to understand the general dynamics of innovation process, they are not directly connected with the community of creation which is the focus of this research. To more detail these stages, it seems necessary to adopt a perspective on innovation diffusion and to question the users' point of view.

The analysis of knowledge stages allows highlighting some elements. First, it is advisable to underline, that the knowledge stages are similar in the four innovation processes. Second, we must notice equally that if the I-Space model can be apprehend as a interesting framework, it requires noticeable adaptations due to the specificity of our research object : the development of a unique approach that is not the simple knowledge transposition and adaptation. "*Valorization"* refers to a process of legitimization of the innovation concept. It symbolizes the political dimension of innovation (Akrich, Callon and Latour 1988), especially in the public sector where the financing of innovation is often little stabilized. *"Problem solving"* deals with the real development of innovation (artefacts building). It can be viewed as a second stage of codification, in the sense of Boisot's Model.
At last, we observe that the innovation processes seem evolve in seven different but interdependent knowledge stages. Interdependent, because we observe a complex dynamics of evolution which is characterized by adaptation loops for some knowledge stages as well as by feedback process between stages.
For illustrate this point, we use the method of visual mapping (Langley, 1999) to shows, with the example of AP-HM TV case, the dynamics of the knowledge trajectory (figure 2).

2.3.2 The dynamics of knowledge trajectory

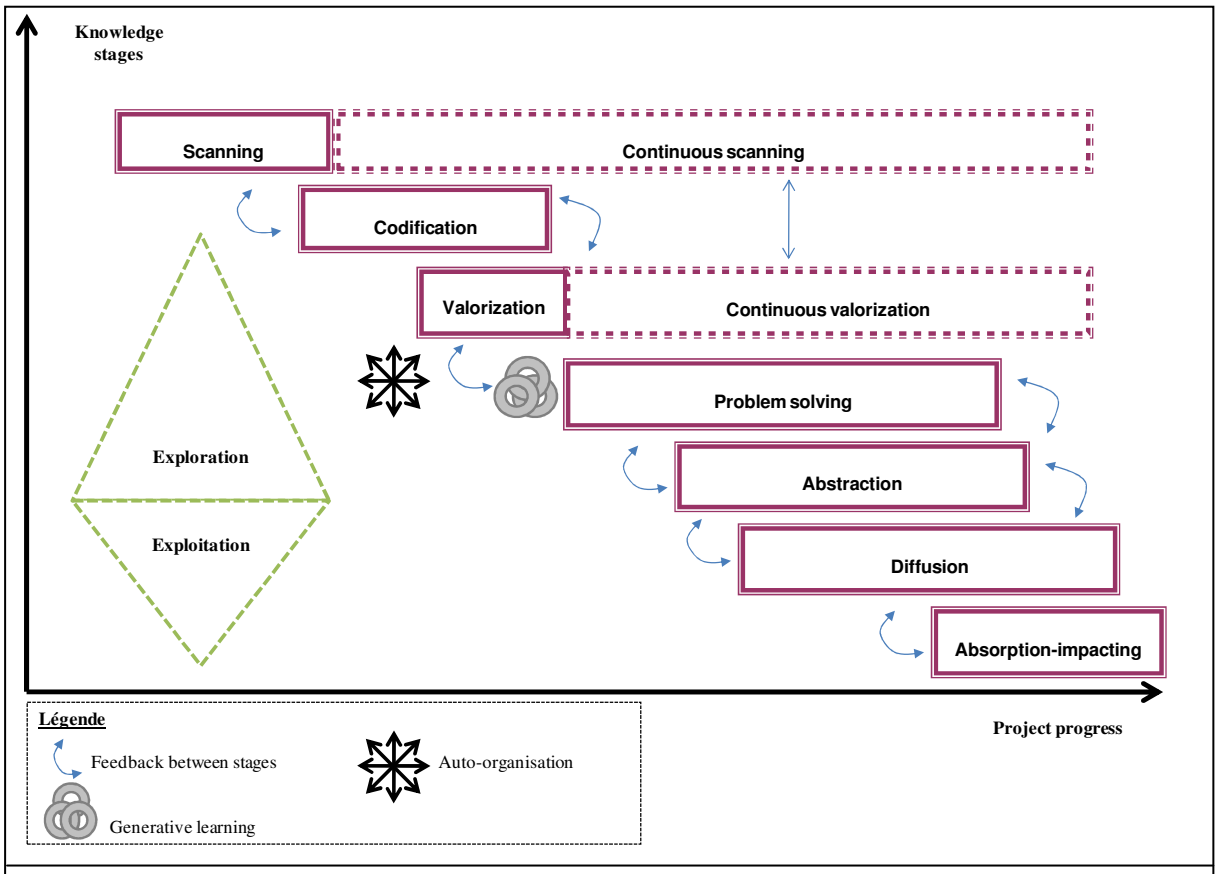

Figure 2: The Knowledge trajectory dynamics within the AP-HM TV project

This Figure reflects the extremely complex dynamics of the AP-HM project. All the stages are inter-connected and the most appear simultaneously. The scanning process is related to a continuous monitoring activity which drives the project realization and allows to grasp the development opportunities. Here also, numerous adaptation loops shape the process where generative learning occurs (Argyris and Schön 1978). It is a creative learning which aims at a new conceptualization of activities, objectives, etc. in order to offer a "palette" of possibilities more extended. It produces a creative destruction of old conceptions. The problems solving stage is subject of arrangements and multiple adaptations. It is extremely chaotic and each difficulty could stop the project. The community of creation develops the innovation essentially with a process of unlearning and new learning (Hedberg 1981). We also observed feedbacks between all stages logically interrelated on the one hand and between valorization and scanning, on the other hand. For example, the diffusion produces new ideas of abstraction; the codification needs to reactive scanning of external environment, etc.
Another specific aspect of this process is the development in parallel of the stages valorization, problems solving abstraction and diffusion. Key actors began, indeed, very quickly to valorize the project in order to facilitate the stakeholders' adhesion and support, without interrupting this stage before the final implementation of channel. The diffusion stage appears very early in the process while the difficulties are not quite resolved.

If each innovation project follows a specific dynamic, some similarities appear. We observe an entanglement of knowledge stages throughout the innovative processes. These stages are widely interdependent, explaining the feedbacks processes. The success of one stage is strongly linked with the success of the other ones. The problem solving stage can be viewed, in all projects, as a stage of chaotic development requiring numerous iterations and adaptations. The diffusion stage is also a delicate process, because the abstraction stage makes it more complex. Finally, in all projects there was a necessity of multiplying scanning activities in order to encourage an optimal development of the projects and to make profitable the realized investments.

We observe equally that the innovation projects integrate both processes of exploration and exploitation (March 1991). The four first stages refer to an exploration process: the innovation concept as well as its "artefacts" are continually experimented, discussed, negotiated and reinvented. The creativity and the improvisation characterise this exploration dynamics. In four case studies, the concrete development of innovation with the problem solving stage takes place at the edge of chaos. The main dimensions of organizational configurations change progressively of form and nature (information flows both emergent and fluid and centralized and programmed, decision process both participative and directive, structure project both flexible and informal and rigid and formal, etc.). The transition towards a more stable state is conditioned by the cohesion and the mobilization of group and so, by the development of a repertory of tacit collective knowledge.
At the opposite, the three last stages concern an exploitation process. The actors apply to take benefits of their experimentations. This exploitation dynamics occurs with the emergence of a new organizational arrangement. Here, organizational capacities of planning and specialization are needed to develop the performance. Little by little, the innovation configuration stabilizes and the actors' work becomes more repetitive.

2.3.3 Discussion of case studies

Between formal and informal: a management of the dialectic order vs. chaos?
On several stages[17] the studied innovation processes reveal the coexistence of informal and formal structure of interactions. More the innovation progresses, more the interactions produce a planned project structure, which constrains, in return, the exchanges between actors. The stability is reinforced in order to "sail" within uncertainty. But in the other way, the informal structures of interaction are kept and widely used by the key actors to favour creativity, autonomy, initiative and flexibility. The movement tends, at the opposite, to the instability. The knowledge creation takes place within the complex system where contrary strengths oppose (Thiétart and Forgues, 1997). Thus, we observe in these case studies a management between order and chaos, at the edge of chaos (Stacey, 1995). These results show that the knowledge creation within innovation processes is not just facilitated by emergent and flexible structures of action and interaction but more than the continuous research of equilibrium between informal and formal.

A tension between the diversity and the intensity of links
These case studies show also a tension between two dimensions of knowledge creation: the diversity of agents and their intensity of links. To develop innovation, the actors of initial group need to mobilize different expertise in enlarging the community of creation. It concerns, in other word, to increase the diversity within the group to explore the different possible solutions and allow their realization. We observe systematically during the stages where the diversity increases (new actors are introduced) the emergence of weak links. Yet, if this increased diversity and weak links favour exploration, experimentation and creativity, they come also with conflicts. The diversity of approaches and the lack of proximity between actors cause a breakdown in shared beliefs and common language of the innovation group. That is to say, a strong diversity does not facilitate the sharing of tacit knowledge if there is combined with strong links. These observations seem to confirm the March' theory (1991) about organizational learning. However, the research underlines the possibility to manage diversity with the preservation of informal spaces of interaction. In the four studied cases, the proximity and the complicity are sought to take benefits of multiple approaches (professional, cognitive, cultural, etc.). The project leaders tend to valorize the "weaving" of strong links within the enlarged group in encouraging continuous and spontaneous dialogue (socialization in the sense of Nonaka, 1994)

Une communication extensive favorable à la création de connaissances
A last interesting element, highlighted by these case studies, is the importance of extensive communication (Brown et Eisenhardt 1997) for knowledge creation. The multiplication of information flows seems favourable to both knowledge diffusion and creation. We observe the alternation of fragmented flows towards internal and external environment of project and concentrated flows within community of creation. The fragmented flows aim to diffuse explicit knowledge and to grasp new knowledge while the concentrated flows allow to develop the tacit collective knowledge which decisive to codify and develop the innovation.

These results show finally three key interdependencies about the knowledge creation within innovation processes: a first interdependence between formal and informal interactions, a second interdependence between diversity and intensity of links and, at last, a third interdependence between information flows within group and information flows with external environment. We propose in the following section the building of an agent-

[17] Valorization, problem solving and abstraction

based model in order to explore more in depth the influence of these interdependencies on the knowledge creation. This next step in our research could be useful and relevant to enrich our understanding of these complex processes. Multi-agent simulations allow modelling and visualizing the key conditions of emergence and auto-organization in complex system (e.g. Cartier 2003; Dooley and al 2003). *"Research in artificial context provided us with the insight that, instead of reducing the complex world to simple simulation models which are never correct, one could equally define some simple rules, which then produce complex behaviour"* (Baets and Van der Linden, 2000).

3. Agent-based model to explore the knowledge creation dynamics within innovation process

3.1 Introductive elements

A multi-agents system (MAS) is selected in this research for two main reasons. First, this simulation method allows to define with precision the attributes of agents. For instance, MAS permits to deal with cognitive agents, able to « reason » and to take decisions departing from their knowledge of environment and other agents. The other simulation methods (i.e. genetic algorithm or cellular Automata) do not provide this advantage. Second, MAS deals with the problematic of emergence, auto-organization and interdependence, and is adapted to explore Complex Adaptive System Theory. It is not necessarily the case of other methods. Genetic algorithm is based on evolutionist perspective of complex systems and deals with the understanding of the optimization or adaptation processes of an agents' population. Automata cellular (as MAS) explores the emergence of structures at macro level from the interactions at micro level but it operates with a territorial representation where the cellular depends on the state of its neighbours (the agents are not autonomous and pro-active). The choice of MAS is justified when the system to simulate must integrate autonomous, decisional and heterogeneous agents.

The model is implemented with MADKIT platform ("Multi-agent Development Kit"). Madkit has the advantage to be based on an organizational model rather than an agents' architecture. As such, this platform is relevant and adapted to our search framework. The different agent models and multi-agent systems are managed through the concepts of groups and roles, while keeping a global structure. Thus, Madkit operates from three principles: the agents, the groups and the roles. The agents are defined as active and communicating entities playing some roles in one or several groups. The groups are similar to agents' aggregations which, in connection with the agents' roles, allow implementing the simulations. Groups also permit to model the interactions between the internal and external agents which are a key element to recreate the innovation project configuration. The roles, finally, are functions or services offered by agents within one or several groups.

The model aims to explore the dynamics of knowledge creation departing from the three key interdependencies underlined with the case studies. This implies to model the main dimensions identified in the literature and confirmed by the case studies. It is necessary to concentrate on few variables in the initial model in order to produce sharp results. Thus, the model set six entering variables:

1. Number of implicated agents (internal and external)
2. Number of link (interaction) between "coordinator group" and other agents
3. Diversity degree of agents (individual and shared mental models)
4. Implication degree of agents
5. Information flow (communication capacity of agents)
6. Interaction structures (formal and informal)

3.2 Model architecture

First, the building of multi-agent model needs to describe the operating principles of model, the agents' characteristics and the simulation environment.

Basic principles

The model makes up numerous agents in interaction to create and diffuse their knowledge. The survival is the aim of agent in the simulation run. It is assessed by the agents' capacity to value their knowledge assets. If an agent does not exchange enough its knowledge assets, he does not create value for the project and goes out the simulation (innovation process). At the opposite, if an agent exchanges too much its knowledge assets, he devalues them – obsolescence phenomena of knowledge – and exits equally the simulation. An experience fund capitalizes for each agent its knowledge assets. It is the financial capital of the agents to create new knowledge

assets (e.g. the costs of interaction and communication). In parallel, new agents can entry in the simulation if the project manager allows it. The rate of entry and exit into the simulation are based on the difference in mean of experience fund between two periods. The rate is set up at the beginning of the simulation for every % change. The innovation capacity produced by the artificial project corresponds to the sum of the all created and diffused knowledge into the periods of simulation.

Agents' characteristic

The agents of model represent the individuals associated to the innovation project. In the initial conditions, each agent belongs to a group and possesses specific knowledge assets (graph of knowledge). We situate the artificial innovation project within an organization which mobilizes internal as well as external expertise in order to facilitate the innovation capacity of team project.

Therefore, the agents of model can belong to:

- *Coordinator group* This group is different of team project. It concerns only the most implicated (in time) two or three agents in the project. The team project emerges from the interaction with the other agents.
- *Internal departments* of the organization which supports the project development (e.g. Executive committee, Information System department, Human Resources department, Juridical department, Marketing department, etc.)
- *External groups* (universities, suppliers, consulting experts, Partnerships, users or customers, competitors, local authorities, etc.)

Moreover, in reference to the CAS theory, the agents of model are viewed as autonomous and heterogeneous entities in interaction with capacities of mobility, communication, cooperation and reaction.

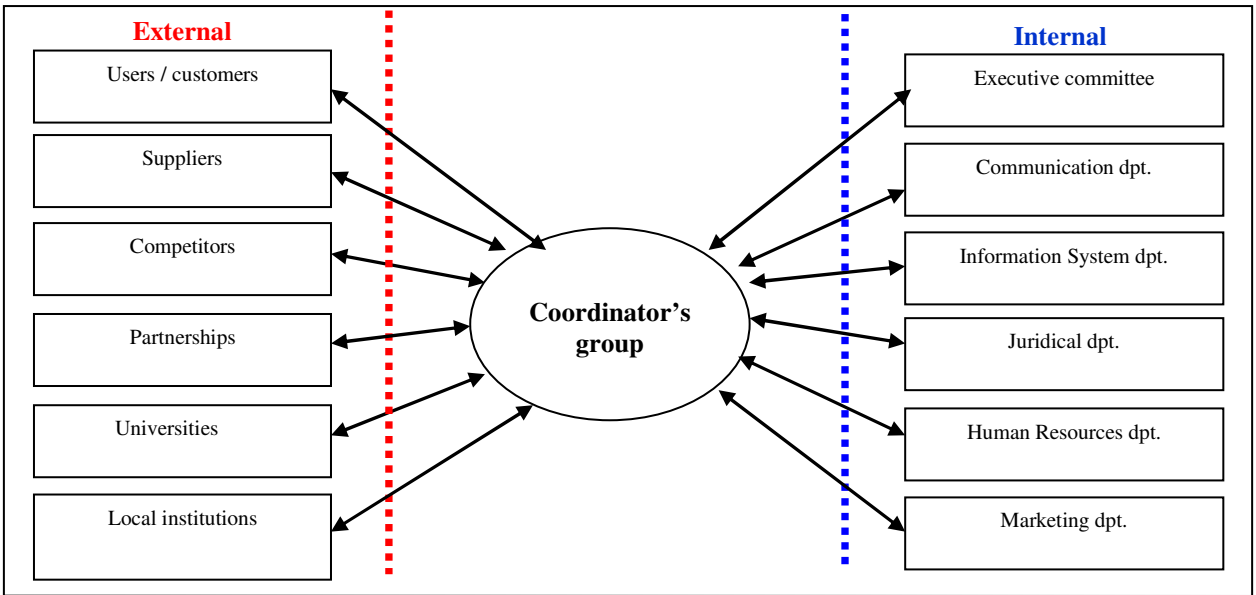

Figure 3 : The social environnement of the Simulation

Environment simulation

The coordinator group is able to associate new internal or external group into the simulation. In parallel, two physical environments are implemented: a formal space (i.e. meeting room) and an informal space (i.e. coffee space or corridor). These spaces allow mobility and interaction of the agents. The group membership sets up the action capacity of agents and their knowledge assets – in the initial conditions. The agents of a same group have mainly a shared knowledge linked to their expertise field (their graphs of knowledge are more of edges in common than with the other group). For instance, the agents of the coordinator group possess a shared knowledge about innovation, in the same way the agents of H.R department have a shared knowledge about Human Resources Management. In the initial model, the shared knowledge for a same group is defined to 60% (60% to have an edge in common) but this rate can be modified. Yet, when they exchange with agents of other groups the knowledge that they can share turns towards a general knowledge. These two kinds of knowledge are completed by a random individual knowledge.

Departing from this knowledge ontology based on graph theory, we calculate the diversity degree of agents according to the number of common edges (in their graph of knowledge). The diversity evolves with the interaction of agents and the knowledge creation process.

3.3 Interaction rules

First of all, the model defines three basic roles:

- Coordinator
- Consultant
- Performer

The internal and external agents can play alternately the roles of consultant and performer in the different groups. For each period of simulation, the roles of these agents are subject to continuous change. The probability to change of a new role is of 20% for a simulation run. The members of coordinator group are the only ones to keep the same role. The roles allow specifying the implication degree of the agents in the project progress. Indeed, for example, the coordinator role implies to be implicated into the innovation project during a large part of the project timeframe. From the case studies analysis, we evaluate that the coordinator's implication is 70% of time, the consultant's role is 50% of time and the performer's role is 30% of time. But, this rate will be modifying with the different scenarios.

In parallel, we define in the model two types of meetings: formal and planed meetings with agenda (group interaction)[18] and informal and emergent meetings without pre-established subject of talk (one to one interaction). For the formal meetings, the exchanged concepts are selected by a random process while for the informal meetings the agents choose the exchange concepts (in their expertise field[19]). According to its rate of implication, the agent chooses to interact either in a formal meeting or in an informal meeting. In the initial conditions, the probability of a formal meeting is of 40% and the one of an informal meeting is of 60%.

The intensity of links is based on the group membership. Four rates are parameterized for each simulation: intensity of link within a same group, between internal groups, between internal and external groups, and between external groups. The intensity of links evolves during the simulation with a "bonus system" for productive interactions (superior to the average of the knowledge creation). More the links are strong between two agents more the probability of interaction within the informal space is high.

The main rules of interaction introduced, it is now necessary to specify the concept of the knowledge assets and the measure of the outgoing variable of the model, the knowledge creation.

3.4 From knowledge assets to knowledge creation

To model with computer the agent's knowledge, it is possible to use a classical system of knowledge representation based on logic models. In this case, the knowledge is modeled in the shape of logic rules and defined often as a function of its nature or ontology – e.g. tacit, explicit, diffused, etc. If these models can be interesting in some cases, they do not permit to analyze the dynamic of the knowledge exchange and creation. According to our research objectives, it seems that the graph models based are more relevant (Boisot and al. 2006). Therefore, we consider that the knowledge of an agent can be modeled with an aggregate of graphs and we use a model called KAGE[20] developed in collaboration with a research team[21] of Paris Diderot University and CNRS.

The knowledge are viewed as an aggregate of concepts (or vertexes) of a graph [(A)] joined between them by oriented links or arcs [⟶]. A knowledge assets can be either a concept, a link between two concepts or a set of connected concepts (a subgraph). The Figure 4 proposes a knowledge representation based on graph.

[18] We limit in this type of meeting the maximum number of participants (in the initial model, it is 10 agents)
[19] The expertise field corresponds to the important "strongly connected component". See the following section.
[20] Knowledge and Agent via Graph Exchange
[21] The name of the research unit is the LIAFA.

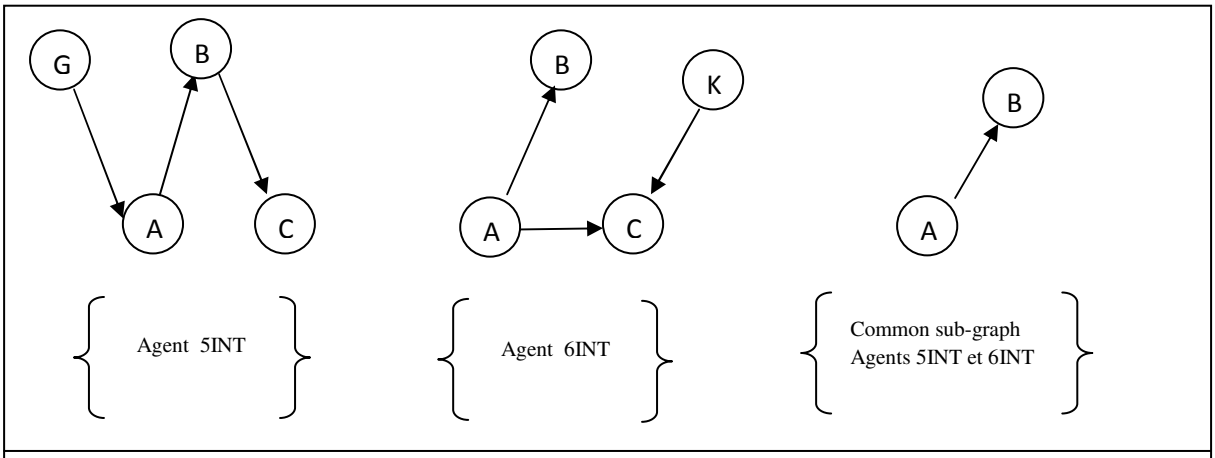

Figure 4: Graph representation of the knowledge assets

In this example, the agents *5INT* and *6INT* share the same knowledge on the concepts {A,B}. This sub-graph {A,B} materialize the common knowledge of these agents. The exchange and knowledge creation can emerge from this sub-graph. Each agent can modify its knowledge graph in taking into account the concepts and links of the other agents. Indeed, after a meeting[22] the agents recalculate and recombine the sub-graphs concerned by exchange. We consider that the knowledge creation takes place when the exchange allows the creation of a "strongly connected component" or composed vertex – {ABC} on the figure 5.

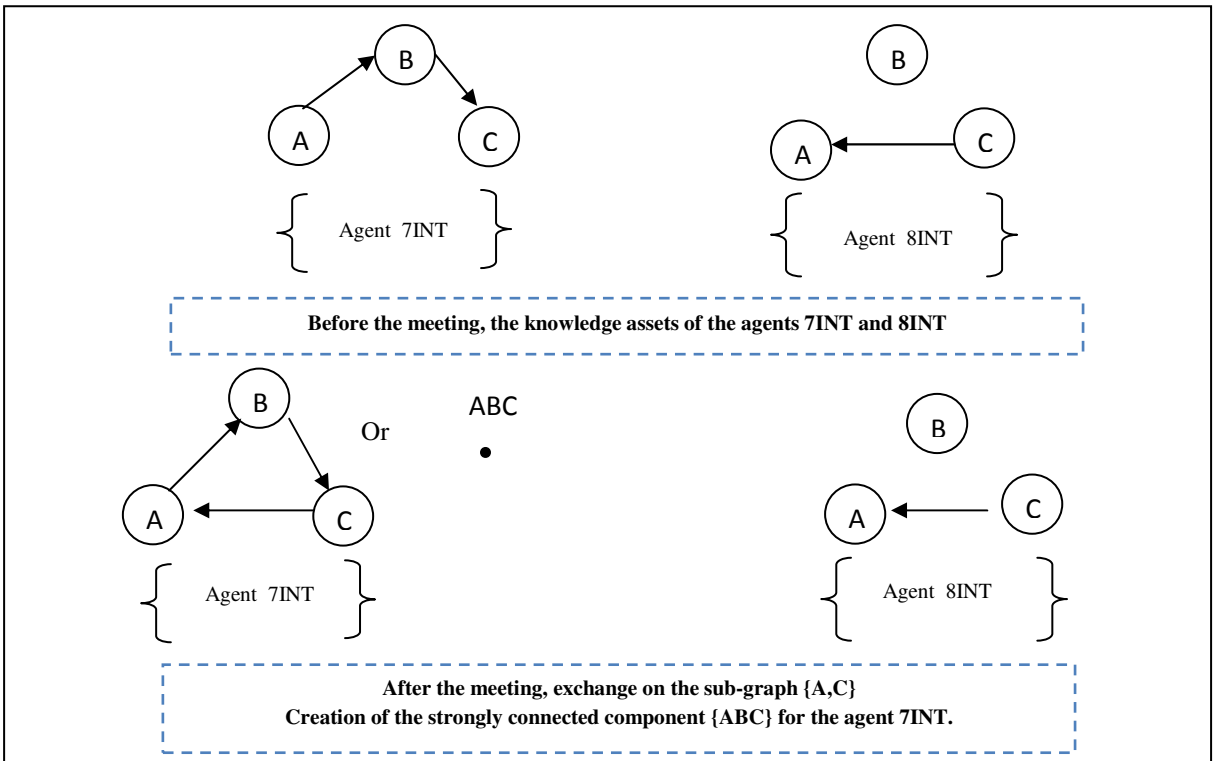

Figure 5 : The creation knowledge process

As the Figure shows it, the knowledge creation is not necessarily symmetric. This process depends on the accumulated knowledge and on the implication of each agent. Over the time, the agents can also lose some of

[22] In the case of formal meeting, the concepts concerned by the exchange are pre-established (e.g. agenda) whereas in informal meeting the concepts are randomly selected.

their knowledge assets. We define a forgetting frequency (5% every 100 cycles) for the edges that are not linked with a strongly connected component.
The agent's knowledge is calculated by a pondered function of the number of simple and composed vertexes as well as the number of arcs. The experience fund allows to synthesize the information linking the individual and collective knowledge assets and their evolution.

3.5 First exploratory results

The simulation was run under varying circumstances (exploratory scenarios) and it lead to some interesting insights about the key dimensions of knowledge creation:
1) In the initial model (moderated diversity and intensity of links), an equilibrium between informal and formal spaces of interaction produces superior results than a configuration of disequilibrium. But, if we change the degree of diversity or intensity of links, the equilibrium is no more the better configuration.
2) A too low diversity does not seem to favor the knowledge creation. The knowledge diffusion and creation "run out of steam". Rapidly, there is no more learning between agents. In this case, the formal meetings are more productive than the informal meetings. If, we decrease the intensity of links, the process of knowledge creation continues longer but the final result of knowledge fund is almost similar. The diversity seems to be a key dimension of knowledge creation.
3) At the opposite, a too strong diversity between agents does not seem equally to favor the knowledge creation, if the intensity of links is moderated. We observe a long period (of simulation) where the exchange of knowledge is redundant and not productive. In this case, the knowledge creation is more important in the informal space when the agents select the exchanged concepts in their expertise field and the intensity of links guides the interactions. If, we increase the rates of intensity of links and the number of informal meetings, the knowledge creation increases equally and becomes widely superior to the first case (low diversity)
4) The results show also that the knowledge creation increases more rapidly if the information flows with external agents is moderated. If only few agents interact with external environment, it is enough to integrate new knowledge in the project group and to reinforce the knowledge creation. The result seems to contradict the CAS theory (numerous information flows with the external environment). Thus, it is necessary to explore more in depth this counter-intuitive result.

Conclusion

In this paper, we show that innovation, understood as a knowledge process, can be usefully informed by the complexity paradigm. By the way of four case studies, we underline that the complex adaptive theory is particularly well adapted to explore the emergent and dynamic trajectory of knowledge within innovation and its key dimensions (interactions, diversity, information flows, and equilibrium between formal and informal). Seven knowledge stages were considered and the key interdependencies between the identified dimensions. The results show that the I-Space Model (Boisot, 1995, 1998) needs to be adapted to the specificities of innovation projects.
Qualitative methodology is useful to understand in depth a social and complex phenomenon as the knowledge creation but seems limited to explore the key interdependencies identified. In fact, it seems that classical methodologies do not reveal the real potential of these ideas from complexity for management issues. Using a complex view to explore the innovation emergent processes has methodological implications. This is why we think that it is relevant to continue this research with a multi-agents based simulation. The first exploratory results seem to confirm the paradox of the diversity for the knowledge creation and to show the interest of an adequate management of diversity. The simulation is, at the present time, in progress.

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