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Orphan innovation, or when path-creation goes stale: a design framework to characterize path-dependence in realtime

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How can we identify whether innovation processes in an organization, a region or a sector are stagnating? Moreover, how can we assess the degree of innovation stagnation? These are issues at the core of the management of innovation literature,and the challenge of how to answer these questions in real time remains a problem yet to be solved, particularly in cases where innovation is highly expected. Most path-dependence studies observe the degree of "innovativeness" in novelty creation and analyze path-dependence and path-creation phenomena afterthefact, relegating the actors to grasping at the lessons learned rather than providing them with a real-time diagnosis of their specific situation. However, in some lock-in situations where the demand for innovation is high –we label theseas orphan innovation situations–characterizing the paths that are potential candidates for path-creation can be critical for the development of the industrial sector.

With the goal of assessing path-dependence in realtime, we develop a framework to visualize three types of innovation pathways (those explored, those not explored but visible in the present innovation field, and those potential pathways that are unknown in the present innovation field). Using C-K design theory as a conceptual framework, we go further and apply this framework to two case studies to explore its utility as a reference for assessing the degree of innovativeness for a field of innovation. We then explore the framework's potential to provide strategic intelligence to break out of stagnant situations.

Keywords: path-creation; path-dependence; orphan innovation; C-K theory

Introduction

Growth and innovation are not always guaranteed in industrial life, even in cases where there is a highexpectation for innovation and where policies, as well as resources, align to provide a stimulus for innovation. Often, when these areas of high expectation become stale, we see the emergence of waiting games or the bursting of the hype bubble,and activity slows down or

vanishes all together. In the case of persevering expectations, these waiting games are often in the form of waiting for “the major breakthrough,” relying on serendipity but also on the potential for the current innovation capabilities in place to produce a truly novel innovation. However, these bubbles often do not burst, the expectations remain and novelty creation advances little, leaving some societal issues orphaned.

Building on the notion of “orphan groups” developed by (Callon&Rabeharisoa 2003), we define an orphan innovation as an innovation highly expected by society, but one which no actor or consortium of actors can manage to process with their current innovation capabilities (Lall 1992; Hatchuel et al. 2006),although all of the institutional conditions to foster it are assembled. An orphan innovation is then a promising innovation field linked to a grand societal challenge, which appears to be stagnating in its innovativeness but still garners high expectations, receives large investments and fosters R&D efforts. Therefore, orphan innovations, despite existing innovation capabilities, rarely arrive to the market and, when they do, are rarely well embedded.

Examining orphan innovation in an unproductive situation, we explore developments in the notions of path-dependence (Arthur 1989; P. A. David 1985) and path-creation (Garud&Karnoe 2001; Meyer & Schubert 2007), not only from a technological and organizational perspective (Mina et al. 2007; Garud&Rappa 1994), but also from a cognitive perspective (Thrane et al. 2010; Kaplan &Tripsas 2008). Indeed, the influence of path-dependence and technological trajectories (Dosi 1982) is of prime importance when explaining technological change. Path-creation brought agency influence back into the picture (Garud&Karnoe 2001; Garud&Karnoe 2003), showing how entrepreneurs can intentionally deviate from existing artifacts and relevance structures. However, if the literature on path-creation shows promise, it falls short indescribingthis phenomenon in real time. Similar to path-dependence, path-creation is always characterized ex-post, when the deviations or path creations

(whether they are successful or not) highlight the paths taken and the other alternatives that have not yet been explored as of a particular point in time. It is then that an examination of past experience can identify the institutional and cognitive mechanisms that lock actors into a particular trajectory.

Thus, how can we assess whether, in the present time, we are in a situation of orphan innovation and locked-into an unproductive state? Moreover, how can we identify and evaluate the possible unknown paths to diagnose the extent of this stagnation and to offer alternatives? These issues appear to remain unanswered in the literature, even though in orphan innovation cases, where the innovation processes have gone stale, it is necessary to unveil these situations to stimulate new industrial dynamics.

The literature has provided a wide set of reasons to explain the lock-in factors, offeredfrom the institutional to the cognitive perspective. However, these factors are intertwined, and it is assumed that there are possible paths that deviate from the path-dependent paths and that these possible paths could be of value tothe entrepreneurs if the lock-in factors could be overcome. However, can we describe at a particular point whichtrajectories are path-dependent and which are deviant, the result of a potential path-creation process? Indeed, it remains unclear how to assess the possiblechoices for exploration to turn awayfrom a current lack of novelty. Thus, this paper builds on the hypothesis that to be able to ascertain the degree of staleness of an innovation process (and therefore to diagnose an orphan innovation situation), one has to capture, characterize and value the pathways that are or have been explored or that remain unexplored.

In this paper, we propose a methodology based on a design framework to demonstrate, in an orphan innovation,how we can assess (1) the paths that are candidatesfor path-creation, and (2) the value these unknown paths could have if they are explored. We further develop these unexplored paths, referred to as paths-in-the-unknown, by drawing on design theory

(Hatchuel et al. 2009; Le Masson et al. 2010)to develop a tool (that we label referential) to ascertain the innovativeness of an innovation field by charting the different paths of innovation. This referencetool not only allows the variety of existing and unknown paths of innovation to be determined, it also provides insights on the value that the paths-in-the-unknown could embed.

We apply this perspective to two cases where the innovative fields appear to be unable to reach the desired degree of innovativeness: (1) ***two-wheeler road safety*** and (2) ***information and communication technologies for autonomy***.In these fields, the innovation activity takes place in the administrative cluster structures known in France, which provide a relevant site for (a) observing exhaustively what happens in the sector; (b) exploring what could cause the orphaned innovation; and (c) discussing with the actors the existing and potential paths. We explore these cases in three steps: (1) the representation of situations where the innovative fields do not produce the expected innovation, i.e., orphan innovation situations, (2) the uncovering of alternative paths that could be explored and (3) the evaluation of these paths in terms of their attainability and potential for the innovation field.

We show how a C-K theory framework helps to represent ongoing path-dependence by visualizing the diverse paths of innovation, both known and unknown. We then discuss these results, showing that the lock-in at the heart of orphan innovation is primarily cognitive and requires the emergence of an actor to overcome innovation staleness, an actor who can play the role of an architect of the paths-in-the-unknown.

Literature review

Path-dependence and path-creation

Lock-in and path-dependence have received much attention over the past few decades (Arthur 1989; P. A. David 1985; P. A. David 2000; Mahoney 2007; Meyer & Schubert 2007; Liebowitz& Margolis 1995; Arrow 2002). Path-dependence initially characterized how historical events could influence the outcome of a stochastic process. The notion was then broadened to emphasize how self-reinforcing processes create a lock-in because of sunken investments and embedding in strongly aligned and widely dispersed networks. More recently, studies have deepened the concept of institutional path-dependence to cognitive path-dependence, showing that cognitive frames are also a factor in path-dependence (Thrane et al. 2010; Kaplan &Tripsas 2008)

Unlocking lock-ins, or deviating from the innovation process, has received growing interest in the past decade (Lampel 2001; Caron &Turcotte 2009). Drawing from the organizational literature, Garud and Karnoe (2001) have argued that there is 'path-creation' just as much as 'path-dependence.' They acknowledge agency influences in the form of 'mindful deviation' and the mobilizing of resources by designers and entrepreneurs leading to the creation of alternative paths (Garud&Karnoe 2001; Garud&Karnoe 2003; Stack &Gartland 2003). Therefore, acknowledging mindful deviation is part of the emerging processes, implying that the real-time modulation of processes is possible if the actor that deviates from the existing paths can bring value to the unexplored paths.

Valuing unexplored paths

The traditional criterion for decision under uncertainty is the standard expected utility. Indeed, actors usually value their strategic choice as an expected value (Von Neumann & Morgenstern 1944) by forecasting the probability of success and the utility produced in the event of success. This formulation of utility is generally applied in the modeling of choice when events

are probabilistic.

However, in the case of unexplored paths, how can an actor forecast the probabilities and the utility of the diverse alternatives when some alternatives remain completely unexplored? Some authors have indeed highlighted the difficulty of assessing the value of innovativeness and deviation with regard to existing systems (Höyssä&Hyysalo 2009), as well as the fact that the value of an alternative path is unknowable at the time a choice is made (Liebowitz& Margolis 1995).

Indeed, whether technical, economic or organizational, uncertainty is an inherent characteristic of innovation. A precise knowledge not only of the potential of an innovative project but also of all of the potential alternatives and possible actions to be taken in the future is difficult to acquire because the design process involved in innovation can lead to unexpected expansions and require unexpected actions (Adner&Levinthal 2004; Fredberg 2007).

Actors value unexplored pathways by comparing them to the set of options they have already explored: they value unexplored paths as the expected benefit that an unexplored path holds in itself, plus the beneficial externalities that this unexplored path can provide for the existing paths.

Assessing potential path-creation in realtime

Literature on path-creation highlights how entrepreneurs design deviation strategies. The challenge is to design these strategies in real time. The present is the ever-changing entanglement of the past and the future. Mapping the past requires advanced mapping tools but is, in effect, the mapping of known unknowns. Capturing future-oriented indications of path-dependence or deviation relies on an understanding of the actor's strategies, the expectations that guide their activities and the regimes in which they work.

Paths-in-potentia (PiP) can be sub-divided into (1) concepts that exist as *unexplored pathways in the current known* space of the innovation field and (2) concepts that exist as *unexplored pathways in the unknown* areas of the innovation field.

Denomination	Description	Innovation capabilities	Value assessment
Existing paths (EP)	Known paths	Product of the existing innovation capabilities	Known value
Path-in-potentia (PiP)	(1) Attainable paths	Attainable with a re-combination of existing capabilities	Forecasted value
	(2) Path-in-the-unknown	Attainable with new innovation capabilities	Unknown value, high uncertainty

Table 1 – Path description

Mapping these pathways provides a reference for evaluating the current strategies. (Robinson &Propp 2008) developed an approach building on PiP(1) as a reference for start-up firms in the lab-on-a-chip technology field. Researchers have proposed tools for real-time path analysis that are based on endogenous futures (indications of the future that are based on the current known knowns or known unknowns) (Robinson &Propp 2008). However, these tools map only EP and PiP(1) and do not take into account all of the possible alternative paths, falling short of unveiling some of the paths-in-the-unknown,PiP(2), that can only be explored by expanding the innovative capabilities of the actors. PiP(2) has not been developed or explored to date; its evaluation remains fuzzy, which is a gap we attempt to fill in this paper.

In this paper, we will reveal a methodology based on a design framework to show how, for an orphan innovation, we can assess all of the paths, includingPiP(2), that are candidatesfor path-creation and how we can value these paths-in-the-unknown if they are to be explored.

Methods and Tools

Generating explored paths and paths-in-potentia using a design-based tool

Exploring unknown paths implies, therefore,that we must reason in the unknown. Design reasoning utilizing the C-K model (Hatchuel& Weil 2009; Hatchuel et al. 2010) is a promising framework to articulate paths-in-the-unknown for innovation fields in a structured way. The C-K framework models the generation process of objects that are unknown as the interaction of two expandable spaces: a space of concepts (C-space) and a space of knowledge (K-space). Exploration in the K-space encompasses the mapping of the knowledge base necessary for the understanding and the success of a project. A concept (located in the C-space) is defined as a proposition without a logical status in the K-Space (i.e., an undecidable proposition: it is impossible to say if the concept is true or false). The C-space is a tree of undecidable propositions, and each node of the tree corresponds to a partition forseveral sub-concepts of the mother concept. The theory can map all of the imaginaries of a domain in the C-space and can connect these imaginaries to the resources (in the K-space) that support the exploration of the C-space.

The framework has proven to be a useful structuring mechanism and has been applied in many contexts (Elmquist&Segrestin 2007; Gillier et al. 2010; Kazakçi&Tsoukias 2005; Hatchuel et al. 2004; Hatchuel et al. 2011). The interrelationships between expansions in the K-space and the C-space provide approaches for describing and characterizing the three types of innovation pathways: existing paths, PiP(1) and PiP(2). Mobilizing C-K theory can generate more paths than conventional methods of creativity and can better account for the resources that are necessary to explore each innovation route, making it possible to build an argument regarding the value of

each path. Of course, alternative pathways could be unattainable in the near or mid-term and, equally,could have no value.

The mapping of current and future competencies and knowledge and the exploration of the diversity of innovation pathways allow us to evaluate which options can be achieved. Going one step further, we propose to assess (a) the “degree of attainability” and (b) the “degree of potential value” of a novel pathway; that is,we assess the potential value in itself plus the potential externalities of this new exploration for the already taken paths, i.e., the increase of the innovative capabilities.

The degree of attainability is then linked to the quantity of new knowledge that needs to be acquired to explore the unknown path: the higher the degree of attainability, the easier it is to achieve. The degree of potential value refers to the new knowledge and competencies that will be gained during the exploration of paths-in-potentia, which can grant value to both the explored paths and to those to be explored.

Case selection

Although our aim is to extract general findings, we have chosen to focus on a particular area that is garnering attention in innovation policy: regional or innovation cluster approaches that focus on networks and alignment around strategic objectives. These approaches take the form of many instruments, such as clusters, consortia, *pôles de competitivité*(poles of competitiveness, or PoC), open innovation arenas, etc. Theseinstruments are often framed as a means tofocus public and private investment toward grand societal challenges that are not easily met, including orphaned societal issues.

We studied two cases with an intervention-research methodology (Hatchuel& A. David 2007): (1) two-wheeler road safety and (2) information and communication technologies for

autonomy. The two PoCs in charge of these topics provided us with access to all of the information on the projects in the two case areas. In addition to this secondary source data, we gathered first-hand data through targeted semi-structured interviews. The interviews focused on the most prominent key actors in these innovative fields.

We applied design theory to identify the variety of innovation pathways and to characterize them as EP, PiP (1) or PiP (2). For each path, we then characterized the innovative capabilities (i.e., the rules and skills) on which the pathway relied.Did they already exist? Did all of the actors share them? Were they consistent with pre-existing paths? Along with this characterization of capabilities, we needed to assess the attainability of the potential paths and the increase of the innovation capabilities that exploringthese paths-in-the-unknown would provide. Phrased another way, we had to build ***a referencefor the possible innovation pathways to identify the types of pathways and to value them.***

To objectify the orphan innovation situation, we used the C-K theory framework to design the references, i.e., the maps of the knowledge base and of the diverse innovation alternatives, independently from the current focus of the projects.

Therefore, we created a list of the possible innovation pathways, capturing the possible generation of new objects and new knowledge within each field. Each reference has been constructed with the knowledge gained from interaction with the relevant actors in the field (project leaders, experts, cluster managers, etc.) in an intervention-research approach.

We first gathered knowledge and expertise from actors in the sector to determine the knowledge base currently used and the concepts currently addressed. We then expanded this knowledge base and the concept space, redefining the relevant actors, experts, skills, and competencies –further developing the map with a broader set of experts to define the references.

We constructed the references through an iterative process with the experts in the field, andthe referenceswere eventually shared with a wider set of actors in dedicated workshops.

The two PoCs

(1) The *two-wheeler vehicle (2WV) road safety* milieu is observed through the PoCMov'eo, financed mainly by public administrations[1]. Mov'eo focuses on "private cars and public transport safe for man and his environment." For this case study, we had access to all of the meetings of the PoC for 6-months, we conducted semi-structured interviews with the main actors in this area, and we studied 32 European projects.

(2) The *information and communication technologies (ICT) for autonomy* sector was observed from the regional PoC I-Care, financed by the Rhône-Alpes region. I-Care's goal is to promote innovation in the health technologies cluster in the Rhône-Alpes region. We followed the PoCover a 12-month period, had access to 20 projects and conducted semi-structured interviews with the primary actors in the field.

Case studies

Road safety for two-wheeled vehicles

In developed countries, road accidents are the third most probable cause of death. Through several policies and actions for car road safety, such as seat belts or radar for speed control, France has been able to reduce the level of accidents by 44% during the 2002 to 2008 period.However,the number of two-wheel drivers killed on the road has declined at a slower rate

1 The two-wheeler road safety case uses the very detailed and complete work of two students from Ecole des Mines de Paris, Marthe Souquière and Julien Guesnier from 2009

during the last two decades than the other driver categories. New solutions regarding this issue are therefore highly desired to decrease 2WV accidents. Public financing in this area is growing.

Road safety for 2WV; an old but still relevant issue

Road safety has been a concern for over two decades. In 1985, a working-group was created to explore 2WV safety within the European Enhanced Vehicle-Safety Committee. This committee was charged with creating new development activities for the improvement of road safety and identified the steps necessary for this improvement, publishing a report in 1985. The committee stated that the case of 2WD safety was alarming, as only very few studies have been performed, especially for cyclists and moped riders (and then these studies were mainly related to helmets and head tolerance).

Since 1985, little has changed. In 2009, the risk for 2WV accidents was estimated to be more than 24 times that for cars, and although they represent only 1.1% of the traffic on the road, bikers account for 25% of all accidents.

Innovations in this area

Our first phase of investigation showed that over the last two decades, improvements have been made: improving helmets, installing ABS, placing hoops on scooters, adding airbags, considering GPS. It appears, then, that it is not for lack of ideas that there has been no significant improvement in road safety for two-wheelers. However, the small impact on safety from these improvements indicates that they maynot address the real needs of this sector. With little or no evolution over the past 25 years, the innovativeness of the field appears to be stagnant.

A comparison with road safety for cars

However, road safety has improved significantly for cars since the 1970s, reducing the annual number of fatalities by three-fold. This massive reduction is due to two key parameters: the technical improvements in vehicles and infrastructure and the implementation of new regulations.

Road safety for cars is classically considered to be either active road safety or passive road safety (Rumar 1999). The goal of active road safety is primarily to prevent accidents by modifying the behavior of the driver, the car or the infrastructure. Passive road safety devices focus on reducing permanent injuries, providing an area of safety around the driver.

The identification of paths-in-potentia: the active / passive / interactive road safety model

Interviews of "accidentologists" who specialize in 2WV accidents led us to the hypothesis that the classic model of "active/passive safety" doesnot explicate all of the possible paths of innovation on 2WD road safety.Indeed, in the case of 2WD, in over 70% of cases, the accident occurs through an interaction with another vehicle. The interaction between the 2WV and a third mobile actor must be taken into account to understand 2WV road safety. The expansion of the knowledge space into new areas such as the interaction between the driver and his or herenvironment, or the sharing of the road space, revealed to us a path unknown to the current actors in the field: the path of interactive road safety.

Moving further, we adopted a new model: active/passive/interactive road safety. The diagram below (Figure 1), constructed using C-K theory, shows the possible alternatives for road safety within the 2WD concept and the subdivisions within each path of innovation. On this map, we overlaid the possible paths of the 32 projects that we investigated regarding 2WV road safety. It appears that all of them are either on the active path or the passive path and that the path of interactive road safety remains to be addressed.

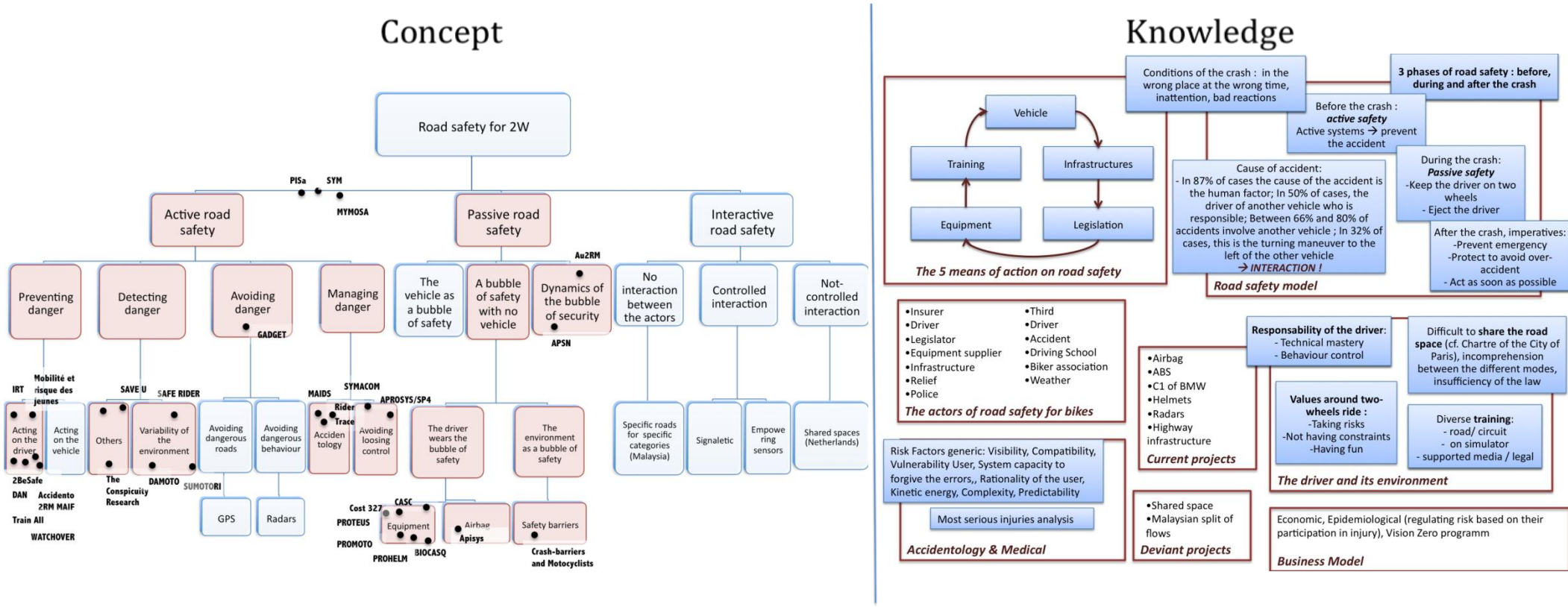

Figure 3: C-K diagram on road safety for two-wheeled vehicles

This diagram shows that the current projects are primarily involved with either passive or active road safety, which is a possible explanation for the current staleness of the milieu. This issue of interactive safety is a highly expected innovation but one that no actor is able to process with the current innovation capabilities, making it an orphan innovation. None of the studied projects focus on this type of safety, and very few experiments acrossthe world over address this PiP(2).

Evaluation of paths-in-potentia: is the 'interactive road safety' path attainable?

Focusing in more closely on "interaction," it appears that even projects on active or passive safety should have gained insights on the possibilities for the interactive safety approach. The driver is not idle but mobile: the driver has many possible actions at the time of the accident. Moreover, a bike is a completely open system (with regards to its environment), a fact that is not reflected by the classic model for cars. When it comes to road safety for 2WV, the interactions are ubiquitous. There are indeed interactions between drivers, interactions between systems, and interactions between drivers and systems.

For instance, an actor addressing passive safety by improving helmets can explore a project on the interactive path, with the helmet being a possible support or a possible media for interaction. Moreover, understanding the type of interaction between a helmet and a car becomes of prime importance.Any project exploring the interactive safety path can provide new insights into 2WV accidentology and improve the innovation capabilities for "classic" helmet projects. The interactive safety path is then attainable, as shown by the detailed projects; it holds value both as a possible path of innovation in itself and in its ability to increase the innovation capabilities of the actors.

Information and communication technologies for autonomy

Context

In the Rhône-Alpes region, the health industry sector and the ICT technologies milieu are two areas that generatethe most dynamic and important activities. There are 250 companies and 19 research centers for health studies, with many subcontractors in different fields (electronics, software publishing, textiles, plastics, etc.). In this context, it is attractive to capitalize on the ICT competences in the Rhône-Alpes to build innovative projects that aim to augment the health sector. We focus on one area in particular that has attracted investment: the need to improve the well-being of people who face a loss of autonomy.

In France (as in Europe) the average age of the population is increasing. The number of French citizens over 75 years will be multiplied by 2.5 between 2000 and 2040, reaching a total of 10 million people, and it is estimated that 1.2 million people will have lost their autonomy by 2040. Innovation using ICT to help people in loss of autonomy is highly sought after.

State of innovation in the field

A number of skills and a significant amount of knowledge must be mobilized to understand the complexities of the issues around the loss of autonomy. There is a plurality of dimensions to consider: ethics (medical ethics), law (privacy, remote processing, medical data), the social area (acceptability, user needs), the technical dimension, the symbolic dimension (connotations of projects, stigmatization of users), and economics (business models, creditworthiness of patients, labeling by social security).

Interviews of cluster managers and entrepreneurs in the field show that the mainstream path in the subject of autonomy addresses monitoring a person in their home with numerous and

various high-tech devices: a medallion that can trigger a remote alarm if necessary, home sensors that can detect when a person falls down and can alert for a rescue. These types of projects have been on the market for over15 years already (and there are plenty of these projects), however, none of them have had any commercial success. Interviews with users reveal that these devices are not well adapted to their needs, they are not user-friendly and they place too much of an emphasis on the user's disability or age. Moreover, as most devices trigger an alert in case of an accident, the accident *still* occurs. Thus, despite a well-expressed need, the innovativeness of the field appears to be stale, leaving the matter of autonomy as an orphan innovation.

We began by defining the actual issue of concern: "ICT and autonomy" was not at the time a clear concept. For sociologists specializingin geriatrics, the term autonomy tends to build a cognitive frame around the issue of disability and the elderly. However, the loss of autonomy canoccur to anyone at any stage of life, through, for example, accident, illness, isolation, or depression.

We redefined the subject "ICT and autonomy" by drawing on interviews with geriatricians to find the boundaries to the issue. We therefore reformulated the problem of autonomy with a new notion regarding fragility or frailty. Fragility has been defined as a "clinical syndrome in which three or more of the following criteria were present: un-intentional weight loss (10 lbs in the past year), self-reported exhaustion, weakness (grip strength), slow walking speed, and low physical activity" (Fried et al. 2001). The notion of frailty was then extended to include psychological and social criteria. The notion describes an intermediate state between robustness and dependence, when the risks of having an accident or developing a disease are higher. This condition is characterized by the risks facing the subject, who can plunge into a loss of autonomy. (Guilley et al. 2003)

The following diagram shows the possible paths of innovation for the fragility issue. We

analyzed projects on the theme of fragility, focusing on either products or services that were already on the market or on ongoing industrial projects. We also positioned the projects financed by the European “Ambient Assisted Living” program currently under development in the Rhône-Alpes region on the diagram.

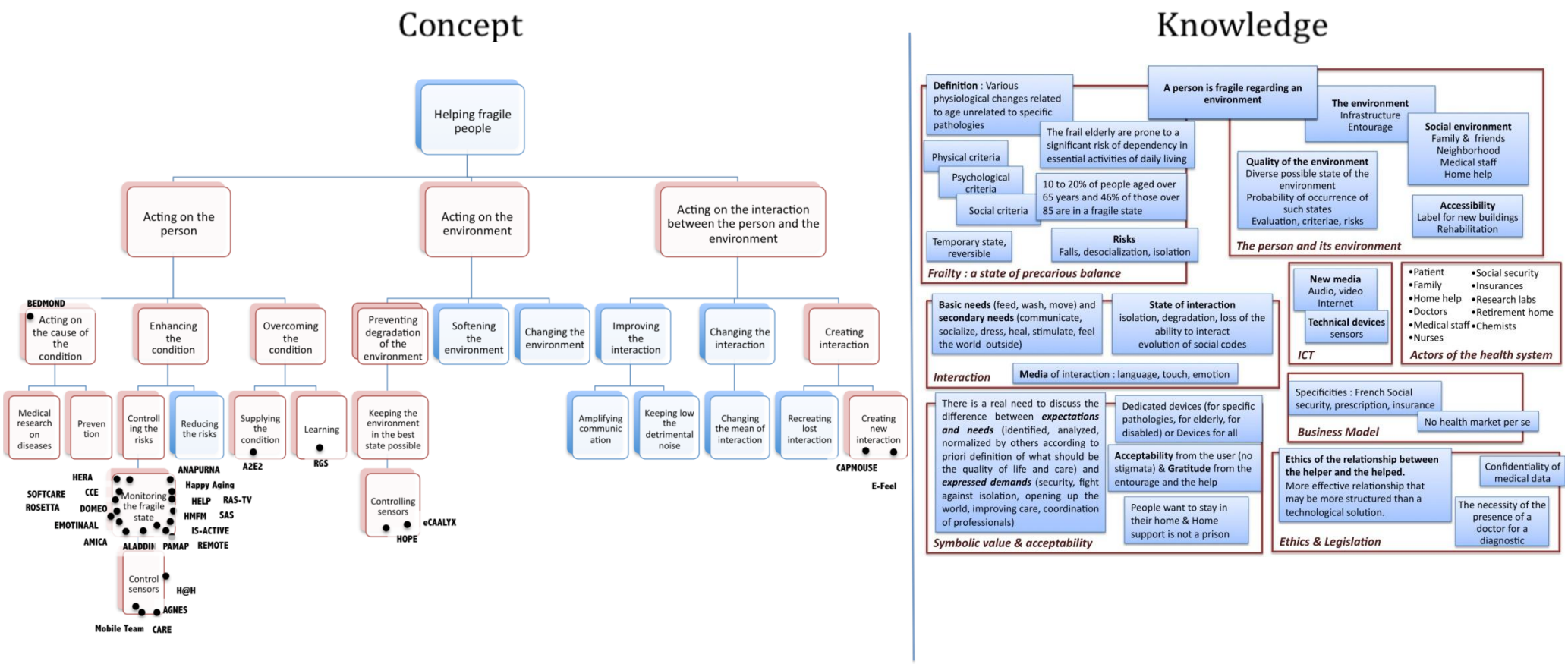

Figure 4: C-K diagram on using ICT to help fragile people

We can identify (a) traditional innovation paths around the subject of fragility, a particularly dominant path which includes 90% of the cases addressed and the necessary skills for any project of this path, and (b) the original paths that are rarely explored and core competencies required to engage in these fields of innovation.

After analyzing the interviews of some of the project managers, it is clear that the actors are focusing on monitoring disabled or aging people, whereas the questions of learning for fragile people, monitoring the quality of the environment or building a new means of interaction between fragile people and their environment remain unanswered. As mentioned previously, this focus on monitoring the person does not respond entirely to the problem, as most devices trigger an alert in case of an accident, but the accident still occurs.

However, these alternatives are attainable: an actor specialized in sensors that monitor, for example, the position (standing or lying down) of a person can position himself on the monitoring of the environment. Instead of monitoring the fall of a person, sensors can, for example, monitor the quality of the environment (the flatness of a carpet, which can be a dangerous obstacle for people with difficulty walking). Moreover, exploring the environment of a frail person and their interaction with it are knowledge bases that will improve the innovation capabilities of actors positioned around the monitoring of the person, granting them a better understanding of the user, their habits, and their entourage.

Synthesis of the two cases

We have described two orphan innovation situations, where some paths of innovation remain unexplored (PiP(2)). Thus, the concept of “interactive road safety for two-wheeled vehicles” cannot be explored by the innovative capabilities in place in France on 2WV road

safety, as the entrepreneurs currently focus on either active or passive safety by improving helmets, designing airbags, and lobbying to modify road infrastructure. In the same way, the issues around a fragile person's environment and the interactions that this person could have with the environment are not yet addressed bythe actors whofocus on harnessing ICT to help people with a loss of autonomy, and most entrepreneurs are involved in designing devices that monitora person'smovement. We next valued these paths-in-the-unknown based on two criteria: the attainability degree, or the quantity of knowledge required to explore the new path, and the potentiality degree, or the improvement this path could bring to the innovation capabilities of the entire milieu. It appears that these paths-in-the-unknown are, in both cases, of great value: (a) interactive road safety will increase the knowledge of the milieu and the abilityof the actors to break from the active/passive model; (b)"acting on the environment of a frail person" will push actors to definethis type of environment and to learn more about the user and their behavior under diverse circumstances.

Discussion

Contribution of the framework

This paper, through the study of two existing cases, has introduced a framework to describe the situation of orphan innovations. In both cases, we have shown that there are some alternate paths, PiP (2), to the current explored paths and the PiP (1); these alternatives are outside of what the current innovative capabilities are able to produce. In other words, there are potential paths of innovation that have value and thatcould be candidatesfor path-creation in both cases.However, the entrepreneurs do not appear to be able to provoke the deviation that would trigger path-creation. The methodology we propose, based on a C-K theory framework, allowed

us to unveil and evaluate the paths-in-the-unknown. The paths-in-the-unknown, PiP (2), highlighted by the C-K diagrams, provide a means to objectify the distance between the expectations in terms of innovation that we have regarding a specific milieu and what the actual innovation capabilities of the sector can, in fact, provide.

A shift in the analysis of industrial dynamics: the cognitive lock-in

Both cases highlight the existence of orphan innovations.The spontaneous innovations of the sector are based on entrenched core-competencies and are not consistent with the identified needs of innovation as they are implicitly focused on a concept that is both restrictive and confining. What we have identified as "attainable" paths, PiP(1), are within the dominant design (Abernathy & Clark 1985) of the field. However, the projects in the EPs and thePiP(1) do not completely cover the field: some paths of innovation (i.e., the matter of interactive security and the environment of fragile person) are not addressed, and the current strategies do not lead to the investigation of these alternatives.

The classic reasons to explain a lack of innovation are usually the inability to achieve a particular technology and the lack of incentives. However, in the case of orphan innovation, the incentives are there: the involvement and support of state structures, huge possibilities for funding, and identified markets. Actually, our case studies show that a possible cause of the lock-in situation is that the current cognitive frameworksfor road safety for 2WD or for the use of ICT for autonomy do not allow the possible deviation that we could expect of entrepreneurs in the milieu. For these actors, the paths-in-the-unknown are not within their scope of design, leading to cognitive path-dependence (Kaplan & Tripsas 2008; Thrane et al. 2010). Thus, diagnosing the potential candidates for path-creation helps to diagnose the nature of the ongoing lock-in factors: paradoxically, the primaryfactors encountered in our case studies are cognitive ones.

Overcoming orphan innovation: breaking from path-dependence

It is evident that this diagnosis of the potential candidatesfor path-creation is not enough to inspire a new dynamic and to overcome orphan innovation. The wait for serendipity and for the heroic entrepreneur able to bear the mindful deviation is, of course,one method for inspiration. However, we would argue for the management of orphan innovation situations, including the emergence of new actors who can play the role of architect for the paths-in-the-unknown, by ensuring the exploration of PiP(2).

Indeed, we can assess that the entire process of unveiling unknown paths-in-the-unknown,PiP(2), requires tight management: generating conceptual expansions, managing knowledge gathering and using design theory imply specific training and methodology. In both cases, the references were exposed to a vast diversity of actors.It appeared that a simple presentation of PiP (2) to locked actors was not sufficient to provoke expansions within the projects of those actors: there is a real need to instrumentalize the un-locking. Overcoming orphan innovation still remains an open question.

Conclusion

The aim of this paper was to present a methodology to characterize orphan innovation situations by assessing path-dependence and potential path-creation in realtime. Because this goal implies identifying both existing *and* unknown paths of innovation, we used design theory to build a referencethat describes (1) the knowledge base of the field and the possible paths of innovation; (2) the position of the existing projects within each path, characterizing these as either existing paths, paths-in-potentia or paths-in-the-unknown; (3) the value of the unexplored paths (as the combination of the attainability degree, or the quantity of knowledge to be acquired to explore the new path, and the potentiality degree, or the improvement of the innovation capabilities of the

entire milieu). We show that in cases of orphan innovation, there are some paths-in-the-unknown that could be of value for entrepreneurs but that these actors do not undertake the mindful deviation that lies at the heart of path-creation. The references built using C-K theory indicate that paths-in-the-unknown existand help to evaluate them, objectifying the gap between expected and attainable innovation.

We have shown how to characterize and diagnose orphan innovation, showing that cognitive lock-in isat the core of this issue; however, the management of methods for breaking out from the cognitive path-dependence and the strategies for an entire milieu to explore paths-in-the-unknown still remain to be addressed.

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