Risk Management strategies in a highly uncertain environment: undesrtanding the role of common unknown

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RISK MANAGEMENT STRATEGIES IN A HIGHLY UNCERTAIN ENVIRONMENT: UNDERSTANDING THE ROLE OF COMMON UNKNOWN

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ABSTRACT

This work deals with strategies of risk management techniques in projects and portfolios in the situation of radical innovation. Existing literature suggests different methods of risk management:

1. Risk minimization at the level of project (S1). These strategies lead to minimize unknown by selecting a priori the less uncertain projects, depending on the identified market risks and technological risk.
2. Risk minimization at the level of portfolio consists in using an existing platform core (minimal system) to construct several options (S2). This strategy increases chances to succeed not by selecting one single, most probable project but by increasing the size of the sample, maximizing the total economic value of the portfolio of derivatives.

These methods consider different level of uncertainties and are independent from each other. Apart from working on different objects (projects or platform derivates) and using different criteria for risk management, they require various competences from managers and different observation techniques.

In breakthrough situations, it is hard to distinguish the management level in between projects and portfolios since the object itself is not defined. To the best of our knowledge in the context of risk management, the link in between literature on uncertainty projects management (S1) and platform management for risk minimization (S2) in radical situations doesn't exist. In practice the tendency is to fabricate exploration project that follows S1' type strategy that is reused as a platform core to address modules of platform after (S1' followed by S2, (S1', S2' – derivatives of S1, S2 in radical contexts)).

We will show that thanks to our literature review there exists another strategy (S3) of working on "common unknown" of multiple options but its managerial implementation is not obvious.

By testing the proposed framework in two cases of Advanced R&D (explorative phase of new technologies development for unknown markets with fixed budget) in semiconductor industry, we compare identified S3 strategy with existing S1' lead by S2'. The paper demonstrates that management of "common unknown" is possible and could be implemented in the context of largely unknown exploration.

The proposed strategy of working on common unknown opens a new way to portfolio risk management in the context of radical innovation. Using S3 framework of knowledge gap identification to construct common unknown core, company can build its innovative capabilities through knowledge management and better position to innovate in emerging fields.

INTRODUCTION

Management of radical innovations is followed by enormous challenges in terms of risks and uncertainty management. How to manage risks when the exploration is in the case of both unknown technology and unknown markets? One would say that it is extremely difficult to proceed in chaos and the exploration is unmanageable.

Let's take a look at concrete worldwide accepted problem of energy harvesting. For society it is well recognized that there is a clear need and the solution will come in a certain technological variety of applications. Energy harvesting is one of well known examples of so called technological lock-in (i.e., Arthur, 1989). The lock-ins are common problems that various industries are facing, their solving is considered to be advantageous for a lot of different communities but solutions are not found yet. Even if for society the need in energy harvesting is known and well spread in between different actors, from innovators point of view, both final forms of market applications and technologies are highly uncertain. Ex post this situations appears to be technological lock-ins and solution that will be created as a common resource. Ex ante the only thing we can argue for is the existence of common unknown. However, the nature of this common unknown is undefined; we don't know what would be the future technological core and which market will be behind. Nevertheless, we know that this lock-in will be common for several markets that don't exist yet. Is it possible to take into account these common emerging needs in technological solutions and reduce risks of exploration based on these common aspects?

Even if each market has a very low probability of occurrence, it is doubtful that none of them will emerge at the end. Supposing we have 20 independent emergent niche markets with probability of occurrence inferior 10%. The probability of at least one market existence at the end is equal to $1-(1-0.1)^{20}=0.878$. The condition for set of emerging markets to succeed is the common interest in between them, a common core. But the challenge is to manage risks on the project that addresses these needs.

Could technological lock-ins be a form of object to manage in between society needs (potential markets) and innovators that allow reducing risks by exploring double unknown? If yes, how do we identify it? What could be the management logic of concept of technological lock-in?

How did they manage steam engine that was an enormous lock-in back in the history? What about invention of worldwide spread plastics? Definitely there is a possibility to discuss lock-ins ex post, but is there possible to manage them to reduce risks of exploration? For example for energy harvesting, how can we identify lock-in? Is it a form of energy control, transformation or storage? The lock-in is a common interest in this case that allows defining the nature of object to manage, a common unknown. Therefore we are interested in risk management strategies that allow working on common unknown.

Literature highlights two strategies of risk management situations, which have a tendency to manage, or unknown or common knowledge:

1. Logic of risk management that considers projects independently (S1). On the level of project there is a tradition of uncertainty diagnosis and risk reduction for pre-defined problem (uncertainty reduction or variation in problem formulation in De Meyer et al., 2002; Loch et al., 2008; Sommer et al., 2009, etc.). S1 lead to minimize unknown by selecting a priori the less uncertain projects, depending on the identified market risks and technological risk. Risks are managed by the project leader. The criterion of "good" risk management is the high probability of success of the project. These strategies deal with projects independently and do not consider common.
2. By comparison, risk management strategies in portfolio (S2) try to take into account common aspects in between projects. The example of this is a portfolio represented by

a technological platform core and its derivatives. The module considered to be defined once the market signal is sufficient enough to conceive it (Baldwin 2008, Baldwin and Clark, 1997, O'Connor et al., 2008, Gawer and Cusumano, 2008, etc.)) (S2). This strategy increases chances to succeed not by selecting one single, most probable project but by increasing the size of the sample, i.e. by being able to play several options, maximizing the total economic value of the portfolio of derivatives. Risks are managed by the portfolio manager or the platform manager. The criterion of "good" risk management is the aggregated profitability of the portfolio (or platform). This strategy works on common, but it is limited to common already known aspects in between projects.

This literature review allowed defining general framework of risk management: objects and nature of risks, actors responsible for risk management and their competence, criteria, and resources necessary to manage risks. We've found out that both defined strategies are contrasted since they don't deal with the same objects (project vs. platform), they are not managed by the same actors (project manager vs. platform leader), require different resources and not based on the same evaluation criteria (success of one single project vs. aggregated successes of multiple projects). They don't treat common unknown.

When it comes to managing the unknown (i.e., technological lock-ins) can one reuse these strategies of risk management? In highly uncertain situations (breakthrough, radical, disruptive, major, etc.), S1 might be impossible, because all projects are too risky and S2 might be impossible because there is no platform available to play several times with limited costs. The literature shows that we have a tendency to fabricate exploration project that follows S1' type strategy that is reused as a platform core to address market derivatives in this case (S1' followed by S2, (S1', S2' – derivatives of S1, S2 in radical contexts)). Don't these strategies attempt to fabricate common unknown as a support for risk management strategies in radical innovation? Thus, can one propose risk management strategy based on common unknown management (S3)? How can we characterize them and compare alternative strategies S3 and combination of S1' and S2' based on the defined framework of risk management? These are precisely our research questions.

Based on literature review, we attempt to define what can be risk management strategies based on common unknown. The purpose is to characterize strategies able to treat risks in double unknown situations.

These questions are not just theoretical, it is crucial to manage risks in high uncertainty environment for high-tech companies. Where should we study our questions? There should be high probabilities of technological lock-ins existence (i.e, various nature of technological problems, challenging competition environment, worldwide spread, etc.), volatile uncertain markets and tremendous amount of potential applications. A priori, in semiconductor industry double unknown situations are not rare. Innovative project teams have to be aware of unknown technologies and commercial aspects in dynamic environment of advanced technology development, take into account emerging society needs and manage technological lock-ins.

In STMicroelectronics (STM), leading European Semiconductor Company, the identification and the development of new technologies is primarily the responsibility of research teams within Technology R&D group. We conduct our case studies at STMicroelectronics, in research units that don't follow classical rules of R&D Management. These groups are not working in the stream of technological effort of "More Moore" (Moore, 1965). Based on The International Technology Roadmap for Semiconductors group (ITRS), this pattern is called "More than Moore" and "Beyond CMOS". There are neither clear scientific question, neither well defined decision to develop new products based on exploration and targeted markets. There is high level of uncertainty both on the level of technology and future markets. Often advanced research initiatives suffer to be accepted by divisions just because they appear to be too risky and conventional marketing risk assessment methods don't justify investment to potentially innovative solutions.

The paper is organized as following. First, we present existing risk management strategies based on literature review and we propose an analytical framework to define and compare them based on: objects, actors and their competence, criteria, and resources necessary to manage risks. Using proposed framework, we characterize strategies that treat double unknown situation and propose a potentially new strategy of working on common unknown (S3). Second, we present chosen research methodology and we analyze risk management strategies in empirical cases of advanced technology development in semiconductor industry in the situation of double unknowness. We identify which strategy of risk management team used through exploration. Finally, we explain the limits and advantages of risk management methods used in advanced technology exploration cases. The article closes with managerial implications of common unknown strategy and directions for further research.

LITERATURE REVIEW AND PROBLEM FORMULATION

Literature and Analytical framework presentation based on strategy of risk minimization at the level of projects and its illustration with platform based strategy

In the literature strategies of risk management at the level of projects are well presented. (Sanchez et al., 2009) showed that project risk management is a well developed domain in comparison to the program risk management and portfolio risk management fields. They stated that for portfolio management it is hard to find particular written methodologies. In portfolios usually we pilot risks case by case without considering influence of project dependencies in overall portfolio performance.

The risk management methods based on uncertainty reduction for identified projects are well represented (a lot of work deals with studies on how decision makers cope with uncertainties (i.e., Lipchitz and Strauss, 1997; Chapman, 1990; projects with variations and foreseeable uncertainties in De Meyer et al., 2002), etc.). Risk management includes techniques to either increase probability of occurrence of an event or increase its impact on the project (or decrease in case of negative risks) (Petit, 2011). These strategies lead to minimize unknown by selecting a priori the less uncertain projects with higher probability of occurrence, depending on the identified market risks and technological risk. The level of uncertainty allows prioritizing corresponding markets (based on market probability) and selects a project associated with maximal economic performance (i.e., Expected NPV, Discounted Cash Flow). The risk management is concentrated on addressing uncertainties associated with project feasibility, market, technology, financial aspects, organizational, etc (Ward and Chapman, 2003).

We analyze risk management strategy that treats risks based on singular projects (S1). In S1 strategy to manage risks one need to know probability of occurrence/success of identified alternatives to be able to prioritize them and select the most favourable project. Marketing should be able to prioritize markets and predefine a dominant one to address. Thus, the resources needed for project risk management are information based on functions, targeted clients, and technical specification. The criterion of "good" risk management is the high probability of success of the project and maximum expected value of identified project with controlled budget. The risk management is concentrated on addressing uncertainties associated with project feasibility, market, etc. Risks in S1 should be managed by the project leaders that are capable to define and calculate information based on probability of success of different solutions, to reason based on both technical and market planning. We consider that the cost of projects exploration is limited by predefined budget of R&D.

Based on strategy of risk minimization at the level of project, we propose a framework of risk management strategy one needs to: 1) establish the context: identify the object of risk itself; 2) identify management criteria; 3) define necessary information to be able to manage risks; 3) choose actor/s responsible for managing and the required level of competence. Therefore, we use this managerial framework to describe and compare identified risk management strategies. For S1 strategy characterization based on four identified comparative criteria see table 1.

Whereas S1 considers projects independently and leads to select more valuable one. The second family of strategies take advantages of interdependencies in between projects. For instance, in case of modularization (Baldwin and Clark 1997, 2004) propose to reuse platform core that helps to address various options that are depending on it. (Baldwin and Clark, 2004) showed how to obtain several available options thanks to common platform. Platforms represent a core of technological system and have to be interdependent with other parts of the system (Gawer and Cusumano, 2008). According to platforms typology (Gawer 2010), we deal with internal, inside firm platforms in this paper. Reusing platform core attempts to minimize risks by constructing several options (Baldwin and Clark, 2004) (S2).

In S2 strategies initial platform core is considered to be available. The objective is to construct market derivatives based on common core. There exist a list of modules with equal rather low probability (not possible to prioritize projects), so one can play several options. Each option attempts to address different market derivative maximizing the total economic value of the portfolio of derivatives. The probabilities of market derivatives are usually low and therefore they are not attractive from S1 strategy point of view.

Expected value of the system is the aggregated profitability of the portfolio (or platform). Aggregated cost value of market derivatives development has to be slightly low and reuse maximally already existing platform core. Each option attempts to address different market derivative maximizing the total economic value of the portfolio of derivatives. Cost of portfolio exploration is predefined by budget of R&D project. Portfolio manager has to know well the platform to identify derivatives. He has to manage the portfolio of options and probability that the set of chosen options is profitable. The information needed for platform driven strategy is based on existence of platform core and cost of each options development (for S2 characterization see *table 1* below).

Table 1 Strategies comparison

Risk management strategy	Objects to manage	Actors	Criteria	Resources
S1	Project	Project manager capable to evaluate potential value, has marketing and technological expertise	High probability of success of identified project Expected Project Value	Information based on: functionality of project, technical principles and future users, etc.
S2	Portfolio of projects (derivatives created by platform core)	Portfolio manager that knows common core and able to define options and test them with low cost	Aggregated expected value of portfolio	Platform core and cost of associated options

We see that both S1 and S2 deal with various uncertainties (mostly variation, foreseeable uncertainties). Interestingly enough, they are actually much contrasted since they don't deal with the same objects (project vs. platform), they are not managed by the same actors (project manager vs. platform leader) and not based on the same evaluation criteria (success of one single project vs. aggregated successes of multiple projects).

When it comes to highly uncertain situations (breakthrough, radical, disruptive, major innovation, etc.), S1 might be impossible, because all projects are too risky. One still could make hypothesis (in case of unforeseeable uncertainty (De Meyer et al, 2002)) based on estimated probabilities of success, that normally change significantly at the end of projects. S2 strategy might be impossible because there is no platform available to play several times with limited costs. In addition, existing literature on product platforms assumes that the platform leader knows the final use of products and is capable to develop these new products (Gawer, 2010). This is definitely not the case in the context of radical innovation when both the selection of platform core and final products use are highly uncertain.

Risk management strategies in double unknown

We call this case *double unknown* because there is both a difficulty to predefine dominant market that can be achieved with associated budget and there is a need of technological effort to develop platform. This is a case where we have both disruptive and breakthrough (radical) innovation at the same time, similar to major innovation (Rice et al. 2008). In these situations risk management is really critical and it is difficult to distinguish if one has to choose a strategy on the level of portfolio or projects. (O'Connor et al, 2008; Paulson et al, 2007) showed that in high uncertainty firms cannot rely as much on existing knowledge as they can in known markets. Uncertainties associated with radical innovation, which requires knowledge creation and application in novel contexts. The risks and unknowns are so high that any Discounted Cash Flow, Net Present Value, or Internal Rate of Return has to be discounted at such a high rate that project or portfolio managers will never accept their too small values (O'Connor, 2006). They indicate that the effectiveness of approaches firms use to manage risk and uncertainty in radical innovation activities is not explicitly addressed.

Various researchers are interested in the way of discovering, managing approaches to double unknown (Loch et al. 2006, Mullines 2007, Krishnan et al. 2002). Innovation journeys (Van de Ven et al. 1992), Discovery-driven planning (McGrath and McMillan, 2009), information gap decision theory (Ben-Haim 2001) diagnosis of unforeseeable uncertainties (Loch et al. 2006 etc.), R&D 2 and marketing 2 (Miller and Morris 1999); (Roussel 1991), a real options approach (O'Connor et al., 2008) propose ways to address double unknown. In real options approach the manage can be based at the level of projects where we explore less risky options to better valorise the project and optimize investments (S1' type). At the same time we can work at portfolio level that able to identify new options, find unexpected market (type S2'). So we have strategies in between S1' and S2'. So we characterize real options approach in between S1' and S2' (S1' followed by S2, (S1', S2' – derivatives of S1, S2 in radical contexts)). What about other identified strategies of management in high uncertainty?

(Loch and al. 2008) provide an overview of existing research on unforeseeable uncertainty. By showing that traditional risk planning techniques are insufficient for management of unforeseeable uncertainty, they suggested that the final method depends on the presence of unforeseeable uncertainty and complexity of the problem. Their work proposed a complementary model for diagnosis of unforeseeable uncertainty by learning problem structure and decomposing the problem. Then by studying each sub problem and isolating pieces by uncertainty they select a trial-and-learning, selectionism or plan-and-achieve target methods. They successfully implemented this strategy to Escend Technology start-up.

This research work summarized two fundamental approaches for management of uncertainty:

- Trial-and-learning approach (Pitch et al. 2002, Van de Ven et al. 1999; Lynn et al. 1998) that consists in iterative trying of selected trials and flexible changes in the course of action
- Selectionism (Lenfle, 2011, Pitch et al., 2002, McGrath, 2001) consists of launching multiple trials in parallel and then selecting the best approach later. Selectionism is often considered to be more expensive and is affordable to use for big problems. Usually selectionism is less time consuming than probe and learning and more suitable for market driven approaches that need faster response.

Based on the framework proposed by (Loch et al., 2008), we can rediscuss identified before risk management strategies in case of double unknown situation:

- Trial-and-learning strategy as innovative problem driven approach is based mostly on S1' because it suggests a process of diagnosing unforeseeable uncertainty by defining the object, problem and knowledge gaps to test potential unknowns (S1'). It provides a certain transformation of initial situation of high uncertainty by formulating the problem and integrating the knowledge. But trials don't just decrease uncertainties, they allow opening new possibilities and knowledge accumulation. This knowledge creates a platform of accumulated expertise that can be used in the next trial. We don't have real S2' platform core that address several options, but trials improve platform itself. It is similar to simultaneous management of S1' and S2'. Interaction of S1' and S2' consists of working on concept of common core even if it is not in the heart of associated risk management strategy. Implicit common core of accumulated knowledge makes these strategies pertinent to manage double unknown. The developed core in S1' strategy then can be reused as a platform core in S2' which is based on potential modules exploration. We call this strategy as (S1' -> S2': trial and learning followed by selectionism or Selectionism type S1' – S2'). The reasoning similar to combination of risk management strategies found in (O'Connor et al., 2006, Van de Ven et al. 1992, McGrath and McMillan, 2009, etc.)
- If we came back to selectionism strategies, we deal with independent equal alternatives. We consider this strategy as project driven at the level of portfolio when dependencies are not taken into account (type S1' on the level of independent projects in the portfolio). Selectionism is S1' type for all the identified alternatives in high uncertainty. Logic of risk management consists of launching several alternatives in parallel that often will increase the budget but not decrease uncertainties.

Both these strategies work implicitly on common core. Based on existing methods, we saw that there is (S1' -> S2') risk management strategy that treats common core as a result of uncertain projects exploration. The identified common core serves as a base of successive explorations. Empirically (Loch et al. 2008, Sommer et al., 2009, 2010) used combination of probe and learn and selectionism method of launching parallel trials in application of Escend Technology start-up. (Sanderson and Uzumeri, 1995) showed how generational platforms were able to coexist within the Walkman product family consequently (S1') and support the development of important sub-families (S2').

We introduce the second family of strategies that don't obtain common core as a result of exploration, but working directly with common unknown as an object to conceive and manage (S3). In S3 we have a tendency to pay exploration phase that help to design common core fabricated to emerging market derivatives.

Finally, we have different logics of risk management (look fig. 1):

1. For independent projects when the level of uncertainty:
    a. low to be able to prioritize different alternatives and select one - *Risk minimization at the level of projects (S1)*
    b. high to be able to select alternatives at the beginning of exploration. Therefore one has to launch several alternatives to minimize unknown and then select a final solution ex post - *Selectionism type S1*
2. For interdependent projects
    a. With existing common platform
        i. Risk management in portfolio and managing dependencies in between projects by reusing existing platform core to address various options – *Platform driven (S2)*
    b. With unknown common platform
        i. Logic that treats common platform core as a result of project exploration (S1') and then use it a base to address multiple options (S2') –*Trial and learning*.
        ii. Logic that treats common core as a target of exploration. It leads to design common unknown to explore and construct platform core based on identified knowledge gaps – *Platform as common unknown (S3).*

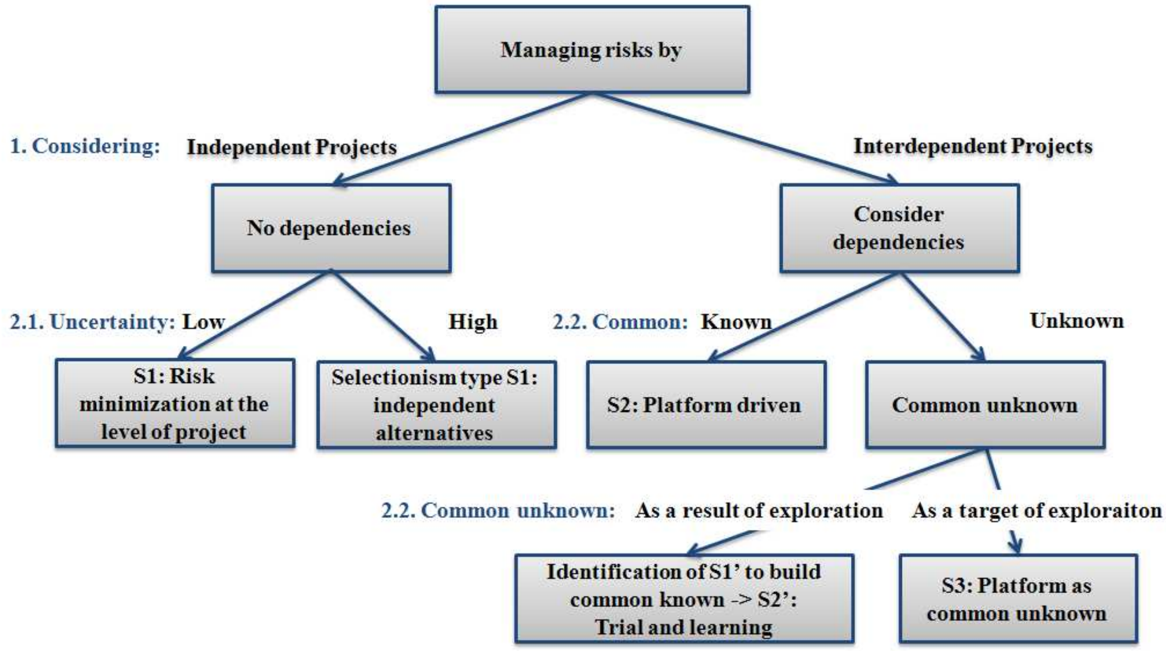

Fig. 1 Risk management strategies classification

This framework leads to propose another topology of « unknown » based on interdependencies and known-unknown commons to manage.

In the following we are interested in comparing S3 and S1'->S2' strategies based on identified analytical framework (see table 2).

So we have S1' –>S2' strategy that allows to minimize risks in high uncertainty. In this strategy platform appears as a result of project investigation in S1'. In the first phase of S1' is hard to prioritize markets. However, we still can prescribe subjunctive probabilities in order not to select dominant market but estimate which of them can be less risky and more accessible for future derivates in options construction after (i.d., which project has a potential to be platform core). The developed core in S1' strategy then is reused as a platform core in S2' which is based on potential modules exploration to construct platform based S2' in high uncertainty.

In these strategies we have double risks: we accumulate uncertainty relative to project selection and developing platform core and risks associated to derivatives management. In addition, there is a risk that S1' will not result in a platform accessible by market options. For project manager in S1' there are the same risks as in S1, just it is much more challenging to identify project without relevant markets distribution. Regarding cost of exploration, there is a high uncertainty in budget required for S2' based on how well S1' was identified and managed. If S1' gives a platform accessible for already identified options, portfolio manager has competence to pilot proposed platform core and associate it with valuable options, otherwise the cost of adaption could lead to expensive and risky development. The information needed for risk management in this case is based on project identification in S1' to define platform. To choose less risky project for future platform core one needs hypothesis on the level of probability distribution for identified project. The resources needed for S2' will be developed in S1' consequently. The actors responsible for management are the same as in S1 and S2. However, while we can identify platform only after project exploration, there could be a lack of competence needed to address future derivatives and identify them (see table 2).

While S1' and S2' deals with platform creation based on exploration to address future modules, there exists a strategy that allows starting not by project to create platform core, but by platform derivatives by prescribing various options in double unknown to construct common core in between different options. The future platform is designed to assure exploration. We call this strategy "common unknown". Usually this strategy is not interested since we consider that we can define neither options, nor platform core in double unknown. We suggest that in double unknown in early stages of innovation exploration it is possible to define concept that creates connections in between optional market derivatives. Definitely, it requires certain strategic vision of industry from both marketing and technical prospective. While working in common unknown one has to be able to define not just potentially interesting options to address, but to define as well the voids and knowledge gaps in between these options that can lead to future "common unknown" to create and design flexible and innovative platform core. While reasoning in common unknown construction for identified options, we could avoid risks related to unsuitable platform that has to be modified each time for particular option. There are clearly some advantages of S3 strategy but is it manageable? How can we define S3 strategy using the proposed managerial framework? What is precisely the common unknown to manage? Can one reuse the same risk management criteria as in S1' and S2'? What are resources necessary to introduce S3 strategy and who are the actors capable to reason in double unknown to construct common unknown? (see table 2)

In the following we attempt to define S3 strategy based on the managerial framework and compare the strategies based on empirical cases of advanced technology development in semiconductor industry. More particularly we are looking for limitation, applicability criteria of each strategy. We aimed at testing if there are cases of technology development that can use strategy S3.

Table 2 Strategies comparison in high uncertainty

Risk management strategy	Objects to manage	Actors	Criteria	Resources
S1'-> S2'	1.Project used as common	Project and portfolio	Expected value of project	Prioritized list of projects/markets to

	unknown 2.Platform derivatives	managers	exploration Aggregated value of portfolio derivatives	identify S1' project
S3	Which form of common unknown are we able to manage?	Which actors are able to manage common unknown?	Which criteria to select for risk management strategy?	What are the prerequisites to launch S3?

RESEARCH METHODOLOGY

This work is based on a long term partnership of Mines ParisTech and STMicroelectronics. Research problematic of "portfolio management in the innovative context" was identified as relevant for both practitioners and researches (Hatchuel 2001). The empirical study was designed as a collaborative case study (Yin 2003; Eisenhardt 1989; Shani 2007). We aimed at testing existing and formulating new hypothesis. The empirical study is based on two technology development cases.

For this empirical study the primary source of data were regular and frequent semi-structured interviews. This work was conducted over 8 months period from (November 2010 – June 2011). Each example of technology development was constructed as a portfolio of Collaborative R&D projects, PhD thesis, and business unit development projects. We organized interviews specialists participating or leading technology development from R&D technology and design unites, business divisions, former PhD students and some associated external research centres. Overall around 40 interviews were performed. The analysis was completed by the scope of documents as European projects reports, research presentations, and thesis manuscripts, database of thesis project descriptions. In addition, data analysis was followed by seminars with company managers (not necessary participating in technology development) to discuss the project, to test the validity of our hypothesis and enrich our propositions.

Research method

We identified strategies that allow working on «common unknown », to define unknown interdependencies in between projects to construct platform core. Knowing the possible risk management strategies in exploration of unknown, it is challenging to define future unknown objects, describe common in between projects that don't exist yet. Which form it should take? How to find common knowledge gap? Which method can be used in this case?

To help identify knowledge creation and follow the cognitive process of innovation, we use a most recent theory of design reasoning - C-K theory (Hatchuel and Weil 2003, 2007, 2009, Hatchuel 2009). This analytical framework will allow describing concepts possibly related to future objects. It has already been successfully used in several empirical cases (Elmquist and Le Masson 2009; Elmquist and Segrestin 2007; Ben Mahmoud-Jouini et al. 2006, etc.)

We conduct our reasoning based on C-K design theory (Hatchuel and Weil 2003, 2007, 2009, Hatchuel 2009). C-K is a general theory of design reasoning based on distinction in between propositions and novel objects (called Concepts) and their interaction with known objects (called Knowledge). Starting by defining initial concept, design leads to transform undecidable propositions in C space into true propositions in K space. During design process C and K expands jointly through the action of design operators. However, when several projects depend on development of particular technology, we can construct hypothesis around this core technology and allow developing application core simultaneously. This is exactly what we consider as common unknown, as common voids in knowledge space that we explore.

To identify platform core to develop based on available or future knowledge, we need to structure K-space to find dependencies in between pieces of projects, challenges, modules, etc. We reuse a notion of models in K-space proposed by (Kazakci 2009, Kazakci et al. 2010). The authors use graph formalism to describe type of objects and systems of related objects. Set of objects related to each other is introduced as Knowledge Island (fig. below, adapted from Kazakci et al. 2010). In the model Learning consists of adding new relation between two existing objects to the knowledge graph. They represented concepts as voids – couples of nodes that are not connected by any chain of relations.

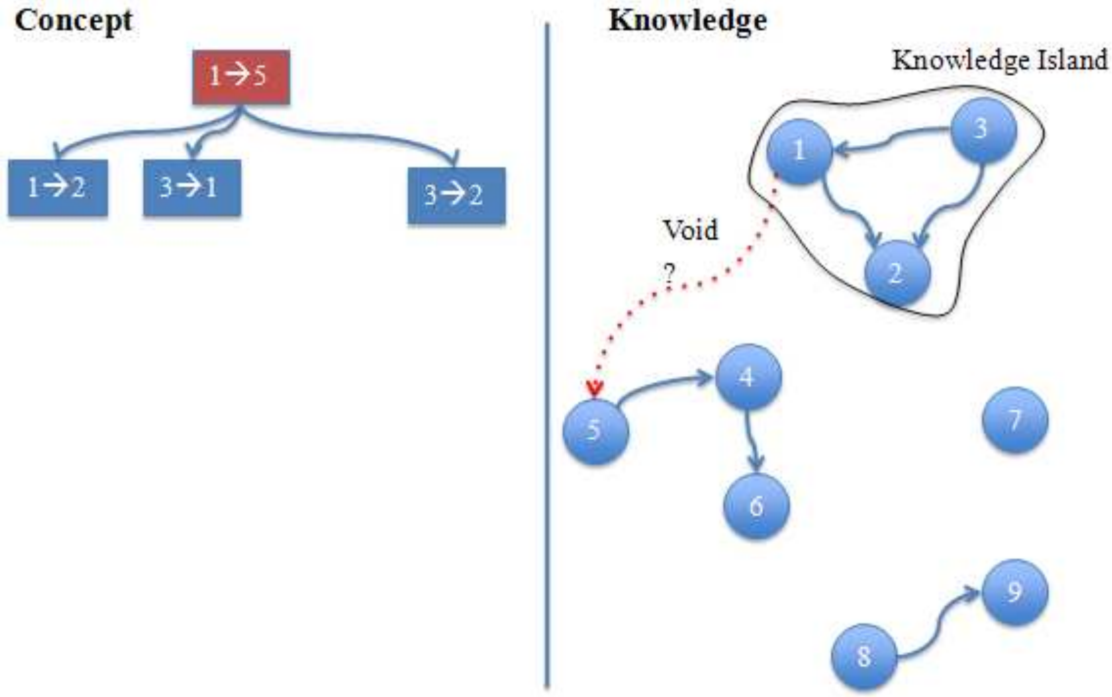

Fig. 2 C-K design theory with K-space structure (adapted from (Kazakci 2009))

Identified in the previous part risk management strategies require different ways of structuring knowledge space:

- S1 leads to voids identification and unknown exploration relative to particular chosen voids (fig. 2).
- S2 is based on knowledge connection in between different knowledge islands (K space on the fig. below). We reason based on existing knowledge. For Knowledge Island 1, the dependencies are indentified with knowledge block (modules 7). Independently, Knowledge Island 2 is interdependent with 7. Based on these identified interdependencies we reuse common core (platform core around project 7) and treat new options after all. Reasoning here is Knowledge-driven and based on Common core creation for platform construction (fig. 3).
- The mixed S1' -> S2' strategy leads to fist to develop 7 that has a potential to fulfil voids. Fulfilled voids connect constructed common core with identified "knowledge island". In the S2' phase, the reasoning is based on multi-options creation based on platform core S1' reuse.

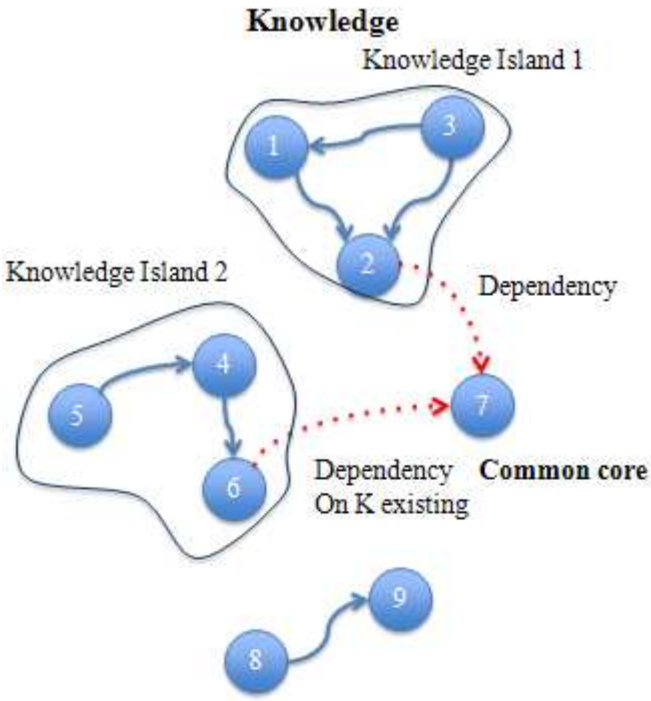

Fig. 3 K-space in Platform based strategy

- S3 relates to common unknown creation that relates different knowledge islands

In S3 there are independent knowledge islands with no identified connections in between. Context is largely unknown. We construct the dependencies in between this knowledge basis regarding the desired concept «common unknown» that connects future options of the portfolio. Reasoning is based on unknown platform creation that is benefiting for all identified and future modules. We introduce the notion of *common unknown (fig. 3)*.

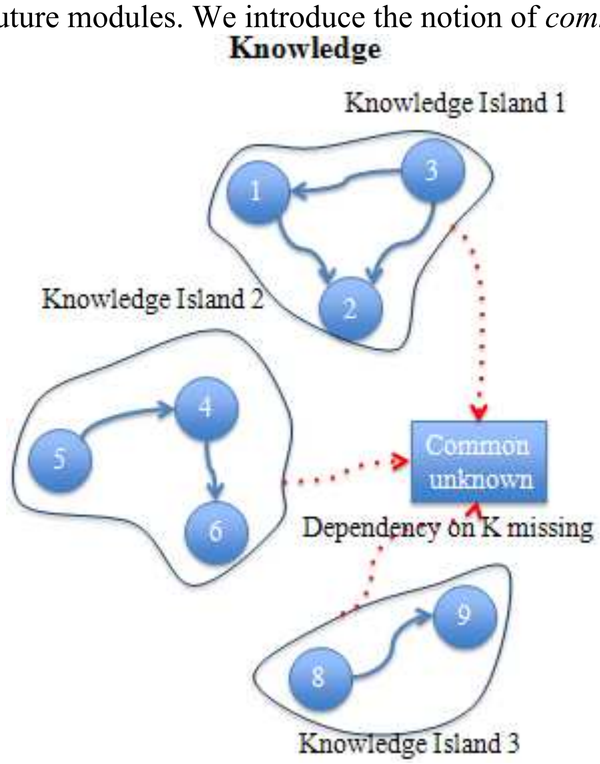

Fig. 4 K-space in "Common unknown strategy"

In the following we use proposed method of knowledge structuring to describe our two cases of advanced technology development.

Relevant field

We conduct our case studies at STMicroelectronics, one of the leading semiconductor companies, in Advanced R&D research units that don't follow classical rules of R&D Management.

The relevance of semiconductor industry for radical innovation studies was showed by various researchers (ex., Cohen, Levinthan, 1989), especially for knowledge creation methods in science-based environments (showed by Le Masson, et al. 2010, 2012) driven by "More Moore" Law (Moore, 1965). Strong competition, fast changing environment relevant to semiconductor industry lead it to explore not just new technologies, but as well new functionalities, creating new products.

Advanced R&D units in STM don't follow "More Moore" law. They are subscribed in diversification approach that is identified by ITRS as "More than Moore" (ITRS 2007). There is neither clear scientific question, neither well defined decision to develop new products based on exploration and targeted markets. There is high level of uncertainty both on the level of technology and future markets.

To better understand the question of addressing double unknown platforms we've chosen two cases of advanced technology developments (Leguay et al., 2011). .

The first case investigated was Integrated Front End Module (FEM) for mobile phone applications using Bulk acoustic wave (BAW) filter technology development. The initial challenge was to provide integrated stable FEM solution by integrating filters and duplexers directly on the board to cut significantly space, and therefore cost of solution. Even existed, the market was new for STM company at that time and innovative technological phenomena was identified through research projects. The development of this technology was initially managed as S1' strategy and then the team reused developed platform core following S2'. We show that initial problem formulation was not well adapted to common unknown management in between different projects. The explorations lead not to convergence but to risks augmentation around technology development. The final decision was to abandon exploration despite of great results and created value in terms of technology.

The second case is BICMOSMW (high performance 0.13µm SiGe BiCMOS technology, targeting very high-frequency applications) technology platform development based on Heterojunction Bipolar transistor (HBT) with unique technology features. Despite of the difficulties in defining both future technology and designing market, the team succeeded to address several markets simultaneously. First analysis showed that the case was not managed completely neither on the level of project based S1' strategy, nor on the level of platforms based S2'. The team leader based the platform exploration in addressing what was unknown for all the targeted markets. The dependences were constructed based on common unknown (S3) and were managed based on the links to allow exploration.

We will further describe both cases, identify which logic the technology development followed and compare performance of different strategies.

EMPIRICAL BASIS

Case description 1. Development of Integrated RF Front-End Module for Mobile phones (FEM)

As was mentioned before this case is based on technology targeting mobile phones market. It was initially requested by the customer of STM that were interested in integrated FEM solution. STM was already providing a part of FEM, only filter blocks were supplied by others. Saturated with Solid Acoustic Waves (SAW) filter technologies (not integrated) at that time, it was a new market for STM Company and they look how to differentiate in technology to address particular client demand and to create new markets. The R&D group was working from 2002 till 2009 to provide feasible solution. The objective at the beginning was to address Integrated Radio Frequency Front-End Module (FEM) for mobile phones (fig. 5). The objective was to introduce compact integrated filter to provide complete solution. At that time the cost of filter application was 30% of the whole FEM.

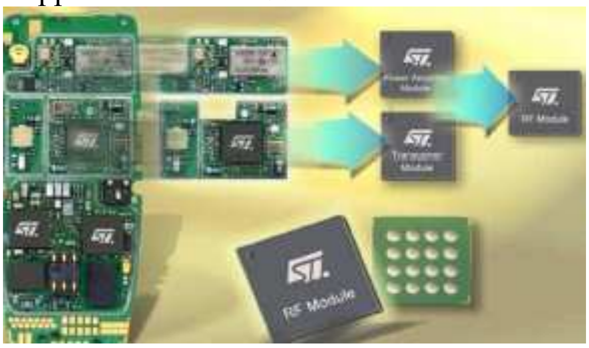

Fig. 5 Identified integration strategy (STMicroelectronics property)

They identified BAW technology for this application. BAW technology is based on mechanical properties of piezoelectric materials to integrate filters and time reference function on Silicon to obtain integrated RF Front-End Module. A BAW resonator is a (Metal-Insulator-Metal) MIM type capacitor with a piezoelectric material as a dielectric.

Starting with BAW Solid Mounted Resonator application for filtering technology, in 2005 research team invented BAW Coupled Resonators Filter (CRF) technology for both integrated filter and also time-reference solution application. In addition to Si integration, the advanced CRF allowed to achieve size decrease till 0.5 x 0.5 mm^2 (instead of 1 mm^2 for standard BAW) and reduced IPAD (Integrated passive devices for RF wireless applications) surface.

However, to be industrialized the technology needed special equipments to be developed and install in the factory (trimmer machines), which required bigger investment that the initially chosen market was ready to pay. The rather complex fabrication process needed 110 steps. In 2007 Research team launched collaborative project based on “Compact RF filters in BAW technology for the Mobile telecommunication system”. The objective of the project was to design and implement future generation RF filters based on BAW technology to meet the specification required the mobile phone applications, reduce the cost of solution. They anticipated the transfer of technology form laboratory to STM fabs and estimated investment cost. The project report states that “Blocking points were not defined”.

But in 2007 the customer interested in technology initially chose another supplier based on SAW technology. To be industrialized the technology needed special equipments to be developed and install in the factory, which required bigger investment that the selected market was ready to pay. The feasibility study of market and needed investment was done only when technology principle was developed; it was too late to test unforeseeable uncertainties in the approach of (Loch et al., 2008). Business Unit 1 decided to stop the development.

The broken link with the market brought R&D group to the hard decision whether to abandon development or try to reuse results for other possible applications. The research group with ongoing projects decided to continue and searched how one can re-use the developed phenomena based on BAW. They looked for additional functions that technology can address. It allowed proposing to the market Integrated BAW oscillators (synchronized time-reference application).

The proposed technology was smaller than stable Quartz oscillator technology, allowing to multi-synchronize the devices in FEM. However, standard Quartz solution is more temperature stable and the identified Business Unit 2 have chosen improved Master PLL solution based on Quartz technology at the end.

Overall, the development of BAW technology lasted eight years. Research team developed initially requested technology and introduced the usage of BAW for new application; they patented more than 30 ideas around this research effort. It allowed the creation of an important ecosystem of laboratories and companies working in the area. The portfolio of projects consisted of 11 successfully accomplished PhD projects, 6 European collaborative projects and 2 development projects. But both products developed by STM never appeared in the market and the development was stopped.

Case analysis 1. Development of Integrated RF Front-End Module for Mobile phones (FEM)

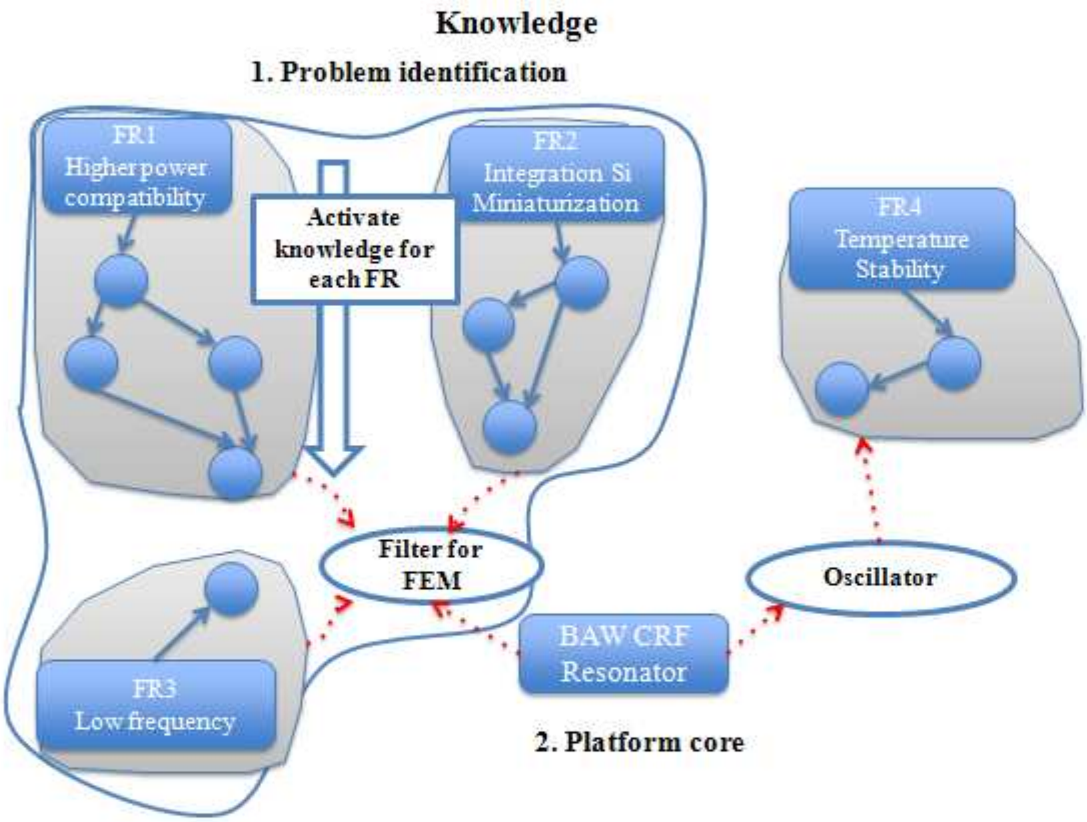

Fig. 2 K-space of BAW technology development (simplified)

The case was initially managed at the level of projects (S1'). Based on initial expertise, client was interested in addressing identified uncertainties at the level of projects. Research team started exploration with a pre-defined market application; the void in K-space was integration on Si filter functions. The problem was formulated to answer to a particular client demand of integrated FEM solution (part 1 in fig. 2). Major functional requirements (FRs) were identified and technological phenomena (BAW resonator) to develop were chosen based on available knowledge. The research projects were mostly concentrated on achieving technological feasibility and improving performance and cost of potential solution (development of BAW CRF based filter). The initially formulated assumptions on availability of market, net present value, final solution and feasibility of BAW as identified solution didn't allow addressing unknowns. The team developed solution to initially defined unknowns but it didn't allow succeeding in general.

On the contrary, the investment needed was much higher than initially expected, market was not ready to pay, competition level from alternative mature technologies (SAW, Quartz, etc.) was not very well addressed, etc. We state that initially formulated problem increased risks instead of reducing it. We highlight it as an unexpected effect of risk management in problem driven approach. The initial formulation of problem could have a crucial effect on project success; it could lead to useless exploration.

In the second phase team attempted to reuse properties of BAW for time reference application to multi synchronize components in FEM. They attempted to reuse initially explored projects as a core to construct platform based on BAW resonator. They transformed S1' strategy to S2' by fabricate a platform allowing new application. They used platform based S2' strategy to reuse BAW resonator as a platform core to address time-reference option. However, constructed common core didn't minimize risks and didn't justify the value of developed technology. Unknowns addressed in the first phase of technology development were poorly reused in the second, they were suitable just for the first identified filter solution.

The failure of this development can't be explain by bad project management. Considering the high level of economical risks, we argue that the results could be different if the team would concentrate in defining common unknown (S3) in order to find necessary knowledge to conduct the reasoning. Instead of exploring the context with problem driven strategy and then reusing it to construct platform core, they could save time and decrease risks by direct platform construction of common unknown (see table 3). Researchers would address a problem in a larger way to search more functional requirements for wider amount of application, allow exploration on the level of system addressing potentially set of markets (constructing "common unknown" around several markets). For example, one of the partners of STM later on introduced advanced solution based on BAW and SAW technologies using the advantage of both: "EPCOS has now combined strengths of both filter technologies for the first time into a single duplexer by using a BAW filter with high power compatibility for the transmit filter in combination with low temperature drift and a SAW filter for the receive filter" (source: www.epcos.com)(see table 3 for comparison in between S1' and S2' formal characterization and presented case).

Table 3 FEM BAW technology development

	Objects to manage	Actors	Criteria	Resources
In case 1	Filter development Time reference option	Technical platform construction done by research team with inputs from marketing divisions	Value Estimation done after launch of projects - ROI only in 2007 for S1' and for S2' separately	Done by marketing function once for filter application - platform core reused but aggregated value of platform wasn't clear

Case description 2. BiCMOSMW platform development

Second case that was chosen is technology platform BiCMOSMW (high performance 0.13µm SiGe BiCMOS technology, targeting very high-frequency applications) (Chantre et al., 2010). (Chevalier, 2007) showed that high-speed BiCMOS roadmap is driven, on one hand by the increase of the optical communications data rate, and on the other hand by the emergence of applications at higher frequencies. It doesn't follow classical More Moore law. Si/SiGeC heterogeneous bipolar transistor (HBT) performances can be pushed forward (with significant advantages over CMOS) and applications at ever increasing frequencies carry on.

In STMicroelectronics, BISMOSMW platform has evolved after several generations of technical solutions. Started with BiPx project it leads to BICMOSMW (specifically designed to address emerging millimeter-wave applications) and beyond. The history of bipolar transistor technology based on SiGe in STMicroelectronics started in 1998 with 0.35 µm technology for wireless communication (Geynet, 2008). The success of the SiGe HBT has come from its compatibility with silicon technology allowing both low-cost and high yield. While bipolar-only technologies are attractive to replace III-V technologies; full benefit is obtained by using heterogeneous solution of BiCMOS + CMOS devices. In spite of the ever-increasing constraints brought about by integration with CMOS (thermal budget, structural issues, etc.), HBT performance was dramatically increased over the past 10 years.

Till 2002 the group was working on optimization of bipolar transistor for analog signal processing to address emerging standard of 60GHz. There was no particular client demand at the beginning. The technological basis that was developed was not ready to address any market that time and the key technology was based on CMOS. In the following 2002 the group was analyzing which potential high-volume market and technological effort needed to develop to address it while reusing the previous research results on bipolar transistor.

The expert (Technology Line Manager) that initiated technology development was looking for a mass market with potentially huge volume to assure return on investment. He identified a particular system issue: the Wi-Fi connections in the big public systems like airports, train stations, and more generally high-density places with a lot of connectivity devices. The current issue was with the standard for Wi-Fi communication (2.5 to 5 GHz), the frequency of processing information was too low to ensure connectivity substantial debit to each device.

Thus, one solution was to use a 60GHz Wi-Fi system with a long range (>10m) to limit the number of base stations and system complexity. However, this kind of system required specific technology:

1. First, the RF platform must be adapted to mm-Wave
2. To obtain high-emission power for long range, the current intensity in power amplifiers must be high enough.
3. The base station system must be compatible with the mobile device Tx/Rx system: thus, it must be an integrated system for mobile devices and a power efficient system.
4. The type of information processing is complex and must be managed by a specific digital platform.
5. The Back End of Line must be adapted to mmW and should allow having high quality factors for the passive elements.

Functional requirements of the artificial system contained both high-frequency emissions that were addresses by bipolar technology developed in 2000-2002 and helped to combine different functional requirements as low power consumption, digital signal treatment, covered distance, etc. They reused existing knowledge to construct modules. This lead to common unknown identification.

In the following the technology platform developed (BiCMOSMW) didn't allow the creation of initially identified system. Nevertheless, it served to different applications such as automotive radar, optical communications, wireless fast download systems, high speed instrumentation and non invasive imaging.

In this example we've seen that the work was not done on the technology and potential market defined at the beginning, Wi-Fi for airport still doesn't exist. It was an artificial concept to reason in common unknown space and it allowed exploring maximum functions with fixed budget of R&D and addresses several markets at the same time.

Case analysis 2. BiCMOSMW platform development

This case was chosen and is particular interesting in testing double unknown situation. The technology developed didn't follow neither pattern of classical project or portfolio management techniques, nor S1' and S2' strategies. The success of portfolio development can be hardly explained by existing methods. Probably the use if S1' strategy would lead to a successful development of one of these markets or even three of them, but it would definitely take more time. We state this based on hypothesis that in problem driven strategy we attempt to stabilize technology or market to test unforeseeable uncertainty. In S2' logic we fabricate a platform core based on available knowledge and then explore independent modules for each market.

In this example the technological phenomena developed addressed maximum functions with the particular budget associated to access one market. The final technology platform addressed three markets with the cost of exploration equal to one phenomenon exploration development. The expert maximized the list of functional requirements (FRs) needed to develop choosing market. He tried to activate maximal number of options (fig. below).

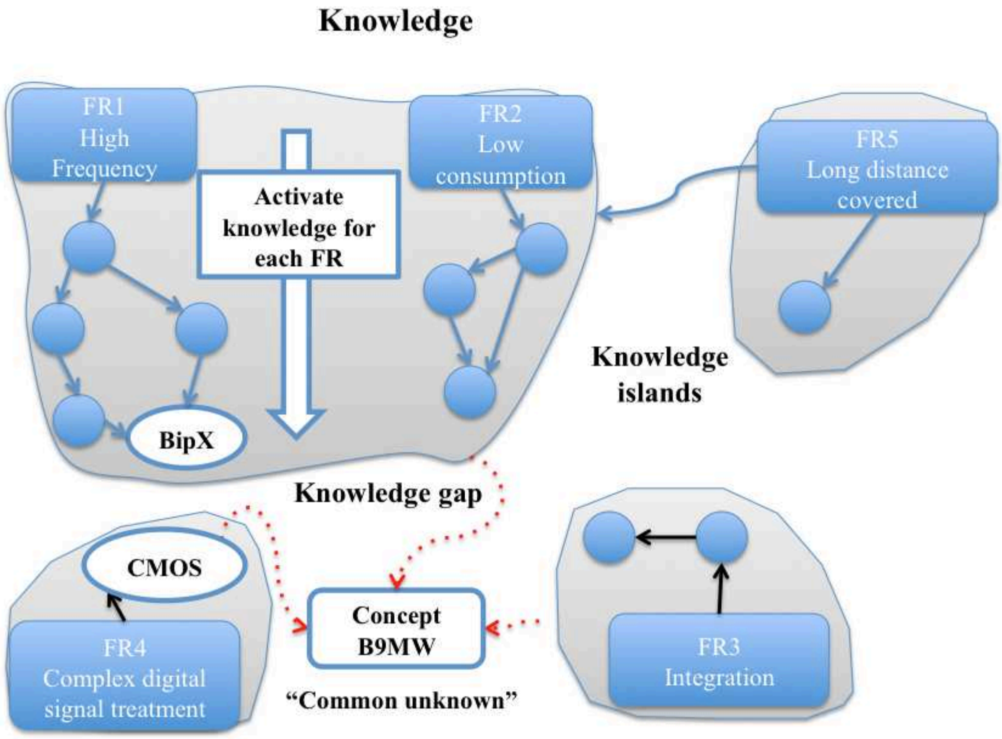

Fig. 6 K-space of BICMOS9MW technology development (simplified)

They activated knowledge around each indentified function to construct knowledge islands of existing knowledge in order to formulate common system to develop. The final system was identified by testing possible dependencies in between all identified options. **Common unknown** was identified as knowledge gap that would connect knowledge islands. The reasoning was based on unknown core to manage (S3).

The expert sort of created an artificial working place in order to conduct exploration with maximum functionality and fixed exploration cost. We state that this reasoning could be a complementary strategy to construct and manage portfolios in high uncertainty situations at least in semiconductor industry.

Fast changing industry dynamics in semiconductor industry, short term market predictions don't allow defining potential applications for advanced technology development, hence we can't make hypothesis on future value of market. But usually we can prescribe the list of future functions that we can attempt to address, identify options based on strategic decisions. Functions which are not relevant to one of existing markets but to the set of them, we fabricate an artificial exploration space that can be presented as **common unknown core** (ex., BICMOSMW concept for WI-FI in public systems). By using the reasoning described above, we list all the potential options; we activate knowledge around each option and define knowledge islands. The following step consists in defining the links between different sets of knowledge, choosing the dependent knowledge gaps to develop – identifying common unknown to address. The proposed strategy S3 permits to work on double unknown situations without fixing concrete market or technology at the beginning (see table 4).

Table 4 BICMOSMW platform development

	Objects to manage	Actors	Criteria	Resources
Case 2	Concept B9MW Market derivatives: wireless, automotive, optical communication, medical etc.	Expert on the level of Techno Line Management able to reason both on common core construction and options. Research engineers working on the project were mostly not aware of common unknown	Aggregated profitability of project platform construction plus portfolio of derivatives	Information regarding market derivatives and technical expertise, existing knowledge to identify common knowledge gap in between markets

Case analysis comparison

Our case studies analysis demonstrates that in two situations we manage different objects, actors are not the same, and strategies require different resources and the implementation conditions are different as well. We outlined case study where S3 that appears to be costly and risky, lead to a successful development. And S1'->S2' that appeared as a natural passage in between project driven exploration that derivatives creation, failed to address identified options.

The first case study was managed as a problem driven strategy S1' that results to platform construction and addressing several options in the second step S2'. In the first phase the uncertainties identified were addressed relatively to filter application for FEM project. In the second phase, for time reference application they attempted to reuse BAW resonator as a common core to minimize risks of portfolio derivatives exploration. However, the uncertainties minimized for filter application, were not relevant for time-reference application. We showed that unknowns we push to explore in problem driven strategy (S1') were weakly reused in platform driven method (S2') after due to problem formulation (in S1', S2'). S1' increase the risk to create irrelevant "unk unks". They explore the identified "unknown" on the level of predefined project. Both S1' and S2' are highly dependent on predefined context. We showed that the common knowledge basis was not sufficient enough to reduce unknown and justify successive exploration in the case of BAW technology development.

The second case corresponds to "common unknown" strategy of double unknown management. The reasoning was built on the unknown concept to address applications for automotive, wireless, health markets and fast-download simultaneously. The platform was design as a common unknown that will connect all these identified emerging applications. We demonstrated that the management of "common unknown" is possible and could be implemented in the context of largely unknown exploration, which is precisely the case of radical innovations. Common needs of various markets appear to be technological lock-ins ex post and the solution is a created common resource. But ex ante, they are precisely common unknowns to construct, the object to manage in S3. We saw that even if nature of this common unknown is undefined and we don't know precisely what would be future solution core and which market will be behind, S3 is still manageable. Nevertheless, we know that this lock-ins will be common for several markets that don't exist yet and we can construct exploration based on this common unknown. "Common unknown" strategy avoids hypothesis on associated context. We showed that in the case of identified options we could construct future platform core based on interdependencies to develop. Thanks to BICMOSMW case study, we were able to characterize S3 strategy based on the proposed managerial framework (see table 5).

Table 6 Risk management strategies comparison in high uncertainty

Risk management strategy	Objects to manage	Actors	Criteria	Resources
S1'-> S2'	1.Project used as common unknown 2.Platform derivatives	Project and portfolio managers	1.Expected value of project exploration 2. Aggregated value of portfolio derivatives	Prioritized list of projects/markets to identify S1' project
S3	Common unknown	Expert in both technical and economical domains capable to identify knowledge gaps	Aggregated profitability of project platform construction plus portfolio of derivatives	Necessity to reason on concept space, Identify innovative paths and accessible common unknown wih low resources

To compare strategies we use two criteria: 1) nature of the controlled risks by strategy or no (based on quality of common core) 2) cost of development in case of each strategy.

In terms of performance case studies reveal that S1'->S2' contains residual risks that are not controlled by strategy. These risks are based on the S1' projects resulted in inadequate common core that requires expensive development to address future options. While starting the development if S1', risk manager normally doesn't take into account future derivatives to address, because his primary goal is the success of S1'. This precisely results in rigid common core based in S1' project exploration. We limit the number of options to address by selecting dominant project in S1'.

The risk management criteria based on uncertainty reduction (max value with min deviation) is not explicit for common core strategy. We are dealing with exploration space where it is impossible to highlight probabilities for markets and technologies that don't exist yet. Instead, we are increasing the variety of options to play. We construct common unknown based on common dependent elements between emerging markets. These dependent elements are common functional characteristics for set of various markets. Then common unknown as a technological building block to addresses certain specific functions and at the end, residual functions that can be addressed in the second time (adaptation). We maximize the variability of options to play later in S3. By introducing S3 strategy, we found out that for good risk management in double unknown it is necessary not just to minimize uncertainties for selected exploration space, but to maximize the variability of future options. This questions existing risk management criteria relevancy for highly uncertain situations and need further investigation.

In S1' –>S2' strategy one has to pay the cost of project exploration. Depending on the first phase, the cost of S2' can be or slightly small or it can require major adaptation and a lot of resources. In BAW case study we saw that the development in S2' required additional resources for S1' reuse that company was not ready to pay. In S3, one need highly competent actor to reason in double unknown, accessible knowledge base on future clients and voids in knowledge to identify accessible with low resources common unknown. Therefore in S3 there is a risk of common unknown identification which requires preliminary exploration cost to construct it. Then, cost of adaptation has to be slightly low to assure the success of portfolio itself. In the case of BICMOSMW we saw that its not impossible to manage cost under control and S3 lead to successful development.

DISCUSSION

We identified original risk management strategies in double unknown that don't deal with the same objects, they are not managed by the same actors, and they require different resources and the implementation conditions are different as well. Accordingly to proposed managerial framework:

1. **Nature of objects to be managed**

In both strategies we deal with common core. With common core as a result of exploration in (S1' - > S2') and as an object of exploration in (S3). In S1' one manages project that potentially can be used as a platform core. It is not sure that in sequential exploration project in S1' will be easily reused as a platform core to address various identified derivatives in S2'. In S3 we have to identify common unknown to construct core in between different options. It is important to mention that S3 doesn't manage common core in between projects in portfolio, but rather in between emerging options. The process of common core identification is based on existing technologies and residual unknowns in between them to identify functional space that the knowledge gaps could address. There is a preliminary phase to build common unknown that is not management of explorative project but a conception of potential commons identification in between techniques (to find a good target that addresses several potential markets). Projects portfolio can be then constructed after all around created concept of common unknown to explore options. To be able to work on common unknown, we have to construct reasoning in common "unknown" voids identification. We used the help C-K framework and especially models of K-space structuring (Kazakci et al., 2010, Kazakci 2009) to conduct reasoning in double unknown. In addition to already existing components of K-models like knowledge islands and voids we introduced *common unknowns*. The utilization of C-K framework helped to guide exploration in common unknown object and to define options to construct common core.

2. **Actors and required competencies.**

S1'->S2' can be managed by classical actors (project and portfolio managers) but not S3. Common unknown strategy requires an expert in both technical and marketing domains, capable to identify knowledge gaps and potential of technology. Both strategies require different prerequisites and different competencies. In (S1' ->S2') one has to identify potential valuable project to create future platform core and then learn and launch several trials. And in S3 there is a need of an expert capable to estimate that the future technological core will be able to address several markets that are emerging and highly uncertain with minimal cost of adaptation. It brings particular usage condition of S3 strategy. Obviously common unknown exploration strategy (S3) needs a really high level of expertise to reason in "unknown space"; common unknown can be enormously big to address. Despite of the high level of competence required for S3 management, we found out that this mode of reasoning is really efficient in terms of risk management. It allows to structure knowledge space to define "common unknown" and construct platform to design highly uncertain technologies. We saw in the second case study the expert who was capable to reason in double unknown. However, to organize the common unknown exploration which actors should we choose? Can it be business angels, techno line managers, etc.? Is it just a matter of expertise or one can teach to reason in "market – technology" links construction?

3. **Criteria**

Risk management for S1'->S2' criteria are precisely the combination of S1 and S2 criteria. In S1' we use the expected value of project exploration with min deviation – expected utility of project value. In S2' it is aggregated value of portfolio derivatives based on common core developed in S1'. Criteria in S3 are based on aggregated profitability of both common unknown exploration in S3) and cost of portfolio derivatives development and adaptation.

4. **Conditions of implementation and necessary resources.**

Both strategies require low cost of development for portfolio of derivatives. S1' and S2' requires list of identified prioritized markets to select exploration project in the first phase. For S2' part platform core will be developed by S1' and one will need to construct derivatives reusing this basis. In S3 strategy managers ought to reason in concept space, identify innovative common paths. Designed common unknown has to assure minimum exploration cost to address each module in S3. If one has to adapt platform core to each of the modules after the common unknown strategy will be too expensive.

Still, even if highlighting major differences in between strategies, the economical conditions of S3 are not explicitly addressed. Further research will lead to a better investigation of identified common unknown strategy to innovative portfolio management, its guidance and more formal analysis of proposed strategy. We need to better understand its limits, advantages and criteria of applicability to other type of projects and industries. We aim to create analytical model to highlight the influence of industry dynamics to particular management strategies and test the interest of emerging strategies to unknown management.

We illustrated implementation of identified risk management techniques on two cases of advanced technology development. While tested the cases in semiconductor industry, more particularly in silicon foundry which is research and knowledge creation driven, we saw that in early stages of exploration experts can reason on common unknown and identify dependencies necessary to connect several options. Definitely, implementation of proposed strategy could be limited to certain industry dynamics. As well as final proposals are valid only in the specific cases we analyzed. In addition, the further research will examine whether identified risk management strategies based on common unknown are limited to semiconductor industry or big high-tech companies and whether S3 can be used for innovative start-ups management.

CONCLUSION

Proposed study contributed to risk management in the case of double unknown when technologies and markets are undefined.

Based on literature review we proposed general framework for risk management strategies. This framework lead to precise identified strategies and associated management context based on the definition (for results see table 1, 2):

- The nature of objects to manage
- Risk management criteria
- Actors responsible for risk management and their level of competence
- Resources necessary for strategy management

Our work highlighted that to manage risks in double unknown, one has to consider the common core. Based on way the common core is treated in the situation of radical innovation, we distinguished two types of risk management strategies:

- The common core as an expected result of exploration (S1') that leads to successive learning and options development (S1' - > S2')
- The common core as a result of working on common unknown as an object of exploration itself (S3).

The managerial framework based on four features (objects, actors, criteria, resources) help to characterize both S1'-S2' and S3. The comparison between both strategies in this framework showed also that S3 is particularly relevant when potential markets are equally unknown and experts are able to identify voids in their competences, which are common to several potential solutions. Conversely it shows that the attractive S1'-S2' strategy is potentially risky when it leads to develop a first project that won't be a good platform to address the following ones. Favoring S1' (try the less risky project) before S2' might actually lead to increase the global risks instead of decreasing it.

This work has several managerial implications. First, we introduced a new way of risk management in the situation of high uncertainty that deals with common unknown management. This strategy requires different competence in managing double unknown, and usage of management criteria. The proposed strategy of working on common unknown opens a new way to portfolio risk management in the context of radical innovation. This strategy aims at knowledge creation but keeps costs under control and maximizes the likelihood of being relevant for future markets.

Second, we found out that evaluation of risk management strategies based on uncertainty minimization is not always relevant in the case of double unknown. In the project exploration there are residual risks based on reuse developed common core in derivatives addressing. By formulating a project in S1' we could increase risks associated with market derivatives instead of reducing it and increase the cost of adaptation. Thus, we maximize risks associated with unknown while decreasing risks associated with the selected exploration space. Instead, in common unknown strategy experts try to maximize variability of options that common unknown will address. The goal is not to manage uncertainty reduction for identified exploration based on existing knowledge. The common unknown strategy brings to wider exploration space and pushes to knowledge creation. We argue that the good strategy of unknown management has to take into account variability of solutions which is precisely the logic of S3 strategy. Even if understanding the importance of variability, it is not obvious to which extent one has to take diversity of solutions and which conditions are favorable for S1' -> S2' strategy or S3. Further research will need to better investigate the performance criteria of strategies in double unknown management, as well as their limits and advantages.

Finally, using originally new way of risk management based on knowledge gap identification to construct common unknown core, company can build its innovative capabilities through knowledge management and better position to innovate in emerging fields.

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