Story of a gradual decline of maintenance skills in a high-risk organization (1980-2020)

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In industry, maintenance work, which is deemed non-strategic, is widely subcontracted. While these activities are essential to maintaining the reliability of high-risk organisations, the fact that they are subcontracted is frequently blamed for industrial disasters. In the short term, this leads to financial gains, but also to adverse effects, especially in terms of skills. An in-depth, longitudinal, and multi-level case study within the high-risk business line of a major government-owned company enables us to map out the skills-loss process, to identify the factors behind it, and to inform the analysis of the relationship between inter-organisational control mechanisms and the skills that are required to perform the outsourced activities.

Although there is a large body of literature on subcontracting, its issues within so-called high-risk organizations (HROs) have been subject to very few empirical studies. However, it is not unusual to see subcontracting blamed for industrial or rail disasters such as AZF, Lubrizol and Brétigny-sur-Orge. Subcontracting issues are all the more critical in HROs as they involve their responsibility for maintaining plant reliability (Bourrier, 2009). Monitored by external regulatory bodies, they are bound by regulations to monitor and report on subcontracted activities, under pain of penalty. Maintenance activities, which have been widely subcontracted since the 1980s but are essential to maintaining the reliability and safety of plants, are subject to sustained vigilance involving both contractor and subcontractors to ensure the compliance of the operations to be carried out and the preservation of the related skills.

Whilst the literature on inter-organizational control has flagged up different control methods and emphasized their impact on skills, very few empirical studies have provided in-depth analysis. In addition, under the combined effects of the economic crisis, encouragement to preserve production equipment and the increasingly complex nature of socio-technical systems and high-risk activities, the maintenance of industrial facilities takes on a whole new importance. This is the conclusion we have drawn from an in-depth case study on changes to management methods in a high-risk industry which shows, amongst other things, their impact on maintenance skills (Masson, 2019). While the company under review (which we will call Alpha)[1] acknowledges a certain decline in its maintenance skills, there are differing interpretations as to its causes and effects. How can the decline in maintenance skills in a high-risk company be explained?

To answer this question, we will be taking a comprehensive (Dumez, 2016) and multi-level (Brabet, 1993) approach. To this end, we will go back over the timeline of the facts and the resulting management decisions, and will match them with the related maintenance practices so as to more closely assess the risk factors with regard to skills. After having provided an overview of our framework for analysis, the company, its background and the methodology used, we will report on our empirical study and discuss its results.

The maintenance outsourcing paradox

Is outsourcing industrial maintenance always compatible with reliability requirements for a high-risk organization? To address this question, we suggest linking three strands of the literature (inter-organizational control, high-risk organizations and maintenance activity).

Cost reduction *vs* skills: tensioning of outsourcing control methods

Concurrently with a company's move to refocus on its core activity, the use of subcontracting meets targets in terms of flexibility and cost reduction, and takes a variety of forms such as outsourcing low value-added activities or the use of expertise seen as too expensive to keep in-house. In all cases, the subcontractor requires the instructing party to make management choices that steer the nature of inter-organizational control devices (van der Meer-Kooistra and Vosselman, 2000;

[1] For the purpose of confidentiality.

Nogatchewsky, 2009). Three control patterns enable instructing parties to influence and coordinate the actions of subcontractors without hierarchy (Nogatchewsky, 2002). The market-based pattern (formal control) is grounded in competition between external stakeholders through, (for example) calls for tender. Bureaucratic-based pattern (formal control) is contingent on norms and standards ensuring supervision and assessment of external stakeholders. Trust-based pattern (informal control), which is also known as social-based control, is based on invisible devices (Beaujolin-Bellet and Nogatchewsky, 2005): trust and forging relational norms (*i.e.* common values, shared expectations) between stakeholders (Barthélémy and Donada, 2007). This means that social control is established at micro level and is reliant on interpersonal relations built up over time, and is the "cornerstone of the cooperation process" (Donada and Nogatchewsky, 2006, p. 283) between stakeholders belonging to different organizations. These control patterns are ideal types as, in practice, they are not exclusive and overlap (Nogatchewsky and Donada, 2005) although one of them will be dominant (van der Meer-Kooistra and Vosselman, 2000).

Nevertheless, owing to the financial deepening of businesses, a model characterized by heightened formal control is tending to take hold with many objectives being contracted out, subcontractors competing with each other through increasingly standardized calls for tender and the proceduralization of work. Beaujollin-Bellet and Nogatchewsky (2005) present the impacts of changing to inter-organizational control patterns using a case study of industrial maintenance outsourcing. This change often took place on a continuous basis drawing on opportunities and local relations – fostering the emergence of a social control pattern – which enabled the subcontractors to acquire specific skills and an in-depth knowledge of the instructing party's facilities, which are guarantees of quality and responsiveness. These skills have cushioned critical situations by compensating the contractor's shortcomings at no extra cost: Subcontractors are used as providing organisational slack. However, cost streamlining requirements leading to the centralization of procurement decisions have led to a preference for the formal market-based pattern. Whilst this reduced immediate apparent costs, it also had adverse impacts including longer facility outages for maintenance, an increase in emergencies and risks, and problems with managing jobs and skills.

Barthélémy and Donada (2007) draw attention to the "skills/control" relationship as control patterns do not only change on the basis of streamlining costs but also according to the extent of the gap between the skills of the instructing party and those of the subcontractor. This gap opens up when the instructing party no longer carries out the subcontracted activities (van der Meer-Kooistra and Vosselman, 2000). Accordingly, subcontracting maintenance work removes the instructing party's employees from the facilities and alters their duties from that of "repairers in direct contact with technical equipment" to that of "supervisors […] tasked with checking the work of others" (Tillement, 2011, p. 124). As skills are built through action (Dietrich, 1999), they are lost as soon as the activity is no longer practiced (Koenig, 1994; Mazeau, 2001).

As a result, the narrower the skill gap, the more formal control patterns appear appropriate (Barthélémy and Donada, 2007). Conversely, the more it widens, the less the instructing party is able to assess the subcontractors' work, clearly state their requirements and decide on the best tender. In this context, the authors advocate the use of informal control (trust-based pattern) to reduce this skills gap by forging interpersonal relations to contribute to mutual understanding and learning. To do so, focus should be placed on the design, quality, and permanence of inter-organizational relationships.

High-risk organizations: The delicate balance of reliability

So called high-risk organizations (aerospace, nuclear, etc.), carrying direct risks for the environment and populations, have been defined in contrast to "classic" ones. Starting in the 1980s, the Berkeley group's work emphasized the complexity and tension within these organizations: between output targets and safety (Rochlin, 1993), and between centralization and decentralization (Eisenhardt, 1993). This literature also flags up two conditions required to safeguard the reliability[2] of facilities:

- A balance between controlling regulation and autonomous regulation (Reynaud, 1997), based on a view of people and their situational intelligence (Zarifian, 1999) as a factor of reliability.
- The presence of organizational slack where the predominant management methods put a continuous drag on resources (Schulman, 1993), whereas maintaining reliability requires substantial financial resources (Wildavsky, 1991; Weick et al., 1999).

Work on ergonomics emphasizes the positive role of teamwork in safeguarding reliability. If a team is well organized, has experience, targets and a common language, it offers the best response possible to safety issues raised by these systems (De Keyser, 1989). It fosters discussions about business activity, capitalizing on experience, reporting abnormal situations, onboarding and training new members and tacit knowledge transfer. It may also have an adverse effect if it is hampered by organizational changes that promoteinward-looking behavior which has an impact on collective due diligence and mutual support (Daniellou *et al*., 2010).

In the same way as "classic" organizations, these HROs have widely outsourced the maintenance of

[2] Reliability embodies the capacity of a system or equipment item to carry out a required function in given conditions and during a given timespan. It has three features – those of a technical (operating without outages under given conditions of use and for a given timespan), organizational (ability to maintain its performance levels in spite of the presence of risks) and human (capacity of an individual or team to successfully carry out an assignment that must be completed within a given timespan and under set conditions) nature.

their facilities, although subcontracting is deemed to have "a direct effect on safety" (Walter, 2017, p. 397). Ironically, the practice has been scarcely analyzed in light of the risks that it can cause (Le Coze, 2017) *e.g.* work-related accidents considered to be more frequent, heightened time pressure and loss of skills in the event of staff downsizing. In addition, the increase in the number of companies involved in maintenance activities represents one of the main safety risk factors (de Bovis, 2009): this issue is even more key as socio-technical systems are becoming increasingly complex due to their becoming part of huge mass networks (Veltz, 2000) in which the slightest malfunction can trigger a chain of disruption with repercussions of variable severity. This unquestionably explains the current focus on understanding maintenance activities and the related expertise and skills.

Maintenance is more complicated than it seems

The purpose of maintenance is the long-term safeguarding or repairs to various equipment items so that they "continue to function like before" (Tillement, 2011, p. 120) and it covers two types of operations: preventive (upkeep, calibration, repairs) and corrective (examining and finding solutions to breakdowns). In a high-risk organization, the primary aim is to avoid malfunctions or breakdowns that would cause a high-risk outage of the facilities. Nevertheless, having been designed as a strategy for avoiding breakdowns, preventive maintenance cannot boast a finished product which means that it is undeniably "invisible". It is implemented so that "everything continues as if nothing has happened" (Denis and Pontille, 2020, p. 2) and is classified as a "hollow" activity (Boissières, 2003). This explains both why it is seen as a non-strategic activity and why it is considered commonplace especially as it is repetitive work that has to be carried out again and again. From this viewpoint, maintenance seems to be a field for mapped-out and procedure-based activities that merely have to be learned in order to be carried out. This interpretation reduces skills to just the technical aspects of the activity which are listed in various documents and which simply have to be applied (regulations, frameworks, ranges, etc.).

Yet, maintenance encompasses a vast range of tasks (Dant, 2010) which, when analyzed, highlight the site-specific investigation work involved (Vinck, 2019; Denis and Pontille, 2021): inspecting the equipment, searching for and repairing faults, identifying the problem, its cause and putting forward solutions. When viewed this way, it may seem straightforward. However, Hatchuel and Weil (1992) had already stressed the importance and the specific nature of the repairer "knowing how to understand" to solve the problems they are faced with. Knowledge and understanding of the day-to-day functioning of the relevant system does represent a prerequisite for carrying out maintenance work (de Montmollin, 1984; Hatchuel and Weil, 1992; Tillement, 2011). This work requires a broader set of knowledge and expertise than is evident, including different functioning methods, and is not restricted to applying operating methods to which it is often reduced. This ability to investigate the state of things is developed with professional experience through a "close, physical relationship with the facilities" (Tillement, 2011, p. 120). However, the investigation is not only technical as its also calls for social interaction, especially when the work is outsourced and involves many stakeholders belonging to "separate yet interdependent groups" (*ibid*., p. 125).

Whilst the literature posits that companies that subcontract part of their activities lose skills, there are few empirical studies that document this process. As a result, we consider it relevant to study it and, thereby, to understand the reasons and implications thereof in a high-risk context.

Research context and methodology

Alpha is a major state-owned French company with both industrial and commercial activities, and which is undergoing significant changes. We will be focusing on its Production Division, which is tasked with a high-risk activity and which is composed of management at national level and a large number of local production sites. Every 12 to 18 months, the Production Division shuts down its facilities for maintenance work which has been outsourced since the 1980s. The Production Division has built up a substantial network of subcontractors which it structures, coordinates and controls. During these outages, the subcontractors carry out preventive (systematic) maintenance, upstream of any breakdown or malfunctioning, to verify the working order of the facilities, compliance with safety standards and to mitigate the risks of problems occurring. There are around 20,000 external participants working for 600 subcontracting companies and representing a large number of disciplines (welding, plumbing, scaffolding, etc.). They travel from site to site to carry out the required work and this doubles, or even triples, the on-site headcount.

The option of outsourcing maintenance goes hand in hand with the Production Division refocusing on its core activity, namely energy generation. The rationale for this choice is a cost-cutting drive which has been stepped up by the company being privatized. Whilst opening up to competition has caused Alpha to lose a large number of customers, the Production Division is confronted with an increase in costs which contributes to Alpha's financial debt: investments are required in light of the increase in maintenance activities due to the ageing of the facilities and also a drive to extend their lifespan. Use of subcontractors is on the rise whereas deadlines and quality requirements have remained the same and the HR department is striving to reduce staff numbers. Moreover, since 2010, the Production Division has been hit by the departure of the generation of "builders", referring to the employees of instructing parties and subcontractors who were involved in building and commissioning the production sites. This has led to major generational renewal[3] which raises

[3] In 2014, 40% of staff had less than six years' experience.

Alpha's national level	Production Division production site no. 1	Production Division production site no. 2
Divisions/departments involved in managing subcontractors. 14 semi-structured interviews (1-2 hrs in length) with: • the Production Division's national level (management team, technical system designers and managers overseeing the work of local stakeholders): senior executives and their team members • the manager of the Technical Department, engineers/designers of maintenance activity management systems (technical management), manager of the department tasked with industrial relations, technical-economic engineers and expert advisers in the industrial relations team • the Procurement Department: the department's manager, procurement strategy managers	Sites selected on the basis of their varying ranking in the subcontractor satisfaction survey (the first and the last). 39 semi-structured interviews (1-2 hrs in length) were conducted with: • the site's management (Production Division): site manager, industrial policy team, contract managers, HR team • the line management (Production Division): managers of the maintenance outage projects, the planning department, the Methods Department, and the business lines (plumbing, boilermaking, etc.) • stakeholders in the field, technicians (Production Division): project managers, oversight managers (junior and senior)[4] • subcontractor supervisors and operators	

Table. Investigated fields.

skills-related issues. Our research, covering the period from 2015 to 2019, has been carried out against this backdrop which is conducive to examining the loss of skills in a high-risk organization.

We considered that a case study (Dumez, 2013) was the most appropriate research strategy for a comprehensive approach (Dumez, 2016) to Alpha's management choices amid significant changes and their repercussions with regard to skills. Drawing up a timeline (Dumez, 2013) means that we can trace the long and complicated skills-loss process and pinpoint the main factors that contributed to this. A multi-level approach (Brabet, 1993) helps understand the different viewpoints concerning the maintenance work and the skills it requires: between stakeholders at headquarters and at the sites, both former and new, instructing parties and subcontractors. Three main "fields" were investigated.

This data was enhanced by examining internal and external documents which was carried out in an iterative manner, with the researchers constantly going back and forth between the field and the theoretical frameworks used. The results were presented to the Production Division's local stakeholders[5], who confirmed their relevance, thus providing a sort of "in-house" validation.

Story of a proven loss of maintenance skills

The hypothesis of a loss of maintenance skills clearly emerges from the statements of the interviewees. They see it as a logical consequence of the decision to outsource:

> "Once activities are outsourced, there's no doubt that the subcontractors are better than us" (Production Division line management, site).

However, this does not explain why this loss of skills by the instructing party becomes critical, nor why it also has an impact on the subcontractors. To address these questions, we will trace the timeline of maintenance organization and management practices.

From the 1980s to the 2000s: Maintaining maintenance skills

Prior to the 1980s, the Production Division was responsible for the maintenance of its facilities and hired technicians for this work. Years of practice combined with training enabled these technicians to acquire strong technical skills and in-depth knowledge of the facilities and their constraints, in light of the safety requirements of a high-risk activity. During the 1980s, the expansion of subcontracting altered these technicians' responsibilities: they became Project Managers and Oversight Managers. Project Managers organize and manage the outsourced work with the relevant external and internal stakeholders. In conjunction with the line management for the many subcontractors, they are responsible for their results. Whilst Project Managers must be familiar with the technical work to be carried out, the skills required for their positions are primarily interpersonal and organizational in nature: thorough knowledge of the site and its operating methods. Oversight Managers are responsible for ensuring the compliance of subcontracted activities with the specifications and for checking that

[4] "Senior" stakeholders in the field belong to the "builders" generation

[5] Alpha did not authorize the presentation to subcontractors.

files are in line with regulations. Since 1984, an order[6] has obliged Alpha to oversee the subcontracted activities itself. Whilst they no longer carry out maintenance work themselves, the Project Managers and Oversight Managers have kept their skills and know-how over time. There are two main reasons for this:

- On the one hand, they are still informally involved in subcontracted activities thereby maintaining their technical skills and transferring their knowledge of the facilities to the subcontractors' operators. However, the Act of 12 July 1990[7] for preventing any improper subcontracting ("délit de marchandage") requires subcontractor companies to oversee their employees themselves. Mixed teams became illegal and the Project Managers and Oversight Managers have been replaced by subcontractor supervisors. Nevertheless, they do forge close relations with the latter in order to provide them with the required information and to inform them of the Production Division's demands.
- On the other hand, the stability of subcontractor companies, due to a lack of competition, fosters a trust-based relationship between the Production Division and its subcontractors. A report from Alpha's R&D department (2004) confirmed that it is in the Oversight Managers' interest to adjust formal rules together with subcontractors so as to avoid situations of work-to-rule and the withholding of information. To understand their headroom with regard to the guidelines, the Oversight Managers continued, despite the ban, to assume their previous responsibilities in order to "fine tune their knowledge and technical command of the activities and systems to be overseen", seen as "the only guarantee of a fair assessment of subcontractors' work" (Alpha R&D Report, 2004).

Trust-based relations with stable partners and technical practice prevented the emergence of a skills differential between instructing parties and subcontractors. Consequently, for twenty years, outsourcing did not cause any major problems.

2000s: Management choices and generational renewal accelerates the loss of skills

The privatization process, which began in 2001, resulted in budgetary cuts to attract new shareholders[8]. Finance-related decisions led to a reduction in payroll expenses and training costs. Consequently, in 2005, the Production Division's national level elected to eliminate the "*pépinières*" ("incubators"), a system for providing support to new recruits prior to taking up their position which was conducive to transferring knowledge and know-how. It was only after 2010, during a huge generational renewal, that the company became aware of the impact of this decision.

> "There was huge pressure to reduce resources and budgets. The '*pépinières*' were phased out at the same time as the renewal of skills was taking place. Now, everyone realizes that this was a mistake. People who worked in the workshops, who still knew how to carry out maintenance work, retired and weren't replaced" (Senior Executive, Production Division, National Level).

When the generation of "builders" retired, the organization lost the technical expertise and the control over the functioning of the facilities that this generation acquired thanks to their involvement in the construction of the sites.

In turn and over time, the Production Division's initial management choices proved to be detrimental to maintaining skills. Starting in the 1980s, the Production Division had opted to entrust the majority of "case 1" work to subcontractors (the subcontractor carries out the work according to its documents, its operating methods, examines the discrepancies and puts forward solutions) rather than "case 2" work (the Production Division's Methods Department prepares the files and procedures, examines the discrepancies and puts forward solutions). This decision gradually moved the Production Division's stakeholders away from maintenance activities:

> "Case 1 is very damaging for skills. A hydraulic test takes 35 days. The Project Manager stays in their office and monitors the schedule but, after three years, they no longer know how to carry out a hydraulic test. Before, these tests were carried out by our teams. It wasn't a problem; we knew what to do. But now, it's a real headache" (Senior Executive, Production Division, National Level).

2010 saw the start of financial problems for Alpha and the introduction of a severe cost-cutting policy. As the "builders" retired, the Production Division focused its HR strategy on cutting staff numbers with a target of "200 employees fewer per year" (HR Support, Production Division, site). Technicians were significantly affected: deferred hiring, periods for transferring skills between outgoing and incoming staff shortened or even cancelled:

> "For fifteen years the Production Division didn't hire and then, suddenly, it began recruiting again. But senior staff left and juniors arrived without there being enough time to pass on know-how" (Senior Oversight Manager, Production Division, Plant).

Against this backdrop, new Project Managers and Oversight Managers arrived at the same time as changes to inter-organizational control patterns.

2010s: A change in control patterns accelerates the loss of maintenance skills

Alpha's financial difficulties led the Production Division to recast management of the instructing party/subcontractor relationship in order to make savings. Two decisions overhauled inter-organizational control patterns, and we will highlight their impact on the skills of those working on the field.

[6] Which we will not identify for reasons of confidentiality.

[7] Act no. 90-613 "promoting stable employment by adapting arrangements for temporary contracts".

[8] The government nevertheless remained the majority shareholder.

Selection of subcontractors becomes the responsibility of the Procurement Department, and market-based pattern strengthens

The combination of bureaucratic and social-based patterns which had governed instructing party/subcontractor relationships was replaced by a combination of market and bureaucratic-based patterns. Selecting subcontractors, which had previously been carried out at local level, was centralized in the Procurement Department – a practice which is, at the end of the day, widespread in the industry. Being centered more on cost-cutting than on fostering interpersonal relations with subcontractors, the business line approach was replaced by a financial one:

> "The Procurement Department is separate from the business lines and is only driven by procurement rules and financial performance levels" (Executive, Procurement Department).

This also represented a breakaway from the policy of the Production Division which had elected to restrict its pool of certified subcontractors[9], as it considered that, over time, working with the same subcontractor guarantees quality of service, encourages shared knowledge of operating methods and the forging of relational standards conducive to asserting social control to mitigate the bureaucratic control applied at local level. Where the Production Division had chosen weaken the market-based pattern, the Procurement Department fostered competition between subcontractors through invitations to tender in order to force them to lower their rates with an eye to offsetting the increase in the overall volume of maintenance work. This heightened market-based pattern compounded the more regular turnover of subcontracting companies which, on each occasion, led to the loss of skills acquired during performance of the contract:

> "A subcontractor company that holds the procurement contract for five years upskills, invests in its staff and therefore increases its rates. For the next invitation to tender, another company wants to win the contract and undercut prices, and it ends up being successful on financial terms but then we have to start all over again from a technical standpoint" (Project Manager, Production Division, Plant).

The management contract strengthens bureaucratic-based pattern

Whilst the market-based devices take precedence over trust-based pattern at the selection stage, bureaucratic-based devices become more robust during the operational stage with the implementation of contract management. This is seen as a measure for improving productivity and calls for strict application of contractual penalties as soon as subcontractors fail to comply with an obligation (deadlines, quality, etc.). While these clauses were already in the contracts, they were not often applied as local stakeholders' "best interest was that relations were as amicable as possible" (Plant Manager, Production Division) and disputes were indeed settled amicably on site. Contract management "sets the record straight" (Executive, Production Division, National Level). However, making the contract central to the relationship "changes relations" between local stakeholders (Senior Executive, Production Division, National Level) and further undermines social-based pattern. Application of penalties makes inter-organizational relations more bureaucratic and inflexible, weakens inter-personal relations between Production Division stakeholders in the field and subcontractors, and has an impact on their cooperation and the opportunities for the joint inter-organizational regulation required for exercising social control:

> "Quality defects are dealt with by the site's management which takes a more contractual approach and this creates tension. If everything in the Production Division was perfect then we could criticize the subcontractors. But the Production Division is far from perfect. However, when there's a quality defect, we tell them: "It's your fault, pay up" (Production Division line management, Plant).

This contractual approach alters the subcontractors' work. With their superiors' agreement, they no longer take the initiative for fear of their company having to pay financial penalties:

> "An initiative can be expensive, very expensive!" (Subcontractor's supervisor).

This heightened bureaucratic-based pattern therefore contributes to the "disinvolvement" of subcontractors as they no longer put forward solutions to identified problems and leave this part of the investigation to the instructing party as part of its regulation of control. The issue at hand is whether or not the latter still has the skills required to solve the problems identified by subcontractors.

The bureaucratic-based pattern spiral: Administrative supervision and a loss of legitimacy for Oversight Managers

Whilst discussions between the Production Division's stakeholders in the field and the subcontractors encourage mutual knowledge-sharing and joint regulation conducive to safeguarding reliability, the junior Oversight Managers' total lack of practical experience means that they simply stick to carrying out formal checks of compliance with guidelines:

> "It's pretty simple to carry out an activity. You take your file, read it, respect the range specified and tick off what you've done. If you do that then no one will see anything in particular. You take the file, read it, watch what the subcontractor's operator does and, as they do it out of habit, they may not read the file; there's something that is written and we don't see them do it. So, we tell them "I didn't see you do that". And we criticize them for not having read it. We don't take them by surprise, we explain that we want to see them do it word for word" (Junior Oversight Manager, Production Division, Plant).

This totally administrative view of supervision carries non-negligible risks of poor workmanship and a lack of control. It reduces the work and its supervision to a list of tasks to be ticked off, to the detriment of actual circumstances and their contingencies:

> "If I assemble something the wrong way round, at the moment, the Oversight Manager isn't aware, they don't see that I've

[9] To reply to calls for tender, subcontracting companies must submit to classification audits on topics that are predominantly technical and organizational. If they pass, they join a pool of companies that may be approached during the invitations to tender.

assembled it the wrong way round but will penalize me for a mistake in the file" (Subcontractor's operator).

Mistakes that are detected too late may have adverse effects on the safety of the facilities, the length of outages, or cause breakdowns that the Production Division strives to avoid.

The Production Division also looks to avoid mixed groups both with an eye to complying with regulations and with respect to liability in the event of a quality defect:

"Today the approach is one of background supervision as we attempt to move away from supervision in the vein of "I'll give you a hand, pass me the spanner" (Senior Executive, Production Division, Plant).

As junior Oversight Managers lack practical experience and knowledge of what the work actually involves, they no longer have the skills necessary to carry out control work:

"We are not competent enough to criticize subcontractors' work and this causes problems. The subcontractors' work should not only be assessed in light of regulations or guidelines, you also need knowledge of the field. This is a problem for our people as they are increasingly less knowledgeable on this matter" (Production Division line management, Plant).

Another adverse effect of the loss of skills by the Production Division's stakeholders in the field is that subcontractors no longer consider the junior Oversight Managers to be competent:

"It's hard to tell someone that "you have to do it like that" if the person has never done it themselves. You need a certain legitimacy to make demands before being able to say "it has to be done by such and such a time". You have to understand whether its achievable or not" (Production Division line management, Plant).

This means that this loss of skills also has an impact on the planning of activities by the Project Managers:

"This is reflected by a lack of knowledge about intervention times. If you don't do it, you don't know how much time is needed for an intervention. This is a fundamental of production management. This skill has very often been lost" (Executive, Production Division, National Level).

Underestimating these requirements has a direct impact on planning and causes greater time pressure which hampers subcontractors' work. This knowledge, which is acquired with experience, contributes to the instructing party's organizational skills. Failure to manage these timeframes compromises coordination of maintenance operations. Having become aware of these problems, in 2015, the Production Division's national level decided to outsource part of this organization work, a decision which, for some, accelerated the loss of technical skills. What is at stake is "the Production Division's ability to work effectively with subcontractors" (Executive, Production Division, National Level).

Discussion-Conclusion

In examining changes to maintenance practices, we can see a continuous increase in skills-related issues and maintenance costs. Whilst the Production Division is continuously striving to cut costs, we can question the logic of decisions "whereby the originators act consistently and intensively against the goals they have set themselves" (Morel, 2002, p. 13). Our empirical study backs up the hypothesis flagged up by the literature of the instructing party's loss of skills when they no longer carry out the activity that they outsource. It demonstrates the effectiveness of the social-based pattern put in place by the "builders" at micro level but also its vulnerability and the harmful impact of its weakening as a result of the strengthening of formal control. It also highlights the importance of collective work and inter-organizational cooperation for maintaining and expanding maintenance skills both for in-house stakeholders and subcontractors. Our study therefore confirms the importance of the social-based pattern when the gap between the skills of the instructing party and those of the subcontractors widens. In particular, it shows how an instructing party whose skills are declining weakens the autonomous and joint regulation which the literature on high-risk organizations indicates as being required.

This leads to a certain number of adverse effects: the Production Division's stakeholders in the field not only lose mastery of technical tasks but are no longer able to assess the subcontractors' abilities in this respect; they fail to notice mistakes by simply focusing on administrative supervision of the work. This means that their loss of skills bolsters formal control which in turn has an impact on the subcontractors' maintenance skills. Lastly, the requisite conditions for safeguarding the reliability of HROs are not met as there is an imbalance in favor of the control regulation and centralization, a loss of organizational slack to which subcontractors contributed, and an erosion of inter-organizational collectives. At the end of the day, in a high-risk context, are budgetary streamlining and subcontracting compatible in light of the control patterns that they require? One drives towards formal control patterns whilst the other requires informal control pattern to be maintained in circumstances where the loss of skills can lead to disaster. The case study highlights how decisions taken to address financial difficulties may have an in-depth effect on the skills needed to maintain the safety of facilities.

Whilst outsourcing is not called into question by the company's stakeholders, the reasons for the loss of skills nevertheless causes controversy in-house. In the divisions/departments, some attribute responsibility for the problems encountered to subcontractors (management difficulties, lack of training for new arrivals). It is true that educational establishments no longer teach the Production Division's technologies which date back to the 1960s and 1970s. Of course, responsibility can be placed on the shoulders of subcontractors tasked with training their junior staff but market-based pattern hardly encourages them to invest in such a specific asset owing to the uncertainty surrounding future contracts. It should be reiterated that the technical skills required can only be acquired by using these technologies. Others (usually those with the most seniority) blame the decline in the Oversight Managers' maintenance skills and its impact on their ability to carry out control duties. These diverging

viewpoints perfectly reflect the complexity of the skills-loss phenomenon.

Consequently, conceptions of work and organizations clash and reveal opposing cultures, confronted with a major challenge for HROs. This is another strength of our study: giving visibility to the ways in which two successive generations work in the same company, and highlighting their opposition by underlining:

- On the one hand, the connection between a robust business line culture, supporting the development of tacit know-how and social control conducive to learning "on the job" and, more broadly, to inter-organizational cooperation. In this context, maintenance appears as a group activity and not as a turnkey service, involving shared responsibility and organizational learning fostering skills development.
- On the other hand, the connection between a financial logic, with concerns about cost-cutting, the standardization and harmonization of practices, and the development of a market-based pattern, in parallel with the bolstering of bureaucratic-based pattern which is detrimental to the involvement of subcontractors. The company's standardization and bureaucratization go against the humanist culture of the "builders". The dominance of prices in the selection process tends to disqualify subcontractors that have demonstrated their know-how, and this prevents experience acquired "on the job" from being capitalized on. According to the Production Division's stakeholders (local level), this side-lining of business line expertise in favor of cost cutting contributes to the loss of skills of the instructing party and the subcontractors which represents an undeniable risk of quality defects.

Nevertheless, no major incident has contributed to establishing a loss of skills which made it all the more difficult for management to accept it. By plotting out the timeline, we have been able to fine tune analysis of the process by which skills declined. It emphasizes the length of time, due to the joint inter-organizational regulation methods implemented by the "builders", and the delaying effects of management decisions which, over time, proved to be detrimental to knowledge transfer. This loss of skills was therefore gradual which makes it barely noticeable in the short term and hampers the company's awareness of the risks it carries.

We highlighted a whole range of factors that have contributed to the slow decline in skills, going so far as to question the organizational competence of the instructing party. The latter's loss of skills combined with the financial difficulties ultimately led to a destructive spiral from which the company has trouble escaping. However, the company is now aware of the scale of its loss of know-how. In this respect, our study flags up the interest in assessing the relevance of the inter-organizational control patterns adopted in light of their impact on skills.

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