Training to safety rules use. Some reflections on a case study

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Vidal-Gomel, C. (2017). Training to safety rules use. Some reflections on a case study. *Safety science,* 93, 134-142. DOI : 10.1016/j.ssci.2016.12.001.

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Abstract: This article proposes to consider training in occupational risk prevention as situated at the crossroads between regulated safety (based on prescribed safety rules and procedures)- and managed safety (based on operators' knowledge and experience). A case study in the field of ready-mixed concrete delivery to worksites is presented. It demonstrates the redefinitions of a safety rule within companies, giving it little operational value for operators, and the resources that they have built with experience. These resources are also shown to be limited. Indeed, not everything can be learned through in situ experience and peer mediation. Thus, the " professional knowledge of reference" needs to be identified in order to design training content that combines the "regulated safety" and "managed safety" that are necessary to produce safe working conditions. This approach to training design, based on the analysis of activity in situ, represents a shift away from the technical-regulatory and behavioral approach that still dominates the field of training in occupational risk prevention.

Key words: training, safety rules, occupational risk prevention, activity analysis, professional didactic

Training in occupational risk prevention is an important issue, notably because it constitutes a prerequisite to improving health and safety in the workplace (Ford & Fischer, 1994). In initial or continuing education, regulations and in particular safety rules[1] represent a large part of the courses.

In this respect, training should be positioned within the existing debate between two models of the relation to safety requirements (Deker, 2003a; Hale & Boris, 2013): the first considers safety rules and procedures as derived from policies developed at the highest level and as the best means of risk prevention. The rules and procedures must be applied. Their non-application is considered to be a violation (Reason, 1990). Suppression of violations thus becomes a major issue (Hale & Boris, 2013), which can go as far as making a "violation" a crime in the case of accident (Dekker, 2003b).

The second model adopts a comprehensive perspective of the relation to safety requirements. It considers that rules and procedures are tools to coordinate and structure an activity with a safety objective. They are not only a means to control and limit human activity. On the one hand, they embody a model of the users to whom they are addressed that is too limited (Leplat, 1998). Indeed, operators do not apply the requirements without understanding the situation (Vidal-Gomel, 2007). They judge their effectiveness and their relevance (Hale, 1990; Leplat, 1998; Terssac, 1992); a judgment that is necessary because to work is "*to be actively engaged, especially in the verification of the domain of validity of the formal rule*" (Terssac, 1992, p. 145). The implementation of a safety rule results from a process of conceptualization of the properties of the rule and an understanding of the situation, and represents only one of the safety means available to operators (Vidal-Gomel, 2007; Munoz, Vidal-Gomel & Bourmaud, 2015). On the other hand, safety requirements cannot control the activity because they cannot fully respond to the diversity, variability and unpredictability of situations. They must be adaptable and adjustable to the characteristics of the situations. "French-speaking[2]" ergonomics (Faverge, 1967, 1970) and researches on the resilience of risk systems (Hollnagel, Wood, Leveson, 2006 ; Hollnagel, Leonhardt, Licu, & Shorrock, 2013) have contributed to highlighting the positive contribution of

[1] "A safety rule is a defined state of a system, or a defined way of behaving in response to a predicted situation, established before the event and imposed upon and/or accepted by those operating in the system as a way of improving safety or achieving a required level of safety" (Hale & Swuste, 1998, p. 164).

[2] See Daniellou (2005) or Fillietaz and Billet (2015).

these adaptations, and more generally of human activity for the reliability of the systems. Indeed, in contrast to the usual discussions on the subject, humans are not necessarily the weakest link in the reliability of socio-technical systems. Thus, since Faverge (*op. cit.*), numerous studies have highlighted how operators produce safe conditions (Nascimento, Cuvelier, Mollo et al., 2014).

Over and above the debate between these two models of the relation to safety rules, contemporary researches have evolved towards the idea of a necessary articulation of a "regulated safety" produced in a top-down manner by the prescribed rules and procedures, and a “managed safety” produced by operators. This articulation represents a means to create a culture of safety contributing effectively to the reliability of the work system (Nascimento *et al.,* 2014).

How can training in occupational risk prevention contribute to the articulation of regulated and managed safety?

To understand this question, we first propose a case study realized in the field of ready-mixed concrete delivery to a worksite, which will allow us to highlight the occupational risks of a particular sector, the difficulties encountered by the operators, the resources they have developed to deal with them and their limits. We then describe the characteristics of two types of training in occupational risk prevention that we have analyzed and present guidelines for designing training in occupational risk prevention combining regulated and managed safety.

1. A case study in ready-mixed concrete delivery

The case study we present is part of a research program focused on the field of ready-mixed concrete delivery and specifically concerned with the management of risks of contact between the delivery vehicle[3] and an overhead power line present on the site. In this field, accidents are rare but they are serious and may cause several victims. Despite previous analyses that gave rise to recommendations (Paques, 1993), contacts with overhead power lines remain a significant cause of fatal incidents involving electricity (Janicak, 2008; Koustellis, Anagnostatos, Halevidis et al., 2011; Chia-Feng, Yua-Yuan, & Mohamad, 2012). In France in the domain of ready-mixed concrete delivery theses accidents worried policymakers, who initiated this research program.

The French UTE C18-510, the reference document for the prevention of electrical risks, defines the "minimum zone of approach", i.e. the distance below which there is a risk of arcing. It is calculated as follows: minimum approach distance (MAD) is equal to the voltage distance [nominal value of the voltage multiplied by t (t = 0.005)] plus the gap distance. For a 20,000-volt power line, this is 0.6 meters.

The regulations also define the “vicinity working distance", the zone reserved for accredited personnel. This is 3 m for overhead power lines of less than 50,000 V and 5 m for those above 50,000V. Non accredited personnel should not enter this zone. The legislator thus ensures that the operator has been trained in the nature of the electrical risks, the dangers for the human body, the means to avoid them and the action to be taken in case of contact.

In the companies we worked with, this rule has been redefined. Operators must stay at least 5 m away from an overhead power line, regardless of its voltage range. In one company, this rule was modified within the last year, setting the distance to 6 m.

In the regulations, the rule differs depending on the population it addresses (electricians and non-electricians). The rule is also redefined within companies, disconnecting the content of the rule from its properties to manage the risks of arcing. The rule is not only defined depending on the

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[3] Three types of vehicle are concerned: drums with conveyor belts, mixer pumps and concrete pumps (see Vidal-Gomel et al., 2009).

(technical) operational principles of risk prevention, but also depending on the model of the operator for which the designer intended it (Leplat, 1998). This process of redefinition also takes into account the fact that it is a social and organizational construction (Bourrier, 1999). We need to ask how the operators use such rules.

Before answering this question, we will provide some details on the methodology of the study.

1.1. The methodology

The data presented in this study are the result of research conducted in France in three different companies from the professional sector of concrete delivery. Two of these companies are located in the Île-de-France region and one in the Pays-de-la-Loire region. All the operators who contributed to the study did so on a voluntary basis. The duration of the interviews was variable, depending on the availability of the operators and their work constraints. However, they never lasted less than 1 h. The data collection was composed of the following elements:

- Collection of information on electrical accidents caused by non-electricity professionals, from reports extracted from the INRS EPICEA database.
- Study of the regulations in the field concerning the prevention of electrical risks.
- Semi-structured interviews with eight operators driving different types of delivery vehicles: four drivers of vehicles equipped with conveyor belts (C1: 10 years professional experience delivering ready-mixed concrete and driving the vehicle; C2: 25 years professional experience and driving the vehicle; C3: 4 years professional experience and 3 months of the vehicle; C4: 3 years professional experience and 1 year of the vehicle); two drivers of mixer pump vehicles (MP1: 5 years professional experience and 8 months of the vehicle; MP2: 5 years professional experience and 2.5 years of the vehicle); two drivers of pump vehicles (P1: 21 years professional experience and 1 year and 3 months of the vehicle; P4: 15 years professional experience and 10 years of the vehicle).
- Observations of work situations: about 80 hours of observation of three operators experienced in the driving of conveyor belt vehicles (over 5 years) and one driver of pump vehicles with one year experience; self-confrontation interviews were conducted with two operators experienced in the driving of conveyor belt vehicles.
- Observation of a two-day classroom training course entitled "safe operation of concrete pumps". The observed session involved three operators (O1: 10 years professional and vehicle experience; O2: 17 years professional experience and 8 months of driving pump vehicles; O3: 10 years professional experience and occasional driver of concrete pump vehicles – about once every 2 weeks for 6 years). Interviews were also held with two trainers (including the trainer who taught the observed course, who has been a former delivery vehicle driver).
- Collective confrontation interviews (Mollo & Falzon, 2004) conducted based on photos from 2 worksites with overhead power lines, held with 4 operators driving pump vehicles (OPE 1: 1.5 years professional experience and driving of pump vehicles, OPE 2: 15 years professional experience and driving of pump vehicles; OPE 3: 7 years professional experience and 5 of driving pump vehicles; OPE 4: 3 years professional experience and driving of pump vehicles).
- Observation of one delivery with a concrete pump to a worksite with an overhead power line (5 hours), done by an operator (CP) with 1.5 years professional experience and driving of pump vehicles, and a self-confrontation interview with this operator (Mollo & Falzon, 2004).

Based on the later observation, we propose the following case study. Because of the difficulty to be present at the exact moment of a delivery in a situation with a power line and due to the difficulties to negotiate an observation with operators of the construction site who did not meet us before, we only observed one situation of delivery with a overhead power line. We will discuss this case including all the data collected during the research, using a triangulation method (Jink, 1979).

1.2. A case study: observation of a delivery situation in order to understand the usages of the safety rules

When it comes to operating a vehicle equipped with a drum or a mixer pump, the driver refers to the order form that he is given by the concrete plant – the company that manufactures and sells the concrete. The vehicle is loaded depending on the type of product ordered. The operator drives the vehicle to the site, contacts the site manager and makes the delivery to the place that is indicated. He must conform to the requirements of the site manager while respecting the safety rules. The delivery procedure differs depending on the characteristics of the vehicle. With a concrete pump, as in the situation we propose to examine, when requested by the plant, the operator drives the vehicle directly to the site and positions it. He then waits for a vehicle equipped with a drum to bring the concrete, to be able to deliver it to the requested location.

We observed the operator CP during a delivery situation to a worksite in the Paris suburbs using a concrete pump. The delivery concerned the realization of a floor for the top level of a small building under construction. A 20,000-V power line was situated directly above the sidewalk.

We notably recorded the location of the vehicle, its stabilization, and the way in which the boom was deployed. Photos were taken of these different operations and the site[4]. These were used as a basis to conduct a self-confrontation interview with the operator.

We observed the work of positioning the vehicle (concrete pump) by the operator to avoid the risk of arcing, which in fact induced the existence of other risks.

The vehicle was placed diagonally in the space between the wall of the site boundary and the construction in progress, so that its front was almost in contact with the construction. The power line was then behind the vehicle. Thus, by driving the vehicle as far as possible onto the site, the driver could deploy the boom while staying as far away as possible from the line.

The operator then stabilized the vehicle. In this case, the operation could not be performed correctly: to the right, a caravan prevented the complete deployment of the stabilizer; to the left, the stabilizer was at the edge of a hole and friable ground. The operator therefore laid crosswise planks to prevent the vehicle’s stabilizer from sinking.

In this situation, due to lack of space, congestion and the state of the ground, the management of the risk of arcing with the electricity line created stabilization problems and a risk of the vehicle overturning. The operator identified the risks and managed them by his operation of boom deployment, but also by his method of pouring the concrete and regular checks.

To deploy the vehicle boom, he stood at the back, under the power line. As for other operators interviewed, the operator considers that this position allows a better assessment of the distance between the boom and the line: "*I'm just below the cables... so I can see the distance*". He deployed the boom using a remote control device.

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[4] It was not possible to film the worksite.

The first arm of the boom was deployed vertically in order to stay away from the line. He therefore integrates the existence of a minimum approach distance (MAD) into his operating methods. It served here as a pragmatic concept that organized the action (Vidal-Gomel & Samurçay, 2002). The distance to the line was estimated to be approximately 2 m by the operator and 2 observers. During the self-confrontation, the operator said that he knows that the company's rule is to maintain a distance of 6 m. From his point of view, there is always a risk when close to a power line, but the delivery was feasible at this worksite.

> "— Observer: Okay, so at 2 meters you think that there is no risk?
> — Operator: I do think that there is a still risk though, because I avoid it. […]
> *Let's say it's due to / I mean every day / we have to turn down sites / even though there are sites where the work is feasible […]*
> *The standards that they gave us are really so that there is no / that there is no risk at all. At 6 meters there really is none / [...] Let's say that it's this year that it was / that it was / they added 1 meter because before it was 5 m."*

The rule does not allow him to do his job, since its application would cause too many worksites to be refused. This assessment is representative of what we saw in other companies in this professional sector, including with the requirement of a distance of 5 m (Vidal-Gomel *et al*., 2009).

Moreover, in the example, the weight of the boom rested on the center of the vehicle, not on the stabilizers: "*The first arm, it was really straight. Like that there's really no risk that it will overturn*". Once this arm was deployed, the operator went up onto the floor to be laid, rotated the boom and deployed both portions of the remaining articulated arm in the direction of the floor to be laid. This time, the weight of the boom was resting more on the stabilizers. Therefore, the operator had to check the stability.

During the self-confrontation, he stated that he performed two types of verification:

- Static: *"at the moment when we placed the pad / when we placed it, because there is a force when we put it on the pads, so it could have sunk*."
- Dynamic, once the boom is deployed, he moves it up and down: *"Yes we move it like that. Let's say that there the boom is on the side of the pad, so I tested it."*

In these first verifications, in addition to the activity of electrical risk management by specific positioning of the vehicle, there was the activity of managing the risk of overturning, which uses the center of gravity, a second pragmatic concept that organize action.

Risk management then continued by regulation of the flow of concrete. Indeed, during the pouring, the pump can cause the boom to jerk, which can disrupt the stability of the whole vehicle and/or bring the vehicle boom closer to the power line. The operator therefore regulates the rate of pouring to minimize these risks.

In this example, it is interesting to note that the distance below which there was a risk of arcing was 0.6 m using the formula indicated by the UTE C18-510. By keeping 2 m away, *a priori* the operator did not run a risk of arcing. This is what he seems to have integrated *de facto* during his professional experience. However, he did not know this. He only knew the rule laid down by his company, which was presented as identical, regardless of the voltage range. The MAD acted as a pragmatic concept that was formed during his experience. The safety rule was known, but not used in the actions taken in situ.

The safety rule of the company would lead him to refuse too many worksites. It seems therefore to have little credibility in the eyes of this professional, especially since refusing a worksite is not commonplace in this domain. We will come back to this point later.

In the situation studied, there is an interaction between the risk of the vehicle overturning due to the lack of space to position it and the risk of arcing. Two pragmatic concepts are integrated into the operating methods: the minimum approach distance and the center of gravity, which are consistent with analyses performed with other operators of this domain (Vidal-Gomel *et al*., 2009). They constitute real tools integrated into action, used to manage occupational risks in situ.

Thus, in this situation, the safety rule as it is formulated and prescribed cannot be a guide or help in the management of the electrical risks encountered daily.

The development of the operator's skills can only build on experience gained in situ and possibly from the work collective. However, this is not enough to understand the diversity of risks, the means for prevention and recovery of situations: not everything can be learned in work situations. For example, in exploratory interviews with other drivers, we found that they did not precisely know the rules setting the safe distance from a power line like the previous operator, or the recovery procedures in case of contact between the delivery vehicle and the overhead power line, which can be a cause of electric shock or even electrocution (Vidal-Gomel *et al*., 2009).

In addition, understanding the usage of the safety rule in work situations requires the analysis of the operators' decisions, reflecting a compromise between conflicting constraints, which can concern four poles of working situations (Caroly & Weill-Fassina, 2007, p. 101):

- "a 'system' dimension, referring to an undertaking's goals and resources (materiel, equipment, rules, procedures, management structure),
- a 'self' dimension, referring to the agents and their personal goals, subjectivity, training, experience, physiological and psychological possibilities, and the meaning they give their work,
- an 'others' dimension, concerned with the goals, obligations and demands of other people (colleagues in the same job, cross-job teams, partner networks)
- a 'person the service addresses' dimension, such as a 'customer', 'patient', 'beneficiary", 'user", 'the public', entourage, family, etc.".

Indeed, although operators are told to refuse delivery when they identify a risk, when they return to their base without having delivered, they can be pressured. Identifying an arcing or overturning risk is not always sufficient to refuse a delivery. A good driver is one who performs the delivery (Vidal-Gomel *et al*., 2009). Thus, other levels of regulation come into play, which involve maintaining good relations with a site manager, for oneself when one is required to meet him again, but also for the concrete plant whose client he is. Finally, it also means keeping one's job. These are regulations at another level (Leplat, 2008), based on reasons in which social, organizational, economic risks and risks of accidents are interwoven. Promoting safer arbitration then requires the transformation of work situations, notably by giving operators the means to deal with the pressures (Vidal-Gomel, Olry, Lanoe, et al., 2007).

2. What form of training should be given in occupational risk prevention?

The study conducted in the sector of ready-mixed concrete delivery highlights both the inadequacies of the safety requirements and the difficulties of learning “on the job” in this area. Training in occupational risk prevention thus appears essential.

Based on activity analysis, several ways to train in occupational risk prevention have been explored (Teiger & Montreuil, 1996; Lacomblez, Bellemare, Chatigny et al., 2007; Delgoulet, Chatigny, Cau-Bareille et al., 2012). Here we will consider the approach proposed by Rogalski and Samurçay, which allows a formalization of the knowledge to be transmitted and proposes ways for its transposition that will allow the design of training situations, in line with professional didactic frame (Mayen, 2015).

Indeed, in this context, the activity analysis prior to the training allows the identification of “professional knowledge of reference”: common knowledge of efficient practices; and “situations of reference”: work situations that should be mastered at the end of the training (Rogalski, 2004; Samurçay, 1995). The characteristics of the reference situations are then transposed to design training situations (Samurçay & Rogalski, 1998), which distinguishes this proposal from those that transpose knowledge but leave little place for understanding the fact that the activity takes place in situ (Daniellou, 2005; Mayen 2015).

These frameworks integrate the notion of instrument (Rabardel, 1995), which can be used to analyze the usage of the safety rules. By taking into account the characteristics of the safety rules, the necessities of their acquisition and their transformation by the operators, they can indeed be analyzed as prescriptive artifacts that the operators should understand in order to constitute one or more instruments, which articulate with pragmatic concepts during development (Vidal-Gomel, 2007).

The process of instrumental genesis (Rabardel, 1995, Béguin & Rabardel, 2000) makes it possible to precisely account for the subject’s construction of his instruments and thus to put the relation to safety rules in a developmental perspective.

More specifically, with experience the prescriptive artifacts and their usages are integrated into real instrument systems, a sort of “toolbox” constituted of redundancy and complementarity relations of the functions used to manage risks (Munoz *et al*., 2015). These systems must be understood in their relation, on the one hand, to the classes of situations, and on the other hand, to the pragmatic concepts, which are involved in the understanding of the situation and direct the effective action (Vidal-Gomel, 2007).

Since the instruments are put to use with the objective of occupational risk prevention, the question of their effectiveness means that precautions should be taken. To judge this, the instruments should be analyzed with regard to the characteristics of the situations in which they are mobilized and their functions of prevention and safety. We focused on their development with the acquisition of experience. However, when it comes to occupational risk prevention, not everything can be learned in situ. Built during action and for use in action, these resources must also integrate the theoretical knowledge underlying safety rules by explaining the relations between variables of situations and objects of action.

Indeed, when the rule is truly designed as an operative principle making it possible to manage risk and when it is consistent with the situations the operator must handle, it can integrate both theoretical knowledge on the risk and its prevention (scientific and technical knowledge) and knowledge acquired in the past, with reference to lessons learned after an incident or accident. As artifacts, safety rules capitalize historical and social acquisition (Léontiev, 1978), which the subject can more or less adopt by developing an instrument from all or part of this artifact (Vidal-Gomel, 2007; Munoz *et al*., 2015).

We need to ask how can training be developed to allow such acquisitions. To answer this question, we will come back to the observed training courses in risk prevention and focus on training content in order to identify the safety and learning models on which they are based, and to compare them with those that can be identified from the activity analysis. This will allow us to see what the nature of training in occupational risk prevention could be like.

2.1. Training in occupational risk prevention disconnected from work, an alternative training model

The training courses in occupational risk prevention that we were able to attend or whose contents we could examine concerned professions in electricity and ready-mixed concrete delivery to a worksite. The training can be described as technical-regulatory oriented (Laberge, MacEachen & Calvet, 2014).

Training in the prevention of electrical risks is highly regulated. Operators must be accredited[5]. The four training sessions in the electrical accreditation that we observed were designed for a population of maintenance electricians. These three-day training courses were organized in two parts: a reminder of the dangers of electricity and their consequences for the human body, and a reminder of all the safety rules that must be implemented. During the four sessions, a work situation (accident) was mentioned once. The courses that we analyzed in a vocational high school – for the 1st year of a professional Baccalaureate in "Electrical equipment and installations" – had the same learning logic: safety rules were disconnected from work situations (Vidal-Gomel & Samurçay, 2000).

For concrete delivery, in France, the only required certification is a driving license for the delivery vehicles. The training course entitled “Safe use of a concrete pump” that we participated in was organized by a trade union for member companies. It lasted three days. For all participants, the training course took place well after they started working with a concrete delivery vehicle. One of them had had a few hours of training in his company on the safety rules. In this three-day training course, risks were presented independently from each other (road risk, risk of the vehicle overturning, electrical risk, etc.) and for each of them the rules to be applied were specified. This time, working situations were a little more frequently referred to, since the trainer encouraged discussions with the operators. However, when trainees reported situations in which they could not use a rule, they were reminded that from a legal point of view they were responsible, which put an end to the debate.

A common point of these training courses is that they were conducted on the regulated safety model, without necessarily trying to understand the rules: everything was done as if the statement of the rule was sufficient for its usage. However, the use of a safety rule depends on a process of conceptualization that concerns both the properties of the rule and the understanding of the treated situation, articulating theoretical knowledge and knowledge of action.

These technical-regulatory training courses are also based on a particular model of the individual at work: that of an individual who should apply the rules and procedures as they are stated and not an individual who should also understand them and understand the situation. They try to shape or change the behavior without taking into account the ensemble of the activity, which makes them similar to a behaviorist model of training (Laberge *et al*., 2014). This model is also

[5] In France: Decree no 2010-1118 of 22 September 2010 concerning operations on or in the vicinity of electrical installations. Since January 2015, accreditation is regulated by the NF C18-510 standard, stating that training should be "theoretical" and "practical", which was not the case at the time of our observations.

demonstrated in mode of validation proposed: electrical accreditation training courses ending with a multiple choice test. They thus focus on the rules and principles memorized by the trainees without questioning the appropriation of their meaning.

Another approach exists that contrasts with the characteristics of these courses, considering instead that training should allow the development of the operators' instruments and their conceptualization (Vidal-Gomel, 2007), taking into account the fact that the safety rules are also rules of law[6], and that the respect of the requirements established within the company is governed by the employment contract, which is a subordination contract[7].

A pedagogy of situations (Mayen, 2015) thus needs to be developed, allowing the implementation of active teaching methods that have shown their utility in the field of risk prevention training (Becker & Morawetz, 2004; Burke, Sarpy, Smith-Crowe et al., 2006; Laberge *et al*., 2014). More specifically, such an approach focuses on action in situ as a means of development by integrating mediation by the trainer and by peers (Samurçay & Rogalski, 1998). It uses both action in situ and the subsequent action analysis (Schön, 1983; Mollo & Falzon, 2004). The design of training situations is based on the identification and transposition of the professional knowledge of reference.

2.2. Design of training in occupational risk prevention integrating regulated and managed safety

The design of training in occupational risk prevention integrating managed and regulated safety requires, on the one hand, an understanding of the practices developed by the operators to manage the risks in situ and, on the other hand, an analysis of the regulations in the domain. Based on this double movement, we propose to identify the knowledge of action and the scientific and technical knowledge relevant to training. These represent the professional knowledge of reference needed for the design of training situations (Samurçay, 1995; Rogalski, 2004).

The professional knowledge of reference is identified from the analysis of the operators' activity, supplemented by an epistemological analysis of the tasks, carried out by the researcher. "*This analysis is equivalent to the epistemological analysis of a domain in didactics of science whose objective is to identify classes of problems for which a given concept represents an appropriate response*" (Samurçay, 1995, p. 116). The result is the integration of an ensemble of theoretical knowledge with the operators' knowledge of action. In the work of Samurçay (*op. cit.*), the analysis of the activity of blast furnace drivers is complemented by an analysis conducted with specialist engineers in the domain.

In this framework, our work is based on the study of the safety regulations, considering that, as prescriptive artifacts, they capitalize on an ensemble of scientific and technical knowledge and past experiences that must be identified.

These points are discussed below based on our work in the domain of ready-mixed concrete delivery.

2.2.1. Professional knowledge of reference for occupational risk prevention in the field of ready-mixed concrete delivery

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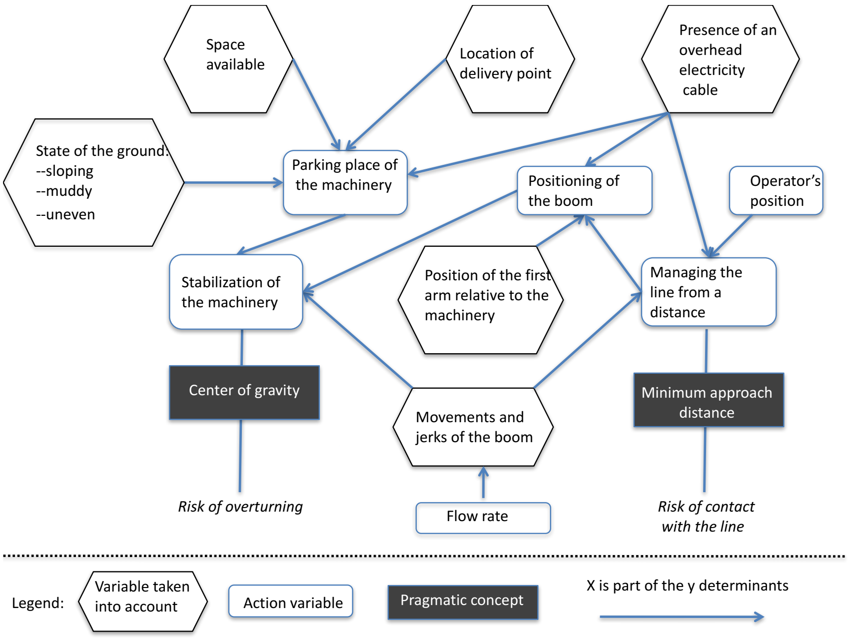
[6] The rule of law is "the legally required standard, whatever its source (customary or legal rule), its degree of generality (general or specific rule), its scope (absolute, rigid or flexible, etc. rule)" (Cornu, 2005, p. 774).

[7] In French law, this is specified in the Judgment of the Social Chamber of 13 November 1996, of the Court of cassation.

The professional knowledge of reference identified for concrete delivery relates to situations where a risk of the vehicle overturning and/or arcing with an overhead power line is present. Several dimensions identified in the case presented above are confirmed in work done with other operators (Vidal-Gomel *et al*. 2009). They were formalized (figure 1) as a set of variables taken into account by the operators, incorporating the two pragmatic concepts originally identified (center of gravity and minimum approach distance). This does not mean that all operators take all of them into account. We aggregate the different pertinent dimensions identified.

Figure 1: Variables and concepts taken into account by the operators to cope with overturning risks and electrical risks



The state of the ground, the space available and congestion, the location of the point of delivery, and the presence of overhead power lines all affect the choice of parking place for the vehicle (figure 1). Parking place of the vehicle, state of the ground and deployment of the boom then all affect vehicle stabilization, which requires center of gravity to be taken into account. The presence of a power line and the position of the first arm with respect to the vehicle, are determinants in the deployment of the boom that is, in turn, a determinant of the vehicle stabilization, an operation that integrates the center of gravity.

During the work, the pouring rate, which is a variable that the operator can adjust, will determine any jerking of the boom that might destabilize the vehicle or reduce the distance to the power line.

These first aspects of professional knowledge of reference must be completed based on those included in the requirements concerning the overturning risk and the risk of arcing with a line.

For the risk of overturning of concrete delivery vehicles on worksites, the regulations to be applied by the driver are given in the highway code (Ferreira, 2010). This specifies the license category that is required for the vehicle driven (here categories B or C). It also indicates that the vehicle must be driven in accordance with the characteristics established by the manufacturer.

The driver should also ask the site manager about the traffic lanes to be used and their conditions of use at the time of his arrival (*ibid.*).

Manufacturers of concrete delivery vehicles provide technical specifications in the form of tables and graphs, indicating the possibilities for deployment of the booms depending on their size and the possible angles of rotation, although they do not provide indicators of overturning risk.

Regulations for the prevention of electrical risks are more extensive and detailed. Based on the UTE C18-510, several classes of situation can be distinguished:

- The first class of situations can be considered as the "nominal situation": the operator has identified the presence of an overhead power line and agreed to do the delivery. In this situation, a non-accredited operator must remain at a safe distance from the power line, as mentioned above.

The other two classes of situation correspond to an electrical incident that the operator can potentially put right:

- In the second class of situations, an arcing between the articulated arm of the vehicle and the power line occurs when the operator is inside the cabin of the delivery vehicle. The recovery procedure is to wait until the automatic resets of the power line have finished[8] before getting out of the vehicle, in order to avoid touching the live metallic mass while in contact with the ground and thus creating a potential difference, which would result in electric shock or electrocution of the driver.

- In the third case, the operator is outside the cabin at the time of the incident. Because of the contact with the line, the live metallic mass of the vehicle may be in contact with the ground, which creates a live zone: from the point of impact a gradient potential is formed on the ground. In this case, there is an important potential difference about every 0.8 m, which corresponds to the distance that an adult covers in one stride. In other words, in this zone, the operator must not move “normally”, but should take small steps or small jumps. To avoid being electrified, he should take into account the "step voltage”.

The procedures defined for the three classes of situations are explained by several concepts taken together: the step voltage and MAD are ways to take into account the potential difference. This notion is itself related to the concepts of air ionization[9], mass[10], resistance, etc., which are common electricity concepts (figure 2).

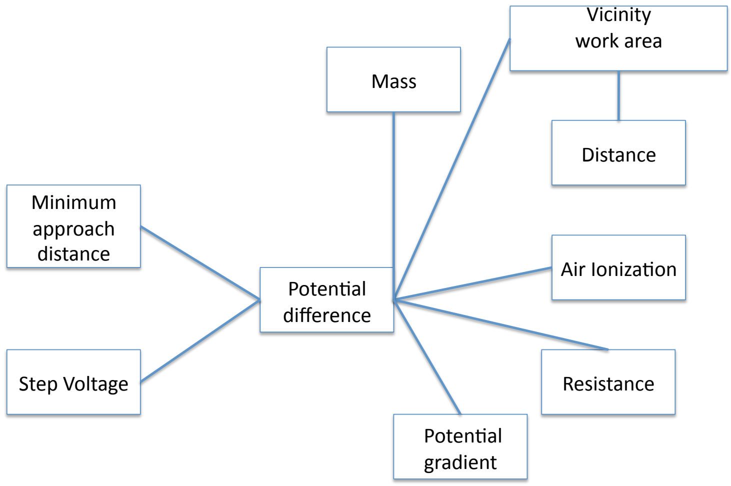
Figure 2 includes all the concepts of these three classes of situations. It summarizes the previously explained relationships.

Figure 2: Concepts involved in prevention of risk of contact with an overhead power line and their relationships

[8] As with any electrical network, in case of incident, a protection is triggered that shuts down the network. For overhead power lines, several power resets are automatically performed before the final shutdown. This avoids shutting down a significant portion of the network for every minor electrical incident.

[9] Process that explains the production of an "arc".

[10] The mass is the "conductive part of electrical equipment that may be touched by a person, which is not normally live, but may become so in case of an insulation fault in the active parts of the equipment" (Decree n° 88-1056 of 14-11-1988). In this form, the notion of mass is a technical concept. The difference we introduce between scientific, technical and pragmatic concepts is presented and discussed in Vidal-Gomel and Rogalski (2007), and more succinctly in Vidal-Gomel and Samurçay (2002).



All of the professional knowledge of reference identified is composed of situational variables, of variables on which the operator can act, and of concepts. These include pragmatic concepts that organize the action, such as the center of gravity or the way operators incorporate the minimum approach distance; scientific concepts such as the potential difference, resistance, etc.; and technical concepts: the voltage step, the minimum approach distance in its computable form, or the concept of vicinity. This professional knowledge of reference has the advantage of repositioning the safety requirements within a wider set of knowledge, combining the classes of situations, the variables taken into account, the concepts that explain them and those that reflect the phenomena involved, which justify the rules and procedures.

2.2.2. From professional knowledge of reference to the design of training situations: some guidelines

The professional knowledge of reference can be used in different ways: for example to design information systems with the aim to support the operator diagnosis in complex situations (Samuraçay & Hoc, 1996). It can also be used to design training (Samurçay, 1995, Caens-Martin, 2005). This can involve simulation, by providing trainers with the opportunity to change the situational variables to modulate the difficulty of the problems.

Other uses merit exploration. The professional knowledge of reference could be used to collectively analyze filmed work situations. These could be proposed to the trainers as tools to design and guide collective confrontation interviews (allo-confrontation, Mollo & Falzon, 2004): classes of situations could be used to identify a set of situations to analyze, and variables could be used as dimensions to be introduced in the analysis if the operators do not do so. In this case, the pragmatic concepts can be used explicitly to analyze the procedures, patterns of use of rules or other instruments, and their interests and limits for risk prevention; and scientific and technical concepts can be introduced to account for the phenomena involved.

This type of training would benefit from the properties of films: a film promotes an anchoring of the reflection on action in situ (Burke, Scheuer, Meredith, 2007). It gives access to the dynamics of the action, makes it possible to understand the complexity while remaining remote (Gaudin & Chaliès, 2012) and allows rewinding, freezing on an image, or scrolling image by image. However, the use of video by beginners can sometimes seem more like "foraging" than analysis (*ibid.*), which makes mediation by the trainer all the more important. This type of training also stimulates peer mediation. Thus, for learners with different levels of experience, it should enable the sharing of individual experiences and collective evaluation of the choice of action and resources (Mollo & Falzon, 2004; Mollo & Nascimento, 2014).

Therefore, films should not be used only as a means to propose case studies, but should be associated with collective debates, thus resembling some methods for the analysis of practices, but empowered by activity traces (the films) and the results of the preceding activity analyses.

This type of method requires the implementation of collective rules of debate and analysis (Mollo & Nascimento, 2014), such as sharing the objective of understanding without judgment, voluntary commitment, and symmetry in relations, while at the same time accepting the trainer's role of regulator. Furthermore, it involves describing and analyzing situations, but also collectively evaluating the acceptability of the practices described by the participants with regard to the risks involved: risk of work accidents or damage to material, but also risks of sanctions. The safety regulations which are enforced by the legislation are rules of law, and compliance with the requirements established within a company is governed by the employment contract, which is a subordination contract. This highlights the limits of training involving the transformation of work situations. It cannot solve issues related to the relevance of the requirements and their coherence, whether this is internal coherence or coherence with a particular organization of work (Leplat, 1998).

3. From activity analysis to the design of training: some proposals

We positioned our questions on training in occupational risk prevention within the contemporary debates about the analysis of work and the relations to the requirements, which led us to consider that such training requires the integration of regulated safety and managed safety (Dekker, 2003a; Hale & Boris, 2013; Nascimento, *et al*. 2014). This also led us to outline an approach for the design of training in risk prevention that goes beyond both the limits of technical-regulatory training and learning by "on the job" situations.

In the situation that we studied, the safety rule validated by the legislator has been transformed and redefined within companies. It has thus been disconnected from the risk that it aimed to guard against, corresponding probably to other objectives. It is also inconsistent with the work situations of the operators, who are unable to use it. Thus, it can no longer be used to guide and manage the reality of daily work. The operators have developed other resources for risk management in situ. Moreover, their training in risk prevention was confined to learning the rules. In this context, the resources they have developed with experience are limited.

Indeed, when it comes to occupational risk prevention, not everything can be learned "on the job", or by peer mediation. Experience may prove insufficient to manage risks when the fundamental knowledge could not be acquired. For concrete delivery to worksites, the risks are linked to the characteristics of the sites themselves (presence of overhead power lines close to the delivery point, ground stability, etc.).

From our point of view, in line with professional didactics (Mayen, 2015), designing courses that integrate regulated and managed safety requires the identification of professional knowledge of reference: common knowledge of efficient practices. It is based on the analysis of activity in situ and on an epistemological analysis (Samurçay, 1995; Rogalski, 2004) of the regulations.

The analysis of activity in situ was designed to identify the knowledge of action developed with experience that allows the operators to more or less cope with the risks in situ. Notably, it makes it possible to highlight the pragmatic concepts that organize the action in situ, the variables taken into account by the operators, and the means that they implement, which are not limited to the safety rules and procedures. Another important contribution of this type of analysis is to highlight the interactions between several risks in situ and to identify the difficulties or impossibilities to implement safe practices. Indeed, social, organizational and economic determinants are involved in the decisions and compromises of the operators.

The epistemological analysis of the tasks was conducted based on an analysis of the requirements, considering that they incorporate a set of scientific and technical knowledge that explains the phenomena involved and the relations between variables, justify the prescribed rules and procedures, and incorporate the experience of incidents and accidents. This analysis thus complements the results of the activity analysis by including the knowledge that cannot be acquired through experience.

To understanding this ensemble of knowledge and then characterize the professional knowledge of reference, it is necessary to examine the functioning of the work system as a whole to understand the operators' room for manoeuvre and the adjustments they are required to make. Restricting the analysis to only the professional knowledge of reference would be taking the risk of not understanding the quality of the safety rules. Thus, in our analyses, we did not forget that safety rules are also a social and organizational structure (Bourrier, 1999), and can be disconnected from the risks that we want to control and/or the reality of work situations.

This professional knowledge of reference can then be used to design training that integrates regulated and managed safety. Our proposal involves (i) understanding the professional knowledge of reference as a tool made available to trainers to identify the characteristics of situations that could be proposed, and (ii) using films of these situations to conduct collective analyses with the learners and stimulate debate on the means used to handle these situations, their advantages and limitations from the point of view of risk prevention. Finally, this proposal involves giving trainers the means to work from their own field experience – since they are often ex-operators – and those of the trainees, without limiting them solely to the requirements. Indeed, in the courses that we participated in, If the trainer puts an end to some discussions by referring to the requirements, it can be because he is unable to understand how integrating the requirement and the reality, although the realization of the work, and the health and safety of the actors are all at stake.

The role of the trainer is changing. It no longer consists of the transmission of knowledge or rules that the learners should retain or learn. This means breaking with technical-regulatory oriented training, which in the end does not provide the operators with sufficient resources to cope with the reality of work, and instead proposing other training models. Training should use the experience of the learners and that of the trainers, with the trainer acting as a mediator between the situations selected, filmed, and presented for analysis and the learners, between the professional knowledge of reference used for the analysis and the learners, and between the learners themselves. Therefore, they should be familiar with the complete set of professional knowledge of reference and have sufficient room for manoeuvre to design and implement such training.

To conclude, our proposals on training in occupational risks prevention must be understood as a one of the means required to develop a safety culture that contributes to the reliability of work system. For example, Hollnagel, Leonhardt, Licu and Shorrock (2013) highlight the interest to understand the daily functioning of the system -- such as the contributions of different professionals to the planning of operations prior to their realization, the activities of adaptation to the variability, diversity and complexity of real situations -- that constitute core dimensions of its resilience in order to elaborate a safety policy.

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Acknowledgment: This research was funding by the Ministry of labor and by the SNPBE. I would like to thank the companies and the operators who accepted to take part in it.