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Maintenance: organizational modes, activities and health and safety. Use of a French national survey and in-situ analyses

Corinne Grusenmeyer *

French National Institute of Research and Safety, Preventive Ergonomics and Psychology Laboratory, 1 Rue du Morvan, CS 60027, Vandoeuvre les Nancy 54519, France

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ABSTRACT

Maintenance activities are identified as critical both to operator safety and to systems safety and reliability. However, it is still difficult to identify maintenance workers in French occupational accident and disease statistics. Moreover, few analyses of these activities and of organizational changes in this field have been conducted. This paper presents two different approaches to this same issue. Analyses were aimed firstly at identifying the occupational exposures of these operators and at comparing them with occupational exposures of production staff and, secondly at developing understanding of normal real maintenance activities, i.e. maintenance activities that are normally actually carried out, while taking into account the socio-technical system and maintenance organization within which they lie.

The use of the French SUMER 2003 survey shows that occupational exposures of maintenance staff to various constraints are more frequent than occupational exposures of their production colleagues. However, maintenance staff appear to have greater independence. Analyses were also conducted in a subcontracting urban public transport company, who outsources some maintenance work. Those analyses highlight a complex network of companies involved in maintenance activities, a substantial number of work interruptions and a significant fragmentation of the internal technicians' activities that can be cognitively costly, reduce anticipation possibilities and lead to incidents or accidents. Above all they underline internal technicians' contributions to the completion of outsourced interventions and interdependent relationships between the activities of the internal and the external technicians.

Outsourcing maintenance interventions thus raises the question of risks associated with the interdependence of actual work activities undertaken by the different types of staff, since they contribute to the same maintenance intervention. This study therefore pinpoints the need to integrate inter-organizational interactions in order to understand the variability of maintenance activities and its relationships with reliability and safety. In this respect, some suggestions are provided with a prevention aim.

1. Introduction

Maintenance concerns the combination of all technical, administrative and managerial actions during the life cycle of an item that are intended to retain it and secure it in, or restore it to a state in which it can perform the required function (Rosqvist et al., 2009). The maintenance function is then cross-cutting, concerning all activity sectors and essential to a company's ability to stay competitive. At the same time, maintenance activities are identified as critical both to operator safety and to systems safety and reliability. As regards operator safety, several studies have emphasized a high level of maintenance-related accidents (Hale et al., 1998; Batson et al., 1999; Ray et al., 2000; Farrington-Darby et al., 2005; Grusenmeyer, 2005; Lind, 2008). According to the European Agency for Safety and Health at Work (2010a), maintenance was associated with 10–15% of fatal occupational accidents and 15–20% of all accidents in Europe in 2006. As regards systems safety and reliability, maintenance failings may contribute to the occurrence of major accidents, such as the Piper Alpha platform explosion, the Embraer 120 aircraft crash in Texas, and the Bhopal or the three mile island accidents (Reason and Hobbs, 2003; European Agency for Safety and Health at Work, 2009). Several accident investigations have identified inadequate or faulty maintenance as one of the main contributors to unanticipated events in various critical safety domains (Reiman, 2011). Thus, relationships between maintenance and safety are contradictory:

* * Tel.: +33 383502166; fax: +33 383502182.
E-mail address: corinne.grusenmeyer@inrs.fr (C. Grusenmeyer).

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maintenance contributes to risk control by preventing and correcting non-optimal operating modes of equipment, which may cause accidents; at the same time, maintenance activities expose maintenance workers naturally to many risks, not least because they interact directly with equipment or installations. Then, as emphasized by Reiman (2011), "*maintenance activities can be considered as having a highly significant positive or negative impact on the effectiveness of the entire socio-technical system, including safety*" (p.339).

Different elements may contribute to the fact that maintenance activities are critical to operator safety:

- nature of maintenance activities: direct interactions with dangerous equipment, installations or products (Lind, 2008); high uncertainty and variability of maintenance work (Bourrier, 1996; Bounot et al., 1996; Garrigou et al., 1998; Grusenmeyer, 2002; Reiman, 2011): task variability, difficulties with planning maintenance intervention times and human resources; high number of unplanned events; no workstation and high mobility of maintenance staff; manual tasks requiring complex reasoning and often informal know-how;
- conditions under which maintenance activities are carried-out: variability of the technological and environmental conditions (De La Garza and Weill-Fassina, 1995); temporal constraints (Vidal-Gomel, 2007); difficult material conditions of maintenance interventions depending on the postures and effort required, for example (Lind, 2008);
- organization of maintenance within but also beyond the company: for example, maintenance tasks allocated to production operators while the number of maintenance operators is decreasing; maintenance workers being overloaded with work due to maintenance shift work teams being removed; great coactivity between numerous maintenance operators during scheduled outages of installations (Bourrier, 1996); but also, outsourcing of maintenance interventions likely to harm cooperation between the different types of staff and consequently to be detrimental to safety: unsteadiness and splitting of work teams (Perraudin et al., 2006), little mutual knowledge of the different operators, various corporate cultures, heterogeneity of employee status (Desriaux, 2005), no sharing of safety rules (Duhamel, 2005), loss of know-how and of overall knowledge of the systems by internal maintenance workers (Largier, 2008; Herrera et al., 2009).

However, it is still difficult to know the number of maintenance workers in France, to characterize this population, or even to identify it in occupational accident and disease statistics. In particular, there are fewer studies focused on professional exposures and diseases of these operators. Nevertheless, the French national survey, named SUMER, which assessed the exposure of employees to the main workplace risks in France, identified a short time ago "maintenance" as a professional domain (Equipe SUMER, 2006).

Otherwise, as emphasized by Reason and Hobbs (2003), maintenance activities received little attention and few prevention studies were actually dedicated to these activities (Ray et al., 2000). Moreover, the most relevant studies on maintenance have focused on human errors and performance. According to Reiman (2011), studies on maintenance were mainly interested in human errors and individual-level issues, even though social and organizational factors have received increasing attention in recent years. In such research, maintenance is considered as a major source of latent errors in generally high-risk socio-technical systems and one of the principal causes of major accidents (Reason and Hobbs, 2003). These studies are focused on post-identification of the most common types of errors, the factors lying behind such errors and ways of preventing these errors (Reason and Hobbs, 2003; Hobbs and Williamson, 2002, 2003; Hobbs and Kanki, 2008; Suzuki et al., 2008), with a rather individual view of maintenance work. A second type of studies examines maintenance interventions as dangerous for humans (Lind, 2008; Lind and Nenonen, 2008). Then, most often, maintenance audits are conducted or post-analyses of accidents having occurred during maintenance operations are carried out in order to identify types of accidents, as well as local and organizational factors contributing to them, and in order to suggest prevention measures (Hale et al., 1998; Main et al., 2002; Lind, 2008; Lind and Nenonen, 2008; Tazi, 2008). Thus ergonomic literature on real maintenance activities and on normal work, practices and cultures of maintenance is rather scarce (Reiman, 2011). Few analyses of these activities have been conducted. Similarly, the consequences on safety of organizational changes in this field, such as outsourcing of these activities, have seldom been studied (see however Carballeda, 1999; Tazi, 2008). Yet "*maintenance activities have been under various organizational changes and restructuring initiatives*" (Reiman, 2011; p.340). This lack of literature and of studies can probably be explained to some extent by the fact that the nature and conditions under which maintenance activities are carried out make observation of them difficult, and even more difficult if they are outsourced, since, in particular, the workplaces are constantly changing (European Agency for Safety and Health at Work, 2010b).

For these reasons, this paper presents two different approaches of the relationships between maintenance and health and safety:

- the first analyses were aimed at better identifying occupational exposures of maintenance staff and comparing them with those of production staff, by using the French SUMER 2003 survey. The general assumption was that, in many respects, maintenance staff will be more frequently exposed than production staff. We also hoped to be able to distinguish exposures of maintenance staff according to maintenance organization (internal vs. outsourced maintenance notably). Finally, the results of the use of the survey should guide the second type of analyses;
- the second analyses were aimed at developing the understanding of normal real maintenance activities, i.e., normal maintenance activities that are actually carried out, their progress and management, as well as risks associated with them, taking into account the socio-technical system and maintenance organization within which they lie. To do this, ergonomic analysis[1] of the real maintenance activities were conducted in a public transport company. More precisely, the analyses should make it possible to understand how maintenance interventions are carried out as inserted into various organizational modes (internal vs. outsourced), how tasks and activities are allocated between these various types of staff and what this implies for prevention.

First of all, the analytical framework used in particular for the in-situ observations will be presented. Then, the material and methods of each of the two phases of the study will be described in detail. Next the main results from the use of the survey and some findings from in-situ analyses conducted in the public transport company will be given. Finally those main results will be discussed.

2. Analytical framework

The analytical framework, on which the in-situ observations are based, is inspired both by the maintenance management

[1] Ergonomic analysis refers here to the analysis of operators' actual activities as inserted in a specific context, in order to improve health and safety conditions at work.