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Safety in machinery design and construction: Knowledge and performance

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ABSTRACT

This paper examines how contextualised knowledge about safety matters shaped the performance of machinery manufacturers for three substantive safety outcomes – hazard recognition, risk control and safety information. These issues were investigated in qualitative research with 66 Australian firms that designed and constructed machinery for supply into local and international markets. The paper identifies the constituents of safety knowledge, and clarifies the relatively minor roles of regulatory sources (Australian and European) and the specialist body of knowledge (human factors/ergonomics, safety engineering), compared with learning about safety through design and construction activities and interactions (learning through practice). Individual factors also played a role as key decision makers had diverse professional and vocational (trade) backgrounds, and personal histories from which to interpret their experiences. Certain practices and individual factors sustained better performance for the substantive safety outcomes. The paper makes conceptual contributions to explain the construction of safety knowledge, drawing on established theories of learning (social constructivism) and decision making (bounded rationality), and concludes with some strategic directions for building capacity through practice-based programs which structure opportunities to learn about safety around authentic design and construction activities.

1. Introduction

How manufacturing firms address safety matters in the course of designing and constructing machinery, and the factors shaping their responses, are topics of considerable interest in view of regulatory, policy and professional pressures to ensure safety early in the life cycle of machinery and other products (Bluff, 2004; European Commission, 1998, 2006; Kletz, 1998; Manuele, 1999, 2008; NOHSC, 2002; Safe Work Australia, 2012; Schulte et al., 2008). In an earlier paper published in Safety Science, Bluff (2014) presented the findings of empirical research investigating how machinery manufacturers addressed safety matters. These Australian based firms supplied machinery into global markets, including the European Economic Area, and had legal obligations to design and construct safe machinery under Australian occupational health and safety (OHS) law (Bluff, 2004; Johnstone, 1997, pp 260–263, 2004, pp 275–280), and the European regulatory regime based on the Machinery Directive (European Commission, 1998, 2006). These regimes share a substantive goal of preventing death, injury and illness (the regulatory goal of prevention).

The research evaluated manufacturers' performance for three substantive safety outcomes – hazard recognition, risk control and safety information, which were critical for complying with the regulatory goal of prevention (Bluff, 2014). Some firms did comply with this regulatory goal as they comprehensively recognized the different types and instances of hazards for their machinery and incorporated more effective safe place controls as the primary risk control measures. That is, they eliminated hazards or incorporated physical safeguards to minimize the risks. These exceptional firms also provided substantial information about machinery safety which was easy to locate, read and understand. Other firms did not comply with the regulatory goal of prevention. They were mediocre performers that recognized only some types or instances of hazards for their machinery and relied on less effective safe person measures for some risks. That is, they used warning signs or devices, or other measures that required workers and others to avoid risks and protect themselves. Also, the safety information provided by some of these firms was limited in scope or hard to locate, read and understand. A third group of manufacturers were least compliant with the regulatory goal of prevention. These poor performers only recognized mechanical hazards and

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no other types of hazards, relied on safe person measures for some risks, and provided very little or poor quality safety information, or none at all.

The present paper turns to the important question of what shaped manufacturers' performance for the three substantive safety outcomes of hazard recognition, risk control and safety information. Based on the same research, the paper focuses on one of the principal elements which the research established as differentiating firms' performance. This was knowledge about machinery safety matters and how knowledge was constructed in the operations of firms and their interactions with external actors. Of interest here are all forms of knowledge about machinery safety matters, encompassing all that individuals knew or believed to be true about these matters, including their personal stock of information, skills, experiences and beliefs (Alexander, 1991).

The paper begins with an outline of the methods for data collection and analysis, including the approach to identifying the factors shaping firm performance (Section 2). The results section which follows describes the different 'constituents' of knowledge about machinery safety matters and discusses the relative contributions of regulatory, specialist and everyday sources to knowledge about safety (Section 3). This section also clarifies the role of individual histories and capacities, before identifying the factors sustaining better or poorer performance for the three substantive safety outcomes. The paper then discusses the conceptual contributions that the research makes to understanding and explaining knowledge, firm performance and compliance with regulatory goals, and sets these findings in the context of established theories of learning and decision making (Section 4). As an underlying aim of the research was to provide firmer foundations for policy and practice the paper also makes a normative contribution, outlining some strategic directions for building capacity for safe design and construction of machinery (Section 5).

2. Methods for data collection and analysis

The qualitative methods for data collection and analysis applied in this research were described in detail in the earlier paper (Bluff, 2014). In summary, the 66 study firms were a mix of small, medium and large businesses[1] which were based in the Australian states of Victoria and South Australia, and designed, constructed and supplied machinery for use at work in a wide variety of industries, within Australia and internationally. In-depth, face-to-face interviews were conducted on site at firms' premises with key individuals who were responsible for making and implementing decisions about machinery design and construction. A semi-structured schedule was used to ask interviewees about consistent topics, which were framed as open-ended questions in order to elicit detailed responses from participants. Interviews collected data about interviewees' experience and qualifications, the machinery produced, markets for the machinery, sources of knowledge about and understandings of machinery safety matters, the firm's actions, practices and processes for addressing safety matters in machinery design and construction (including risk management, testing and examination, production of safety information). Interviews also canvassed awareness and understanding of relevant legal obligations, experience of inspection and enforcement by state regulators, and other actors or circumstances influencing their responses. Data collection also involved observation of machinery, and review of documentation and audio-visual materials including product information, technical standards and other information resources, risk assessments, design documentation, and records of safety testing or examination, as available for the firm.

[1] Small = <20 employees, medium = 20–99 employees and large = 100 or more employees.

Interview, observation and documentation data were analyzed qualitatively applying the core analytic procedures of immersion in the data, generating conceptual and thematic categories and coding data, and interpreting and developing explanation (Marshall and Rossman, 2006; Mason, 1996; Richards, 2005). In essence the approach involved systematically reading and reflecting on the data from different sources, recording concepts or themes, inductively devising categories for coding data relating to particular topics, and retrieving and analysing data on these topics. For example segments of data about interactions with customers, referring to technical standards and other practices were respectively coded and analyzed for the purpose of describing and comparing ways of learning about safety (Sections 3.2–3.6) and to identify factors linked with markedly[2] better or poorer performance for the substantive safety outcomes, when compared with the performance of firms in the sample overall (Section 3.7). This last analysis involved systematically reviewing the data about the performance of firms that engaged in particular practices (situational factors), firms with key individuals with particular capacities (individual factors) and firms with particular characteristics (firm size), and reflecting on plausible relationships between these factors and standards of performance. The method involved inductively developing explanation which accounted for differences in firm performance for the substantive safety outcomes, and did not presume direct causal relationships. Summary statistics were used for the purpose of comparing the performance of firms with particular practices, capacities or characteristics to the performance of the sample of 66 firms overall. The standard for comparison here was the research finding (Bluff, 2014) that in the sample overall 30% (20/66) comprehensively recognized the hazards for their machinery; 14% (9/66) had a blinkered focus on mechanical hazards; 47% (31/66) used safe place controls as the primary risk control measures; 17% (11/66) used some advanced or innovative safe place controls; and 24% (16/66) provided substantial, good quality safety information.

3. Results

3.1. Scope of this section

The 66 study firms produced a wide variety of machinery including cranes and other lifting equipment, agricultural and horticultural machinery, boilers and pressure vessels, industrial cleaning systems, and machinery for processing, handling or packaging food, timber, minerals and other products or waste materials. In the course of designing, producing and supplying their machinery into Australian and international markets, these firms constructed knowledge about machinery safety matters, to varying extents, through regulatory, specialist or everyday sources. This section examines the different constituents of machinery safety knowledge. It then identifies the factors that sustained better performance for the substantive safety outcomes which were critical for complying with the regulatory goal of prevention (hazard recognition, risk control and safety information), or were linked with poorer performance for these outcomes.

3.2. State regulation – laws and regulators

State regulation is one of the elements of interest in understanding manufacturers' performance for machinery safety. The principal legal obligations for Australia-based firms were established in the general OHS statutes, underpinned by regulations

[2] The analysis focused on factors for which the proportion of firms performing at the specified level for a particular substantive outcome was at least 10% above or below the proportion of firms performing at that level in the sample overall.