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Assessing the compatibility of the management of standardized procedures with the complexity of a sociotechnical system: Case study of a control room in an oil refinery

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ABSTRACT

Although the need for the management of complex socio-technical systems (STS) to be compatible with the nature of those systems is widely recognized, there are few guidelines on how to determine the actual extent of this compatibility. The purpose of this study is to assess how compatible the management of standardized procedures (SPs) is with the nature of a complex STS. To this end, a case study was made of a control room in an oil refinery, involving the following stages: (a) delimitation of the investigated STS; (b) description of the STS according to a set of characteristics of complex STS; (c) application of two types of questionnaires to thirty workers – one of them to assess their perceptions about the applicability of seven principles of SPs management in complex STS and the other to determine their perceptions about the actual use of these principles; and (d) a feedback meeting with workers to discuss the results of the assessment. The assessment is discussed in terms of its limitations, usefulness and ease of use of the data collection and analysis tools.

1. Introduction

The use of standardized procedures (SPs) has been a marked characteristic of industrial and service organizations for decades (Drews et al., 2012). A SP is a script for the execution of a task, typically specifying sequences, times, outcomes and requirements that should be met before starting production (Spear and Bowen, 1999). The standardization of a procedure means that it has been documented and that those who undertake the task are expected to follow it as uniformly as possible. Indeed, SPs have a key role to increase predictability (Hollnagel and Woods, 2005). Of course, not all procedures are standardized. Some of them are tacit, since they are neither documented nor verbalized, although they are usually shared by a group of people.

In this study, SPs are investigated mostly in terms of their impact on both individual and process safety, which are regarded as inseparable from production performance (Hollnagel et al., 2011). Although failures in SPs design and implementation have often been pointed out as factors contributing to accidents, understanding the broader organizational context is crucial for devising effective preventive measures (Baker, 2007; Dekker, 2003; Snook, 2000).

This study uses Complex Systems Theory (CST) as the main basis to describe the organizational context. CST can be used to call attention to important features of organizations and to advocate particular styles of management (Rooke et al., 2008). CST has become, in business circles, of great interest for its strategic implications, and for ergonomics as applied in organizational improvement as well (Siemieniuch and Sinclair, 2002). For example, Dekker (2012) used insights from CST for analyzing the impacts of new technologies in healthcare, and Carayon (2010) identified critical factors in the success of patient safety innovations, from a CST perspective also.

While it is likely that all sociotechnical systems (STS) have at least some characteristics of complexity, some systems such as power plants, aviation, healthcare, computer security, and petrochemical plants are often regarded as strongly complex (Carayon, 2006; Perrow, 1984). Nevertheless, even among such systems, the various characteristics of complexity may be present to a different extent (Perrow, 1984). In this study, a system is defined as a set of elements standing in interrelations (Bertallanffy, 2009:55). If those elements include humans, machines and their work environment, the system can be described as a socio-technical one (Emery and Trist, 1960). In turn, a complex STS is one that has particular

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characteristics, such as a large number of dynamically interacting elements which result in unpredictable behaviors (Cilliers, 1998) – a more detailed description of the characteristics of complex STS is presented in Section 2.

The management of complex STS is often out of step with their nature, since those who work in such systems have a tendency to treat working situations simplistically (Blakstad et al., 2010). This tendency is visible, for example, in a number of accident investigations, which mistakenly assume linear and clear cause–effect relationships, thereby leading to the design of inadequate corrective measures (Dekker, 2011). The incompatibility between the nature of a complex STS and its management strategies is partly due to the lack of guidelines on how to assess this compatibility. This study discusses the assessment of the compatibility between the nature of a complex STS and the management of SPs, a cyclical process that involves its design, use and continuous improvement. This process has a major knowledge management role, since a SP encapsulates key information about task operations and contextual factors (Siemieniuch and Sinclair, 2002).

As a requirement for this type of assessment, an STS must be described as a complex one. In fact, if the system does not have strong characteristics of complexity, its management according to CST does not make sense. However, there is a lack of methods for characterizing a system as complex, and complexity is difficult to quantify (Vesterby, 2008; Cilliers, 2005). Although a number of studies have proposed generic characteristics of complex STS (e.g. Cilliers, 2005; Perrow, 1984), they normally do not show, based on primary empirical data, how an actual STS can be described according to the proposed characteristics. The descriptions presented in the literature are often based either on hypothetical cases or conjectured from secondary data (e.g. Dekker, 2011; Sweeney, 2006).

Another requirement to assess the compatibility between SPs management and a system's complexity is to establish a benchmark on how that management should look like in a complex system. In this respect, a number of studies discuss the limitations of SPs and present recommendations to their management in complex STS (Dekker, 2003; Sharit, 1998; Degani and Wiener, 1997, 1994). In this context, the main research question addressed in this study is as follows: how can one assess the compatibility between the management of SPs and the nature of a complex STS? The investigation is based on a case study of the control room of an oil refinery, an environment usually regarded as highly complex (Perrow, 1984). From a practical standpoint, this assessment is aimed at contributing to the identification of improvement opportunities in SPs management.

2. Characteristics of complex STS

Complexity is never easy to define, and the term is therefore often used without definition (Hollnagel and Woods, 2005). Nevertheless, a number of concise definitions of complexity are available in literature. For example, Pringle (1951) defines it as the number of parameters needed to define a system fully in space and time. Siemieniuch and Sinclair (2002) define complexity as the interactions between the organization's entities that result in unpredictable behaviors.

However, those concise definitions of complexity capture only some of the dimensions of the concept. This study treats complexity as a multidimensional construct, whose characteristics are stronger in some contexts than in others, in line with Perrow (1984). It is assumed that the characteristics of complexity can be systematically described with the purpose of shedding light on each of them. This does not necessarily mean that complexity can be easily measured in quantitative terms, regardless of existing guidance for this purpose (Vesterby, 2008). Moreover, this article recognizes that different observers may perceive differently the complexity of a certain system, while accepting that the system has elements and interactions which constitute evidence of objective complexity. This is the position adopted by Snook (2000) and Weick (1995:37) when investigating the functioning of socio-technical systems.

In order to define a set of characteristics of complex STS, two kinds of studies were considered: (a) studies that emphasize complexity in *socio-technical* systems, taking it as a basis to question established management approaches (e.g. Page, 2007; Sweeney, 2006; Kurtz and Snowden, 2003; Perrow, 1984) – this group is relevant for the present study due to its focus on STS rather than on other types of systems, such as biological and ecological ones; and (b) studies that emphasize complexity from an epistemological perspective, suggesting it as an alternative to the so-called Newtonian scientific view, which is portrayed as relying too much on reductionism and unambiguous cause–effect relationships (e.g. Èrdi, 2008; Vesterby, 2008; Cilliers, 2005) – this group is relevant for this study since, due to its high level of abstraction, it is useful across different domains and scientific disciplines.

Thus, based on fifteen studies associated with those groups, a set of characteristics of complex STS were identified and grouped according to their similarity, resulting in four categories (see Appendix A, which has a Table showing the characteristics of complex STS versus studies that cited them). As an indication of the low level of agreement among the different studies, only 22.1% of the cells in the Table presented in Appendix A are marked with an "X", which means that a study cites a certain characteristic – i.e. 92 out of the 435 cells were marked. If all studies had cited the same characteristics, the agreement would be 100%. Therefore, the categories of complex STS defined in this study should be interpreted as a compromise solution. The choice for grouping the characteristics into just four categories had, as a premise, to encourage the joint discussion of interconnected characteristics.

Over the description of the defined characteristics, the word "element" is generically used to refer to any part of a system (e.g. human, technical, managerial). Of course, each element could be regarded as a system in itself (Checkland, 1999), which can potentially be a complex system as well. The use of the term "agent", adopted in other studies on CST (Cilliers, 2005), is in this article restricted to human elements. The four categories of characteristics of complex STS are presented below:

2.1. A large number of dynamically interacting elements

While complex STS are usually formed by a large number of elements, this only becomes a defining characteristic of complexity if the elements are dynamically interacting, which implies that the system changes over time (Vesterby, 2008; Snowden and Boone, 2007; Cilliers, 1998; Williams, 1999). Of course, the more elements a system has, the greater is the potential number of interactions, and so the greater is the number of other elements that an element is likely to influence or be influenced by Vesterby (2008) and Perrow (1984).

The interactions in a complex STS may be non-linear. This is a term borrowed from mathematics that refers to the fact that small changes in the cause can imply in dramatic effects in the outcomes. Other terms often adopted to refer to this characteristic are sensitivity to initial conditions and butterfly effect (Snowden and Boone, 2007; Cilliers, 1998; Perrow, 1984). Also, the interactions take place among tightly-coupled elements (e.g. interdependence in terms of tasks, teams, production sequence), which allow for the quick propagation of errors and create difficulty in isolating failed elements (Christoffersen and Woods, 1999; Williams, 1999; Perrow,