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Integrating sustainable development in the supply chain: The case of life cycle assessment in oil and gas and agricultural biotechnology

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Abstract

It is widely accepted that firms play an important stewardship role in addressing sustainable development concerns. A key challenge in this role is to balance the often conflicting pressures created by sustainable development—firm-level economic performance versus environmental degradation and social disruption. Drawing on complexity theory, risk management, stakeholder theory and the innovation dynamics literature, we discuss the problems of integrating sustainable development concerns in the supply chain, specifically the applicability of life cycle assessment (LCA). Many authors have emphasized the importance of the ''cradle to grave'' approach of LCA in optimizing closed-loop supply chains, improving product design and stewardship. Based on two case studies (an agricultural biotechnology and an oil and gas company) with supporting data collected from key stakeholders, we argue that sustainable development pressures have increased complexities and presented ambiguous challenges that many current environmental management techniques cannot adequately address. We provide a framework that addresses these deficiencies and discuss implications for practitioners and management theory.

Keywords: Life cycle assessment; Sustainable development innovation; Complexity theory

1. Introduction

It is widely recognized that firms play an important stewardship role in addressing sustainable development pressures, and such concerns have become part of many companies' operational and competitive strategies (Angell and Klassen, 1999; Bansal and Roth, 2000; Hart, 1995, 1997; Hart and Milstein, 1999; Porter and Van der Linde, 1995; Shrivastava, 1995; Sharma and Vredenburg, 1998). A number of authors have emphasized the importance of such tools as life cycle assessment (LCA) to optimize closed-loop supply chains as well as improve product design and stewardship (e.g. Krikke et al., 2004; Sarkis, 2001; Sroufe et al., 2000). The ''cradle to grave'' approach of LCA that extends throughout the supply chain represents an evolution over environmental assessments focused on firm-specific impacts and end-of-pipe analyses, and is now part of many organizations' broader sustainable development efforts (Mihelcic et al., 2003). Such an approach is theoretically elegant when key interacting variables and boundaries of responsibilities are well understood. Unfortunately, such situations are rare, while the benefits from sustainability efforts have been

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elusive (Bowen et al., 2001; Hall and Vredenburg, 2003; Walley and Whitehead, 1994). In reality, practitioners continue to grapple with how and when LCA should be applied, due to the complexities and uncertainties of environmental systems involved, imperfections of human reasoning and impossibility of ideal societal decisions (Funtowicz and Ravetz, 1992; Hertwich et al., 2000; Allenby, 2000). In the operations management area, specific challenges of closed-loop supply chains may be intensified by complexities associated with product, remanufacturing, testing, evaluation, returns volume, timing and quality (Guide et al., 2003).

Because of complexity, decision-makers are limited in what they can know (bounded rationality) and thus rational calculations cannot guarantee optional solutions (Simon, 1962, 1969). These difficulties are exacerbated when dealing with novel and complex technologies such as genetic technology, because they involve science that has yet to be established within an accepted paradigm (Kuhn, 1970). New technologies may also create new industry structures, require new regulatory frameworks, generate consumer uncertainty (Ansoff, 1957; Martin, 1994; Nelson and Winter, 1982; Rogers, 1994; Utterback, 1994) and suffer from 'liabilities of newness' (Stinchcombe, 1965). In these situations, uncertainties about possible environmental, health and social impacts are more salient (Hall and Martin, 2005). More complexities can be expected when dealing with sustainable development because it involves a higher number of interacting parameters (i.e. economic, environmental and social, the popular 'triple bottom line' (Elkington, 1998) diagram of three overlapping circles). Indeed, the seminal definition of sustainable development (WCED, 1987, p. 43), ''*meeting the needs of the present generation without compromising the ability of future generations to meet their own needs*'' emphasized the temporal and dynamic aspect of sustainability, thus exacerbating complexity.

According to Hall and Vredenburg (2003, 2005), innovating for sustainable development is also usually more ambiguous, i.e. when it is not possible to identify key parameters or when conflicting pressures are difficult to reconcile. Such ambiguities make traditional risk assessment techniques unsuitable, as the estimation of probabilities through for example actuarial sciences, surveys, simulations and cost–benefit analysis would be based on unacceptably high degrees of imperfect information. They further argue that sustainability concerns frequently involve a wider range of stakeholders, many of whom are not directly involved with the organization. Decision-makers are thus likely to have significant difficulties in dealing with sustainable development. A better understanding of complexity and ambiguity may allow practitioners to determine the appropriateness of LCA in the extended supply chain.

According to Simon (1962), a complex system is characterized by a large number of interacting parameters, and it is difficult to infer properties of the entire system. Interdependence (positive or negative) and intensity (interaction strength) alternate with time, as well as parameter importance (Ethiraj and Levinthal, 2004). Related to complexity theory is the biological concept of fitness landscape (Wright, 1932), a distribution of possible genotypes (i.e. fitness values) mapped from an organism's structure to its fitness level. Kauffman (1993) argues that a landscape can be more or less rugged depending on the distribution of fitness values and interdependences among the parts—the more complex a system, the more rugged the landscape.

A number of management studies have applied Kauffman's concepts, such as Frenken (2001) for product evolution, Rivkin (2000) for firm development, Rivkin and Siggelkow (2003) and Levinthal and Warglien (1999) for organizational design, Gavetti et al. (2005) for strategic analysis, Choi et al. (2001) and Choi and Krause (in press) for supply chain management and Wolter (2005) for industrial cluster coordination. In general these studies argue that smooth landscape designs (low interdependence) result in relatively stable and predictable behaviour. Conversely, rugged landscape designs (higher interdependence such as diversification of functional teams) lead to greater exploration of possibilities of actions, at the cost of increased difficulties in coordination. Here we expand on Choi et al. (2001) and Choi and Krause (in press) application of complexity theory to supply chain dynamics by analysing its integration with sustainable development parameters.

We consider sustainable development an inherently rugged landscape that requires coordination of social, environmental and economic dimensions. Environmental tools such as LCA should thus be 'connected' with social and economic dimensions, and is only meaningful if applied as part of a decision-making process and not a ''disintegrated aggregation of facts'' (Hertwich et al., 2000, p. 15). The use of LCA explored in this paper thus differs from other operations and general management literature, which discusses LCA disconnected from social issues (e.g. Bovea and Wang, 2003; Geyer and Jackson, 2004; Mehalik, 2000; Mattheus, 2004; Sarkis, 2001). A key difficulty is the decision-maker's limitations to deal with uncertainties and ambiguities, i.e. the level of interdependence among the dimensions and the degree to which key