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Marrying supply chain sustainability and resilience: A match made in heaven

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ABSTRACT

Sustainable supply chain management has become an integral part of corporate strategy for virtually every industry. However, little is understood about the broader impacts of sustainability practices on the capacity of the supply chain to tolerate disruptions. This article aims to explore the sustainability–resilience relationship at the supply chain design level. A multi-objective optimization model featuring a sustainability performance scoring method and a stochastic fuzzy goal programming approach is developed that can be used to perform a dynamic sustainability tradeoff analysis and design a "resiliently sustainable" supply chain. Important managerial and practical insights are obtained from an empirical case study.

1. Introduction

Sustainability has become a major buzzword in business vocabulary in recent years. Supply chain (SC) professionals are in an excellent position to broadly impact sustainability practices through the integration of economic, environmental and social goals when designing and planning the SCs. More organizations are realizing the strategic importance of sustainability investments. In this environment, the development and availability of analytical models and decision-support tools can help organizations make more effective and informed decisions. To respond to this call, academic research on sustainable SC design and management has seen substantial development over the past two decades (Brandenburg et al., 2014; Fahimnia et al., 2015a,b; Seuring, 2013). Most of the efforts to achieve SC sustainability have been predominantly directed at reducing environmental burdens of the SC, commonly measured in terms of greenhouse gas (GHG) emissions and resource consumption (Fahimnia et al., 2014b). The social sustainability aspect has focused more on the potential damage to human health and the community/society at large (Boukherroub et al., 2015).

Despite the growing efforts on sustainable SC design and management, the broader impact of sustainability interventions on the overall resilience of the SC has remained unexplored. Sustainable SC management in an environment characterized by frequent unavoidable disruptions necessitates sustainability modeling and analysis that can accommodate this complexity and dynamism. Static sustainability analysis[2] is simplistic because the economic and non-economic sustainability performance of a SC can be affected by disruptive events such as supply disruptions. This calls for management approaches and optimization

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[2] "*Static sustainability analysis*" refers to the study of SC sustainability performance in business-as-usual, situations, disregarding the likelihood of external disruptions occurring. "*Dynamic sustainability analysis*" studies the SC performance in both business-as-usual and disruption situations.

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techniques to develop resilient and sustainable SCs, or what we term as "*resiliently sustainable SCs*", wherein sustainability performance remains unaffected or slightly affected in disruptions.

"*SC resilience*" can be defined as the capacity of a SC to absorb disturbances and retain its basic function and structure in the face of disruptions (Pettit et al., 2010; Walker and Salt, 2006). Given the increasing frequency and intensity of natural disasters as well as the continuous stream of anthropogenic catastrophes (Jabbarzadeh et al., 2014), the riskiest thing a company can do is to have no contingency plan. A general consensus is to improve the SC resilience given the demonstrated quantifiable benefits that can be obtained from investments in resilience (Cutter, 2013). We aim in this article to investigate how SC sustainability analysis and resilience improvement can be coupled for developing resiliently sustainable SCs.

Discussions of marrying sustainability science with resilience theory are at a relatively early stage of development (Derissen et al., 2011; Fiksel, 2006; Perrings, 2006; Walker and Salt, 2006). At the organizational level, the incorporation of sustainability and resilience measures into SC practices pose significant management and modeling challenges. Some of these challenges that we tackle in some form in this article include identifying, quantifying and weighting of the sustainability and resilience performance measures, and exploring the real-world application of the associated modeling efforts. Essentially, our primary aim is to answer a critical question: under what circumstances is it possible for a SC to concurrently sustain economic growth, minimize social and environmental impacts, and yet be resilient to disruptions? We limit the boundary of our study and investigation to the suppliers' sustainability performance and its impact on the general SC resilience. An explicit focus on upstream SC operations is of paramount importance due to the global price-based sourcing trends forcing organizations to purchase from cheaper but "less reliable" and "less sustainable" suppliers. This is exemplified in our empirical case study of a sportswear manufacturing company where the primary concerns are the sustainability performance and reliability of its synthetic fiber suppliers.

The remainder of this article is continued in Section 2 by a review of the related SC modeling literature and the introduction of an important research gap which this study will address. Problem description, the mathematical model and solution approach are then presented in Section 3. An execution of the model using real data from a multinational sportswear clothing company is presented in Section 4. Numerical results from static and dynamic sustainability tradeoff analyses and related discussions are presented in this section. Section 5 includes a summary of the research contributions and implications, model and study limitations, and future research directions.

2. Review of the related literature

Given the explicit focus of this study on integrating SC sustainability and resilience, in the following sections we first provide a review of the modeling efforts in these two areas and will then draw upon those to position our work in the nexus of these two topics.

2.1. Measuring and modeling SC sustainability

Research in the area of SC sustainability has tended to focus on empirical and conceptual studies with only a scant, but rapidly growing, number of articles published on analytical modeling and quantitative analysis of the related problems (Brandenburg et al., 2014; Fahimnia et al., 2015a,b). Most of these modeling efforts locate within the context of green or environmentally sustainable SC which involves the incorporation of economic and environmental sustainability measures when designing and managing SCs (Fahimnia et al., 2014a). Minimization of GHG emissions has been the most popular environmental objective (Benjaafar et al., 2013; Tang and Zhou, 2012) which is not surprising given the global emission reduction forces and environmental regulatory mandates to tackle climate change. Green SC modeling efforts have been expanding in the following six directions:

(1) optimization models for strategic SC design seeking to balance SC cost and carbon emissions (Brandenburg, 2015; Elhedhli and Merrick, 2012; Rezaee et al., in press; Wang et al., 2011);
(2) tactical and operational planning tools for SC cost-emission tradeoff (Fahimnia et al., 2013a, 2014a; Zakeri et al., 2015);
(3) design and planning of closed-loop SCs focusing on cost/emission performance of the forward and reverse networks (Chaabane et al., 2011, 2012; Fahimnia et al., 2013b);
(4) integration of life cycle assessment principles for environmental impact assessment of SCs (Bojarski et al., 2009; Hugo and Pistikopoulos, 2005);
(5) development and application of multiple performance measures (more than just emissions) for green SC design and management (Fahimnia et al., 2014b; Nagurney and Nagurney, 2010; Pinto-Varela et al., 2011; Pishvaee and Razmi, 2012); and
(6) introducing and investigating environmental policy instruments in SC planning and optimization (Diabat et al., 2013; Fahimnia et al., in press; Zakeri et al., 2015).

Apart from studies on green SC design and management, there is only a handful of modeling efforts incorporating performance measures in three sustainability dimensions. The fact that a consensus on measuring and reporting SC social sustainability does not exist (Varsei et al., 2014) is the primary reason for research scarcity in this space. Pishvaee et al. (2012) use the number of jobs created, the use of hazardous material, and the labor working condition as social metrics in a sustainable