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# An integrated risk assessment model: A case of sustainable freight transportation systems

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ABSTRACT

The major challenge in the development of sustainable freight transportation systems (SFTSs) is due to the involvement of numerous dynamic uncertainties and intrinsic sustainability risks. Sustainability risks are potential threats that can have undesirable impacts on the sustainability of a system. The main objective of this study is to identify and evaluate the sustainability risks associated with freight transportation systems (FTSs). Accordingly, a risk analysis approach is developed by innovatively integrating the intuitionistic fuzzy set theory and D-number theory to quantitatively model the sustainability risks. Intuitionistic fuzzy numbers can examine both the membership and non-membership degrees of an element while the D-number theory increases the objectivity of assessments by fusing multiple expert judgments. The proposed risk assessment model facilitates the managers in the development of SFTSs by ensuring visibility, predictability and measurability in freight operations. Unlike the conventional perception, the findings indicate that most of the high priority sustainability risks in FTSs are socially induced rather than financially driven and consciousness in people's conduct is must to attain the positive results. The analysis alerts the freight managers toward the high priority sustainability risks and guides in pro-active strategy formulation and optimum allocation of mitigation resources to minimize disruptions in SFTSs.

## 1. Introduction

Freight transportation (FT) is the key to ensure seamless functioning of supply chain and logistics systems (Bai et al., 2017). The objective of freight transportation systems (FTSs) is to timely transfer the right quantity and quality of raw materials, inventories, finished goods etc. from the origin to destinations using different modes such as road, rail, air and water (Stank and Goldsby, 2000). FT accounts for about one third to two third of the total logistics cost, which is equivalent to 10–20% of a commodity's price (Farahani et al., 2011). Furthermore, about 80–90% of carbon emissions in logistics operations are due to freightage activities (McKinnon, 2010). Hence, inefficient freight movements can have an ominous influence on the supply chain sustainability and can disrupt the economic efficiency of the whole system (Lindholm, 2010). As a result, freight operations are becoming the main focus of supply chain managers during recent years.

Globalization and outsourcing activities are lengthening the supply chains leading to a drastic rise in FT demands (Marchet et al., 2014). According to ERTRAC research and innovation roadmaps (2011), as compared to the GDP growth of about 2.5%, the FT demand is growing worldwide at a rate of about 2.7% annually. Furthermore, it is expected that between 2000 and 2050, the freight

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tonne-km will increase at a rate of 2.3% per annum (McKinnon, 2010). As a result, while the greenhouse gas (GHS) emissions from most of the sectors are reducing, the output emissions of the FT sector are still increasing (Goldman and Gorham, 2006). In European Union, 23.8% of GHG emissions and 27.9% of carbon dioxide are attributed to transportation. Estimates suggest that if FT continues to escalate at the current rate, the resulting CO2 emissions may increase by an additional 109 percent by 2050 (Piecyk and McKinnon, 2010). Concerns are mounting over these negative externalities of FT operations and immediate interventions are necessary to make it more sustainable (Demir et al., 2015). The conventional view to just focus on the cost minimization is therefore changing and organizations are becoming more responsive towards the adoption of sustainability in their strategies for the evolution of sustainable freight transportation systems (SFTSs). Sustainable freight transportation (SFT) offers a great potential to combine environmental stewardship with monetary benefits through cost reduction, revenue generation, customer retention, value addition and improvement in living conditions (Stank and Goldsby, 2000; Seuring and Muller, 2008; Abbasi and Nilsson, 2016).

### *1.1. Need for the study*

Business Communities are characterized by rising levels of uncertainty with frequent unavoidable disruptions (Faisal et al., 2007; Heckmann et al., 2015). Apart from the conventional risks, growing awareness about sustainability issues including economic, social and environmental impacts of business practices on the society has resulted in the emergence of a new category of risks known as "sustainability risks". Sustainability risks are potential threats that can have undesirable impacts on the sustainability of a system and act as impediments in the implementation of triple bottom line (TBL) framework. Recent global events like Volkswagen's emission scandal, Brazilian mining tragedy, Horsemeat scandal in Europe, Rana plaza disaster, unhealthy working environment in Apple's suppliers, Japanese tsunami in 2011, the Ebola outbreak 2014, the Uttarakhand and Chennai floods in 2013 and 2015, the Paris terrorist attack 2015 etc. have highlighted the adverse impacts of sustainability risks on supply chains (Giannakis and Papadopoulos, 2016). Similarly, uncertainties related to delivery, demand, infrastructure, cost, technology, legislations etc. can negatively affect the sustainability of transport operations and give rise to sustainability risks in FTSs (Rodrigues et al., 2010). These risks hamper the integration of sustainability in FTSs and result in undesirable consequences. Strategic management of sustainability risks is therefore essential for the development of SFTSs and to avoid the inherent consequences (Christopher and Peck, 2004; Fahimnia et al., 2015; Choi et al., 2016).

Accordingly, the study proposes a comprehensive framework comprising a sustainability risk management process, which needs to be institutionalized as an integral part of FTSs to control the associated sustainability risks and achieve the desired sustainability goals as shown in Fig. 1. The framework conceptualizes sustainability risk management elements in the context of FT by sustainability goals, FT actors and the risk management process. The coherence of these constructs is represented in Fig. 1 and described in detail

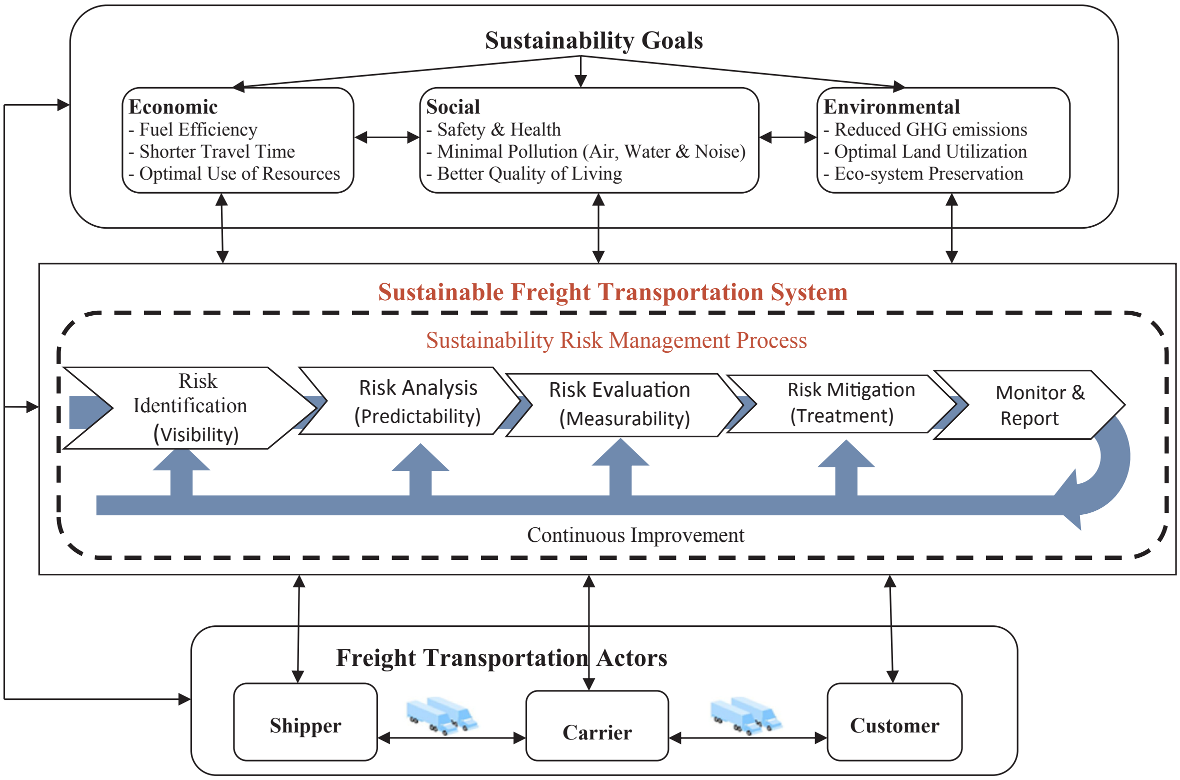


**Fig. 1.** Framework for Managing Sustainability Risks in SFTSs.