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Risks, determinants, and perspective for creating a railway biodiesel supply chain: case study of India

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ABSTRACT

Globally, the demand for energy is increasing, and the transportation sector is a major consumer of energy. There has been a momentum and a mandate to promote the use of biofuels. Although biofuel usage has been analysed extensively from the technological viewpoint, very few researchers have studied biofuel implementation and the supply chain. Biodiesel is being considered as an alternative fuel for railway transportation, which poses some challenges given the structural constraints of the industry. As has been argued, for the successful implementation and adoption of biodiesel in the railway sector, a tailor-made country-specific supply chain should be designed. The paper discusses how geographically diverse demand and common technological usage points complicate the decision to make or buy in the context of railway transportation. Furthermore, the biodiesel and diesel supply chains are compared, risks of a biodiesel supply chain are identified, and implementable strategies are suggested. Indian Railways is a bulk consumer of fuel, and as a public sector focal firm, it should take the lead in sustainable transportation solutions in view of energy security requirements. This study is unique because it deals with a biodiesel supply chain in a public sector transport organization in an emerging economy.

1. Introduction

Designing a biodiesel supply chain for a railway system is a unique problem because of the risks and uncertainties (Escobar et al., 2014) posed not only by the supply side but also by the nature of demand usage in the transportation industry, especially railways. Most studies on biodiesel are focused on the manufacturing sector. Studies in the transportation sector are limited to vehicle fleet and road transport (Lonnqvist et al., 2015; Pereira and Gomez, 2015) and are strongly influenced by country-specific policies (Falde and Eklund, 2014). Studies on biofuel usage in a railway system from the supply chain perspective are rare and have to be understood because of their distinctiveness. The present study is based in India, and this poses the challenges of vast geographical disposition and extreme climate fluctuation, along with the limitations of an emerging economy vis-a-vis a developed economy. This leads to the question of having either a large- or medium-scale centralized system (Skarlis and Kondili, 2012; Ramdhas et al., 2005) or small local biodiesel production units (Ewing and Mangi, 2009; Bot et al., 2015). In this paper, the biodiesel scenario in India, which has a common single railway system, is reviewed, and the constraints faced in developing a biodiesel supply chain are analysed.

The paper contributes to the literature on biodiesel and sustainability by focussing on a specific transportation industry in an actual scenario. It provides a comprehensive policy perspective on the design of a biodiesel supply chain for a focal railway transportation company. Moreover, it contributes to the transportation and railway fuel literature by highlighting the differences between diesel and biodiesel usage from the demand and supply chain perspectives. The literature on sustainable supply chains is also benefitted because of the analysis of uncertainties and the risk management strategies presented herein.

2. Global scenario

Globally, the use of alternative fuels, including biodiesel, has increased substantially owing to legislation that mandates their blending with fossil fuels. In February 2008, Virgin Atlantic used a 20% biofuel blend in one of its engines on a London–Amsterdam

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Table 1
Biofuel consumption and production (thousand barrels per day).

Region	Year									
	Consumption					Production				
	2007	2008	2009	2010	2011	2007	2008	2009	2010	2011
North America	494	676	769	891	946	473	666	769	917	1005
Europe	173	238	293	331	344	154	198	233	255	250
Asia & Oceania	46	69	83	92	102	49	76	94	100	118
World	991	1350	1585	1772	1820	1103	1477	1635	1865	1897

Source: (US EIA, 2014).

flight, while Amtrak conducted a yearlong trial with B20 in 2010 (Sims, 2011).

Table 1 summarizes the biodiesel consumption and production trends of different regions over the years. North America is the largest producer and consumer. Most regions consume their produce, except Asia, which exports its biofuel produce. Most biofuel is ethanol, and it is used for blending with petrol and biodiesel. Among countries, Germany and Brazil are the world leaders in biodiesel production. The motivations for biofuel production and use are different in different countries. The US does it for saving fuel import costs, Europe does it as a climate change mitigation measure, and countries such as Brazil do it for providing social benefits and inclusion to poor farmers. Brazil's Federal Government created the 'Social Fuel Seal' (SCS), according to which biodiesel manufacturers are required to purchase a minimum quota of raw material from small farmers, thereby integrating the small farmers into the supply chain as raw material suppliers (Leao et al., 2011). Bioethanol is also popular because it has a lower gestation period (time between plantation and production of biofuel) of 1–2 years compared to biodiesel made from crops such as jatropha, which requires 4–5 years, thus lengthening the investment payback period. In all of these countries, government mandates and the taxes imposed on CO_2 emissions incentivize biofuel use.

In India, the installed biodiesel capacity is about 1.2 million metric tons per annum (MTPA), and most of this is in the private sector. Against this, actual consumption from 2009 to 2014 was about 0.11 MTPA against a consumption potential of 33 MTPA. Biodiesel exports are in the range of 0.18 MTPA, and they have been growing at a compounded annual growth rate (CAGR) of 13% since 2009. Therefore, the need for policy intervention on both the supply and demand sides for incentivizing the use of biofuels in the domestic market is apparent. Furthermore, the success of such an intervention/program will depend on the effective design and implementation of the associated value chain (Biswas and Pohit, 2013).

Biodiesel has various advantages, the most important being that it is a clean and renewable fuel (Leonardi et al., 2012). The by-products of the esterification process employed to manufacture biodiesel, such as oil cake and glycerol, have economic value and reduce the cost of biodiesel. Moreover, according to the well-to-wheel approach, biodiesel production requires the least amount of energy compared to the production of any fossil fuel. It is carbon-neutral because the CO_2 generated in biodiesel manufacturing is consumed by the oil seed plant. Moreover, biodiesel emits reduced levels of pollutants such as unburned hydrocarbons, carbon monoxide, sulphates, and particulate matter compared to diesel: blends as low as B20 can bring about a substantial reduction in greenhouse gas (GHG) emissions. The cultivation of jatropha and similar feedstock on semi-arid land increases green cover and reduces GHG emissions. With continued cultivation, such semi-arid land will become fertile in due course, and it could then be used for cultivating food crops.

3. Biomass supply chain

The biomass supply chain involves end-to-end management, starting from the farmer to the end user, and it comprises many actors including farmers (harvesters), transporters, warehouse operators, energy plant developers, energy producers, the government, utility providers, and end users (Adams et al., 2011; Annevelink and de Mol, 2007; Gold and Seuring, 2011). The special characteristics of this chain include seasonal availability of inputs, demand variation due to uncertain energy production, and variability of biomass, and the underlying objective is to reduce environmental impact and minimize costs. Organizations will have to follow different supply chain configurations, ownership arrangements, and norms (Mafakheri and Nassiri, 2014; Mafakheri et al., 2012; Lloyd and Dey (2014).

The biomass supply chain is laden with uncertainties (Beamon, 1999; Ramadhas et al., 2005) studied the large-scale production of biodiesel, while Skarlis and Kondili (2012) explored the small-scale dynamics of biodiesel production on Crete Island. Escobar et al. (2014) performed lifecycle assessment of two alternative supplies in Spain. Bot et al. (2015) studied the biodiesel supply chain for remote areas in Indonesia. This situation poses its unique challenges and a small-scale bidirectional supply chain, in which the producers are the consumers, is an option. The present paper further suggests the existence of two types of bidirectional supply chains, namely, fixed and mobile, wherein the processing unit itself is moved (Oliveira et al., 2009). Mirkouei et al. (2016) looks at the efficiencies of this unit. The broad uncertainties (Awudu and Zhang, 2011; Bot et al., 2015) listed in the literature are as follows:

i) Biomass Supply Uncertainty—variability in the yield and quality of the supplied inputs. Biomass supply is affected by seasonality, whereas demand is continuous, which poses the challenge of storage (Yue et al., 2014). This uncertainty is pronounced in decentralized and mobile processing because of variability and reduced control over produce (Iakovou et al., 2010; Banister, 2005).
ii) Transportation and Logistics Uncertainty: In the case of fixed processing units, the low energy density of biomass necessitates the transport of larger quantities, and from the viewpoint of mobile processing, density differences and timeliness can pose problems (Fredericks, 2012).
iii) Production and Operations Uncertainty: This uncertainty could be attributed to poor inputs, quality, and machine and operator failure.
iv) Demand and Price Uncertainty: This uncertainty is related to the price of alternative fuels and other inputs.
v) Government and regulatory uncertainty.

Researchers have studied the technical and economic prerequisites for reducing CO_2 emissions through the use of biomass-based energy in the transportation sector (Johansson, 1996).