Journal of Cleaner Production 180 (2018) 107–115

Contents lists available at ScienceDirect

Journal of Cleaner Production

journal homepage: www.elsevier.com/locate/jclepro

Transportation sustainability index in dairy industry – Fuzzy logic approach

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ARTICLE INFO

Article history:
Available online 28 January 2018

Keywords:
Transportation
Environmental indicators
Sustainability
Dairy products
Food mile

ABSTRACT

Sustainability has become a concern in transportation of food. This paper provides an analysis of transportation sustainability performance using fuzzy logic. Recognizing the lack of evidence for claiming that "local food" is more sustainable, the challenge before transportation was how to evaluate two opposed dairy distribution systems - local and cross-country. The proposed model presented in this paper compromises four criteria – resource depletion, climate impact, economy and society with a total of 13 indicators into one transportation sustainability index. The model was validated for two dairy products from data presented by four dairy plants representing 32% of total raw milk processed annually in Serbia. The novelty of this approach lies in identifying economic and social factors applicable to local and big dairy companies. Findings suggest that big dairy plants with a developed distribution system, joint with social and economic indicators have better results in terms of transportation sustainability. As a conclusion, ideas hidden behind term "localism" in food systems in relation to transportation impacts may need to be reconsidered. The results indicate that this model is capable of assessing transportation sustainability and has practical relevance in the food/dairy sector. The strength of this approach is its practical applicability and the ability for researchers to deploy this model to other food sectors.

1. Introduction

In line with the increased global attention of environmental and sustainable impact of the food chain, transportation environmental impacts became polemic tools in various environmental and food policies (Coley et al., 2009). The food product distribution is required to deliver often-perishable products on constrained timetables, and is pertinent given the interplay between transportation logistics, food perishability, environmental issues and costs (Heard et al., 2018). From an environmental point of view, some authors assume that transportation of trade goods enhances over 20% of total global CO_2 emissions (Davis and Caldeira, 2010; López et al., 2015). Food products are part of this phenomenon, sometimes interpreted in relation to food-miles calculated for domestic and international agricultural products (Weber and Matthews, 2008). Food-mile may be considered as a sustainability indicator (with environmental and economic impacts) when analyzing sustainable consumption and production in the food supply chain (Govindan, 2017).

However, deploying this problem to specific food brings us to many estimations, with the most explored one stating that "the average item of food on your plate has traveled 1500 miles", with no explanation how was this assumption made and by whom (Schnell, 2013). Supporters of this attitude promote local food, local eating, local producers, local agriculture and local restaurants. As a result, back in 2007 the Oxford American Dictionary named "locavore" as the "word of the year" (OUP, 2007). The word was coined to promote local residents to purchase and consume food grown/produced within a 100 mile radius.

Different approaches to this issue have been explored by scientists, mainly on a macro level, analyzing specific food in terms of local economies/countries. López et al. (2015) evaluated food-miles emissions in Spain while Kissinger (2012) analyzed international food trade in Canada from a food-mile perspective. These authors conclude that transportation of food becomes a challenge, especially because import of food is growing. Weber and Matthews

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https://doi.org/10.1016/j.jclepro.2018.01.185
0959-6526/

(2008) assume that transportation contributes up to 11% of total emissions of greenhouse gas (GHG) within the food life cycle while Sim et al. (2006) believe it's around 3.5%. Also, not all food miles are calculated equally and there is a difference, in both energy use and emissions, depending on the means of transportation (Schnell, 2013). Today, it is expected that green transportation will mitigate air pollution and that the promotion of electric/hybrid transportation vehicles joint with modeling transportation routes to minimize transportation emissions and costs will be one of the hot research topics in near future (Lee et al., 2017).

However, traditional transportation performance metrics, fail to assess the degree that lead to sustainable outcomes (Zheng et al., 2013). Widening the picture from an environmental to a sustainable perspective enables introduction of a variety of criteria how to evaluate the transportation impact. Increased interest for local food among consumers, the media and academia is based on beliefs that such food is more sustainable (Adams and Salois, 2010). However, studies of the benefits of local foods remain limited due to inconsistency in defining “local food” and means to measure their impact on sustainability (Schmitt et al., 2017). Govindan (2017) assumes that sustainable food supply chain research on the problem of increasing transportation and transporting food around the world is needed (Govindan, 2017). However, Schmitt et al. (2017) in their study on sustainability of local and global food products in Europe conclude that the main sustainability factors related to local products are linked to localness criteria such as identity, know-how, size and governance, rather than distance and carbon footprint linked to transportation.

1.1. Literature review

There are several methods that tend to analyze the sustainable perspective of food transportation. Life cycle assessment (LCA) is a method that mainly considers polluting emissions and resources used during the life course of a product (Awasthi et al., 2011). Assessment indicator models use several indicators to assess sustainability of transportation systems (Tao and Hung, 2003). Cost-benefit analysis calculates the economic dimension of direct transportation costs, but shows difficulties in estimating external and social costs such as air pollution, noise pollution and accidents (Awasthi et al., 2011). Zheng et al. (2013) analyze the process for developing a composite index for evaluating transportation sustainability in domains of the three sustainability pillars. Such composite single index represents the degree of satisfying economic, social and environmental objectives (Maoh and Kanaroglou, 2009). A comprehensive review was provided by Wellar (2009) presenting over 40 different techniques that could be used in improving sustainable practices (Rajak et al., 2016). Heard et al. (2018) propose a sustainable model of autonomous vehicles for food distribution that benefit from two transformations – environmental (decrease of emissions and optimization of transportation routes) and economic (increased profit).

Integration of environmental and social thinking in supply chain management led to the development of a new research domain in the last decade - Sustainable Supply Chain Management (SSCM) with sustainable distribution being a part of it (Rajeev et al., 2017). Elhedhli and Merrick (2012) advise that proper design of logistics systems will create positive impacts on SSCM. Bendul et al. (2017) developed a sustainable supply chain model focusing on the social pillar of sustainability in developing countries in order to bypass differences in terms of framework conditions and distribution systems. Eco-design of transportation in SSCM was modeled by Ji et al. (2016) using data envelopment analysis as a non-parametric approach that overcomes conflict of factors from the three sustainable pillars.

Fuzzy logic as a tool for calculating and interpreting transportation sustainability has been used recently in several studies. Awasthi et al. (2011) used fuzzy logic in evaluating sustainable transportation systems using 24 sustainability indicators. Govindan et al. (2017) focus on strategic integration of forward and reverse flows while designing closed loop supply chain network model under a fuzzy environment. Urban transport sustainability performance evaluation using fuzzy logic was performed in the work of (Rajak et al., 2016) using 20 transport sustainability criteria.

Sustainable transportation has been broadly covered by many papers in the last years where fuzzy logic was used as one of the modeling tools. However, based on the literature research it has been revealed that transportation of specific food products were more in focus from an environmental than sustainable point of view. Also, the majority of sustainable transportation research deal with generic transportation systems excluding specific characteristics of food/dairy supply chains and this was defined as a research gap by the authors. The objective of this research was to assess transportation sustainability footage in terms of environmental, economic and social impacts in dairy industry using a fuzzy logic approach. Working hypothesis assumed that local and small dairy plants do not have better transportation sustainability footage.

2. Materials and methods

The model proposed in this section is developed based on the following conceptual framework: (i) data collection from dairy plants; (ii) life cycle assessment of transportation to calculate environmental impacts mainly in terms of climate change indicators; (iii) calculation of food miles and resource indicators based on transportation such as energy and fossil fuel usage; (iv) development of a fuzzy logic environment and (v) calculation of a single score - the transportation sustainability index.

2.1. Demography of the dairy plants

Four dairy plants (DPs) producing dairy product in the Republic of Serbia were included in this study. Data were collected during on-site visits to selected DPs. Plants were requested to provide information on their number of employees, implemented management standards, certifications status and production/transportation data for a calendar year, on a 'whole of factory basis'.

According to their total annual input, these dairy plants represent 32% of total raw milk processed annually in dairy industry in Serbia. In respect to daily processing capacity, two were categorized with big processing capacity (>20,000 L of milk/d), and two with small processing capacity DPs (3000–20,000 L of milk/d) (Analysis, 2012). Related to the market coverage, one DP has a national, one DP has a regional and two DPs have local coverage. In the selected DPs, raw milk was processed into two products pasteurized milk and yoghurt. They were further examined since those two products participate in at least one third of dairy production in these plants.

Liquid final products were expressed in kilograms (estimated density of milk was 1030 kg/m3, while of yoghurt was approximately 1040 kg/m3) (Fox and McSweeney, 1998). Serbian legislation recognizes yogurt as a fermented liquid milk product. It is produced by using symbiotic cultures *Streptococcus thermophilus* and *Lactobacillus delbrueckii* subsp. *Bulgaricus* (Djekic et al., 2013).

Two out of four DPs have a certified food safety system while three out of four have a certified environmental management system in place.

2.2. Life cycle approach

In order to evaluate transportation impact of dairy industry, a