H2020 VALUMICS Project Environmentally Conscious Transportation and Logistics Modelling for Agri-Food Supply Chains: An Application to Norwegian Salmon

VALUMICS
Food Systems Dynamics

Research Findings Brief
September 2021

Content

The transportation sector is a major contributor to global carbon emission. Food products provide additional challenges for logistics and transportation due to their complex supply chain.

This brief discusses how an inter-modal logistics model could address environmental aspects by minimising fuel cost and carbon emissions, using real-world data from a globally integrated Norwegian salmon supply chain.

Salmon value chain

Norway is one of the largest producers of salmon globally and exporting a significant volume to Europe where it is processed further in e.g Poland, Denmark, and France. Filleting and smoking are the main value-added processing activities

Introduction

Transportation has significant impact on food costs and the environment. It is a major contributor to carbon emissions, accounting for almost a quarter of the $CO2$ emissions in the EU, of which 30% is attributed to the food sector[1] (OECD/ITF, 2017). Logistics, in general, implies a high financial cost for manufacturers[2] (Fang and Natarajan, 2020), but greening supply chain management practices, including transportation, are complex, due to customer requirements, product specificities, cost pressures, and strict regulations[3].

Food products provide additional challenges for logistics and transportation due to their perishability, limited storage capacity, safety and traceability requirements[4]. At a global level, food supply chains have become increasingly complex encompassing multiple actors (e.g., producers, processors, wholesalers and retailers), hence transportation costs and related carbon emissions can be high, prompting a search for efficient management solutions.

To address these issues a logistics mathematical model is proposed, drawing on evidence from a real VALUMICS case study of a globally integrated food supply chain, i.e., a Norwegian salmon (Figure 1). The mathematical modelling aims to optimise the cost and effectiveness of logistics operations. It also allows for the integration and consideration of environmental aspects within transportation, processing and distribution operations.

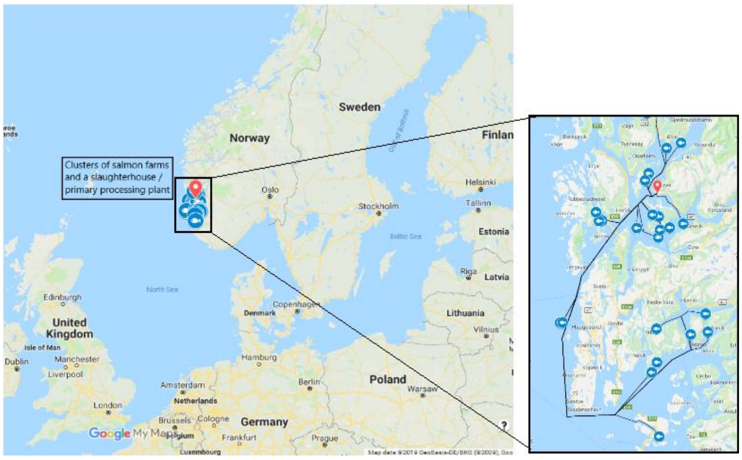

Figure 1. Salmon farm's locations and links to a slaughterhouse/primary processing plant, before being exported; Source: SINTEF

[1] OECD/ITF. ITF Transport Outlook 2017. Retrieved from Paris: https://www.oecd-ilibrary.org/transport/itf-transport-outlook2017_9789282108000-en
[2] Fang, F. and Natarajan, H.P. (2020) 'Sourcing and Procurement Cost Allocation in Multi-Division Firms', *Production and Operations Management*, 29(3), pp. 767-787
[3] Golicic, S.L., Boerstler, C.N. and Ellram, L.M. (2010) ''Greening' Transportation in the Supply Chain', *MIT Sloan Management review*, 51(2), p. 46
[4] Azoury, K.S. and Miyaoka, J. (2013) 'Managing Production and Distribution for Supply Chains in the Processed Food Industry', *Production and Operations Management*, 22(5), pp. 1250-1268.

The Logistic Model

The model has two objectives. Firstly, to minimize total costs associated with transportation, fuel consumption, inventory holding, processing and residuals/waste. Secondly, to reduce CO2 emissions incurred by production at plants, transportation from suppliers to plants, and transportation from plants to customers. Constraints related to supply, processing capacity, storage capacity, demand, carbon emissions, inventory balancing, transportation capacity, and different modes of transportation between different types of plants and facilities are also consider within the model. Figure 3 illustrates the mathematical model function with input and output parameters.

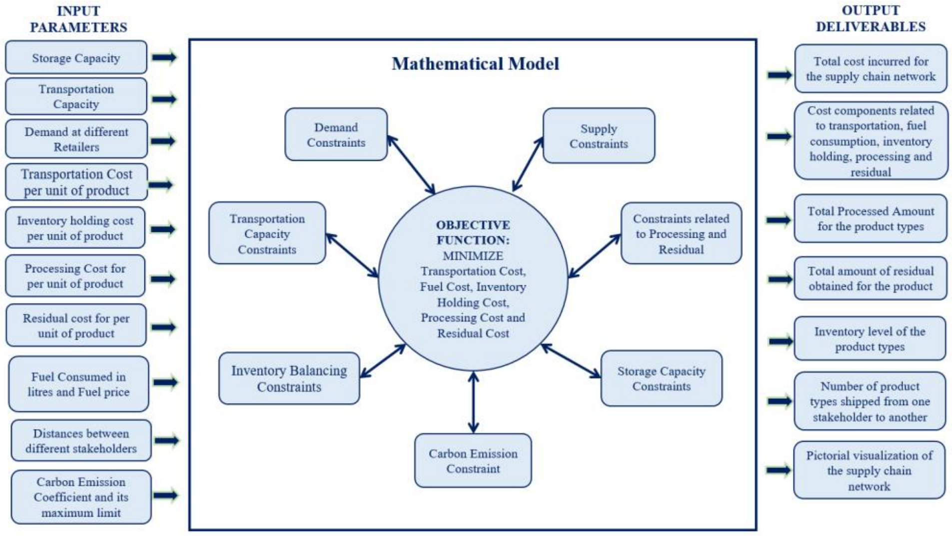

Figure 3. Framework for our logistics model. Source: Authors' construction

Before modeling, consultation with salmon supply chain actors occurred as a first step to map the supply chain linkages. This involved expert interviews with VALUMICS partners. Based on the mapping of the supply chain, a mathematical model was developed. However, given the complexity of the supply chain and the limited information that can be drawn from a single company which completely covers both the supply and the demand ends of the value chains, the model was divided into two stages (Model N1 and N2).

First, it optimises the supply chain network from salmon farms, abattoirs, primary processing plants, secondary processing plants and wholesalers so to meet the demand of the Secondary Processing Plants and Wholesalers for Fresh HOG (Head-on-Gutted) product (Model N1) (farm to wholesaler). Second, it addresses the supply chain from the secondary processing plants and wholesalers to retailers. The secondary processing plants process HOG into whole fillet, salmon by-products and some residual amount so to meet the demand of retailers (Model N2) (wholesaler to retailer).

An additional model (Model M) allows for the optimisation of the overall supply chain network where, for example, a Company X tries to meet the demand of retailers in different time periods (farm to retailer). A transportation scenario analysis was also conducted by considering options for various maritime transportation routes from primary processing plant to secondary processing and primary processing plant to various wholesalers[5].

Key findings

- Environmental impact is generally measured by fuel consumption during operations and in the case of food chain, transportation and distribution are important contributors via the use of fuel-based vehicles, sea vessels and/or airplanes. The transportation scenario analysis

Multi-objective optimisation

The model follows a multi-objective optimisation approach that captures the trade-off between total logistics cost and the environment

Stages of model development, validation and policy recommendation

(i) mapping supply chain linkages and product flows, (ii) designing the mathematical model, (iii) data collection for parameters of the model and (iv) model validation and deriving policy recommendation.

Optimise overall supply network

The results from the three models highlight that it is essential for any company to optimise the overall supply chain network system (from farms to retailers), as the total cost for model M is relatively much lower than the combined total cost of N1 and N2

[5] All equations and mathematical formulation are thoroughly described in Section 2.4.1., Deliverable 7.1, VALUMICS project.

Fuel cost and consumption

Each model with different demand scenarios shows that the supply chain network is sensitive to fuel cost and consequently to fuel consumption and distances between actors.

highlights the importance of adopting maritime transportation routes in terms of significantly reducing the total cost, fuel cost and overall carbon emission. Hence, shifting certain logistics operations from road to maritime transportation from the perspective of economic and environmental benefits is preferable.

- For short to medium distances (using vans, trucks, rails and sea vessels) that covers transportation trips to reach airport hubs and big cities, lowering CO_2 emissions depends on the emissions ratio (the relative emissions impact of delivery vehicle when compared to personal vehicle, and mostly applied in urban logistics) and customer density.
- For long distance transport (air), environmental improvement can be mainly achieved through technological development and this has been well supported by research dedicated specifically to address EU aviation industry challenges.

Options for improvement

A move away from road transport to moving goods by sea wherever possible could significantly reduce both total costs and overall carbon emissions. However, judgements have to be made about the relative benefits of delivery versus personal vehicles (and their costs) on a case-by-case basis.

Key policy recommendations

Our mathematical models (N1, N2 and M) are developed for a planning horizon consisting of discrete time periods, aiding the possibility of studying demand and supply uncertainty and its consequences in the supply chain decision making. The models could be applied more widely to different food products across the food chain and be used by both practitioners and policy makers to identify changes in a specific supply chain network when different transportation routes are adopted. For example, to identify whether maritime routes can be adopted (or not) instead of road/rail transportation to address environmental concerns related to fuel consumption and carbon emissions. More specifically, practitioners could apply the models to manage their supply chain under various circumstances of demand and supply, and to identify the most cost-efficient transport options while reducing CO_2 emissions. Policymakers could employ them for a better understanding of the costs and emissions associated with different food supply chains as well as the effects of particular policy interventions and market changes or developments.

Some specific recommendations on how CO_2 emissions might be reduced while minimising costs are also made:

- A move away from road transport to moving goods by sea
- Long distance transport will usually be by air and improvements to emissions in this sector can mainly be achieved through technological advances.

Key sources for further information

This brief is compiled by Carmen Hubbard from Newcastle University. It presents some key insights reported in VALUMICS Deliverable D7.1

To discuss the research presented in this brief, please email carmen.hubbard@ncl.ac.uk

References: **Deliverable Report**

Paulus Aditjandra, Arijit De, Matthew Gorton, Carmen Hubbard, Gu Pang, Shraddha Mehta, Maitri Thakur, Roger Richardson, Sigurdur Bogason, Gudrun Olafsdottir, Report on findings on transportation and logistics of selected food value chains: Salmon to fillet case study, VALUMICS, Deliverable VALUMICS "Understanding Food Value Chains and Network Dynamics", funded by European Union's Horizon 2020 research and innovation programme GA No 727243. **Deliverable: D7.1.,** Newcastle University, UK, 94 pages. https://doi.org/10.5281/zenodo.5105433

H2020 VALUMICS – Understanding Food Value Chains and Network Dynamics

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"This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 727243"