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 sector1 (OECD/ITF, 2017). Logistics, in general, implies a high financial cost for manufacturers2 (Fang and Natarajan, 2020), but greening supply chain management practices, including transportation, are complex, due to customer requirements, product specificities, cost pressures, and strict regulations3. Food products provide additional challenges for logistics and transportation due to their perishability, limited storage capacity, safety and traceability requirements4. 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.

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.

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

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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 considered within the model. Figure 3 illustrates the mathematical model function with input and output parameters.

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.

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

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5 All equations and mathematical formulation are thoroughly described in Section 2.4.1., Deliverable 7.1, VALUMICS project.
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 CO2 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.

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 CO2 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 CO2 emissions might be reduced while minimising costs are also made:

- 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 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

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References: Deliverable Report
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