SmartChain
Blue Bioeconomy Solutions

BlueBio SMARTCHAIN Project

Optimizing the seafood supply chain: Maximizing efficiency, advancing sustainability, and promoting circularity

Research Findings Brief

September 2024

Application of optimization in seafood supply chains

SMARTCHAIN focuses on optimizing the process and supply chain by developing a production planning model for the optimal utilization of seasonal raw materials to analyze and enhance logistics flows.

These efforts aim to improve efficiency, sustainability, and circularity in both logistics and production activities across the seafood supply chain.

The increasing importance of sustainability and the circular economy is being recognized across various industries, including the energy-intensive fisheries sector. With global seafood demand on the rise, there is growing pressure on fisheries to operate more efficiently and sustainably with a strong focus on incorporating circularity principles. Circularity emphasizes reducing waste and extending the lifecycle of resources, which is essential in addressing issues like overfishing and the generation of excessive by-products. The challenge of balancing economic viability with environmental responsibility is becoming increasingly urgent. Traditional fishing and processing practices are proving insufficient in the face of issues like overfishing, high energy consumption, and excessive waste. The industry is now increasingly focused on responsible resource management, where the circular use of resources such as reusing by-products, recycling materials, and reducing energy consumption, becomes a critical competitive advantage alongside regulatory compliance and ethical responsibility (Stevens et al., 2018)[1].

In this evolving context, optimizing operations in the fisheries sector is essential. Companies must adapt to changing market demands and stricter environmental regulations while also managing external factors such as fluctuating fish populations and climate change. Incorporating circularity in the seafood supply chain can enhance sustainability by ensuring that resources are not wasted and that by-products are utilized effectively, whether in secondary industries like biogas production or through innovative uses of fish processing waste. Meeting these demands necessitates maximizing the value of each catch through careful planning and optimization of operations, including vessel routing and scheduling, production processes, and resource allocation. Developing advanced models that support decision-making, enhance resource utilization, reduce energy consumption, and promote circularity is crucial for maintaining profitability and ensuring long-term sustainability.

The SMARTCHAIN project has addressed these challenges by developing several data-driven optimization models to account for both final product revenues, energy costs, and circularity aspects, using Brim hf, a fishing and fish processing company in Iceland, as a pilot case. These models are being used to enhance operational efficiency, financial performance, and resource recovery, reflecting the need for innovative solutions in the fisheries sector. As the industry moves towards more sustainable and circular practices, these models highlight how maximizing resource use and minimizing waste can contribute to a more resilient and circular seafood supply chain.

[1] Stevens, J. R., Newton, R. W., Tlusty, M., & Little, D. C. (2018). The rise of aquaculture by-products: Increasing food production, value, and sustainability through strategic utilization. *Marine Policy*, *90*, 115-124.

Data-Driven optimization model

Data driven decision making

The current model enables data-driven decision-making by determining the optimal timing for fishing activities and the most efficient routes for vessels, aiming to reduce oil consumption while ensuring that the fish are landed in the freshest possible condition. This optimization of timing and routing shows potential in minimizing energy usage and maximizing the utilization of landed raw materials, contributing to both operational efficiency and sustainability.

Scenarios

The scenarios are exploring the effects of fluctuations in key variables such as oil prices, market prices of primary products and by-products, fish availability, the quality of the landed fish, and its utilization rate. Additionally, factors such as vessel sailing speed and catch rate during trips are being analyzed to understand their influence on the operational efficiency.

The scheduling and routing of vessels for Brim hf, which processes raw fish into primary products (fillets) and by-products (fish meal and fish oil), is being optimized over a planning period, with seasonality and fish availability as key considerations. While the initial results are promising, this model remains in its early stages, with further development required to refine the approach and incorporate more advanced circularity strategies. Figure 1 illustrates the problem, where vessels are deployed to different fishing areas based on fish availability, with routes designed to minimize energy consumption. After returning to the harbor, the catch is assessed for quality, determining whether it is directed to fillet production (low energy-intensive) or fish meal/fish oil production (high energy-intensive), with each process operating within the constraints of the total allowable catch (TAC). As the model is refined in future phases, it will primarily focus on tactical and operational decision-making, which can significantly influence strategic outcomes over the long term. By optimizing day-to-day operations and resource utilization, the model is expected to support more sustainable and circular fishing and processing practices, ultimately contributing to better-informed strategic decisions that align with long-term sustainability goals.

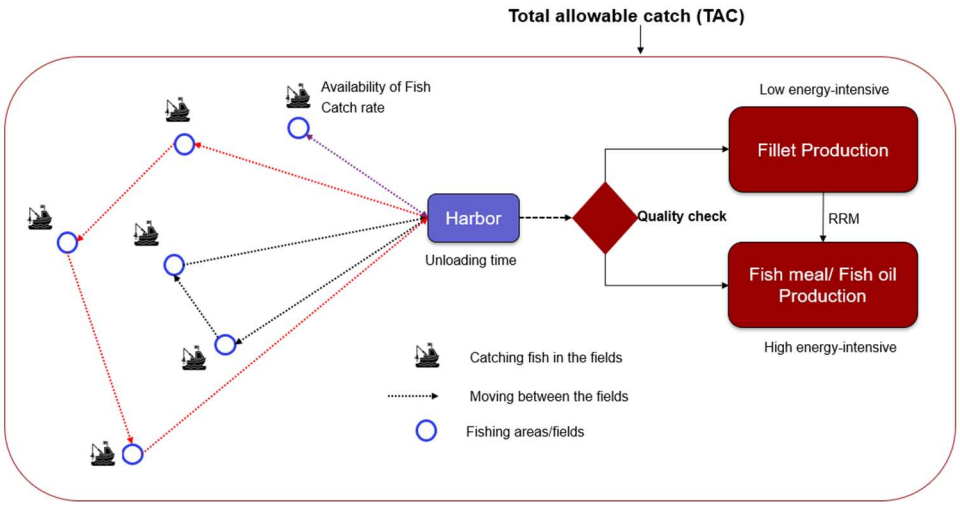

Figure 1 Schematic representation of vessel scheduling, routing, and processing operations

A verbal description of the optimization model is presented as follows:

Objective*: *Maximization of Profit

- ***Profit*** = *Revenue - Costs*
  - ***Revenue*** = *Revenue from selling primary products + Revenue from selling by-products*
  - ***Costs*** = *Oil usage for fishing + Oil usage for processing primary products + Oil usage for processing by-products*
- ***Subject to***:
  - *Vessel routing constraints*
  - *Scheduling constraints*
  - *Vessel capacity constraints*
  - *Production capacity constraints*
  - *Fuel capacity constraints*
  - *Fish availability constraints*
  - *Quota allowance constraints*
  - *Raw material quality constraints*

Scenario analyses

Our scenario analyses are being built through extensive collaboration with Brim hf, allowing us to tailor each scenario to real-world conditions and test how fluctuations in key factors impact both economic performance and sustainability.

Circularity

By incorporating circularity principles such as reducing waste and maximizing the use of by-products, the initial results provide valuable insights for decision-making in dynamic operational environments, helping to align business practices with both financial goals and sustainable resource management.

Strategic planning

Strategic planning should focus on aligning operations to maximize fillet production and enhance overall profitability. Also, by incorporating circularity principles such as maximizing the yield of fish oil by fully utilizing all parts of the catch, can enhance profitability while reducing waste.

Preliminary findings and recommendations

Following the validation and verification of the preliminary optimization model, various scenarios are being examined to assess how changes in market conditions could impact both economic performance and environmental sustainability. These scenarios are being built using real data from Brim hf, ensuring that the analysis is grounded in practical and relevant operational realities.

By simulating these conditions, the model has the potential to inform tactical decision-making, enabling vessel operators and fishing companies to better manage risks, optimize resource use, and adapt to evolving market demands, all while maintaining a strong focus on sustainability and circularity. The following preliminary findings are based on the initial results of the implemented scenarios, with further insights expected as the model continues to evolve and develop.

1) Optimizing vessel routing for cost efficiency

Fuel consumption and oil usage are significant cost factors in vessel operations. Prioritizing nearby fishing areas and shortening trips can reduce fuel costs while preserving the quality of the catch, which enhances raw material utilization and product value. A large portion of operational expenses is linked to vessel operations, making vessel efficiency improvements a key area for cost savings. Optimizing routing, reducing trip durations, and investing in fuel-efficient technologies could lead to substantial cost reductions and improve overall financial performance.

2) Improving raw material utilization

Initial findings from the model indicate that the most effective scenario for boosting economic and environmental sustainability is improving the quality of the landed fish, which directly enhances raw material utilization. This can be achieved by minimizing the duration of fishing trips, as shorter trips result in fresher fish that allow for more effective processing, particularly for fillets, thereby increasing revenue and reducing waste. However, while shorter trips improve fish quality, they also lead to more frequent round trips as vessels need to return to sea more often, which increases overall energy usage. Balancing trip duration and energy consumption is crucial for optimizing both efficiency and sustainability.

3) Maximizing revenue by prioritizing primary product

The preliminary analysis demonstrates that fillet production contributes the largest portion of the company's revenue. Prioritizing the catch for fillet production allows the company to achieve higher financial returns compared to diverting resources toward by-products such as fishmeal and fish oil. This initial finding underscores the importance of ensuring that most of the catch is processed into fillets, where the revenue potential is significantly greater. A key factor in this process is the quality and freshness of the landed fish, which is heavily influenced by the time between catching and landing. The shorter this time, the higher the quality of the fish. Higher-quality fish not only increases the amount processed into primary products, resulting in greater income, but also reduces energy costs, as fillet production is less energy-intensive than by-product production

4) Recognizing the value of by-products

Initial findings from the model indicate that, although fish oil is produced in smaller volumes compared to fillets, it remains a highly valuable by-product and contributes significantly to overall revenue. Despite its lower production share, fish oil recovery

has been shown to play an important financial role, suggesting that it should continue to be a focus in operations. By strategically balancing the prioritization of fillet production with efforts to optimize fish oil recovery, companies can improve both revenue and sustainability, aligning with circular economy goals.

Optimization in seafood supply chain – Recommendations

The preliminary findings highlight the need for seafood companies to align vessel operations and production processes with financial, circularity, and sustainability goals. To fully capture these benefits, optimization must extend beyond vessel operations to include production and processing. Incorporating circularity principles, such as minimizing waste and maximizing by-product use, is key to improving sustainability outcomes. Streamlining production flows and processing both primary products and by-products is expected to efficiently reduce costs and improve resource utilization. A key area for improvement is the availability and accuracy of fish stock data, which impacts the data-driven model's performance. Technology-driven approaches like AI, machine learning, and satellite data are expected to provide real-time insights into fish availability, enhance vessel routing, reduce overfishing risks, and better align operations with sustainability goals. Integrating advanced data analytics with optimized production processes is anticipated to help seafood businesses remain competitive and resilient in a circular, sustainability-focused market.

Key sources for further information

To discuss the research presented in this brief, please contact: Allan Larsen alar@dtu.dk and Ali Ghavamifar aghava@dtu.dk, DTU Management, Technical University of Denmark.

Scientific dissemination:

An optimization approach for vessel routing and scheduling: Insights from implementation in the Nordic fishing industry. Intended for publication in a scientific journal

Deliverables:

Ghavamifar, A. Larsen, A. (2023). Logistics optimization. The SMARTCHAIN project co-funded by ERA-NET, EU Horizon 2020 G.A. No 817992, and Norges forskningsråd (RCN), Innovation Fund Denmark (IDF), and The Icelandic Centre for Research (RANNIS) / Technical Development Fund (TDF). Deliverable: D2.4, Technical University of Denmark, Lyngby, 10 pages.

Ghavamifar, A. & Larsen, A. (2024). Production scheduling. The SMARTCHAIN project co-funded by ERA-NET, EU Horizon 2020 G.A. No 817992, and Norges forskningsråd (RCN), Innovation Fund Denmark (IDF), and The Icelandic Centre for Research (RANNIS) / Technical Development Fund (TDF). Deliverable: D2.3, Technical University of Denmark, Lyngby, 16 pages

Conference presentation:

Ghavamifar, A., & Larsen, A. (2024). From catch to coast: An optimization approach for vessel routing and scheduling in the Nordic fishing industry. 33rd European Conference on Operational Research (EURO), Copenhagen, Denmark.

SMARTCHAIN – Smart solutions for advancing supply systems in blue bioeconomy value chains

https://bluebioeconomy.eu/smart-solutions-for-advancing-supply-systems-in-blue-bioeconomy-value-chains/
https://www.sintef.no/en/projects/2021/smartchain/

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