Era-Net Transport – Sustainable logistics and supply chains
(ENT III FLAGSHIP 2015 CALL)

MultiStrat final report

Multimodal strategies for greener and more resilient wood supply

Dag Fjeld, Aron Davidsson, Petrus Jönsson, Christoph Kogler, Peter Rauch, Karin Westlund

era-net TRANSPORT
mindfuel at the heart of transport research

Multimodal strategies for greener and more resilient wood supply

1. Key findings

The objective of MultiStrat was to establish an integrated framework for testing multimodal strategies for greener and more resilient wood supply, delivered as a supply chain simulation model for participatory evaluation and implementation of results. The work was structured in 3 work packages: WP1 Supply chain mapping, WP2 Supply operations analysis and WP3 Supply chain modeling and evaluation. The project spanned 3 climate zones; continental (Austria with rail transport), sub-arctic (Sweden with rail transport) and oceanic (Norway with sea transport) and therefore started with the development of common frameworks to enable comparative cataloguing of regional challenges, capacities and solutions.

WP1 Supply chain mapping – In a supply chain context, resilience represents the ability to sustain supply in the face of disruptions. This work package started therefore with mapping of disruptions (event, impact and frequency) for all three regional cases as well as the management processes which respond to these (annual, intermediate and monthly/weekly cycle). In all three cases, the most critical risks are found on the supply side and related to weather events (Austria; wind storms, Sweden; varying terrain and road bearing capacity, Norway; bearing capacity and occasional wind storms). The agility required of the organization to meet disruptions typical for the region was generally reflected by the frequency of control and planning cycles and their time horizons. The Swedish case forest owner association, for example, relied on a rolling monthly re-planning cycle for updating the following 3–months (sharp plan for the first month, prognosis for the following 2 months). The Norwegian forest owner association had 4 re-planning cycles per half-year with a sharp plan for the upcoming period and updated prognoses for the following periods. In contrast, the Austrian organization (with its own forest) could allocate 60 % of monthly harvesting at the beginning of the annual cycle, leaving 40 % in reserve to meet disturbances. At the operational level (weekly, daily) the greatest need for coordination was between truck arrivals and multimodal departures. A general process framework was drafted to capture the typical sequence of management activities used in forecasting, planning, execution and control of wood supply (7 processes, 22 activities with categories for time horizon and flow resolution).

WP2 –Supply operations analysis – Given the variation in conditions between regions, this work package started with developing a common framework for analysis of organization-level variation in harvesting production and multimodal transport, as well as the driving factors behind this variation. The framework enables presentation of multi-year time series with relative weekly production and transport pace (% of annual average) with the corresponding weekly temperature, precipitation and snowdepth. Using this framework, the effects of driving factors for variation in production and transport pace could be more clearly seen and compared between regions. The three regions demonstrate contrasting seasonal patterns of supply pace. The most fundamental difference is that the snowpack in the Austrian case often represents an extra cost or direct hinder for wood supply, while in the Swedish and Norwegian cases snow enables access to wood supply for areas of low bearing capacity. In the present data weather parameters could explain up to 50 % of variation in weekly production and transport pace. The region-specific differences between production and transport pace determine the time spent in roadside stock before delivery to mill or multimodal terminal. The typical lead times for the respective regions varied therefore accordingly. The highest proportion of roundwood transported with multimodal solutions was highest in the Austrian case and lowest in the Swedish case. In the Austrian case, direct loading from truck to block-train solutions (up to 9 –wagons) caused a maximum 5 day prolongation of the lead time between harvesting and mill. In the Norwegian case, the time for vessel cargo accumulation (2500-5000 m3) caused an 2,4 weeks prolongation of lead time, on average. The quantitative analysis of weather parameters was useful for structuring the effects of weather on supply challenges. The driving factor for variations, however, starts with roundwood prices and the forest owner's willingness to sell wood. This study has focused more on quantifying the residual short-term variations in wood supply within a given market situation.

WP3 Supply chain modeling and evaluation. This work package focused on developing supply chain simulation models for testing multimodal innovations and enabling participatory evaluation of strategies to counter supply chain risks. The respective researchers focused on key aspects for the regional cases. The Austrian work continued with a simulation study for quantifying the effect of fixed levels of multimodal transport (0, 50 %, 100 % of volume via block-train solution) on system KPIs (three typical scenarios: business as usual, high snowfall levels and windstorm salvage). The Swedish work focused on further simulation studies of lead times for direct and multimodal transport (system-train solution) in order to test the simulation approach and compare values with those empirically mapped in WP2. The Norwegian work focused on development of two demonstration modules for testing management alternatives for entire supply systems over the whole supply organization. The first (supply chain demo I) provides weekly visualization of the geographical distribution of production, truck and vessel transport. The second (supply chain demo II) provided an optimization tool based on the same graphical interface, used for testing and visualizing the effect of multimodal strategies (cargo volume class and terminal capacity as well as load collection practices) within the seasonal trends mapped in WP2.

Compared to truck transport alone, the Austrian results showed a 6 % reduction of $C0_2$ emissions and 29 % reduction of lead times from forest to mill for the current block-train solution. The reduction of lead times for multimodal solutions increased further to 54 % for the increased wood flows after wind storms. The Swedish results show that the simulated lead times for truck transport varied between 11-43 days, in contrast to the annual median of 37 days resulting from the methods used in WP2. The simulated values for lead time from forest to pulpmill via the system-train solution increased to 50 days. Regarding tools for working at the organization-level, the Norwegian results provided optimal truck/vessel solutions for pulpwood deliveries during 12 balance periods (4-5 weeks) throughout the yearly cycle. The optimal proportion of vessel use followed the same seasonal pattern as provided by transport statistics in WP2, but with a slightly lower overall level. The optimal solutions enabled access to a wide variety of geographies with minimal variation in sum transport system costs, providing a good demonstration of the structural flexibility enabled by multimodal solutions.

Synthesis. In all three regions, multimodal system provides a robust base level of transport capacity to ensure stable deliveries from terminal stocks regardless of varying operating conditions. However, WP2 showed variation in production pace was greater than for transport pace, and that the bottleneck for improved supply chain performance was therefore production. The simulated re-scheduling of production based on weather-based modeling of weekly bearing capacity presented a plausible alternative for evening out production from the head of the value chain. The experiment provided a simple demonstration of the potential for improved resilience to operating conditions through an adaptive management response enabled by weather-based modeling of site availability. Following this direction of development enables further exploitation of the structural flexibility inherent to multimodal solutions. The improved supply chain coordination between production and transport is synonymous with higher capacity utilization and shorter lead times. For the forest sector, better control over lead times ensures higher roundwood freshness and reduced deterioration/degradation. This translates directly to lower costs and higher product value; with direct impacts for competitive advantage.

2. Project progress and deliveries

The project had an allotted time frame from June 1, 2016 to Sept 29, 2018. The original time frame extended to 29.June 2018, and a 3-month extension was granted due to low initial progress during data collection. All three work packages were completed by the final date. Final reporting was done in Oct 2018.

The project had 5 milestones marking progress from common understanding of supply chain challenges (MS1) with a draft model architecture (MS2) before completion of supply operations analysis (MS3) for validation of regional models (MS4) and final analysis (MS5). Work packages 1 and 2 were dependent on developing common frameworks to enable direct comparison between the regional cases. This work proved to be more time consuming than expected, because of the need for consensus between countries with varying data availability and resolutions. The approach helped to better identify the relevant supply chain challenges.

Table 1. MultiStrat project milestones.

	MS1	**MS2**	**MS3**	**MS4**	**MS5**
WP1 - Supply chain mapping	Common understanding of challenges achieved				
WP2 - Supply operations analysis			Harvesting and transport analysis complete		
WP3 - Supply chain modeling and evaluation		Model architecture drafted		Models validated	Final analysis complete
MS reached	Q2/2017	Q2/2017	Q2/2018	Q3/2018	Q3/2018

In the course of working through towards MS1 (WP1) and MS3 (WP2) supply chain challenges became clearer. Regarding solutions, managerial response should ideally handle an entire supply organization, with the full selection of terminals used by management to balance supply pace and demand. The results of this was the branching of WP3 into 3 models: i) the originally drafted single-terminal simulation model providing an advanced management cockpit interface (Austria), ii) a single-terminal simulation model focusing on the consequences of seasonality for lead times (Sweden) and iii) a multi-terminal tactical model providing geographic interface for visualization and analysis for a whole supply organization (Norway). The resulting documentation of planned deliverables is indexed below.

Table 2. MultiStrat deliverables and WP-report documentation index.

Deliverable	Name	Documentation index
1.1	Catalogue of typical risk scenarios	WP1 report: 3.1
1.2	Common definitions and resolutions for risk, disruptions, scenarios	
1.3	Catalogue of system elements and manager business processes	WP1 report: 3.2, 4.1
2.1	Variation in organization-level variation in production pace and driving factors	WP2 report: 3.2, 3.5, 3.6
2.2	Variation in organization-level variation in transport pace and driving factors	
3.1	Final model architectures (revised after original draft)	WP3 report: 3.3, 5.3
3.2	Validated regional supply chain simulations models with manager-generated multimodal strategy options implemented.	
3.3	Quantitative analysis of the effect of multimodal strategies on supply chain resilience and sustainability.	WP3 report: 3.4, 5.4

Participatory evaluation of the multimodal strategies was run in the Austrian case (WP3 report: 6). Participatory evaluation of production strategies and resultant modeling of potential for re-scheduling of production were run in the Norwegian case (WP3 report: 5.5). Additional content outside of the planned deliverables include development and testing of methods for analysis of lead-times (WP3 report: 4.3, 4.4).

3. Achievement of objectives

The objective of MultiStrat was to establish an integrated framework for testing multimodal strategies for greener and more resilient wood supply, delivered as a supply chain simulation model. The objective regarding integrated frameworks were fulfilled via the common frameworks from work packages 1 and 2 and the corresponding analysis. The objective regarding delivery as supply chain simulation models was based on the original ambition in work package 3 for a "one-size-fits-all" simulation model. This ambition had to be re-worked to meet the challenges which arose in WP1 and 2. The resulting spatial scale of the WP3 supply chain models increased considerably from the Austrian (1-terminal) to Norwegian (10-terminal) models, with a corresponding progression from simulation to optimization to handle the increased complexity. The increased focus on lead-time analysis provided by the Swedish simulation model was not envisioned at the time of project initiation, but added during the work with WP3. The Norwegian workshop for testing production management strategies, while not in the original plan, was straightforward. The Austrian participatory evaluation of multimodal strategies was done according to plan. The Norwegian follow-up study of the potential for production re-scheduling was enabled by a prototype developed in a parallel project. In conclusion; the original objectives were fulfilled, and additional ambitions which arose underway were also reached.

The project work has two noteworthy aspects. The first concerns the structure of the project work content. The progression from risk/management process mapping to quantitative supply chain operations analysis provided a launch pad for the analysis approaches which were finally developed and used. The second concerns advance beyond state-of-the-art. The project constitutes the first international comparison of seasonal variation in wood supply chain operations, driving factors and resulting lead times. In hindsight, it may seem obvious that this was the correct path to follow, reaching consensus on common frameworks proved to be a time-consuming iterative process, which in the end paid off in terms of increased insight. Compared to monthly-level statistics typically used for such analysis, weekly aggregation of daily data gave more consistent trends, and the possibility to correlate these with weather data. Initially, the choice of regions (continental, sub-arctic, oceanic) may also seem extreme but this selection served to capture sufficient variation in operating conditions to provide contrasting seasonal trends.

Regarding internal research team interactions, the integrated framework was enabled by the portfolio of competencies brought into the project by the respective partners. Examples include: Norwegian and Austrian supply chain mapping experience and syntax in WP1, Swedish data reporting and operations analysis in WP2, and comprehensive simulation and optimization experience from all parts in WP3.

4. Recommendations

In general, multimodal solutions are known to provide both reduced emissions and transport costs. In this context environmental goals go hand-in-hand with economic efficiency. However, the capability which multimodal systems provide to reduce system shock after both minor and major disturbances is important for sector resilience. The structural flexibility to both re-source and re-route wood flows with limited extra costs is a key to development of new collaborative approaches in wood supply.

While often considered the realm of company strategy and investment, investment in terminal networks increases sector resilience forg both existing and new industries in the growing bio-economy. The optimal design of such bio-economy networks varies between regions. Optimal design should be analyzed further to provide decision-makers, both public and private, with a better foundation for investment decisions.

Regarding the continuation of research work, an important result was the reduced lead times provided by multimodal solutions after major natural events such as windstorms. This reduces the subsequent risk for raw material deterioration, however further insight and development requires concurrent modeling of raw material value based on seasonal weather. A project proposal for further work on lead-times and wood value (GreenLane), has been submitted to the upcoming Era-Net Forest Value call. The GreenLane proposal builds on the MultiStrat frameworks and modeling approaches.

5. Project evaluation

As noted under point 3, the original project objectives were fulfilled. Additional ambitions which arose underway were also reached. With such a small research team, project management was kept informal, and enabled flexibility to react to regional challenges. However, the project time plan was optimistic for work packages 1 and 2. More unified progress in work package 3 would have been aided by an industrial steering committee.

6. Dissemination

Publications, presentations

Asmoarp, V, Davidsson, A, Jönsson, P ; (2017): Prediction model for variations in harvester production. Precision Forestry 2017 – Producing more from less: towards optimizing value in the bio-economy from data driven decisions. Stellenbosch Feb 28-Mar 2, 2017. Proceedings

Asmoarp, V, Davidsson, A ; (2017): Prognosemodeller för att förutse volymutfall I virkesforsörjning. Skogforsk arbetsrapport 958-2017.

Fjeld, D; (2017): R&D in the production-transport supply chain: status, ongoing work, future paths. Steering committee ARENA SKOG Infrastruktur. Presentation 17-08-11.

Fjeld, D; (2018): Transport lead times in Trøndelag – how can we optimize these? ARENA SKOG Timber Logistics Seminar. Presentation 18-01-18.

Fjeld, D; (2018): Wood supply strategies – Scandinavian trends and highlights. Symposium: Operations Management in Wood Products Industries, 17.5.2018, Vienna, AUSTRIA. Presentation.

Fjeld, D; (2018): Seasonality of truck transport lead-times in coastal Norway. Proceedings of the Nordic-Baltic workshop Cost modeling approaches and latest news from the front. Oslo 11-12th Sept, 2018. Proceedings.

Fjeld, D; (2018): Seasonality of wood supply operations in coastal Norway. FORMEC 2018 Madrid 24-28th Sept, 2018. Proceedings.

Fjeld, D, Westlund, K, Rauch, P ; (2018): MultiStrat – veier til mer robust virkesforsyning. Norsk Skogbruk Nr. 10 2018.

Kogler, C; Rauch, P (2017): Multimodal strategies for greener and more resilient wood supply in Austria. Symposium on Systems Analysis in Forest Resources, AUG 27-30, Seattle, USA. Presentation.

Kogler, C; Rauch, P (2018): Wood Procurement in Austria. Symposium: Operations Management in Wood Products Industries, 17.5.2018, Vienna, AUSTRIA. Presentation

Kogler, C; Rauch, P (2018): Workshop zu multimodalen Strategien für eine nachhaltige und resiliente Holzlieferkette bei den Österreichischen Bundesforsten. Workshop Österreichische Bundesforste, 5.7.2018, Purkersdorf

Kogler, C; Rauch, P (2018): Workshop zum Aufzeigen von multimodalen Strategien für eine nachhaltige und resiliente Holzlieferkette bei den Österreichischen Bundesforsten. Workshop Österreichische Bundesforste, 28.09.2018, Purkersdorf

Kogler, C; Rauch, P (2018): Discrete event simulation of multimodal and unimodal transportation in the wood supply chain: a literature review (accepted Silva Fennica).

Rauch, P Kogler, C; (2018): Forstlogistik 4.0. Österreichische Forstzeitung, 08/18, 6-8. (Forest Logistics 4.4, Austrian Forestnewspaper).

Rauch, P; (2018): Finding robust strategies to overcome biomass supply risks . [Poster] [EUBCE 2018 European Biomass Cinference & Exhibition, Kopenhagen, MAY 14-18, 2018]

Rauch, P; (2018): Finding robust strategies to overcome biomass supply risks .Abstract In: ETA-Florence Renewable Energies, Proceedings of the 26th European Biomass Conference and Exhibition

Rauch P; (2018): Multimodal wood supply chain simulation. Presentation, [8th Edition of the International Symposium FOREST AND DEVELOPMENT, Brasov, OCT 25-27, 2018]

Rauch, P; Kogler, Ch (2017): Simulating multimodal wood supply chains including risks agents. Abstract In: INFORMS, INFORMS Annual Meeting 2017 Houston – Proceedings

Rauch, P; (2017): Simulating multimodal wood supply chains including risks agents. [INFORMS Annual Meeting 2017, Houston, TEXAS, OCT, 22-25, 2017] Presentation.

Steininger B., Gronalt M. (2017): Strategien zur robusteren Holzlieferkette. Holzkurier, S5. Article in forest based industry sector newspaper.

Project reports

Fjeld, D, Davidsson, A, Kogler, C, Rauch, P, Westlund, K ; (2017): MultiStrat interim work report for WP1 Supply chain mapping. Era-Net Transport 39 pp.

Westlund, K, Jönsson, P, Fjeld, D, Kogler, C, Rauch, P ; (2018): MultiStrat interim report for WP2 Supply chain operations analysis. Era-Net transport 36 pp.

Kogler, C, Rauch, P, Westlund, K, Jönsson, P , Fjeld, D; (2018): MultiStrat interim work report for WP3 Supply chain modeling. Era-Net transport 39 pp.

Pending submissions

18th Symposium on Systems Analysis in Forest Resources (SSAFR) Mar 3-7th 2019, Chile:

Fjeld, D, Davidsson, A, Kogler, C, Rauch P, Westlund, K. A common framework for comparison of system risks and management processes in multimodal wood supply - report from ERA-NET project MULTISTRAT (WP1).

Westlund, K, Jönsson, P, Fjeld, D, Rauch, P, Kogler, C. A common framework for analyzing seasonal and weather effects on wood procurement in the forest supply chain – report from Era-Net project MULTISTRAT (WP2).

Fjeld, D. Managing seasonality of wood supply with multimodal systems in coastal Norway.

Kogler, C; Rauch, P. Evaluation of resilient and sustainable strategies based on scenario analyses of a discrete event simulation model for the wood supply chain in Austria

Rauch, P; Kogler, C. Testing multimodal wood transport options with discrete-even simulation.

Winter Simulation Conference (WSC) 2018, Dec 8-12th 2018, Gothenburg, Sweden:

Kogler, C (2018): A discrete event simulation model to test multimodal strategies for a greener and more resilient wood supply in Austria