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QUALITY DRIVEN TRANSPORT STRATEGIES FOR THE WOOD SUPPLY CHAIN

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ABSTRACT

Fresh sawlogs lose quality during storage at roadside primarily through blue stain and insect infestation leading to wood value loss. The potential of wood quality forecasting to prioritize wood piles at risk of devaluation for transport has not been evaluated thus far. Consequently, a virtual wood supply chain environment containing dynamic altitude zone-based risk forecasts for blue stain and insect infestations was developed. Based on a discrete event simulation model, unimodal and multimodal wood supply chains were simulated to track sawlog quality development from roadside stocks to the wood-based industry. This enabled identifying and modelling the relationship between lead time and wood quality devaluation as well as applying this knowledge to evaluate innovative transport strategies. Respective regression analyses showed that the procurement lead time is a significant predictor of the downgraded wood amount, explaining over 98% of the variance of downgraded wood in quadratic and cubic relations.

1 INTRODUCTION

In scientific literature, wood transport is dealt with operations research methods such as optimization (D'Amours et al. 2008, Acuna 2017, Kogler et al. 2021) and simulation (Kogler and Rauch 2018, Kogler and Rauch 2019, Kogler et al. 2020), successfully applied for contingency planning (Kogler and Rauch 2020a) and game-based workshops (Kogler and Rauch 2020b). The impact of introducing quality development data for spruce sawlogs in wood transport planning to observe the relationship between lead time and the downgraded wood amount has not been evaluated thus far. This research gap has alarming implications for wood supply chain management because sawlogs lose quality over time primarily through blue stain and insect infestation leading to devaluation and wood value loss. Wood value loss can be avoided if transport capacities are synchronized with harvesting capacities to keep lead times short. Increasingly frequent and extensive forest calamities limit those coordination capabilities and produce salvage wood amounts that dramatically exceed regional available transport capacity. Consequently, innovative transport strategies based on forecasting models that take into account altitude zones with different weather conditions are needed.

2 DISCRETE EVENT SIMULATION MODEL

A discrete event simulation approach was chosen to model the wood supply chain on a detailed abstraction level and operational planning horizon. The simulation model supports analyses of wood flows from the forest module via truck, rail transport and terminal modules to the final industry module in six different views for animations, scenarios, statistics, supply chain processes, terminal processes and detailed system status. The forest module generates wood entities, representing one cubic meter of wood according to the harvesting weeks and quantities of input data in three sources, representing altitude zones. After wood is harvested and extracted, it is batched to a pile representing a truckload of 25 cubic meters of wood, which is exposed to the risk of quality deterioration due to blue stain and/or insect infestation. The truck transport module generates and controls self-loading trucks and implements the pickup prioritizing decision of truckloads at forest street landings according to the predefined management strategy. Within daily working times, truckloads are either directly transported to industry or transshipped to wagons at the terminal. The rail transport module controls the pickup of fully loaded wagons for train transport to industry. The industry module covers the unloading of self-loading trucks and train wagons. Thus, the wood flow corresponds to the real wood supply chain process in great detail.

3 RESULTS AND DISCUSSION

Lead times of the simulation scenarios are well in the range of reported lead times in Norway (45 days), Lituania (45 days), Poland (56 days), Sweden (57 days), Austria (63 days) and France (67 days), underlining both the realistic simulation setting and the applicability of the proposed management strategies (Puodziunas 2013, Westlund et al. 2018). Regression analyses proved that the procurement lead time is a significant predictor for the amount of downgraded wood in the wood supply chain. A quadratic as well as cubic regression with downgraded wood volume as the dependent variable and lead time as the explanatory variable is significant for all transport strategies ($p < 0.001$). Depending on the strategy, more than 98% of the variance of the devalued wood quantity can be explained by the variable lead time. Consequently, the lead time is an easily measurable and manageable key performance indicator to preserve wood quality supporting wood supply managers in controlling and further developing wood supply chains.

The presented analyses provide a robust basis for resilient and efficient planning, management and control of the wood supply chain. Thus, threatening efficiency and resilience losses beyond the wood devaluation prevailing in practice, especially in times of extensive forest calamities when commonly trial-and-error approaches are applied, can be avoided due to the simulation model support of lead time and weather data driven transport strategies. Integrating new findings on the wood quality development in different types of dry and wet stockyards enable further investigations on the relationship between lead time and wood quality. Future models and case studies observing the procurement lead time along wood supply chains provide further research opportunities.

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