Improving the Environmental Sustainability of Pallet Logistics through Preemptive Remanufacturing: an Integer Linear Optimization Model

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BACKGROUND

• Wooden pallets are the most widespread packaging type for material handling and transportation → 2 billion pallets/year in the US, 300 million pallets/year in EU

• Closed-loop pallet systems recover pallets after use for repair and reuse.

• Pallet fail by component, depending on handling/loading conditions.

OBJECTIVE

Demonstrate that optimal preemptive remanufacturing policies, where repair or replacement of pallet components can occur earlier than required, may result in a reduction in CO2-eq transportation emissions.

METHODOLOGY

• Integer linear optimization model

• Data on pallet cycles from Service life analysis Pallet Design System (PDS®)

• Data on CO2-eq emissions from carbon analysis of pallet remanufacturing operations

• 5 handling and loading scenarios considered.

• Sensitivity analysis on distance (50 km, 100 km, 150 km).

MODEL FORMULATION

Minimize emissions (Transportation + opportunity loss + operations)

$$\text{min} \left( \sum_{c} \sum_{e} A Y_{Sc} + \sum_{c} \sum_{e} \sum_{j} \sum_{p} h_{psj} t_{psj} + \sum_{c} \sum_{e} \sum_{j} \sum_{p} e_{psj} x_{psjc} \right)$$

s.t. 

$$\sum_{j} x_{psjc} \leq M Y_{Sc} \forall c \in C$$

$$x_{psjc} \geq d_{psjc} \forall p, c \in C, j \in J$$

$$I_{psjc} = I_{psjc-1} + X_{psjc} - d_{psjc} \forall p, c \in C, j \in J$$

$$X_{psjc} = \{0, 1\} \forall p, c \in C, j \in J$$

$$Y_{Sc} = \{0, 1\} \forall c \in C$$

RESULTS

![Graph showing emissions comparison for different scenarios]

CONCLUSIONS

• Remanufacturing emissions decrease in all scenarios [11 - 41%]

• Highest improvement and lowest emissions with light loading.

• Worst performance with rough handling and heavy loading.

• Sensitivity analysis confirms these results. Light load policies have the greatest potential improvement with preemptive policies.

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