Advances in Forestry Control &
Automation Systems in Europe

REACTIVE WOOD TRANSPORTATION PLANNING WITH AN OPTIMIZATION-SIMULATION APPROACH

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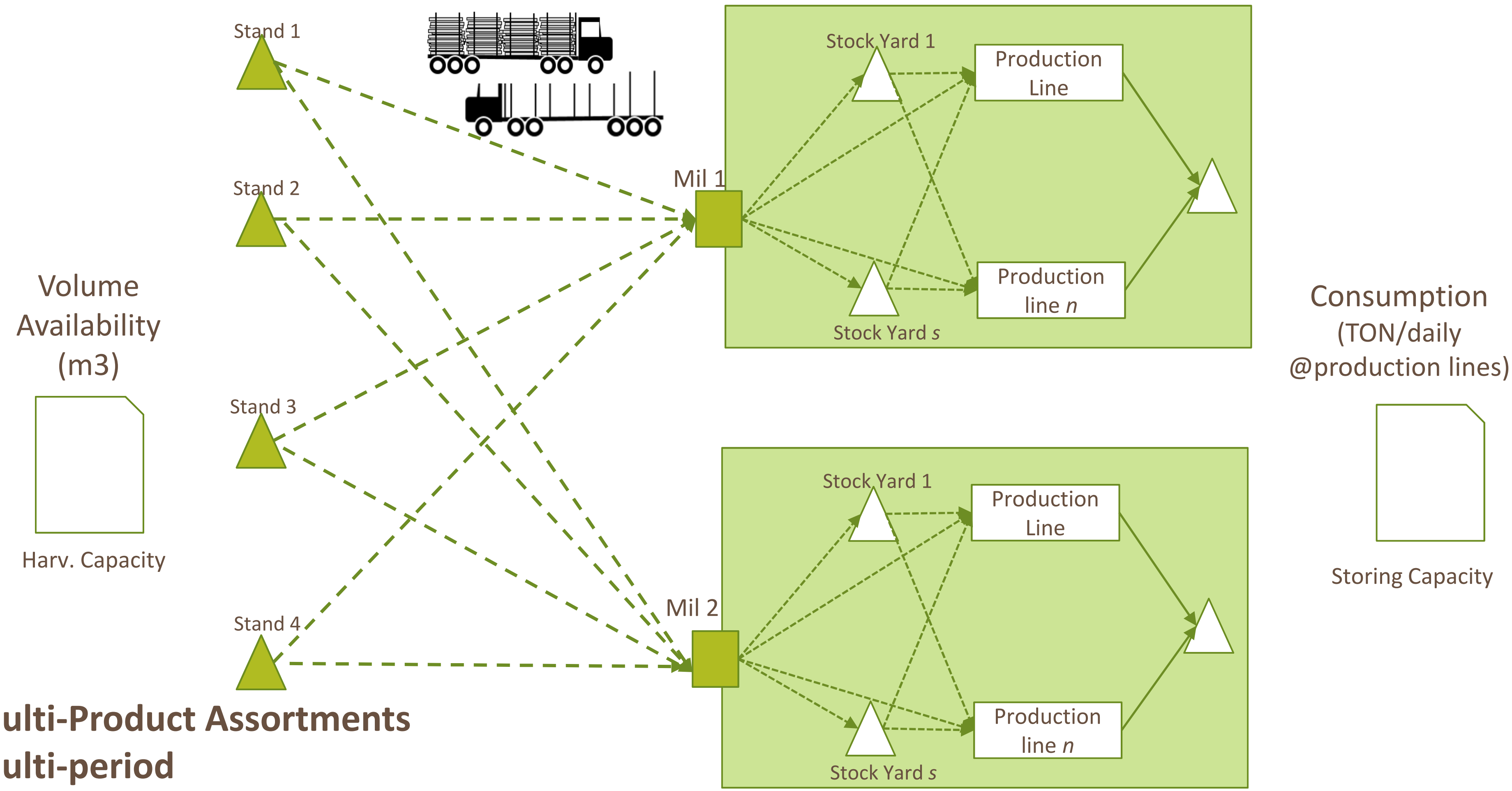
Agenda

Advances in Forestry Control & Automation Systems in Europe

1. Why? Motivation and State-of-the-art
2. How? Proposed approach
3. The case study: Pulpwood transportation to a pulp mill in Portugal
4. Computational results
5. Concluding remarks

Wood transportation planning:
sequence of spacially distributed decisions….

Harvesting stands **Mills**

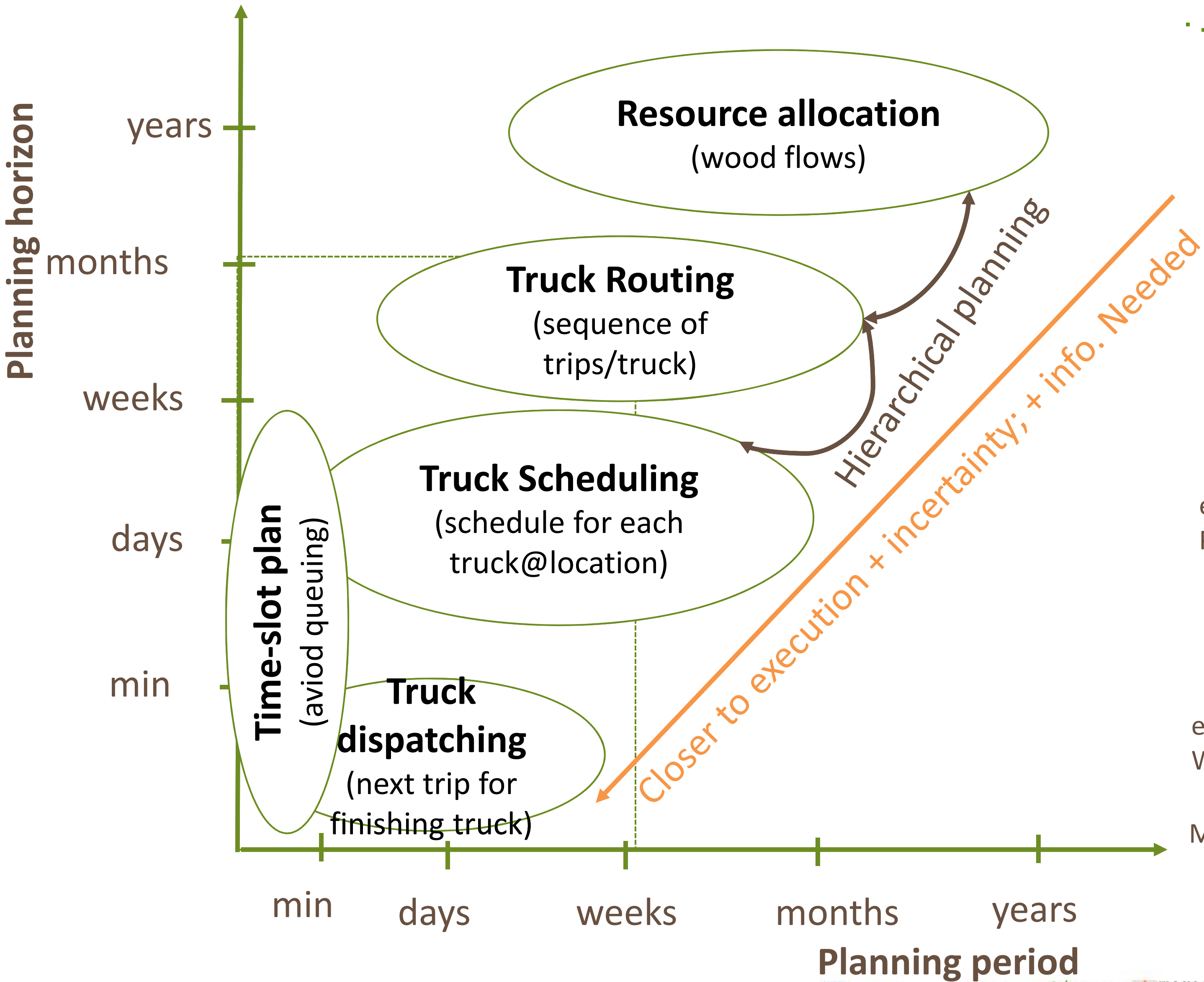


Multi-Product Assortments
Multi-period

What is the optimal monthly wood flows (origin-dest-assortment-period)? How much trucks?

Truck's daily route?
Truck's unloading location / time slot in the mill (to avoid queuing)?

Wood transportation planning:
sequence of decisions … at diferent time scales



e.g. Carlgren et al. 2006; Forsberg et al. 2005; Carlsson and Ronnqvist 2007

e.g. Rey, P.A., et al 2009; …

e.g. El Hachemi, N., 2014; Palmgren, M., et al 2004; …

e.g. Rönnqvist et al. 1998; Weintraub, A., et al. 1996

Marques, A. et al 2013.

We usualy assume that execution will go as plan…
…but it is hardly the case due to uncertainty…

planning under uncertainty:

Predictive planning ≠ *Adaptative planning*

Predicts sources of uncertainty and their impact in the outcome of the plan

↓

Robust plans
i.e. outcome not affected by realization of uncertain events

Plan reacts in the face of disruptions in the original plan

↓

Flexible, dynamic plans
new plans are generated whenever a significant disruption is detected by the control, based on information about current execution.

↓ ↓

Frequent approaches combine optimization (deterministic) with forecasting/ simulation (stochastic)

e.g. Laumanns, M. 2011; Shobrys and White (2002)

Reactive (wood) transportation planning:

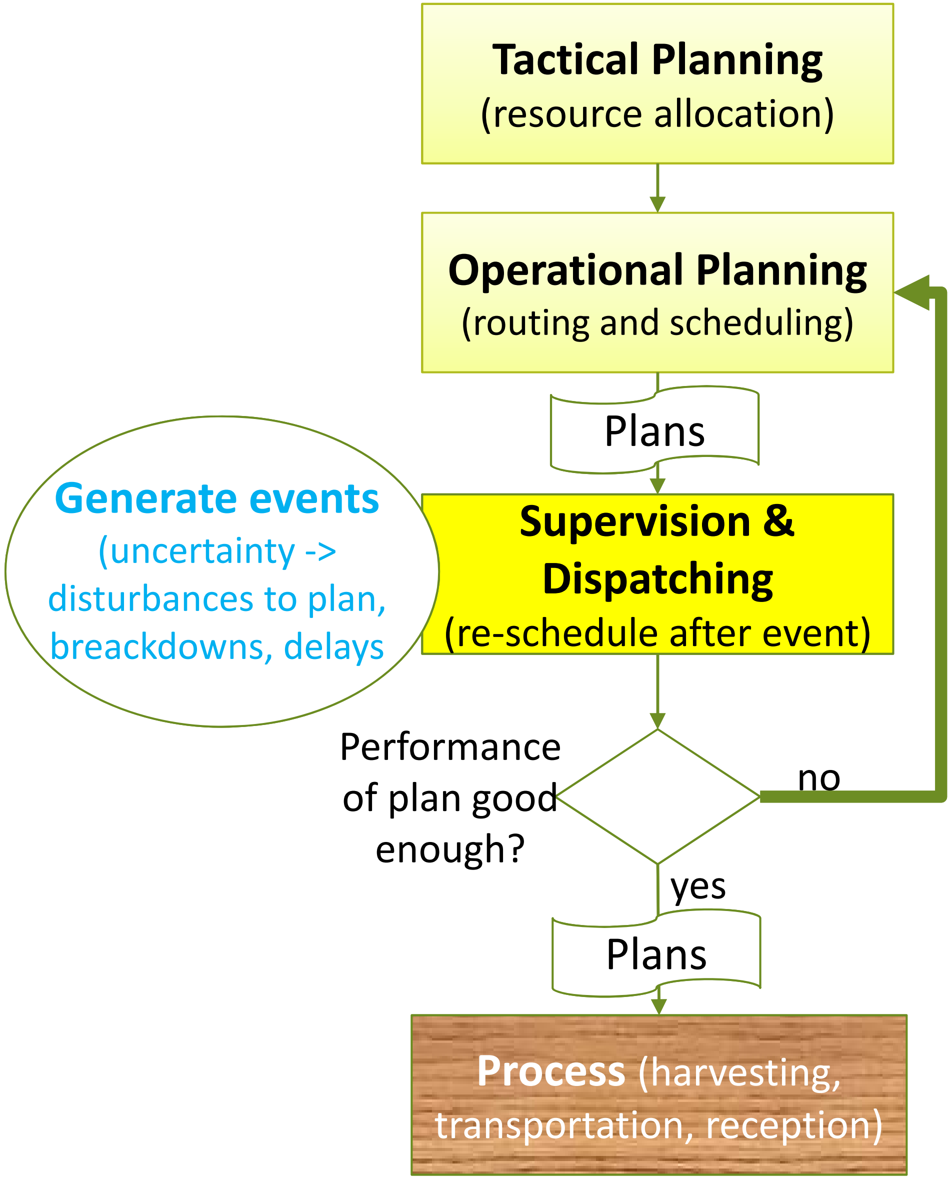
The goal is to **find high performance plans and schedules** that can coupe with the uncertainty and expected events (predictive mode),

AND

During the execution of the plans and schedules,
Control/supervise the impact of unplanned events over the expected plan outcome and whenever possible **react**,
Whenever needed, **generate a new schedule** (or even a new plan) for the following operations, based on the current context (adaptative mode)

Inspired in Model-Based Predictive Control

New optimization-simulation approach for reactive wood transportation planning <u>on predictive mode</u>



Mixed-Interger model
Decision variables:

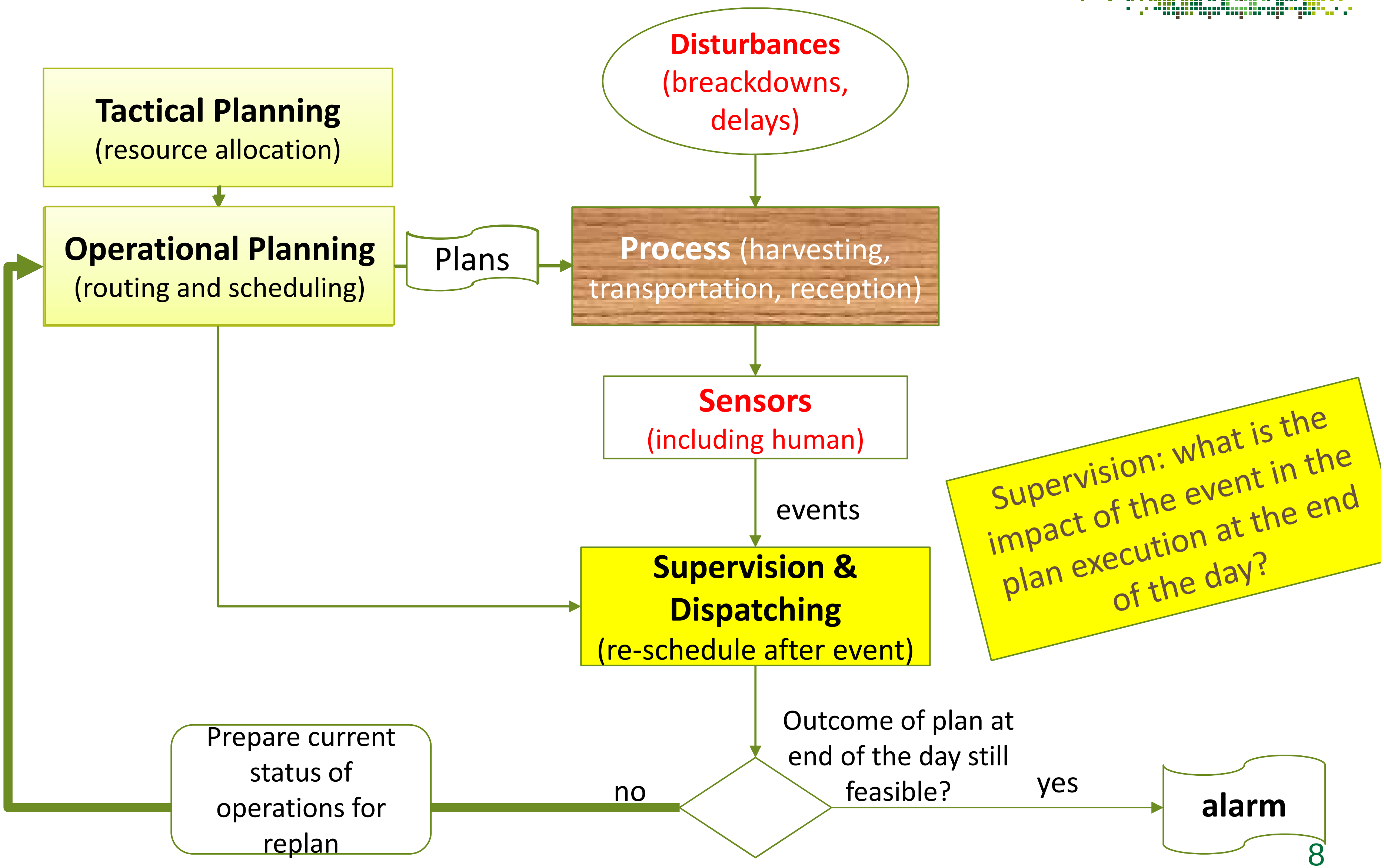
Heuristic approach
(e.g.)

Dispatching rules implemented in a Discrete event-simulation model

planner

Supervision: what is the expected performance of the plan considering uncertainty in distrubances and unplanned events

New optimization-simulation approach for reactive wood transportation planning on the adaptative mode



Feedback Loop from Simulation to Optimization
Means changing the data set and re-run the same opt-sim models

Predictive mode

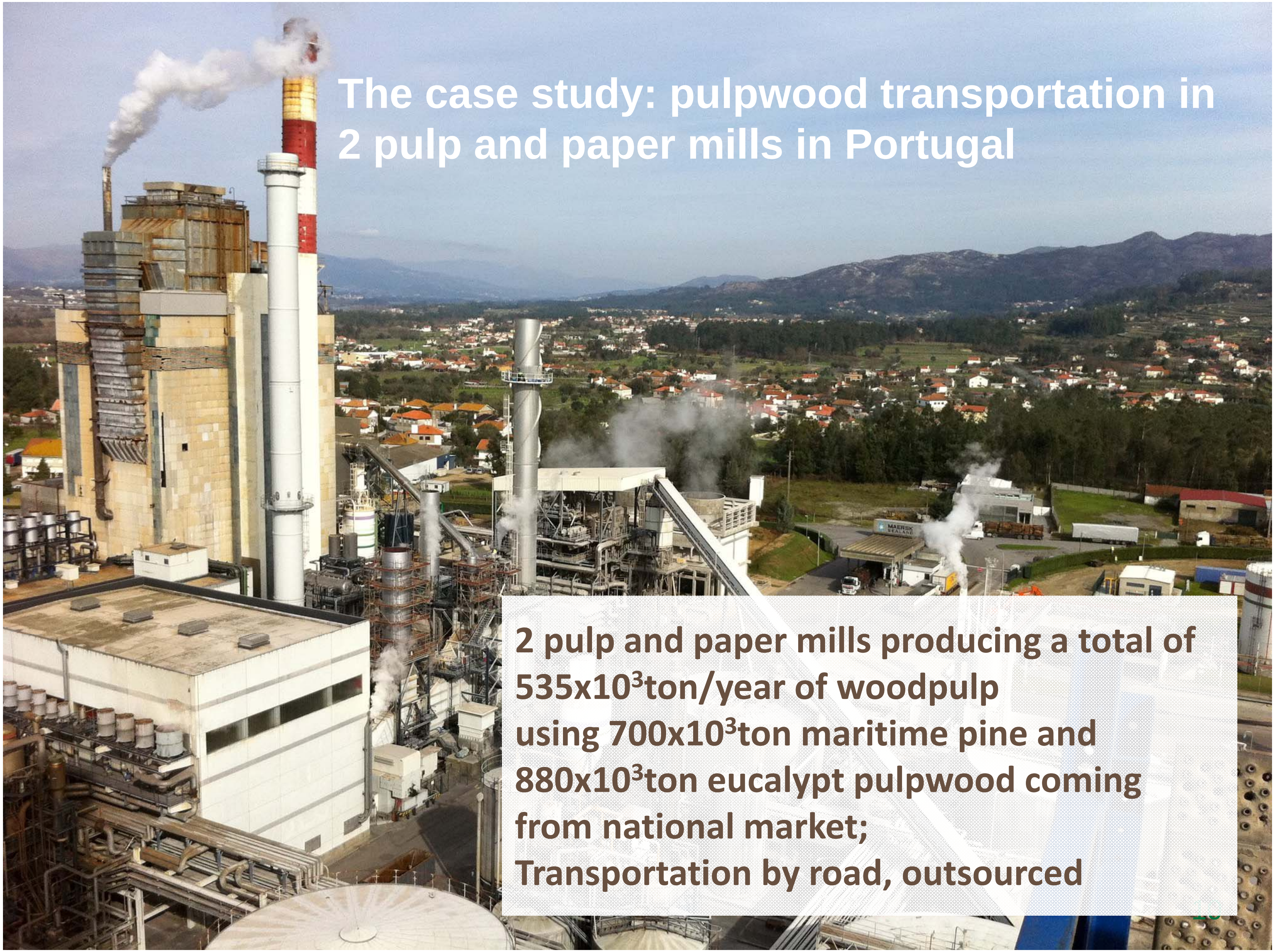
- ✓ **Change parameters affecting the plan's performance**
  - e.g. increase number of trucks
  - e.g. increase supply points
  - e.g. decrease demand@mills

Adaptative mode

- ✓ **Update status reflecting events until the moment when simulation stops:**
  - e.g. remove operations already done and ongoing by all trucks
  - e.g. Update arrival times of trucks in queue
  - e.g. Add unplanned arrivals until that moment

- ✓ **Increase the length of working hours**

The case study: pulpwood transportation in 2 pulp and paper mills in Portugal

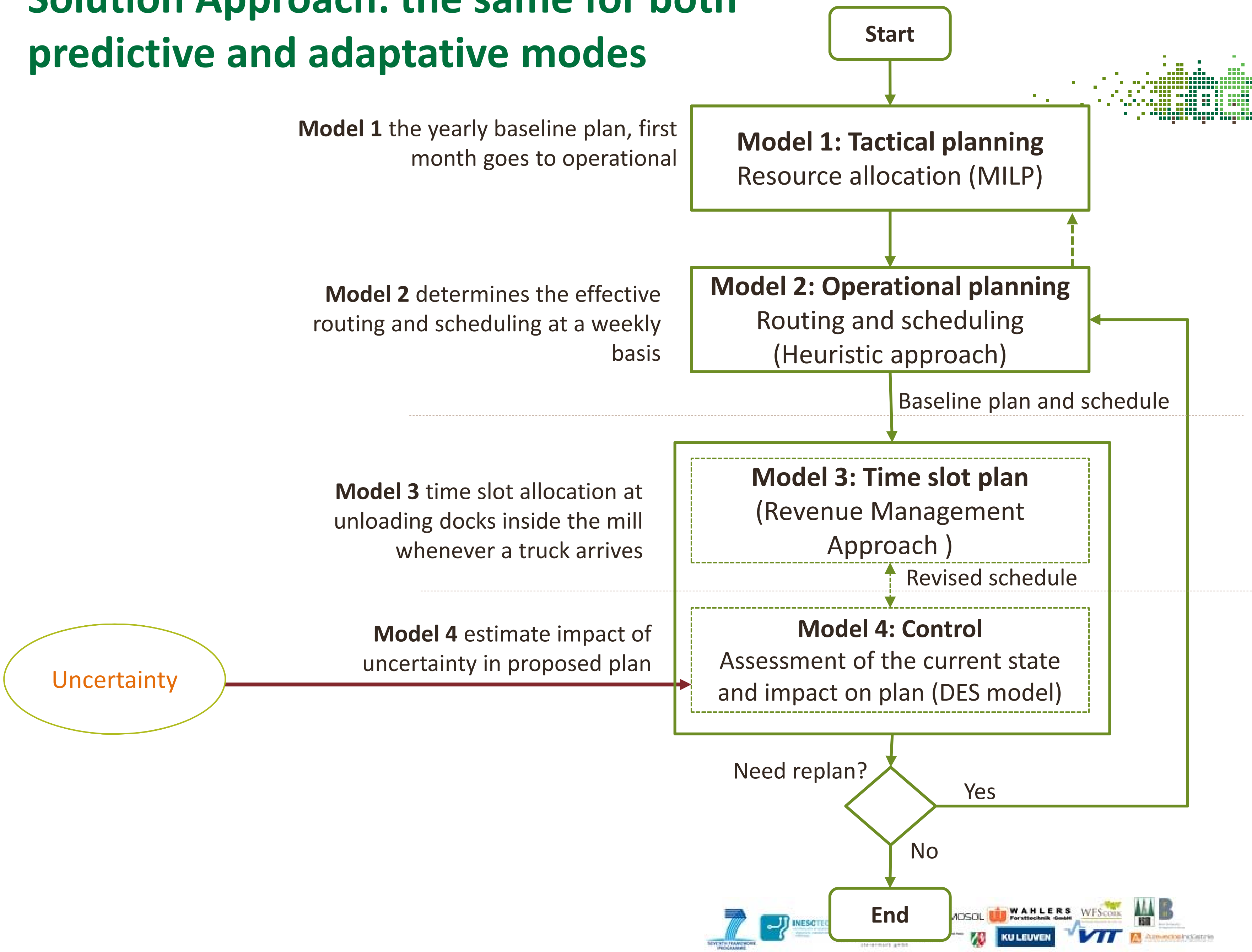


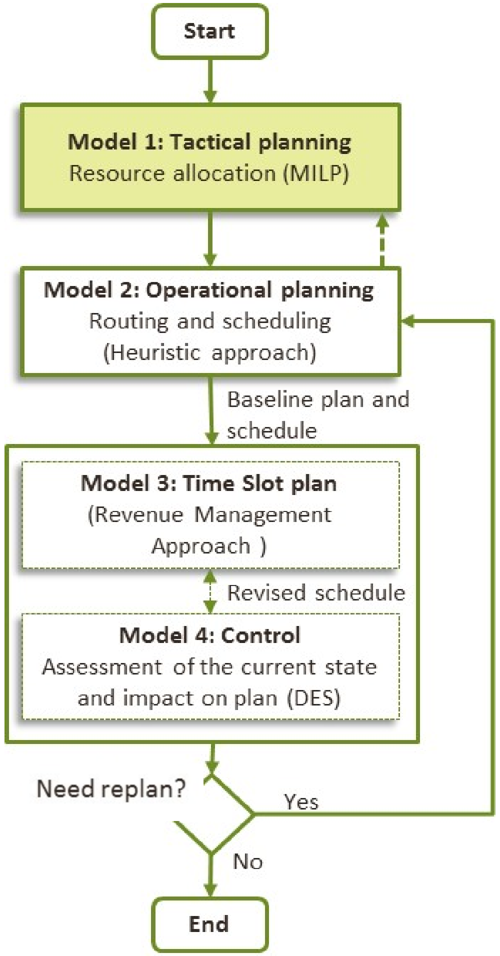
2 pulp and paper mills producing a total of $535x10^3$ton/year of woodpulp
using $700x10^3$ton maritime pine and $880x10^3$ton eucalypt pulpwood coming from national market;
Transportation by road, outsourced

Case study characteristics

Case study characteristics	
Number of mills	2
Total demand	$1780x10^3$ ton per year
Number or supply locations	4
Total availability	$1754x10^3$ ton per year
Daily deliveries (mill 1)	120: 72 planned + 48 unplanned
Assortments	3
Production Lines	3@mill 1 + 2@mill 2
Loading and unloading time	15min -> length of the time slots
Reception time	7min -> length of time slots@gate
Waiting cost	0.51€/min/truck
Material handling cost	0.35€/ton
Cost working extra hours	0.51€/min
Transportation cost	0,021€/km/ton (full), 0,84 €/km (empty)
Harvesting cost	10€/ton

Solution Approach: the same for both predictive and adaptative modes





Model 1: Tactical planning

Multi site, multi period, multi product wood flow problem

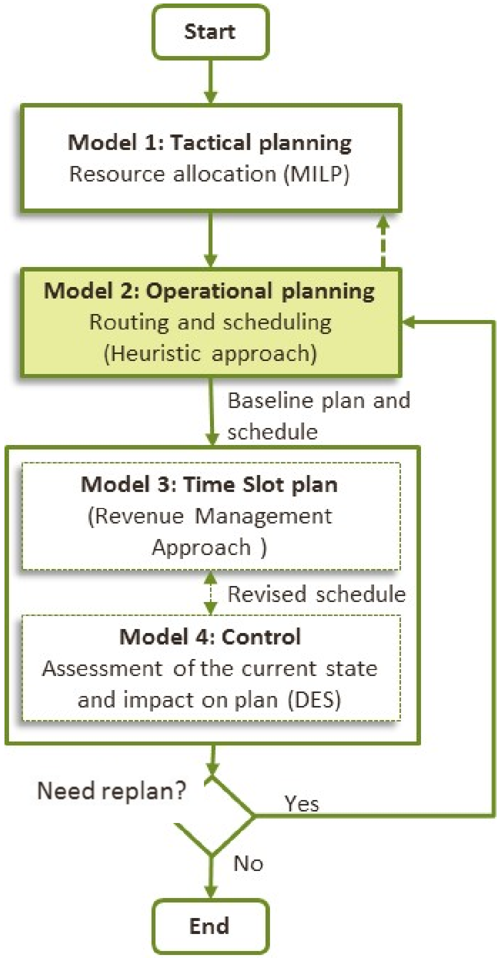
x_{it} = 1, if stand *i* is harvested in period *t;* 0 otherwise
y_{ijpt} = Quantity (tons) of assortment *p* transported from stand *i*, to mill *j*, in period *t*
z_{it} = *1* if stand *i* started harvesting in period t; 0 otherwise

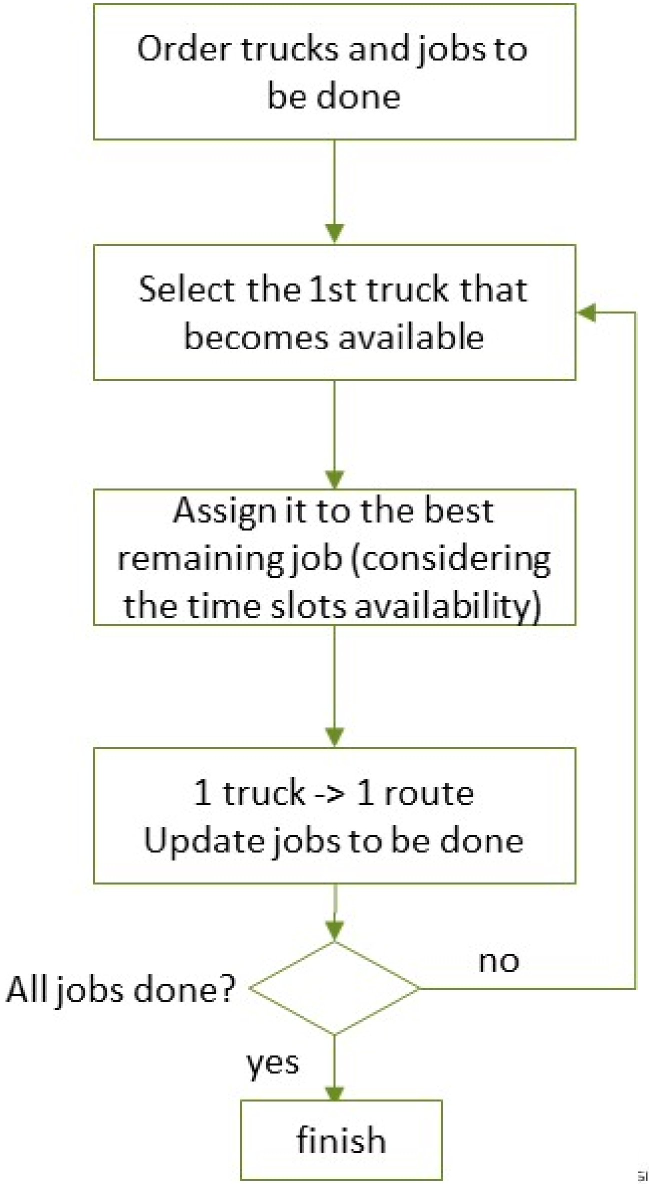
Objective: Max profit = revenue – costs
Subjected to:

1. Harvesting at stand *i* only once
2. Even harvesting flow across the periods
3. Timber harvested is transported to mills *j* in period *t*
4. Inventory of assortment p at the mill j in period t
5. Storage capacity of the mill j in time period t

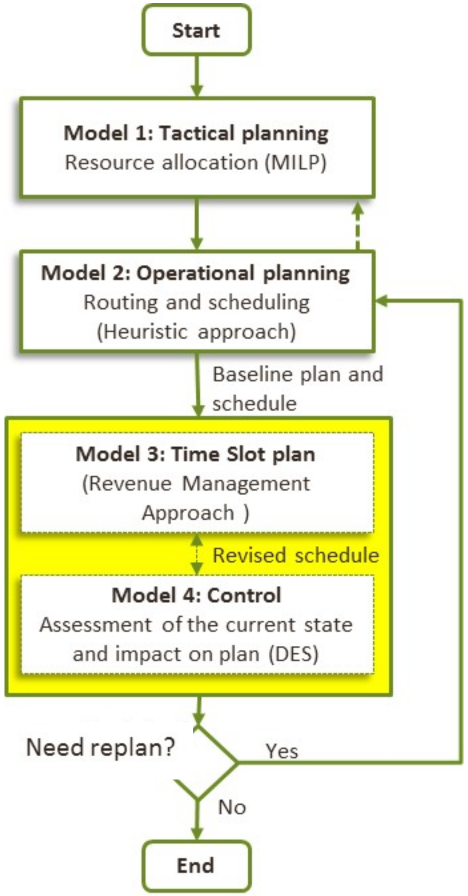
MIP formulation -> solved optimally with GUROBI

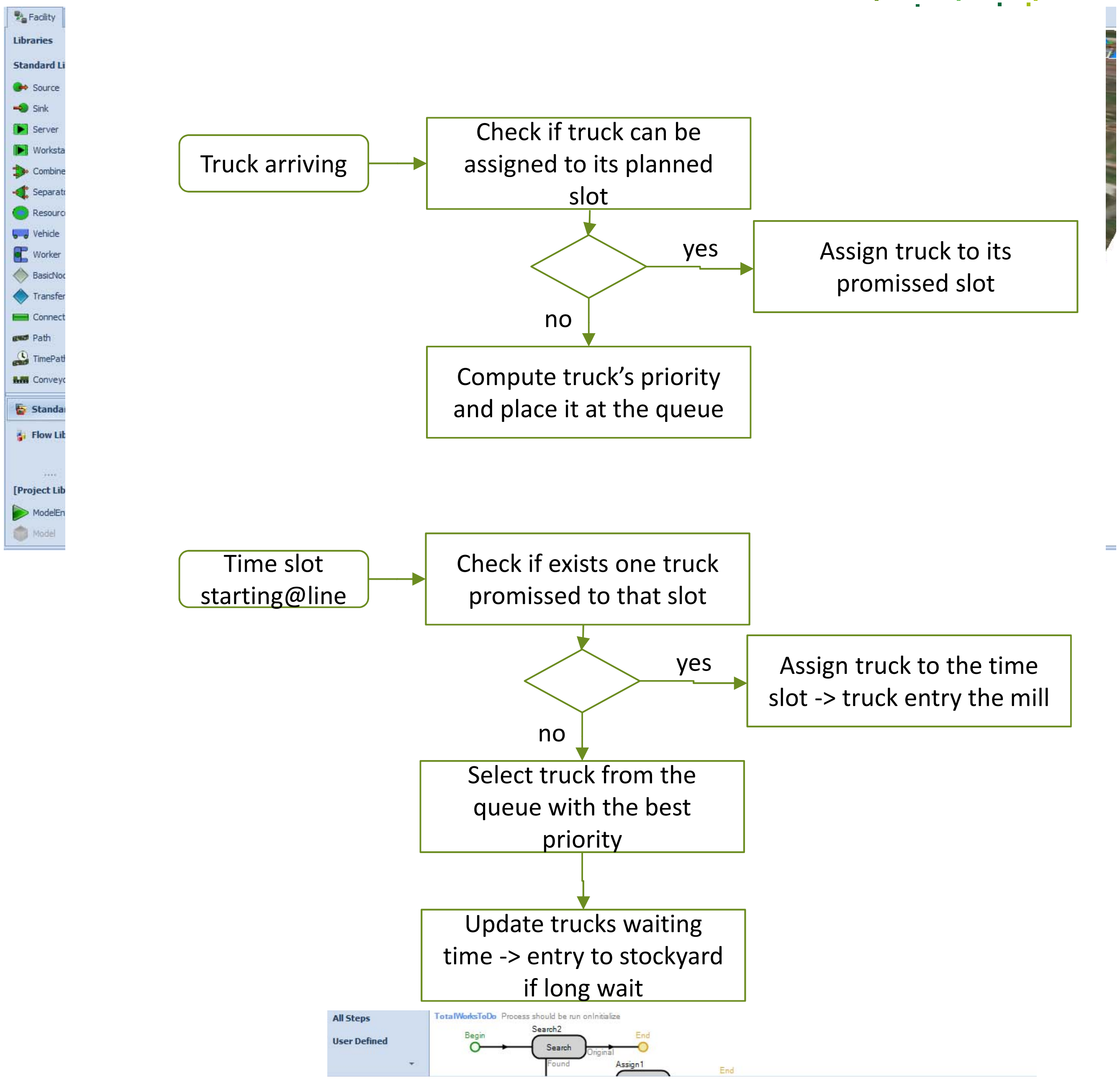
Model 2: Greedy routing heuristic (inspired in ASICAM)



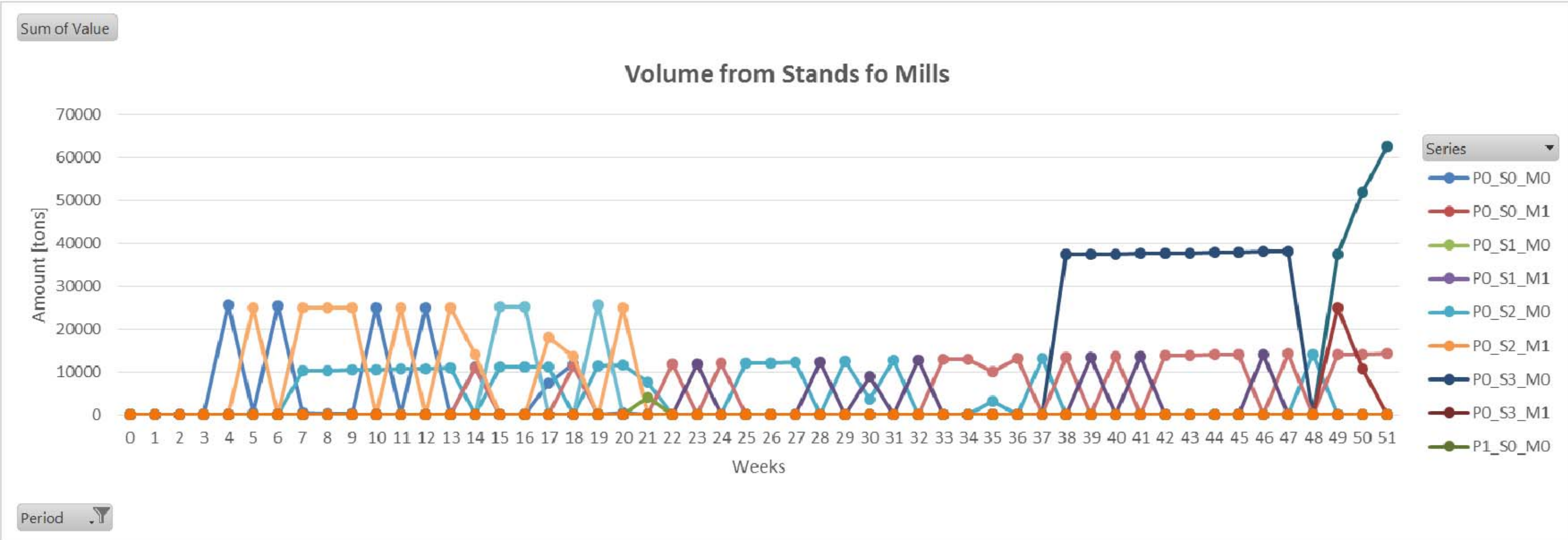


Model 3+4: Time slot plan and control





Preliminary Results – MILP model



Flow of assortments during 1 year of operation

- The quantity (in tons) of assortments transported from stands to mills in each week
- Mill 0 receives 976,763 tons
- Mill 1 receives 577,944 tons

Preliminary Results – routing and scheduling

One Day

Total waiting costs (euros): 5249.4

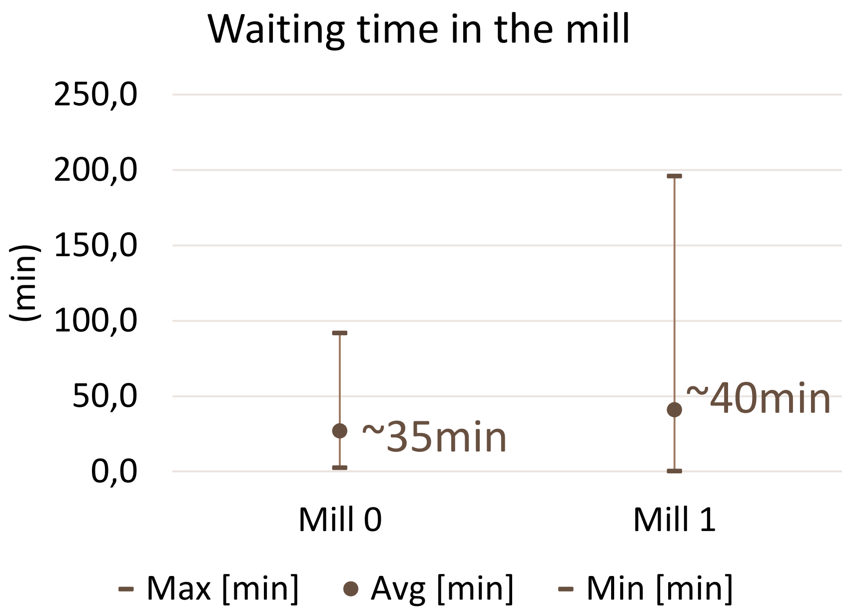
Total number of loads: 135

Total number of routes: 44 (nº trucks)

Extra hours cost (euros): 176

Number of loads afterhours: 23

Average N. loads/route: 3

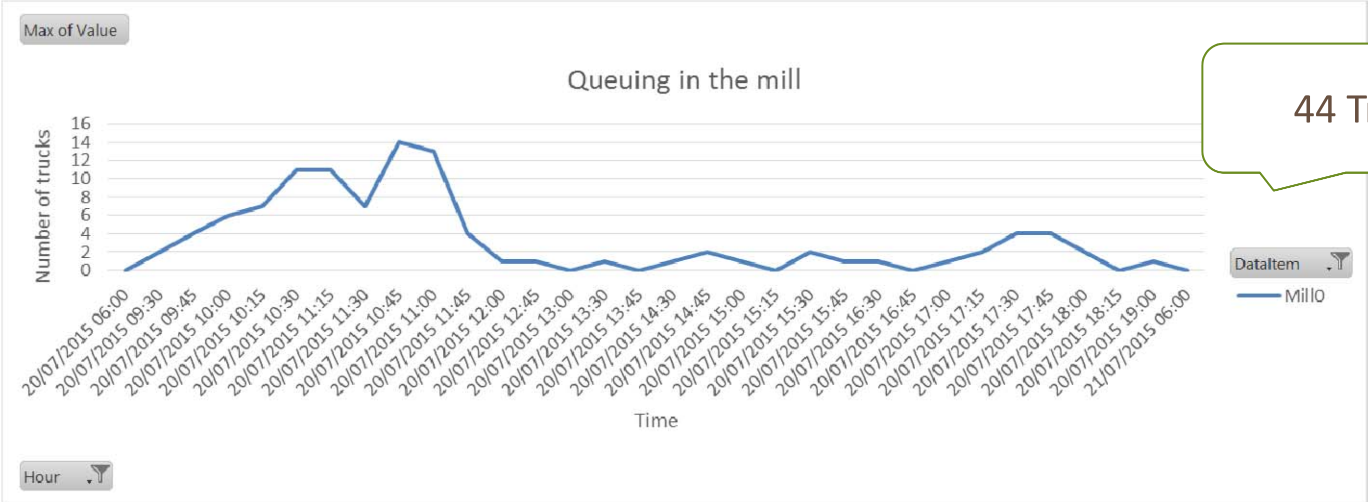


FIFO~90min

Destination ID (Mill line or stockyard)	Number of Loads
1	15
2	23
3	0
4	7
5	0
6	0
7	0
8	41
9	0
10	49

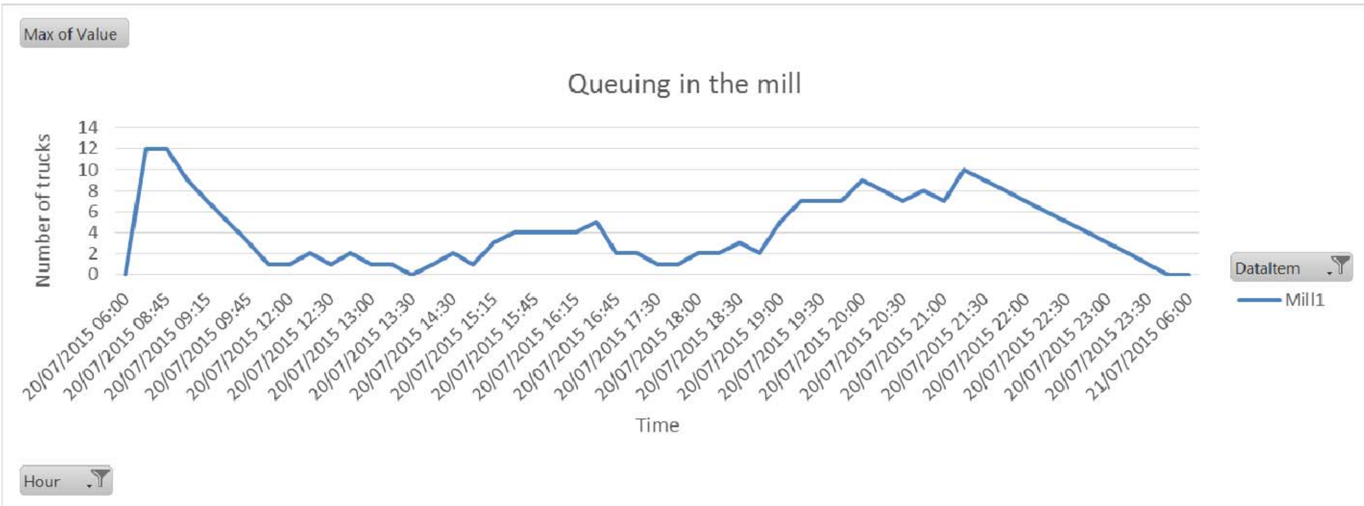
Preliminary Results - Simulation model

RM Queuing in the mill 0



44 Trucks

RM Queuing in the mill 1



Concluding remarks

What?

A **new reactive planning concept** is proposed for wood transportation planning

Why?

The proposed concept is a way to deal with uncertainty and **generate better plans that make use of information about operations execution**, leading to increased performance of the supply chain and reduced transportation costs by better user of the transportation resources and avoiding queuing effects.

How?

The approach is built on a new **simulation-optimization approach**, inspired in MPC

is expected to reduce the queuing effects and the material handling cost when compared with FIFO (ongoing work)

Next?

Under the framework of FOCUS 7FP project:

- ✓ Compare results with FIFO
- ✓ Wrap-up this approach into a collaborative DSS to support the new processes
- ✓ Integrate with sensors

FOCUS in a nutshell

What?

7 FP SME-target collaborative RTD project
01-01-2014 to 30-06-2016 (30 months)

Why?

Need for integrated processing and control systems for sustainable production in farms and forests.

How?

New FOCUS technological platform that combines sensors and sophisticated software solutions for integrated control and planning of the whole forest-based value chain.
7 Work Packages encompassing specification, development of data collection tools as well as control and planning tools, integration; assessement of prototypes into 4 pilot cases.
Covering the value chains in Europe of lumber, pulpwood, biomass and cork transformation; from forest planning to industrial processing.
Total budget of ~4M€ (~3M€ EC funding)

By whom?

Consortium of 6 SMEs and 6 RTDs from Portugal, Finland, Belgium, Switzerland, Austria and Germany, combining expertise in forestry, sensors, automation and software development.

The goal of FOCUS is to improve sustainability, productivity, and product marketability of forest-based value chains through an innovative technological platform for integrated planning and control of the whole tree-to-product operations, used by forest-producers to industry players.

www.focusnet.eu

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Thank you!

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