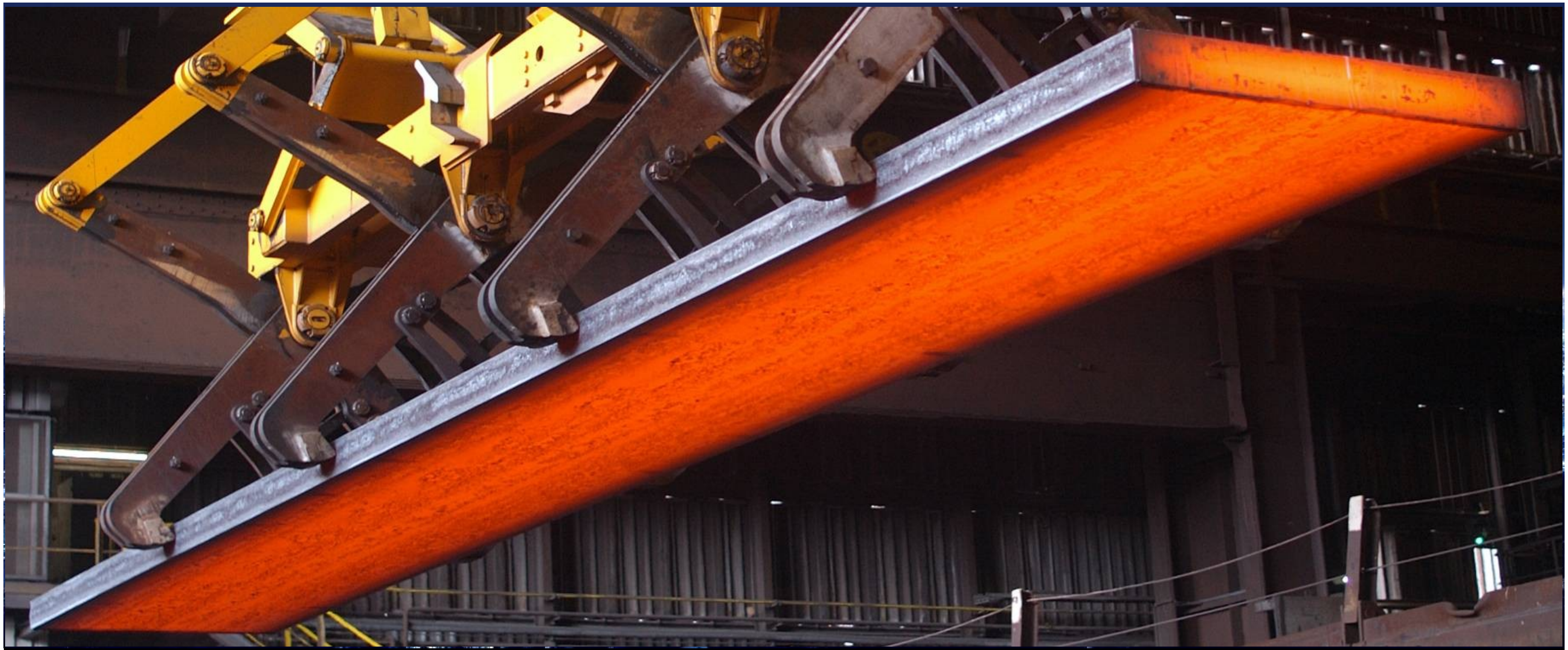
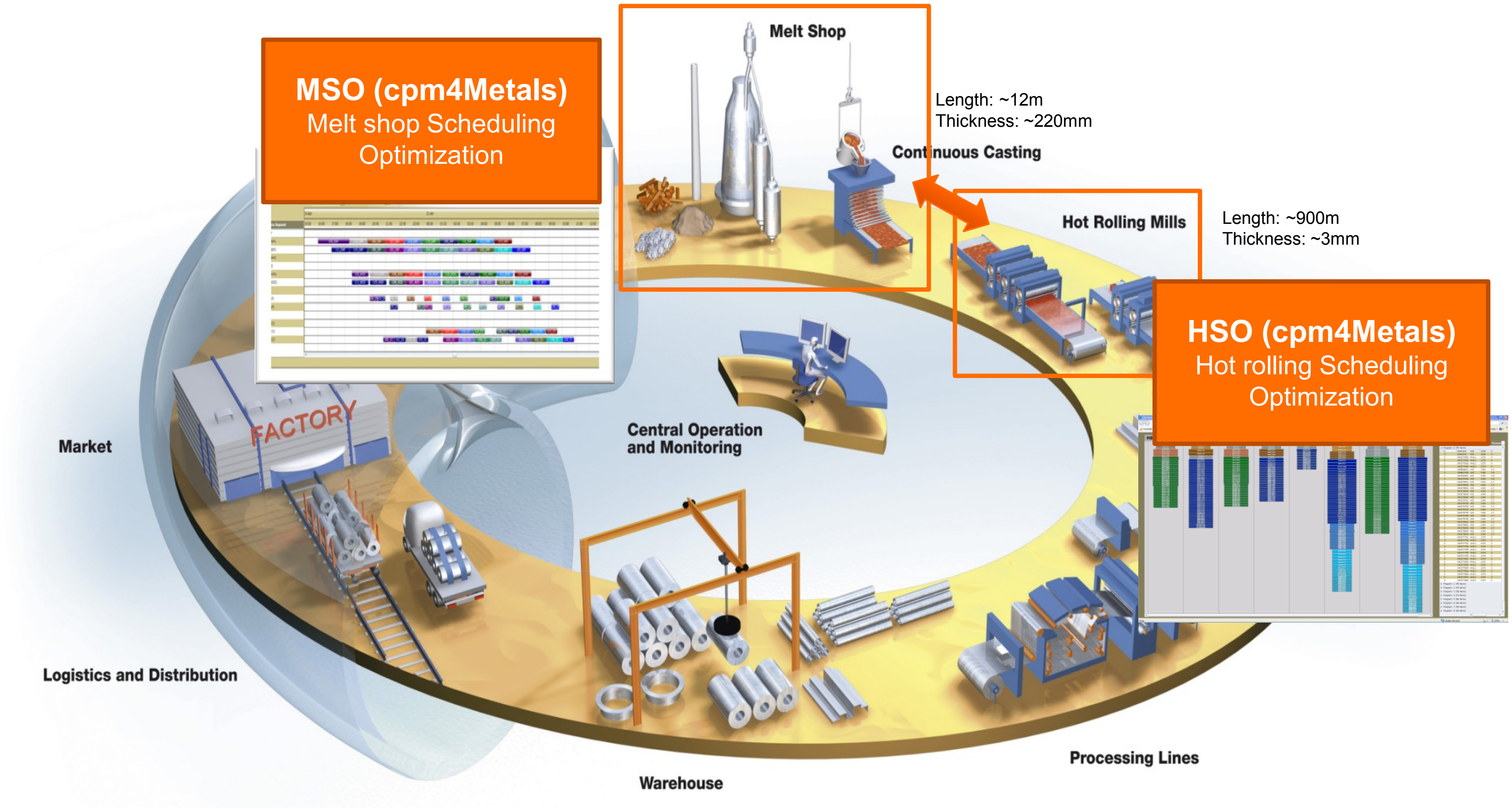


Chaojun Xu – ABB Corporate Research Center Germany, Prof. Dr.-Ing. Sebastian Engell – TU Dortmund, Sep 4, 2012

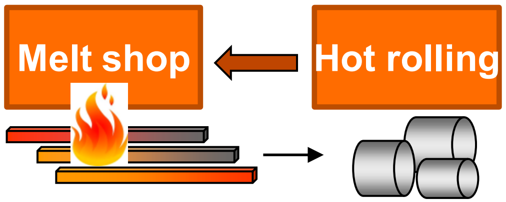
Unit coordination for energy saving in the steel plant

HYCON2 Workshop on Energy

Collaborative Production Optimization (CPO)
Coordination between Melt Shop and Hot Rolling Mill



Collaborative Production Optimization (CPO)
Today: Neither Pull nor Push is optimal in general!



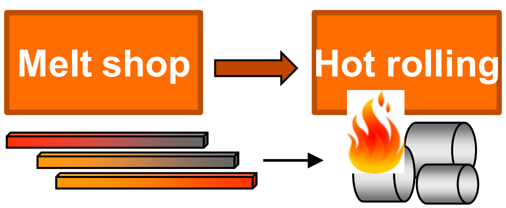
- **Order pull (Kanban)**

  Hot rolling orders → hot rolling scheduling → slab orders → melt shop scheduling

  + Low slab yard inventory

  + Slab hot charging in hot rolling mill possible

  -- High set-up cost/time in melt shop , due to short campaign schedule



- **Melt shop driven (push)**

  Campaign orders (heat orders) → melt shop scheduling → slab availability → hot rolling scheduling

  + Efficient melt shop operation

  + Caster throughput high

  -- Large slab inventory

Collaborative Production Optimization (CPO)

Plant-wide productivity instead of section wise

Melt shop

Hot rolling

Coordination

- reduce storage inventory
- save reheating energy
- improve overall productivity

Cost of slab:
50 000 €/slab

1000°C
25 ton
10m x 1m x 0.2m

After 3h : 700°C

After 12h: 100°C

100-200 slabs/day
500-1000 slabs in slab yard

1000m^3 natural gas
~ 540 €/slab

1200°C

Challenges of coordinating MSO and HSO
Coordinate differences to a joint decision

Different optimization features of	MSO	HSO
1. Different optimization objective	Tailored Benders decomposition heuristic for coordination of large-scale and grey-box scheduling optimization problems	
2. Different and implicit optimization constraints		
3. Heterogeneous scheduling entities	Virtual slabs & incidence matrix	
4. Complex nested scheduling algorithm	Planning & scheduling decomposition	
5. Different schedule time horizon	Rolling horizon approach	

Benders 1962, Geoffrion 1972, de Miguel 2001, Xu&Engell 2012

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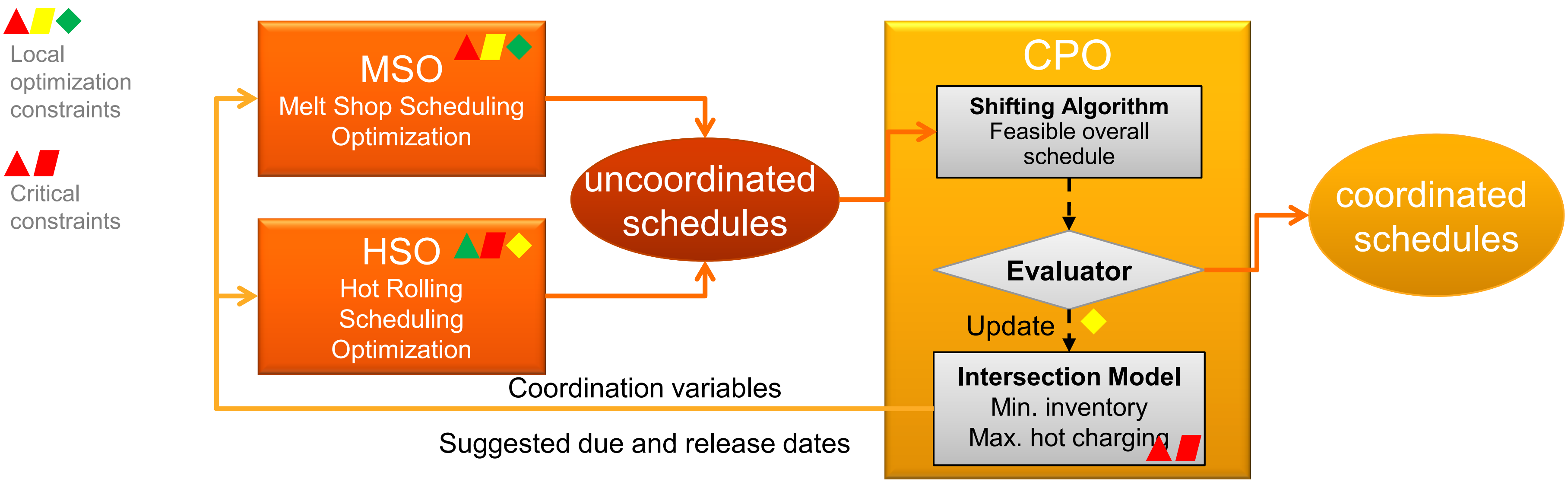
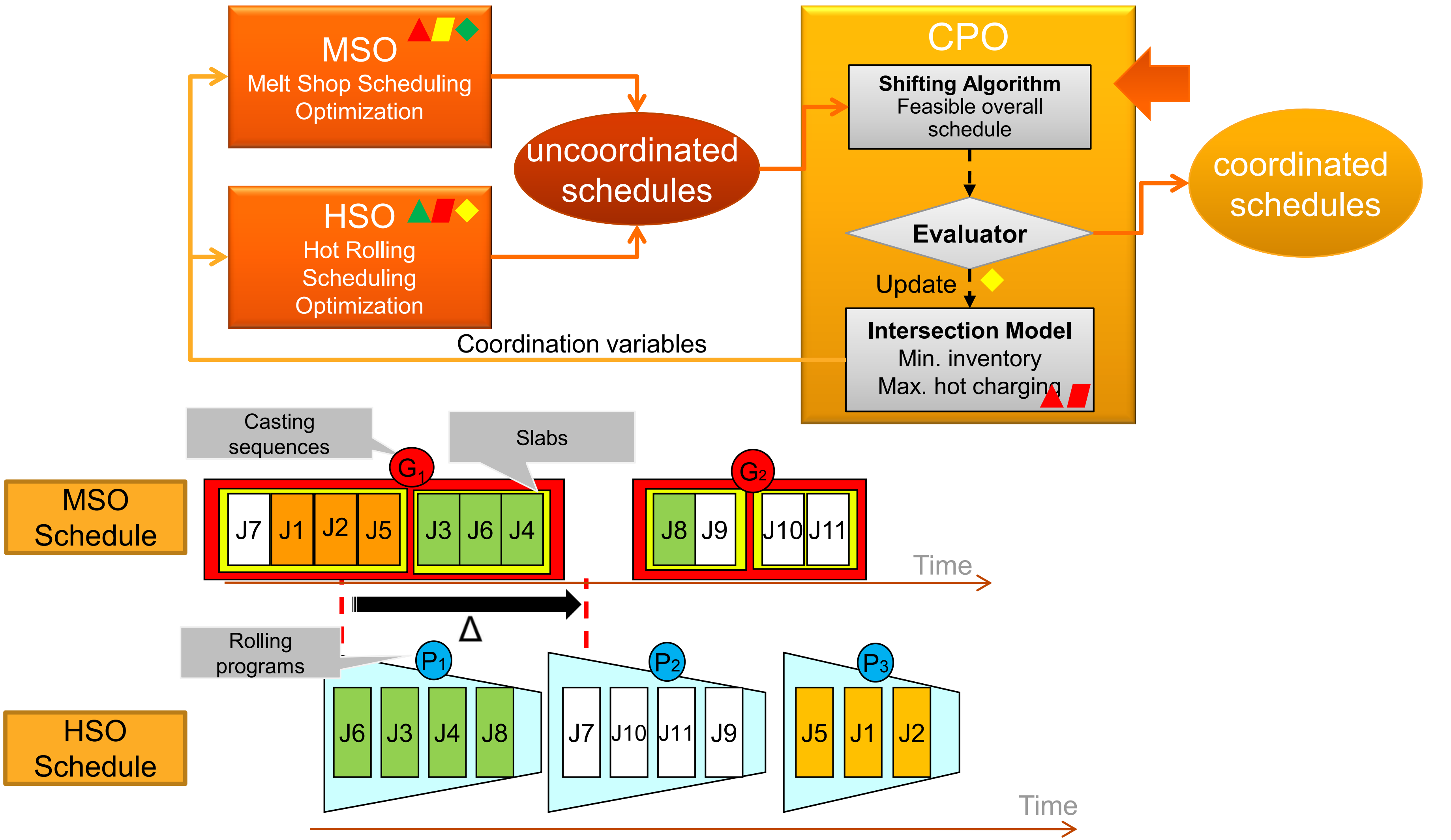
Algorithmic Solution of CPO
Algorithmic benefits



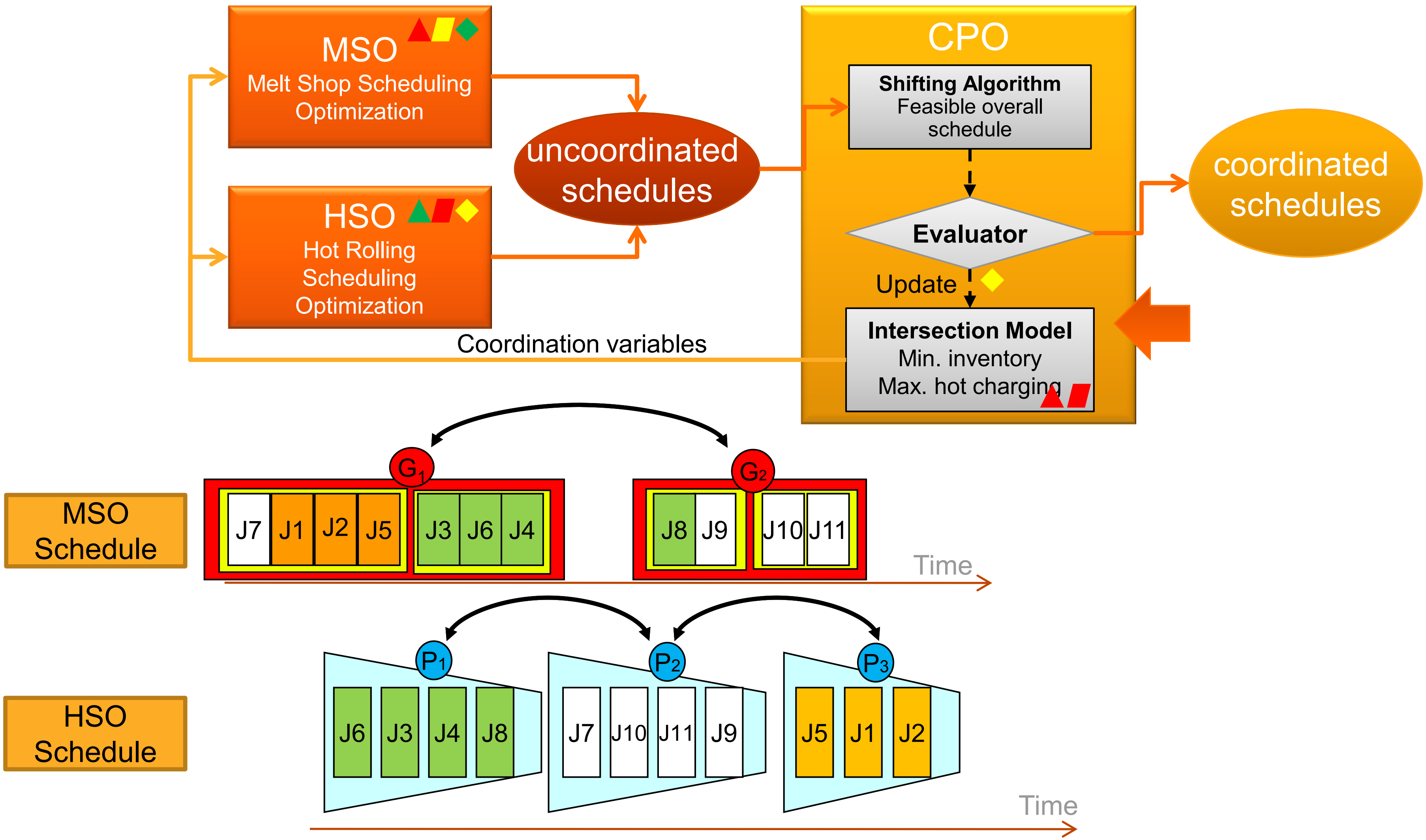
Reusability	• Minor changes in existing solutions
Robustness	• Back-up feasible solution ensured in every iteration
Optimality	• Continuous improvement of overall productivity and hot charging ratio
Performance	• Parallel computing of MSO and HSO

Algorithmic Solution of CPO

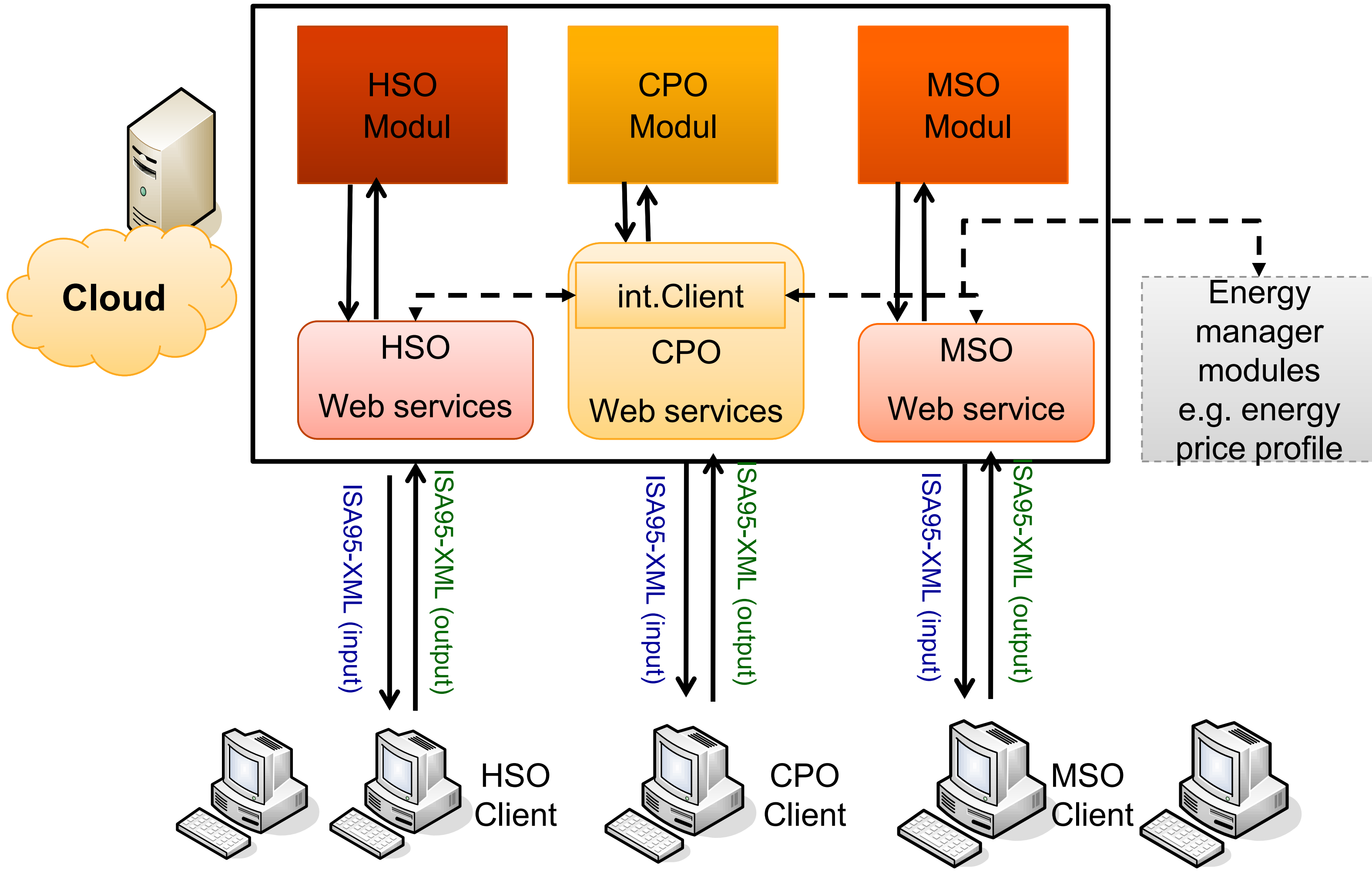
Shifting Algorithm – ensure overall feasible schedule



Algorithmic Solution of CPO
Intersection model optimizes different coordination obj.



Software Architecture of CPO
ISA-95 compliance & service solutions via Web Services

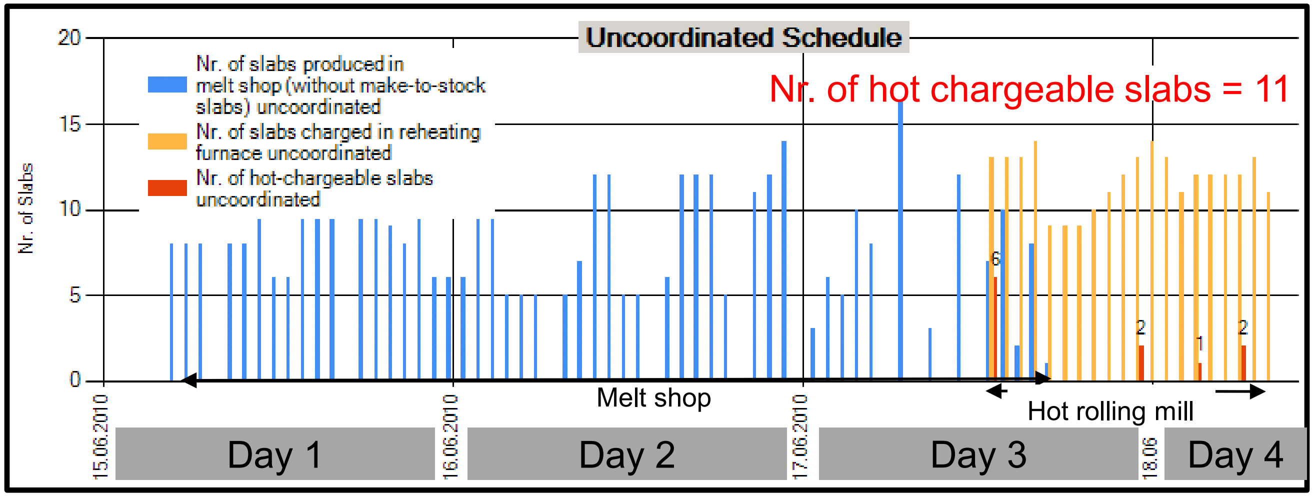


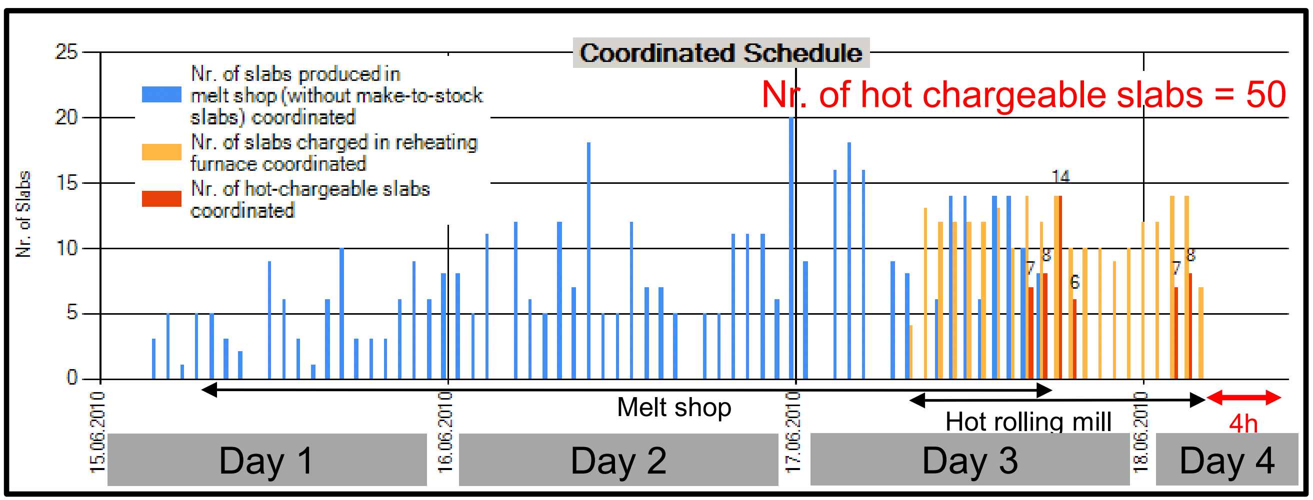
Validation of CPO on the production data

More productivity but less energy consumption

Hourly Histogram (each column = slab produced or charged within 1h)

320 slabs; 2.5 days melt shop production; 1 day hot rolling mill production



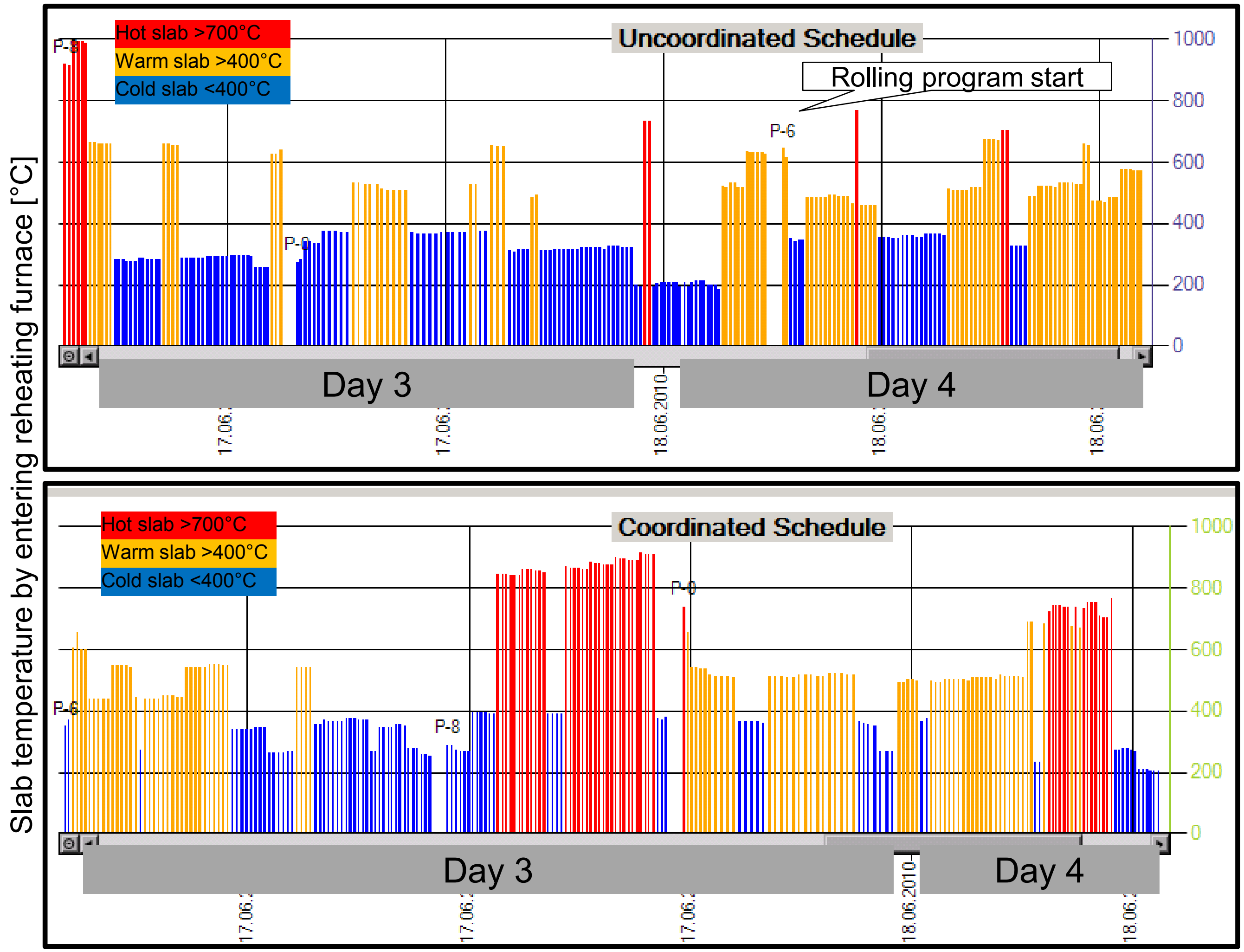


Validation of CPO on the production data

Increases hot/warm slabs, prevents ramping in reheating

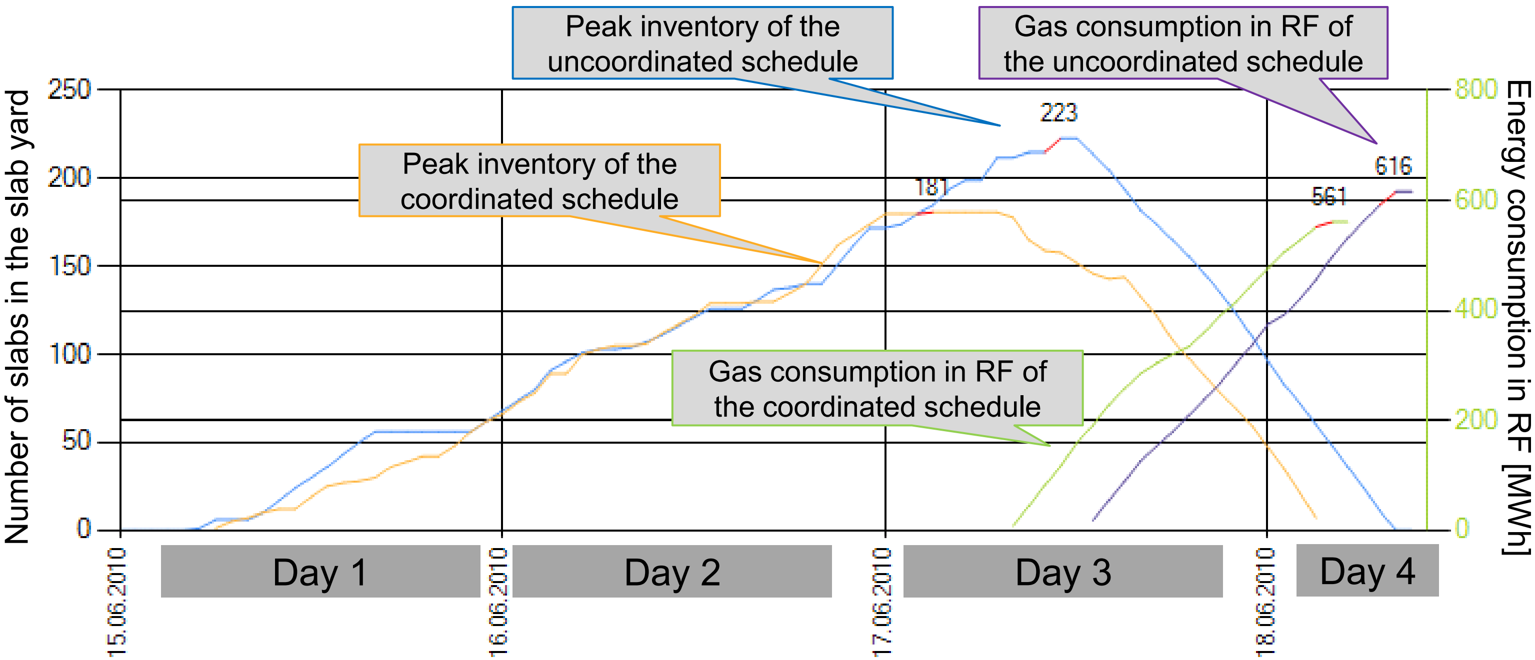
Slab Histogram (each column = the charging temperature of 1 slab charged in the reheating furnace)

320 slabs; 2.5 days melt shop production; 1 day hot rolling mill production



CPO Validation on the production data

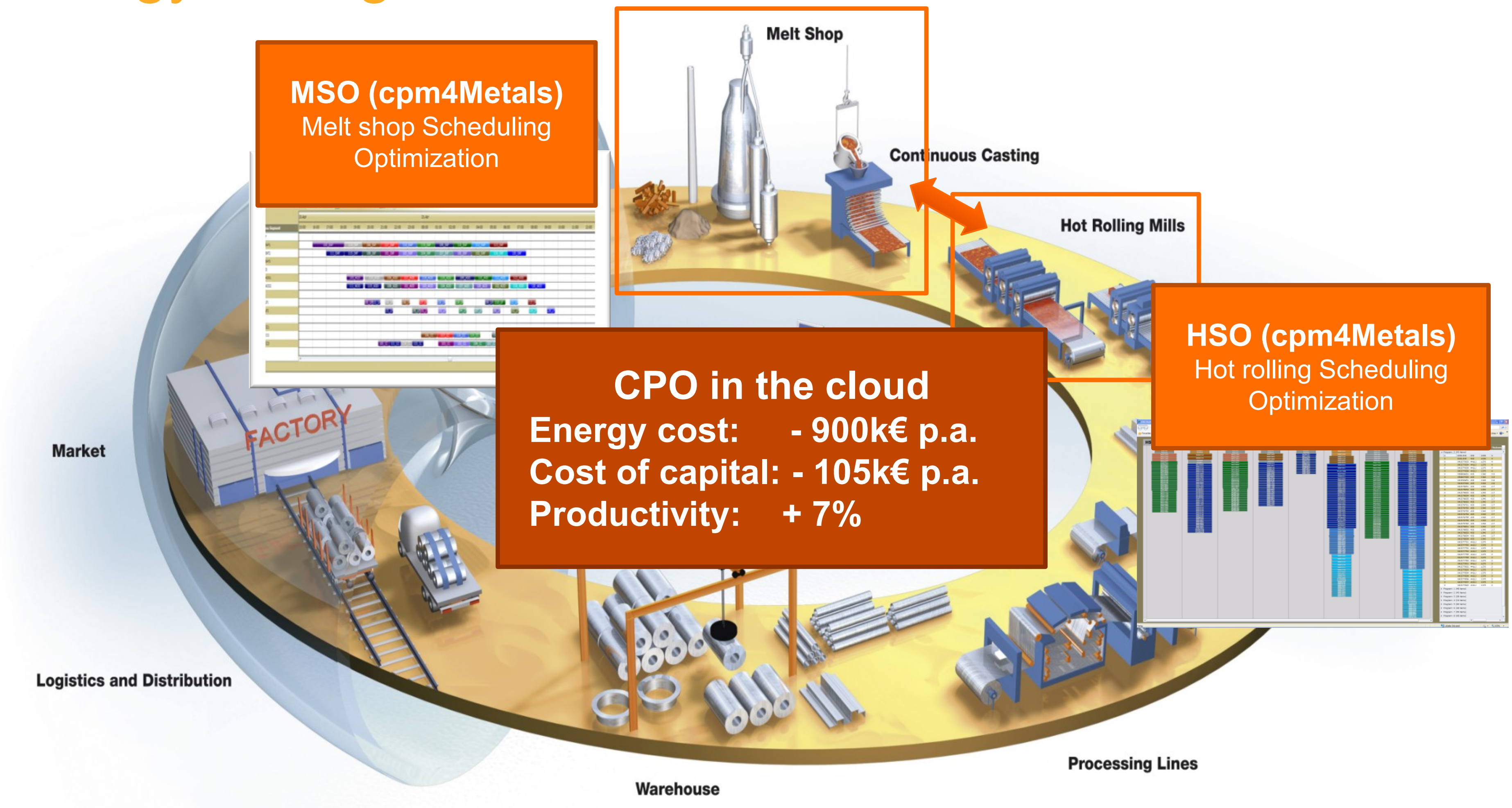
Slab yard storage saving 18% and RF energy saving 9%



- Cost of capital saving in the slab yard: **42slabs**, 50k€/slab; 2100k€ x 5% p.a. = **105k€ p.a.**
- Reheating furnace (RF) energy saving **55MWh/day** = Energy cost saving **>900k€ p.a.**

Collaborative Production Optimization (CPO)

Take home message – energy saving without hardware investment



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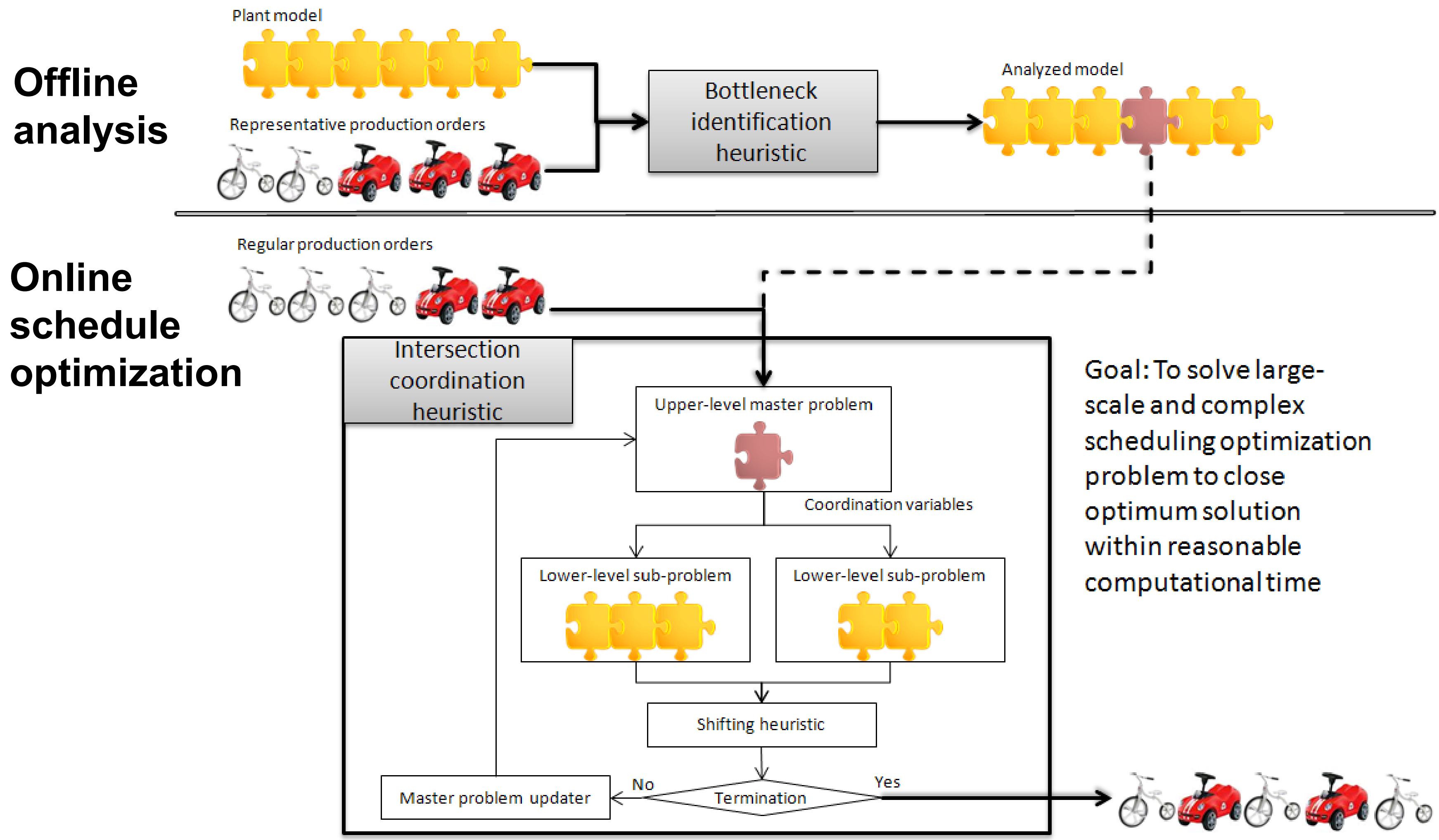
Generalization of Intersection Coordination Heuristic

Bottleneck-based decomposition and coordination framework



Goal: To solve large-scale and complex scheduling optimization problem to close optimum solution within reasonable computational time