Optimization in Supply Chain Planning

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THE BEST-RUN BUSINESSES RUN SAP

Agenda

Introduction

Hierarchical Planning Approach and Modeling Capability

Optimizer Architecture and Optimization Strategies

Customer Cases

System Demo

Introduction: Supply Chain Management

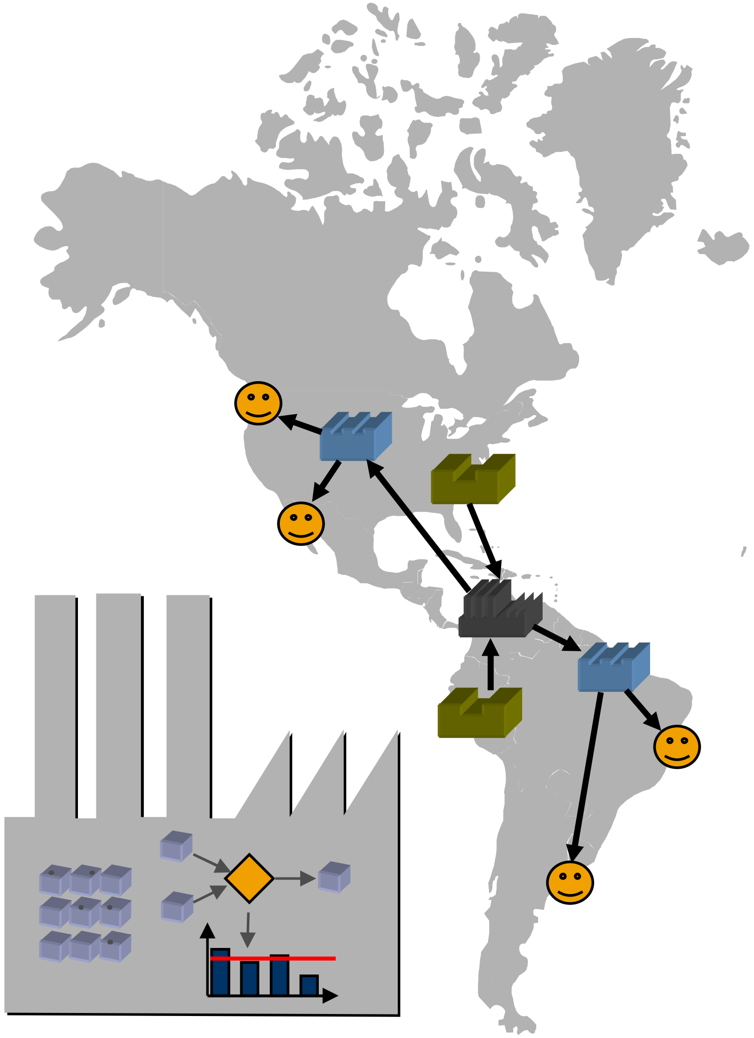
Supply Chain Management: Set of approaches utilized

- to integrate suppliers, manufactures, warehouses and stores
- so that merchandise is produced and distributed
  - with the correct quantity
  - to/from the correct locations
  - at the correct time
- in order to minimize cost while satisfying service level requirements

Prerequisite: Integrated Supply Chain Model

Supplier Plant DC Customer

Introduction: Supply Chain Management



Master Data Model

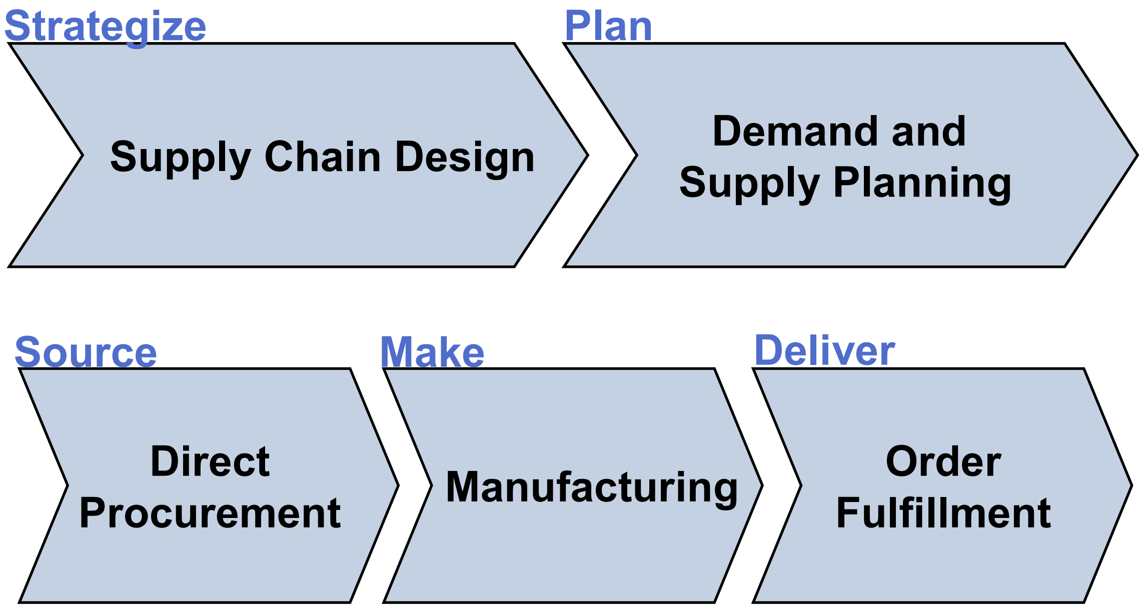
- Location (Plant, DC, Supplier, ...)
- Lane
- Product
- Production Process Model (PPM)
- Resource

Operational Data

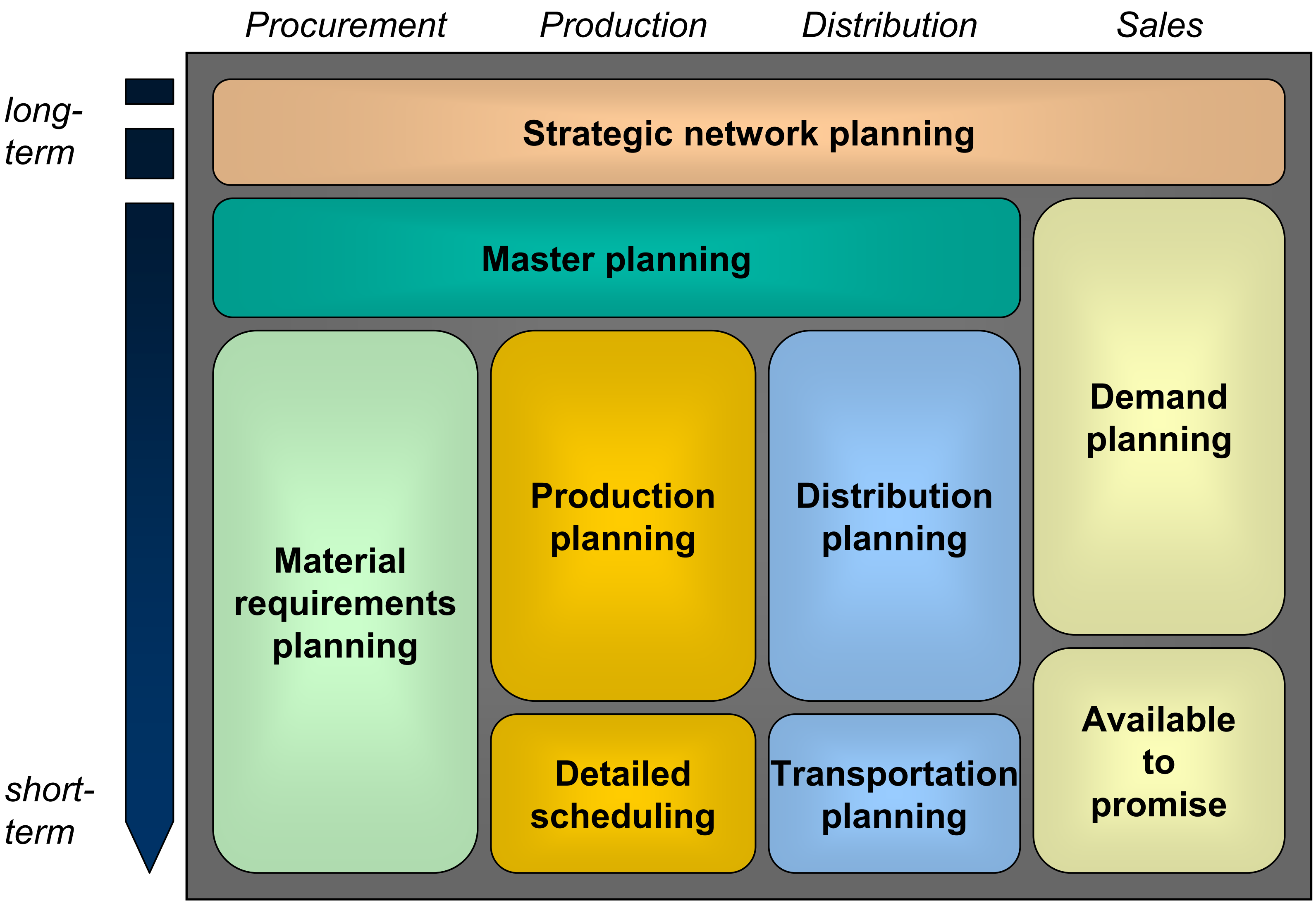
- Demands
- Orders
- Capacity Profiles

Resource Product Supplier Plant DC Customer

mySAP SCM Solution Overview



Supply Chain Planning Matrix



(Stadtler/Kilger, 2005)

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How to deal with planning complexity?

Basic idea: Hierarchy of relaxations

Relaxations are derived by Aggregation

- Time → Periods
- Product → Product groups

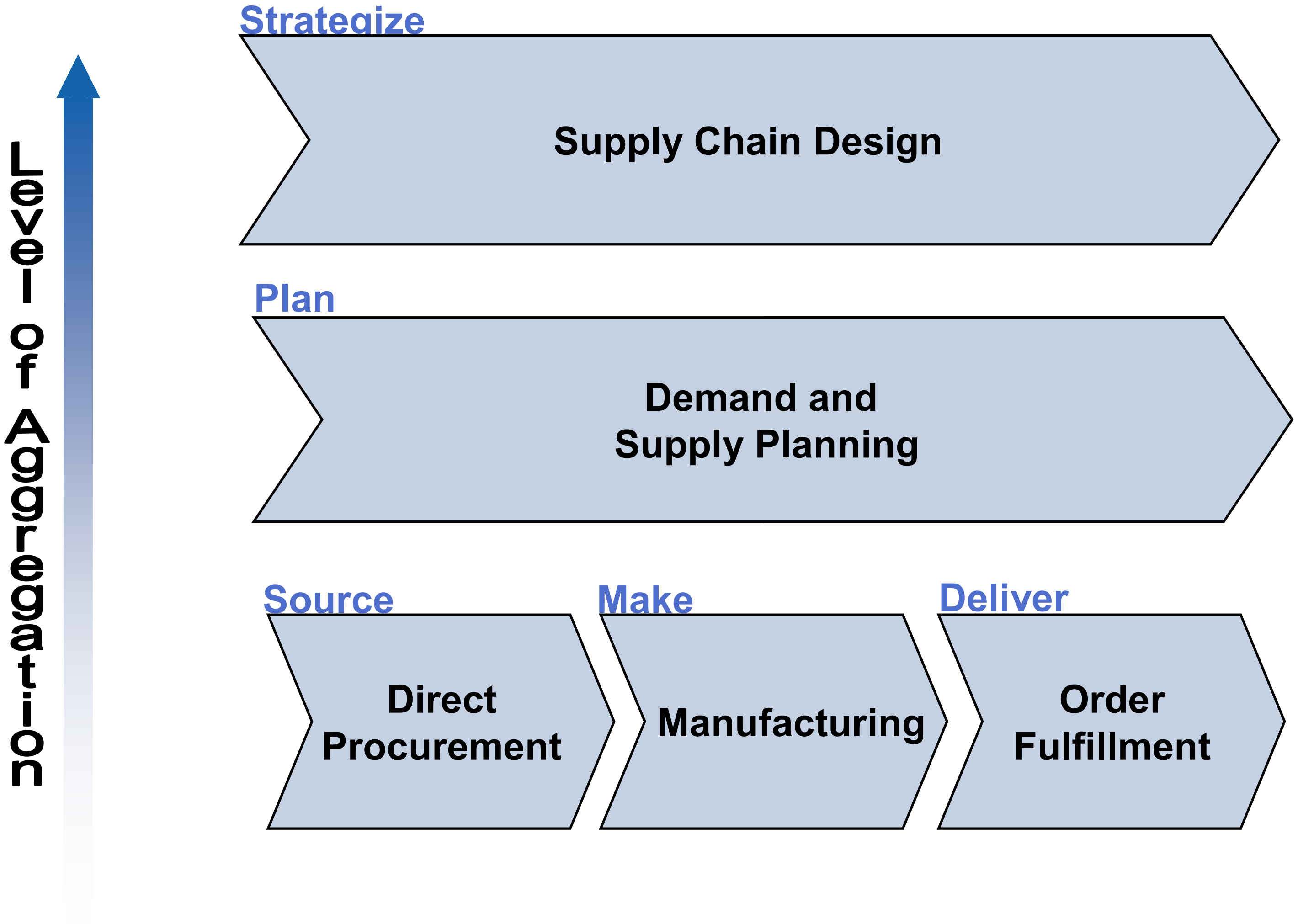
  (e.g. ignore country specific documentation in packaging a product)
- Resource → Resource Families

  (e.g. summarize similar resources into one resource with cumulative capacity)
- Locations → Regions

  (e.g. aggregate different locations into a transportation zone (postal code areas)

Integration between different relaxations: Disaggregation

Hierarchical Planning



Supply Network Planning (SNP)

Strategize

Supply Network Planning (SNP)

- Combined production and distribution planning
- Mid-term to long-term planning horizon
- Quantity-based
- Aggregation
  - Time → Buckets, max. daily precision
  - Products, Resources → Families

Supply Network Planning Procedures

SNP Heuristics

- Material availability constraints
- Rule-based
- First feasible plan

CTM (Capable To Match)

- Material availability and production capacity constraints
- Constraint-based propagation with backtracking search
- First feasible plan

SNP Optimizer

- Material availability and all capacity constraints
- (MI)LP and others
- Cost-based optimization

SNP Optimizer Application

Sourcing

- **Product-Mix**

  Which products and how much of them should be produced, transported, procured and stored?

- **Technology-Mix**
  - Which recipes (PPMs) should be applied?
  - Which transportation type should be used?
  - Which resource should be used?
- **Temporal:** When should we produce, transport, procure and store?
- **Spatial:** Where should we produce, procure and store? Wherefrom and whereto should we transport?

Finite Planning

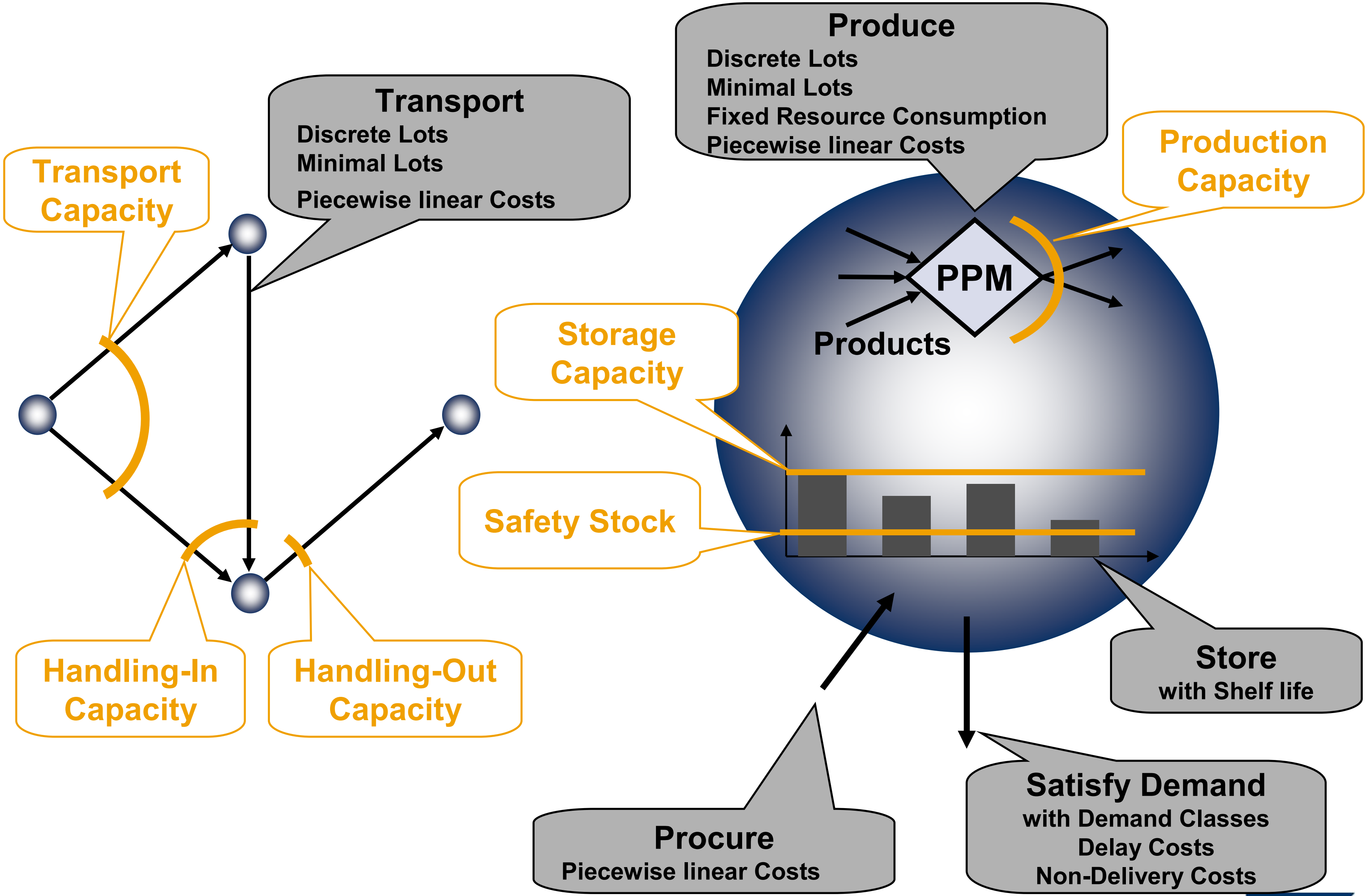
Lot-Sizing

- Multi-Level-Capacitated Lot Sizing (MLCLSP)
- Campaign Planning

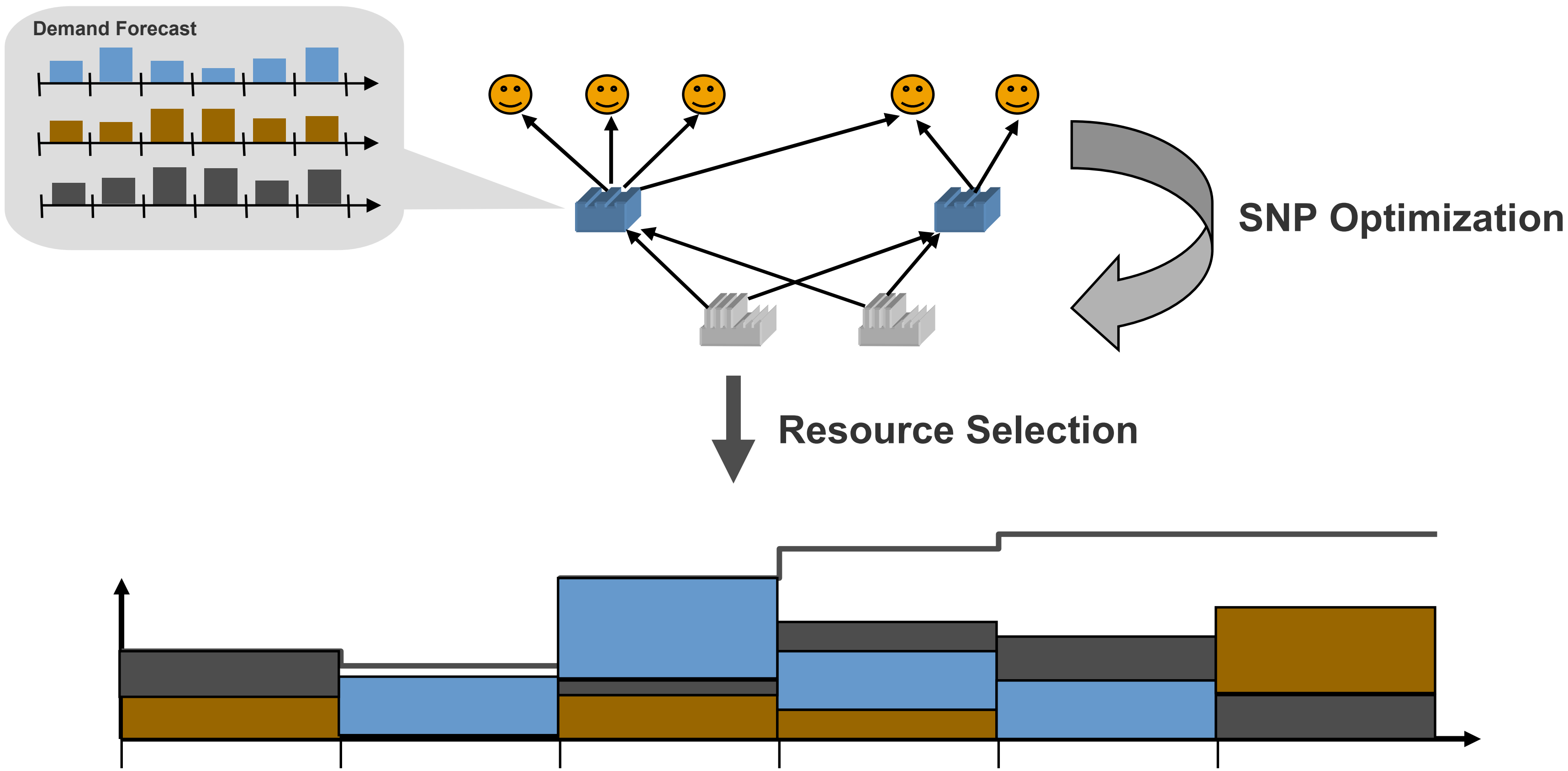
Inventory Control

- Target Days of Supply
- Shelf Life

Supply Network Optimization: Model Building



SNP Optimization Run



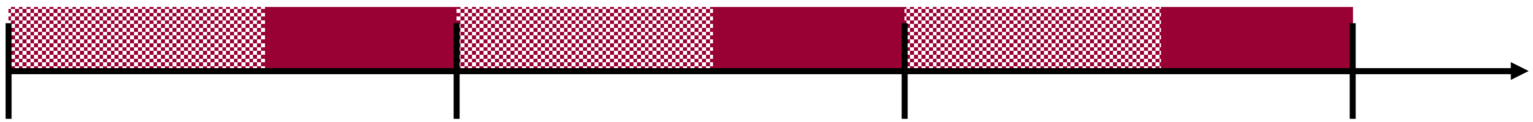
Supply Network Optimization: Lot-Sizing

Multi-Level Capacitated Lot Sizing Problem (MLCLSP)

- Setup cost and/or consumption in each bucket
- Good results
  - ◆ Setup cost small compared to storage cost (→ Small lots)

  - ◆ Setup consumption << bucket capacity

- Bad results
  - ◆ Setup cost large compared to storage cost (large lots)
  - ◆ Setup consumption big compared to bucket capacity



Supply Network Optimization: Lot-Sizing

Proportional Lot Sizing Problem (PLSP)

- Setup cost and/or setup consumption only if different PPM starts
- At most one startup per bucket

.Constraints on cross-period lots (= campaign quantity)

- Minimal campaign quantity

- Campaign quantity integer multiple of batch size

Manufacturing (PP/DS)

Strategize

Supply Chain Design

Sour

P

.Manufacturing (PP/DS)

- Combined material and capacity planning
- Short-term to mid-term planning horizon
- Order based
- Time continuous

PP/DS Planning Procedures

PP/DS Heuristics

- Material availability, single-level finite
- Priority-based planning
- First partial plan

CTM (Capable To Match)

- Material availability and production capacity constraints
- Constraint-based propagation with backtracking search
- First feasible plan

PP/DS Optimizer

- All constraints
- Genetic Algorithm and Constraint Programming
- Cost-based Optimization

PP/DS Optimizer Application

Feasible compact schedule

Delay Reduction

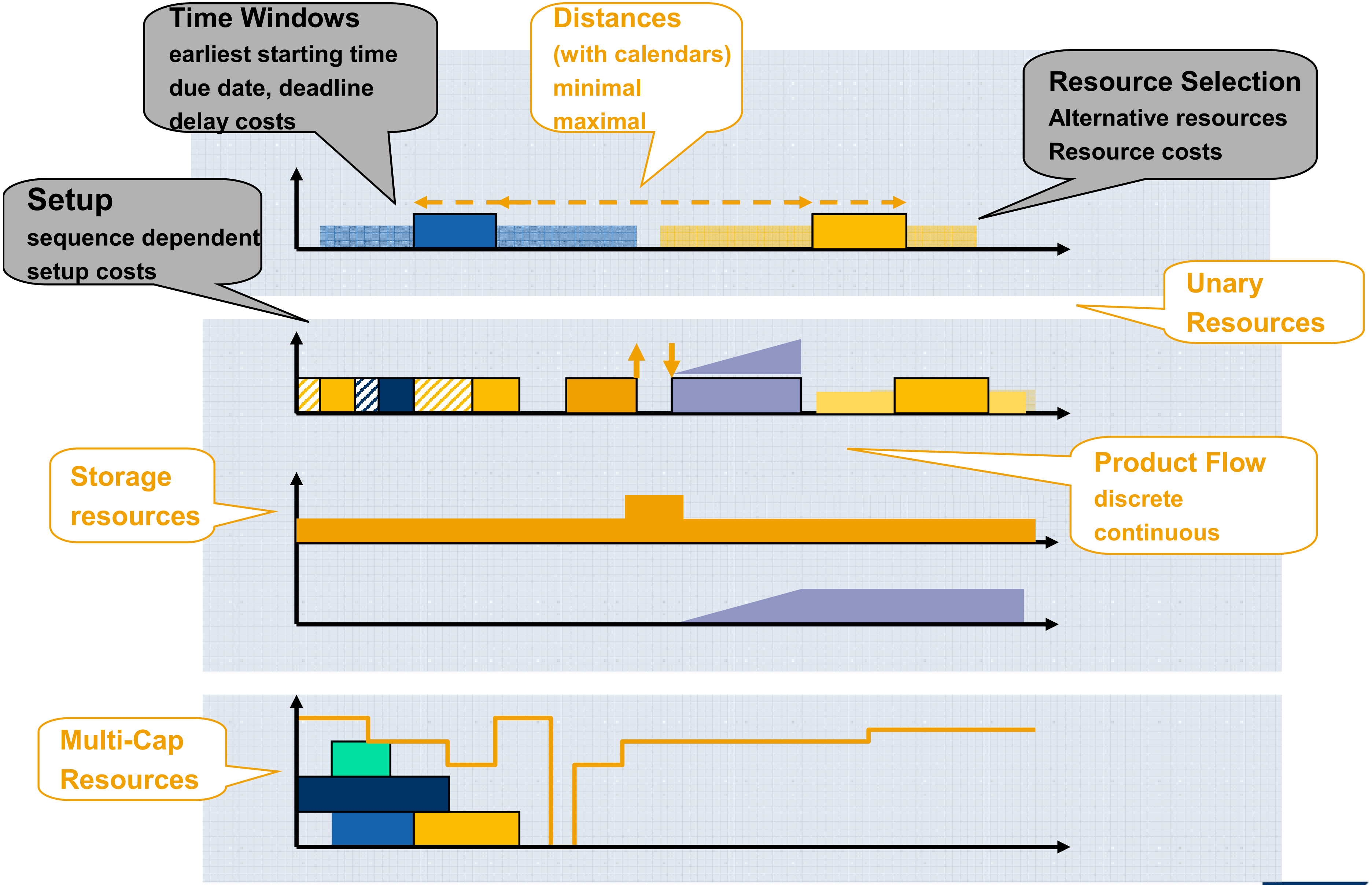
Makespan Minimization

Setup Minimization

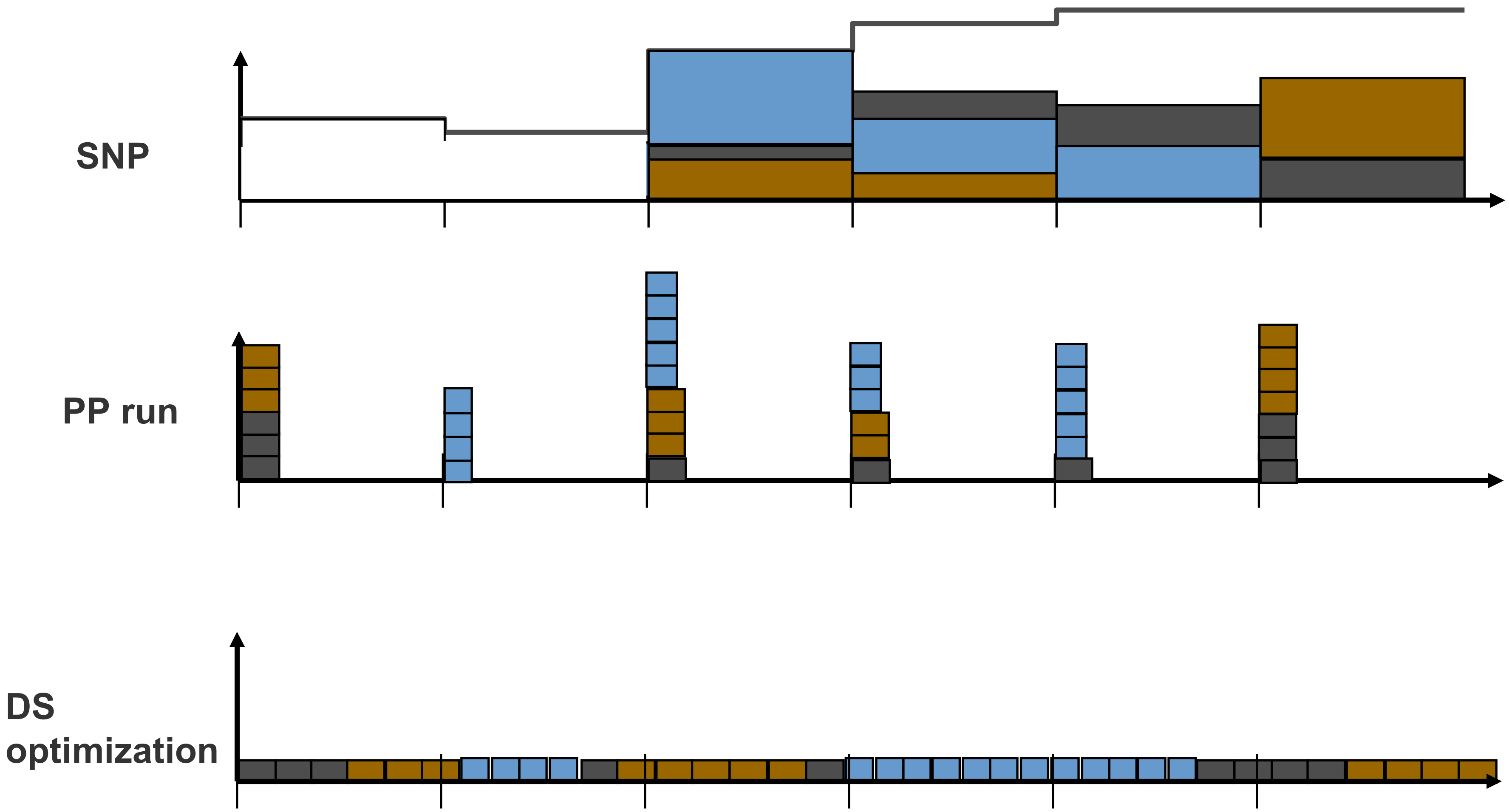
- Time
- Cost

Resource Selection

PP/DS Optimizer: Model Overview



PP/DS Optimization Run



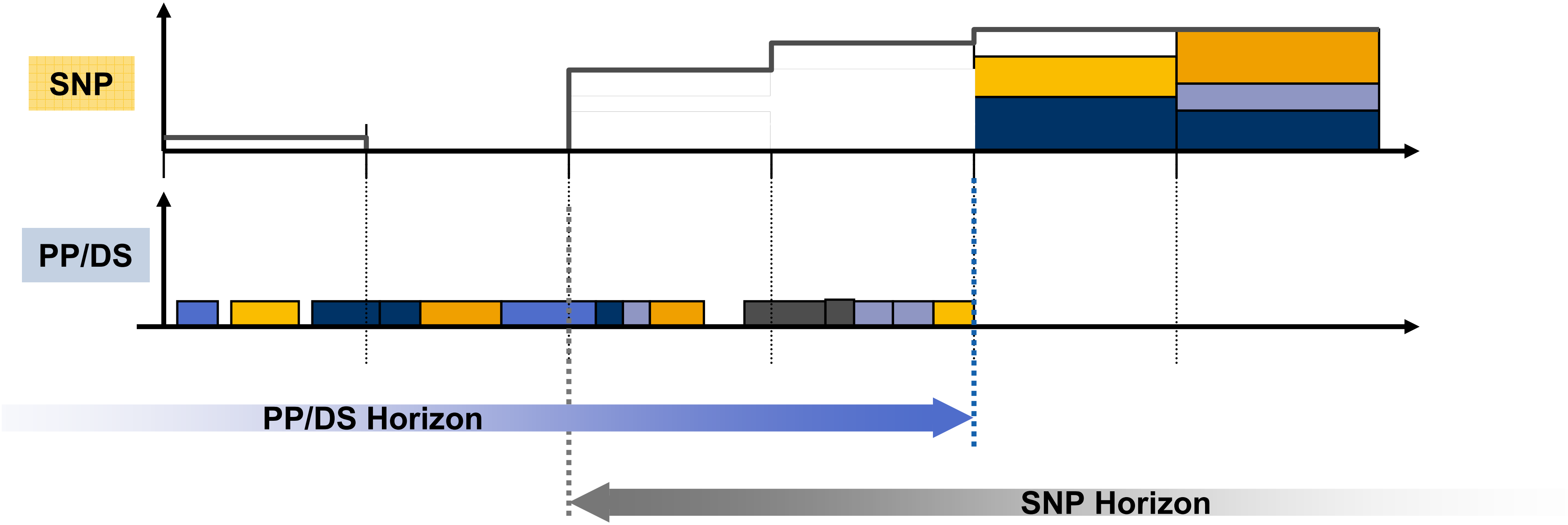
Integrated hierarchical planning

.SNP

- Planning only in SNP horizon
- Release SNP Orders only PP/DS horizon
- Respect PP/DS orders as fixed
  - capacity reduction
  - material flow
- Respect PP/DS setup state

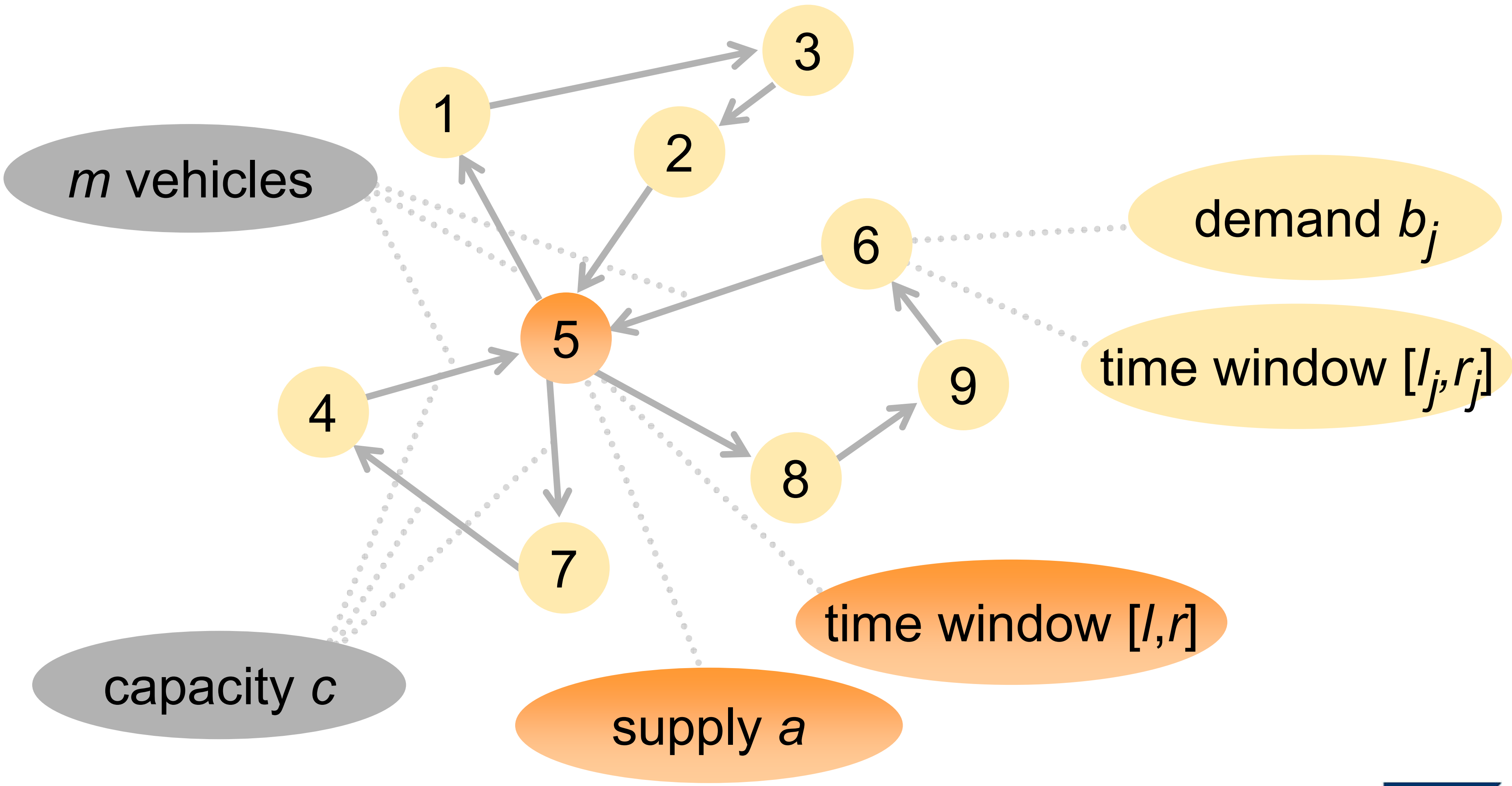
.PP/DS

- Respect pegged SNP Orders as due dates
  - No capacity reduction
  - But material flow
- No restrictions for scheduling PP/DS orders



VSR: Model Building

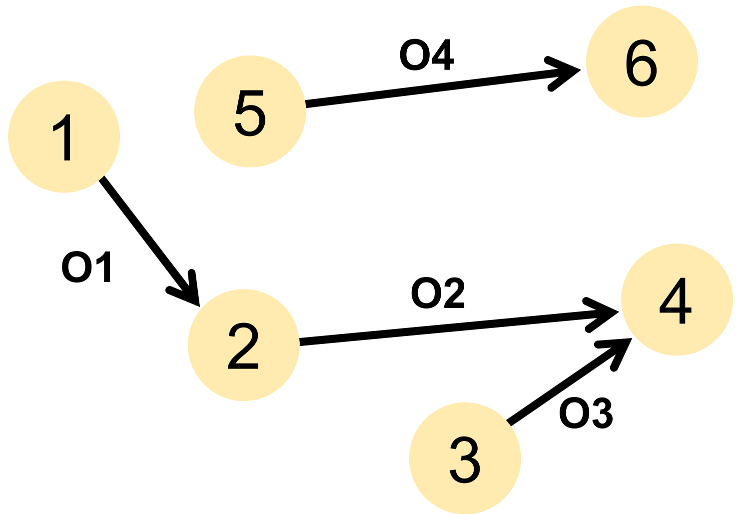
Classical vehicle routing problems: CVRP, CVRPTW



VSR: Model Building (ct'd)

Extensions towards APO VSR (1):

- Order-based model
  - Source location and destination location per order (Pickup and delivery problem)

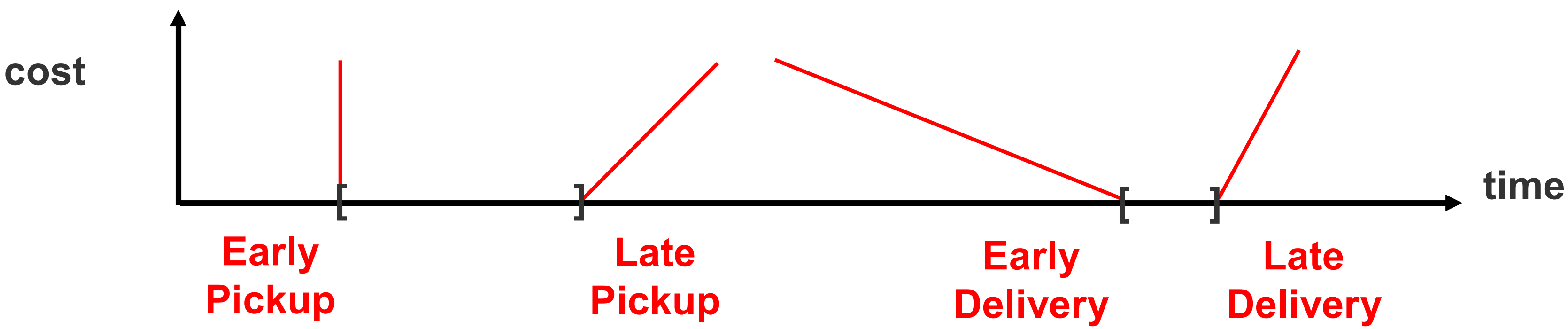


  - Quantity regarding loading dimensions (tons, m^3, ...)
  - Material type (chemicals, food, ...)
  - Service times for loading and unloading (depends on vehicle)

VSR: Model Building (ct‘d)

Extensions towards APO VSR (2):

- Cost for not delivering an order
- Soft/hard time constraints per order:
  - Earliest date for pickup
  - Due date for pickup
  - Earliest date for delivery
  - Due date for delivery



VSR: Model Building (ct‘d)

Extensions towards APO VSR (3):

- Per vehicle:
  - Travel characteristics (time, distance per lane)
  - Start location and end location
  - Constraints
    - Capacity per loading dimension (tons, m^3, ...)
    - Limit for time, distance, number of stops
  - Break calendar
  - Costs:
    - Fixed cost
    - Traveled time
    - Traveled distance
    - Number of stops
    - Distance x Load (e.g. miles x tons)

- Vehicle type = vehicles with identical travel & cost characteristics

VSR: Model Building (ct‘d)

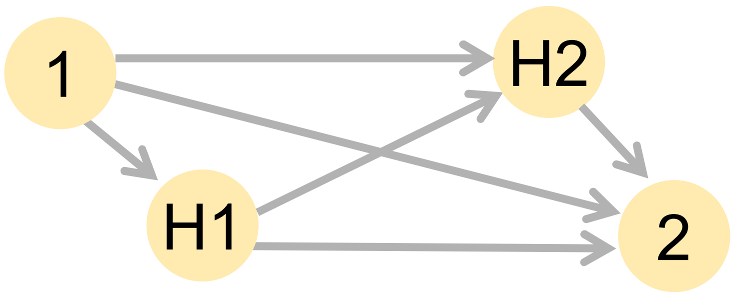
Extensions towards APO VSR (4):

- Per location:
  - Deliveries require inbound resource
    - Opening times
    - Capacities
  - Pickups require outbound resource
    - Opening times
    - Capacities

VSR: Model Building (ct‘d)

Extensions towards APO VSR (5):

- Incompatibility constraints:
  - Between material types
  - Between vehicle types and material types
  - Between vehicle types and locations
- Schedule vehicles (e.g. trains, ships)
  - Route and schedule is fixed a priori
- Hubs
  - Indirect shipment through hub(s) versus direct shipment
  - Maximum waiting time at hub



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Challenge: Generic Optimizer

Generic and Best of Breed

- planning level
- vertical industries
- run time requirement
- model complexity (size, constraints, objectives)

Generic Model (-> planning level)

- aggregated planning (LP / MILP)
- detailed planning (scheduling)

Customization (-> vertical industries)

- specialization the generic model to customer problem
- scripting the strategies (decomposition, goal programming)

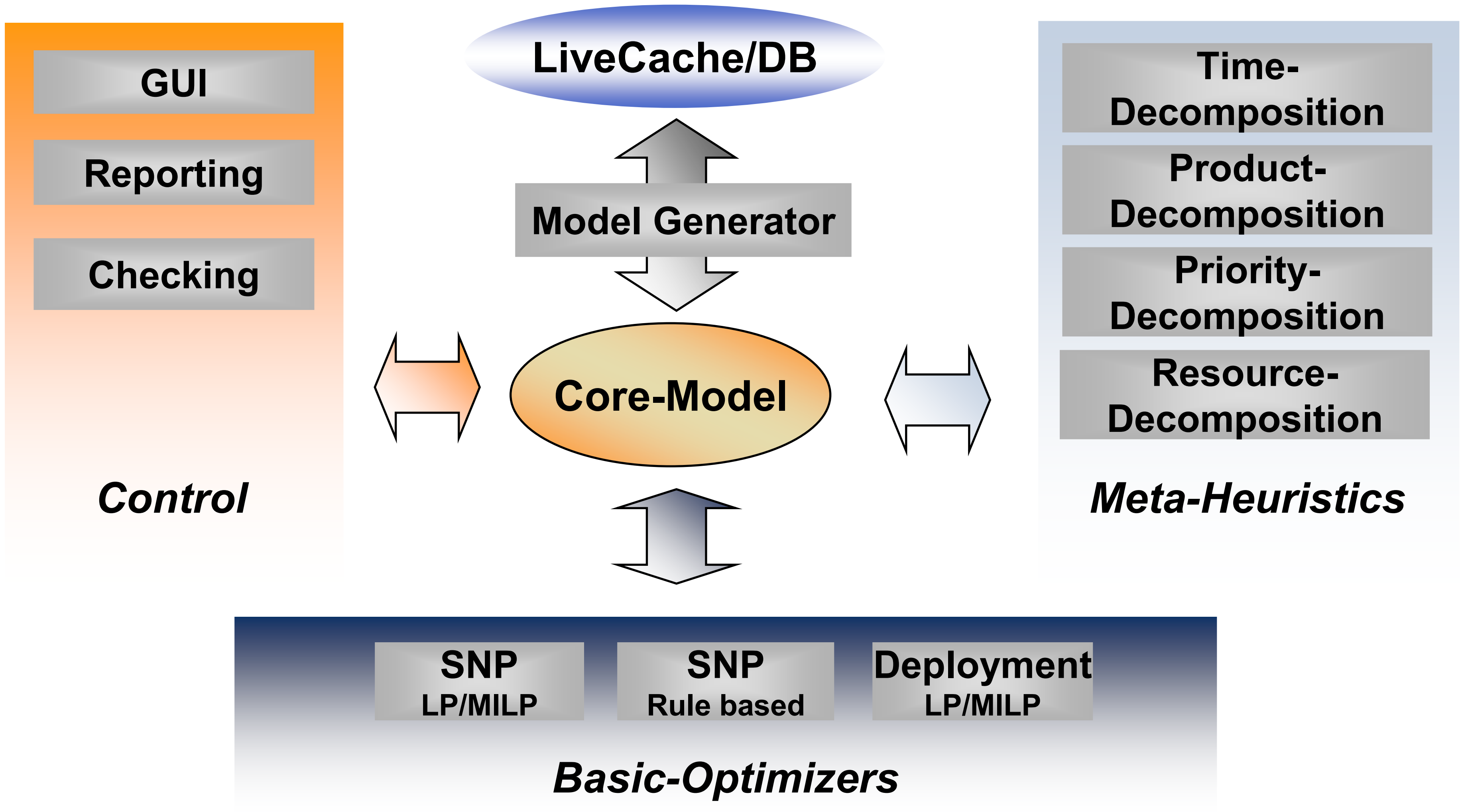
Scalability (-> run time)

- greedy versus complex optimizations strategies
- parallelization

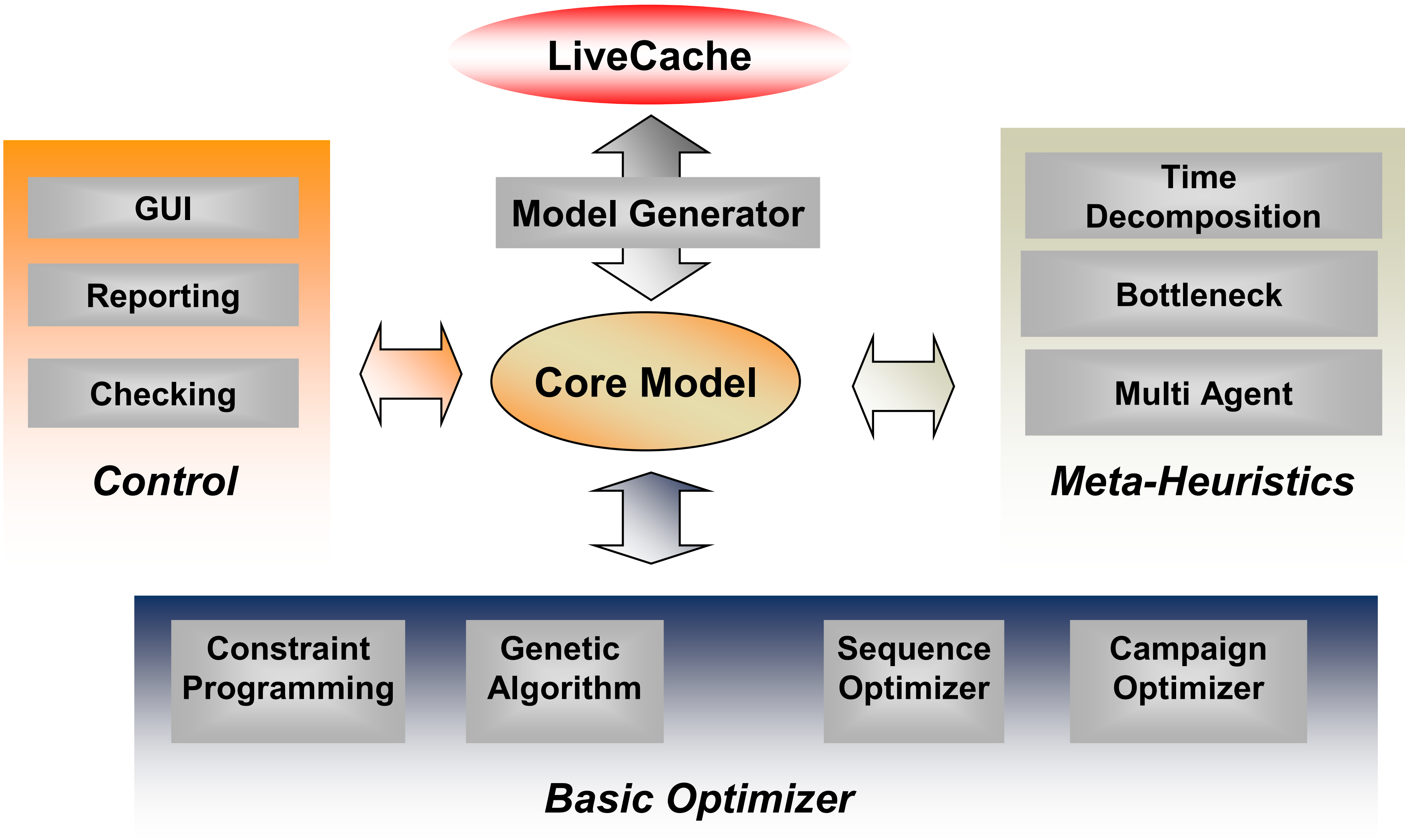
Open Architecture

- internal: adding new special optimizer (software evolution)
- external: integration of optimizer packages

SNP Optimizer Architecture



Scheduling Optimizer Architecture



Mastering the algorithmic complexity: Decomposition

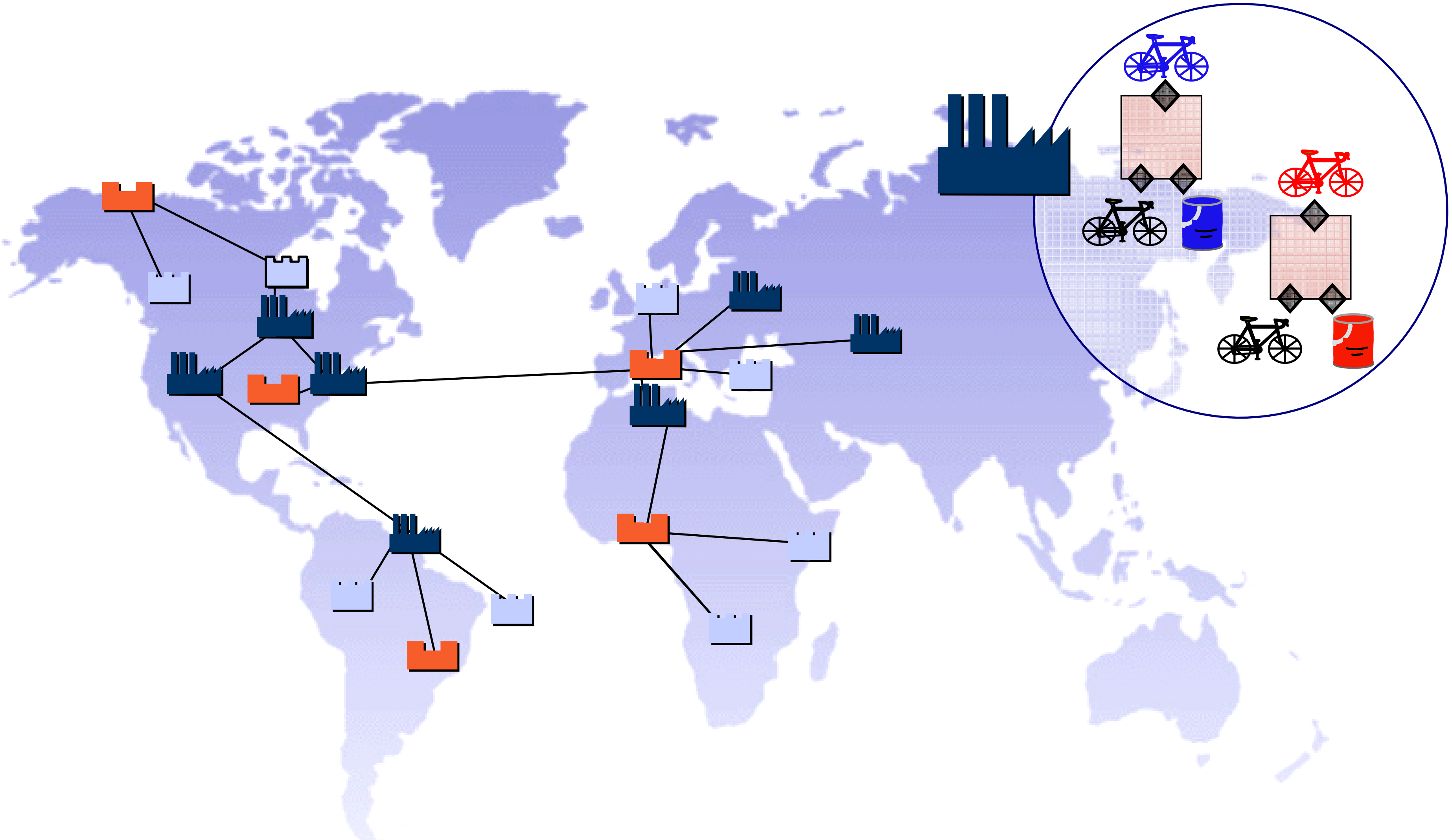
Global versus local optimality -> SNP + DS

- Local optimality depends on neighborhood
- High solution quality by local optimization
- Local Optimization = Decomposition

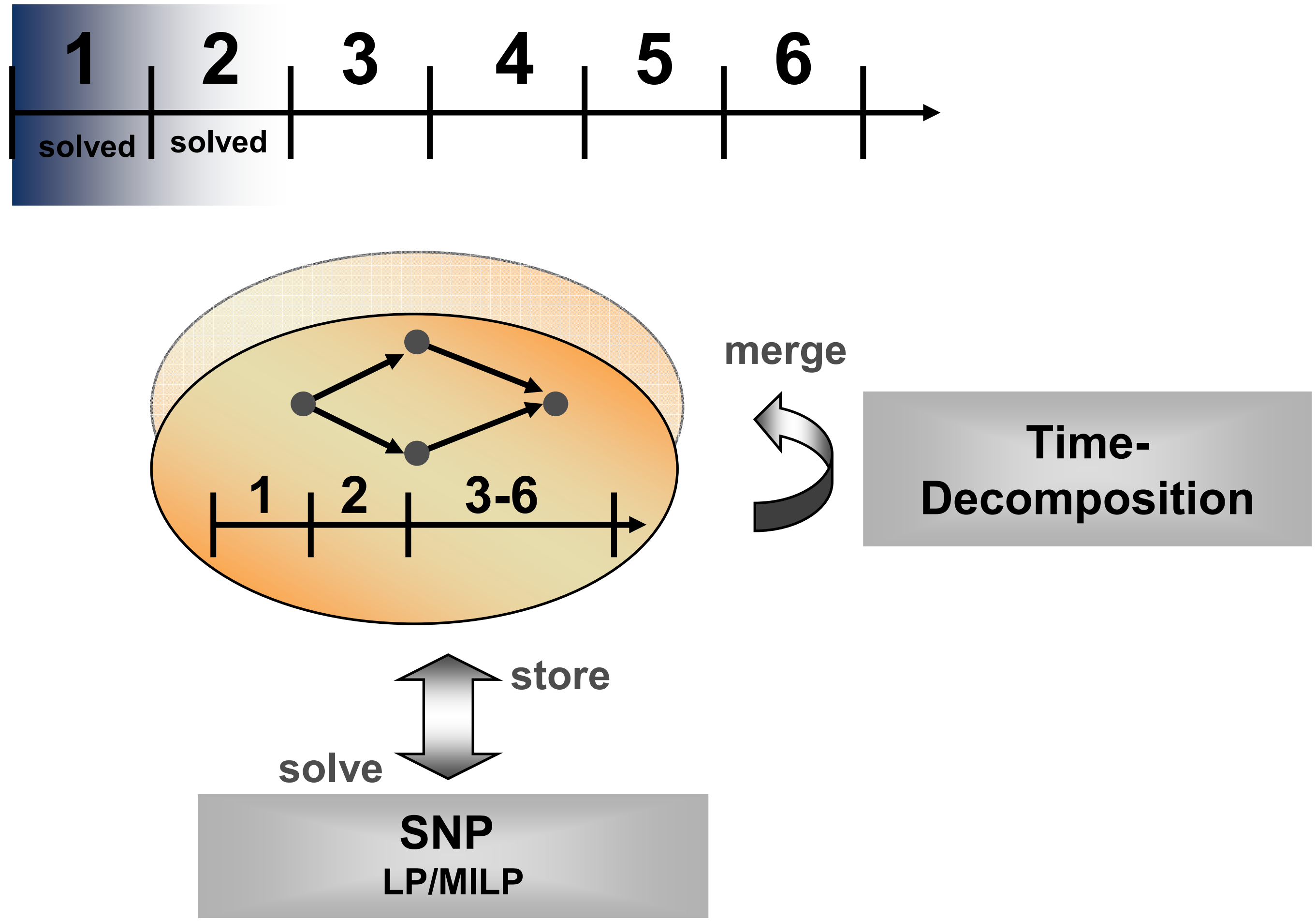
Decomposition strategies

- SNP: time, resource, product, procurement
- DS: time, resource
- (Parallelization by “Agents”)

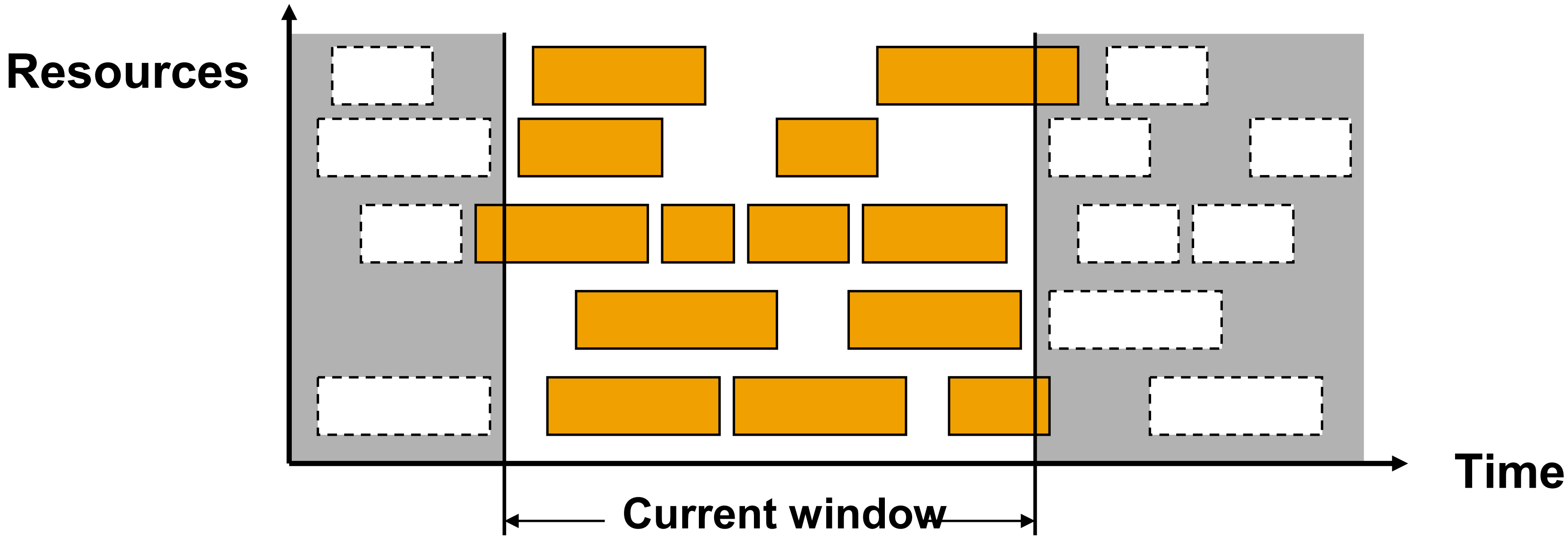
SNP Product Decomposition



SNP Time Decomposition



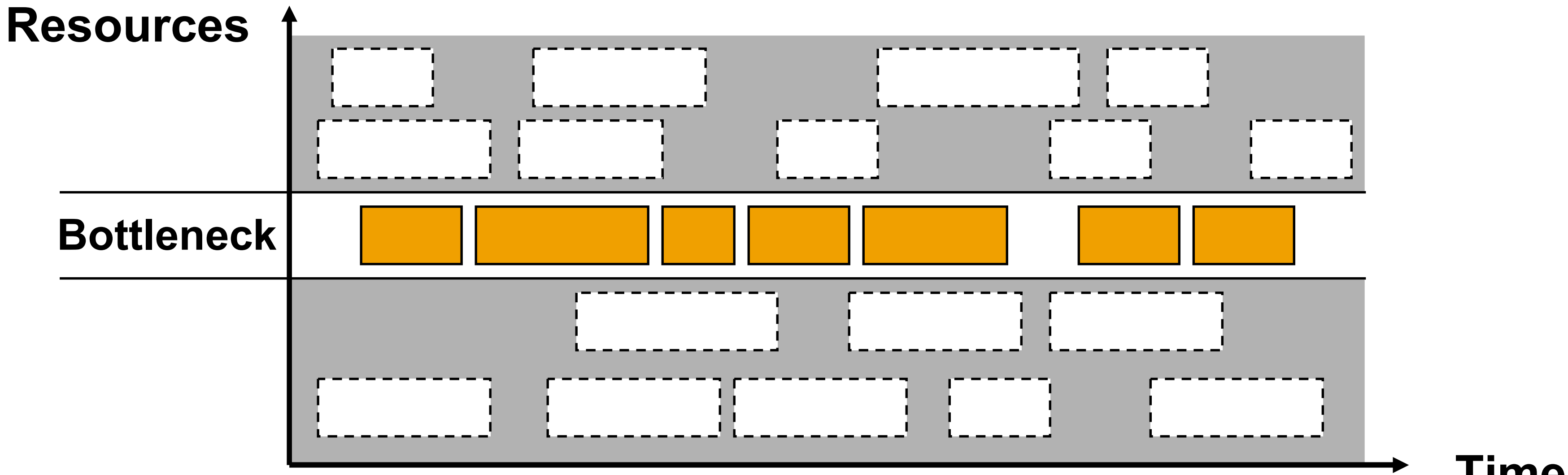
DS Time Decomposition - Local Improvement



Gliding window script

1. Optimize only in current window
2. Move window by a time delta
3. Go to first step

DS Metaheuristics - Bottleneck

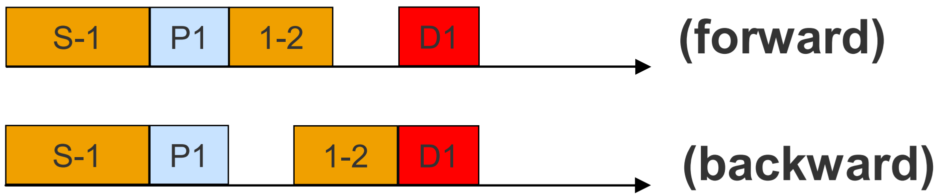


Bottleneck Script

1. Determine bottleneck
2. Schedule bottleneck resources only
3. Fix sequence on bottleneck resource
4. Schedule all resources

VSR: The Optimizer

- „Generic“ Optimizer
- Preprocessing
  - Which orders cannot be delivered at all?
  - Which order can be processed by which vehicle?
- Postprocessing
  - Shift travel activities forward or backward



VSR: The Optimizer (ct‘d)

- Evolutionary local search (ELS) with small population (3)
- Uses GENEAL (GENeral Evolutionary Algorithm Library)
- Direct solution representation
  - Assignment of orders to vehicles
  - Routing of activities on vehicles
  - Scheduling of activities on vehicles
- Each „atomic“ move has three phases:
  1. Change assignment
  2. Change routing
  3. Change scheduling
- 19 „atomic“ moves, classified into
  - Assignment moves
  - Routing moves
  - Scheduling moves

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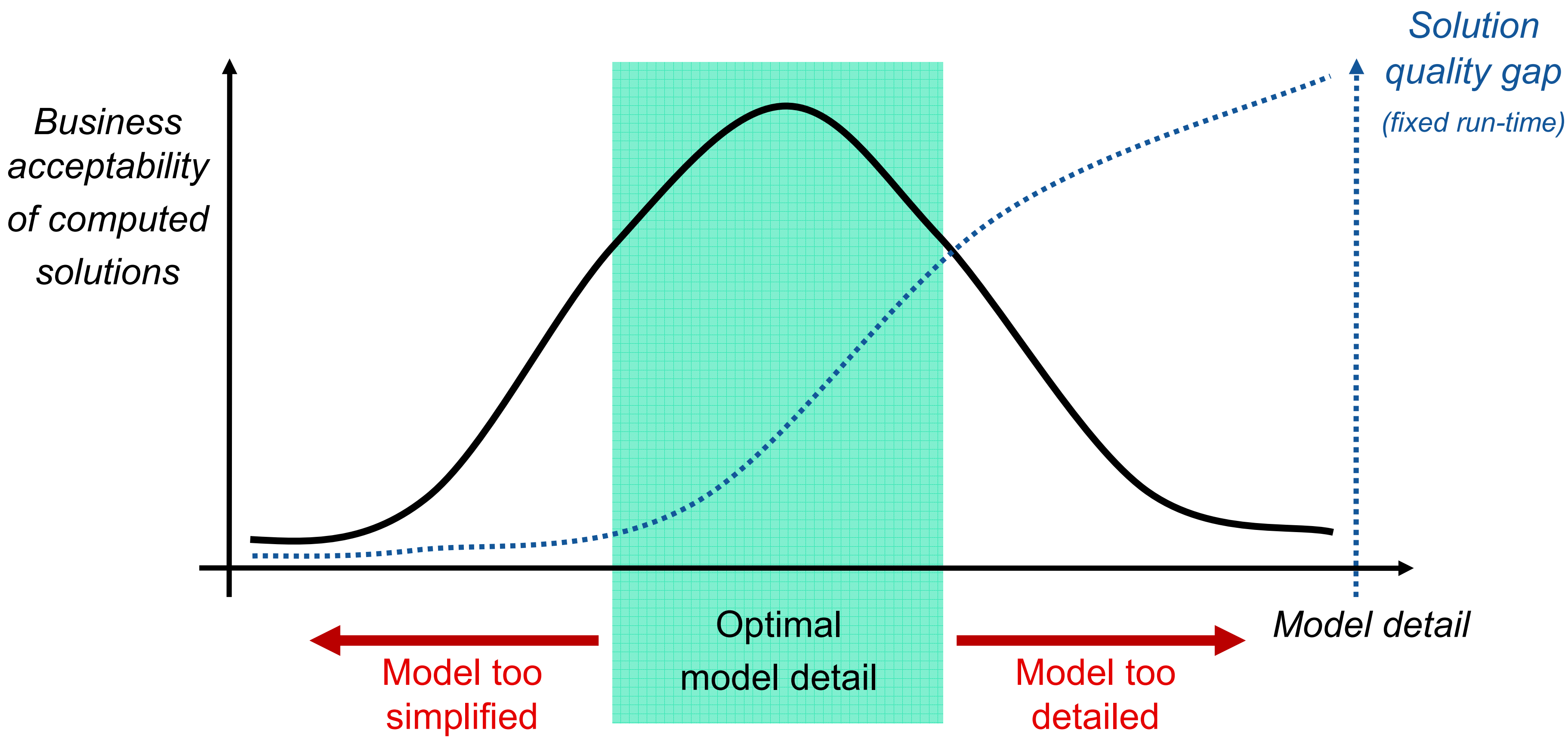
Challenges in modeling real-world problems



Generic nature of the SNP optimization model restricts exploitation of specific problem structure

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