Uncertainty and Dynamicity in Real-World Vehicle Routing

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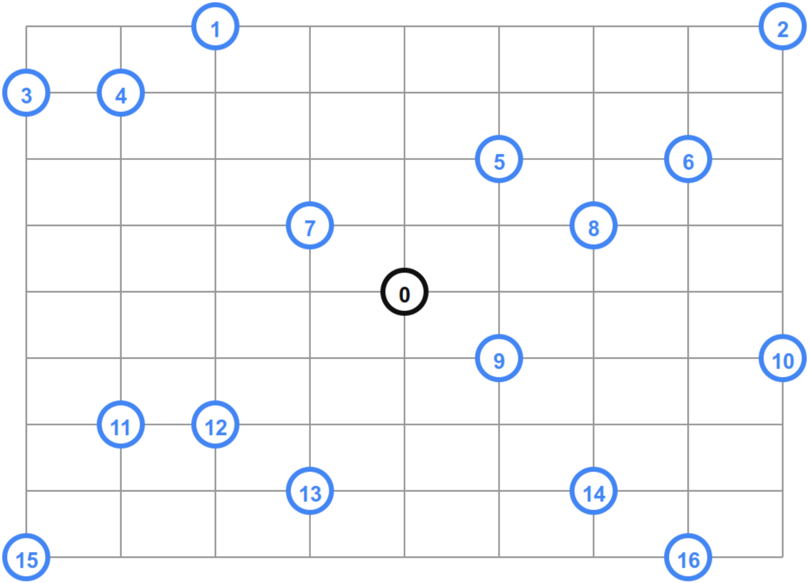
Vehicle Routing Problem



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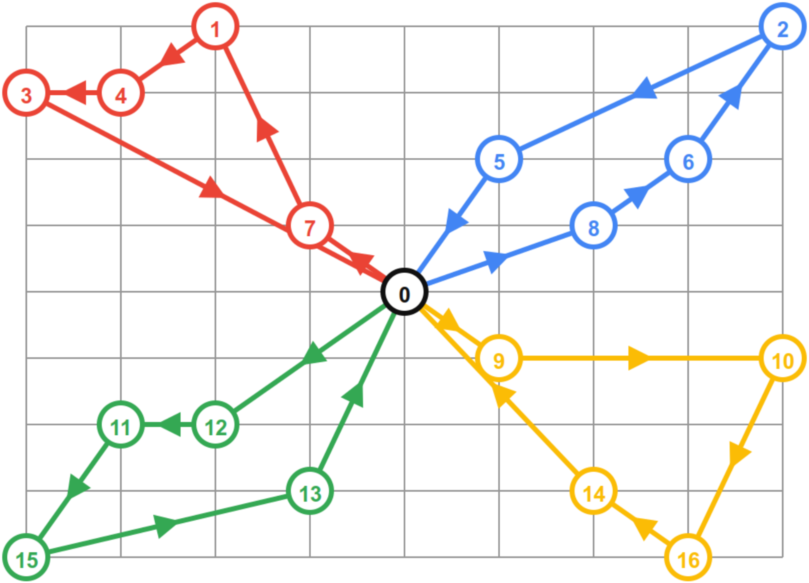
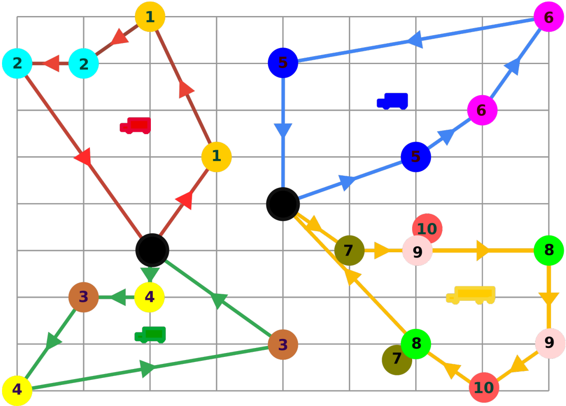


Real-World Vehicle Routing

Problem and data provided by company wereldo.com

- Pickup-Delivery VRP
- Time windows
- Capacities
- Multiple depots
- Route duration limit
- Heterogenous fleet
- ...



Existing solver

- Original version from the thesis of Vojtěch Sassmann
- Adaptive large neighborhood search
  - Remove part of existing solution
  - Repair the solution
  - Accept/reject as a new solution
  - Repeat for many iterations
  - Return the best solution
- Challenge: efficient implementation
  - Bottleneck: finding the best position for a customer within a route
  - Constraint checking
- Currently: all constraints are checked in $O(1)$

Issues in practice

- Existing solver already used in production
  - Assistive tool helping dispatchers plan routes
- Limitation: solutions not always applicable in practice
  - The input provided to the solver is subject to uncertainty
  - The input is incomplete

- Inspiration by human dispatchers
  - Intuitively understand risky routing patterns
  - Assess plans with incoming changes in mind

- Current solver
  - Lacks any notion of risks (capacities, time)
  - Completely blind to incoming changes

Motivation

- Goal: solver producing solutions that the dispatchers like
  - Risk-awareness
  - Planning with input incompleteness in mind
- Requirements:
  - Natural extension to the existing solver
  - Minimal/no performance overhead
  - Minimum assumptions about the data on uncertainties
  - Intuitive modeling

Uncertainties

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Sources of uncertainty in real-world problems

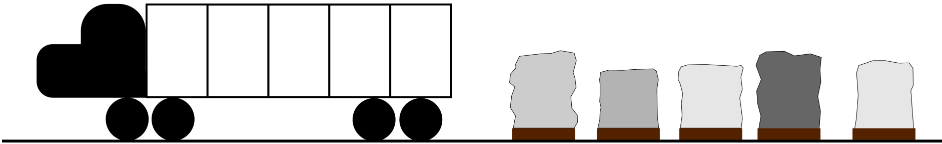
Capacities vs. demands

- Regular customers: require service every day, but demand highly varies
- Freight loading: $1 + 1 \neq 2$
  - Balancing truck axles
  - 3D Tetris

Times

- Travel times: traffic
- Service times: freight (un)loading

Sad pallets and angry drivers



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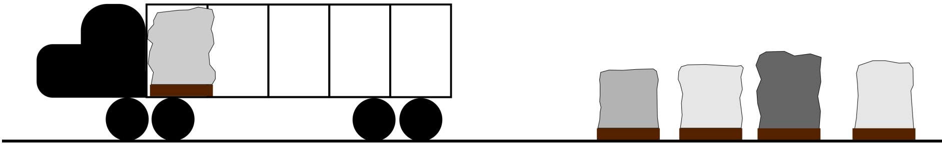

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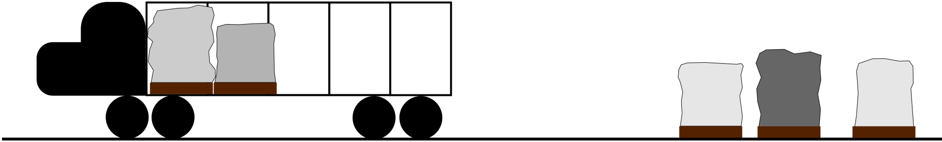

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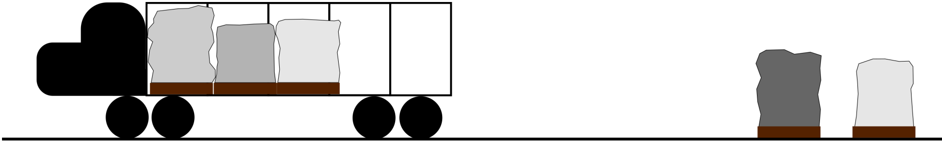

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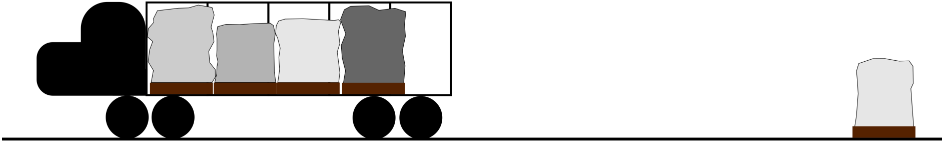

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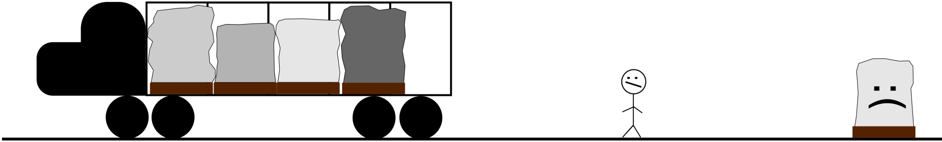

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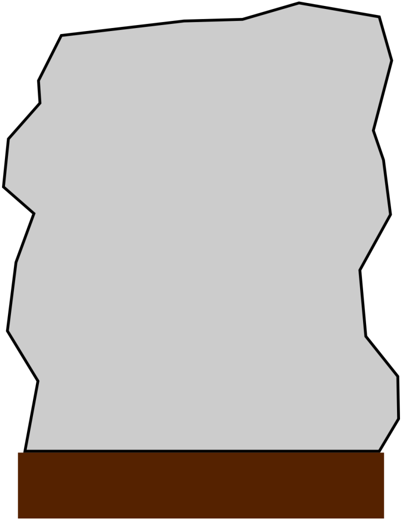
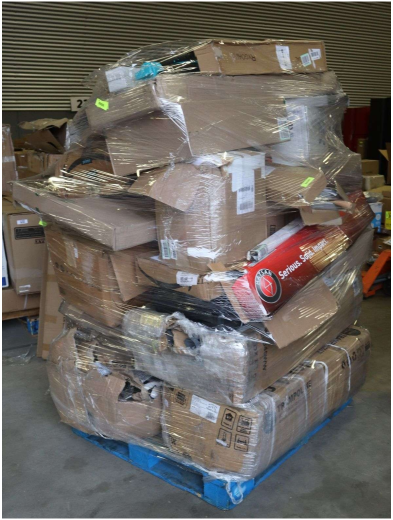
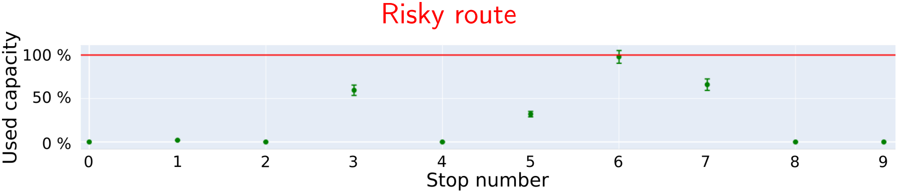
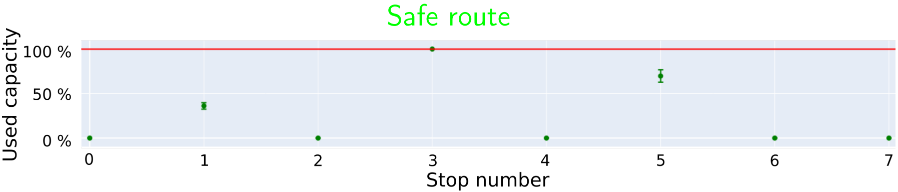




Source: https://www.matthewsauctioneers.com/auctions/26398/lot/76606-pallet-of-c-grade-read-description

Uncertainties and risks





Generic approaches to uncertainties

Incorporate the knowledge about the uncertainties by either

1. Inflating the demands
2. Deflating the resource
3. Quantify and penalize/forbid the risk

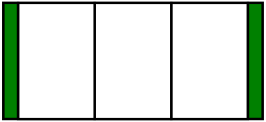
Capacities

1. Plan with larger loads
2. Plan with smaller vehicles
3. Penalize/forbid routes risking vehicle capacity overflow

Times

1. Plan with larger travel/service times
2. Plan with smaller time windows
3. Penalize/forbid routes risking late arrival to customers

Generic approaches to uncertainties – examples



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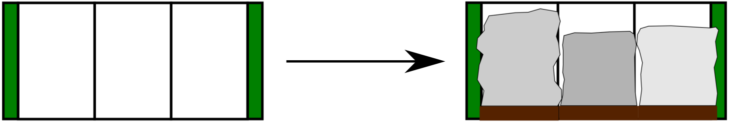

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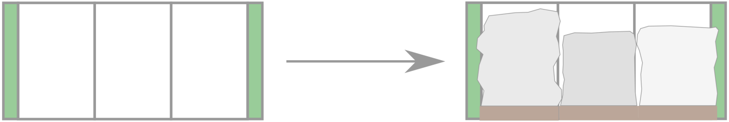

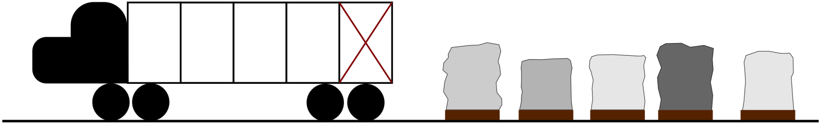

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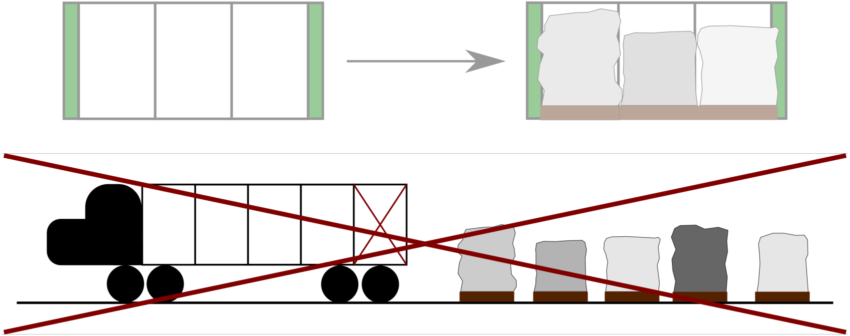

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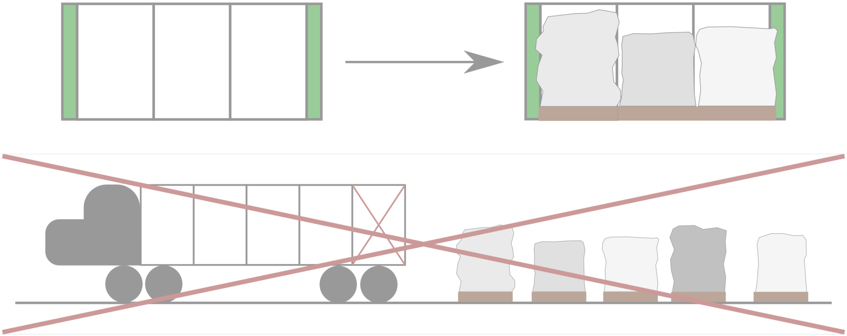

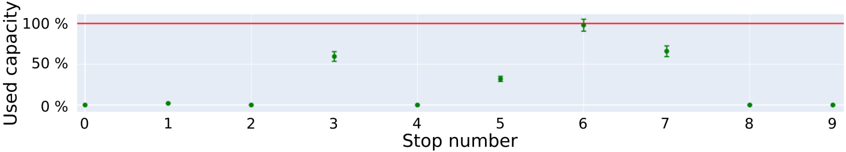

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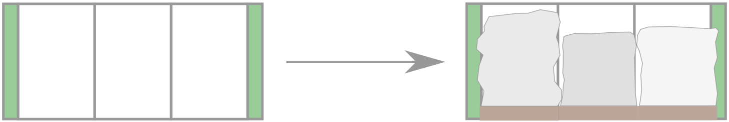

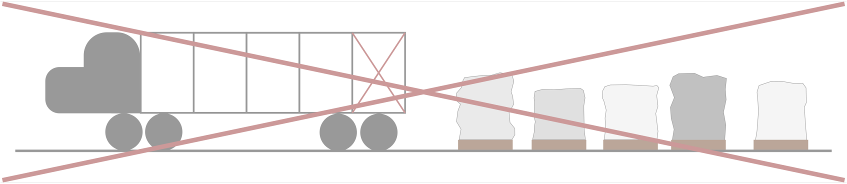

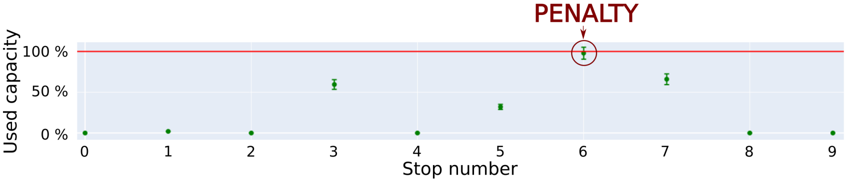

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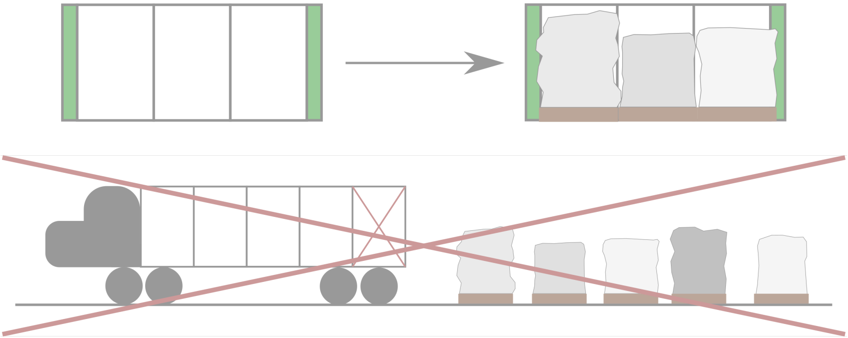
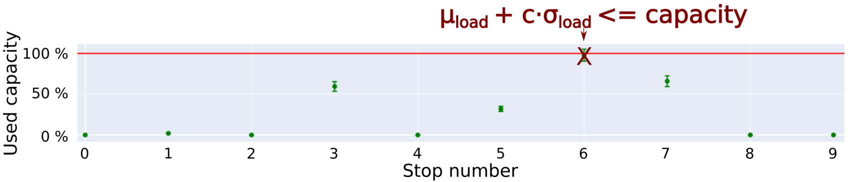




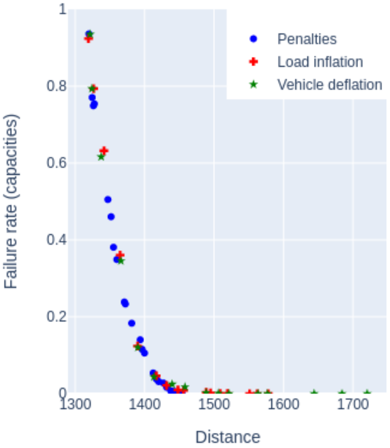
Modeling and implementation

- Inputs about uncertainty: $E(X)$, $Var(X)$
  - Minimum information to express reasoning about uncertainties
  - Minimum assumptions on the data
  - Approachable level of abstraction for the end users
- Minimum performance overhead
  - Capacities: all additional computations in $O(1)$
  - Times: same as capacities with the exception of risk penalties
- Simple integration of all three methods:
  - Demand inflation: data manipulation
  - Resource deflation: data manipulation
  - Risk penalty/constraints: implementation similar to existing constraints

Method comparison

Preliminary experiments with capacities

- Comparable results may be achieved with all three methods
  - Parameter choice is crucial
  - Parameters strongly correlated with routing plan fail rates ($\rho \approx 0.75$)
- Theoretically, methods have different properties (and weaknesses)
  - Vehicle deflation: large uncertainties, heterogeneous fleet
  - Load inflation: adversarial instances



Dynamicity

Sources of dynamicity in real-world problems

Dynamic customers

- Some customers call on the day of delivery
  - These customers are not known at the time of route planning
  - The information is revealed during the execution of our routing plan
  - Adjustments to our routing plan are needed

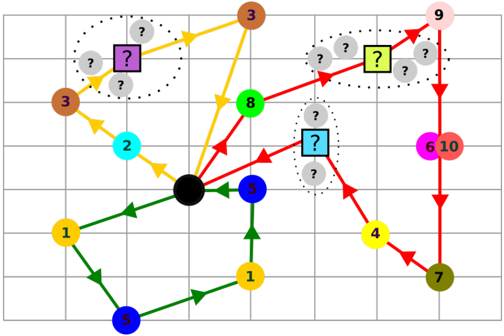
Realization of random variables

- Previously uncertain values (demands, times) are revealed during the day
  - We may update our risk-related calculations
  - We may adjust our routing based on the new information

Anticipation of potential changes

Goal: build the routing plan with potential changes in mind

- Introduce dummy requests
  - Optional service for reward
- Spatiotemporal coverage
  - Space: locations of past customers
  - Time???



End-to-end vehicle routing

Routing algorithm capable of assisting dispatchers with the daily operations

1. Initial routing plan (day before)
   - Proactively prepare for potential dynamic events and uncertainties
   - The final routing should largely overlap with the initial plan
2. (Preferably) small adjustments during the day of execution
   - Ideally stick to the initial plan as much as possible
   - Continually use the revealed information to improve the plan and reasoning about it

Ultimate objective: optimization of the result at the end of the day