Network Design For SBB Cargo

Project report

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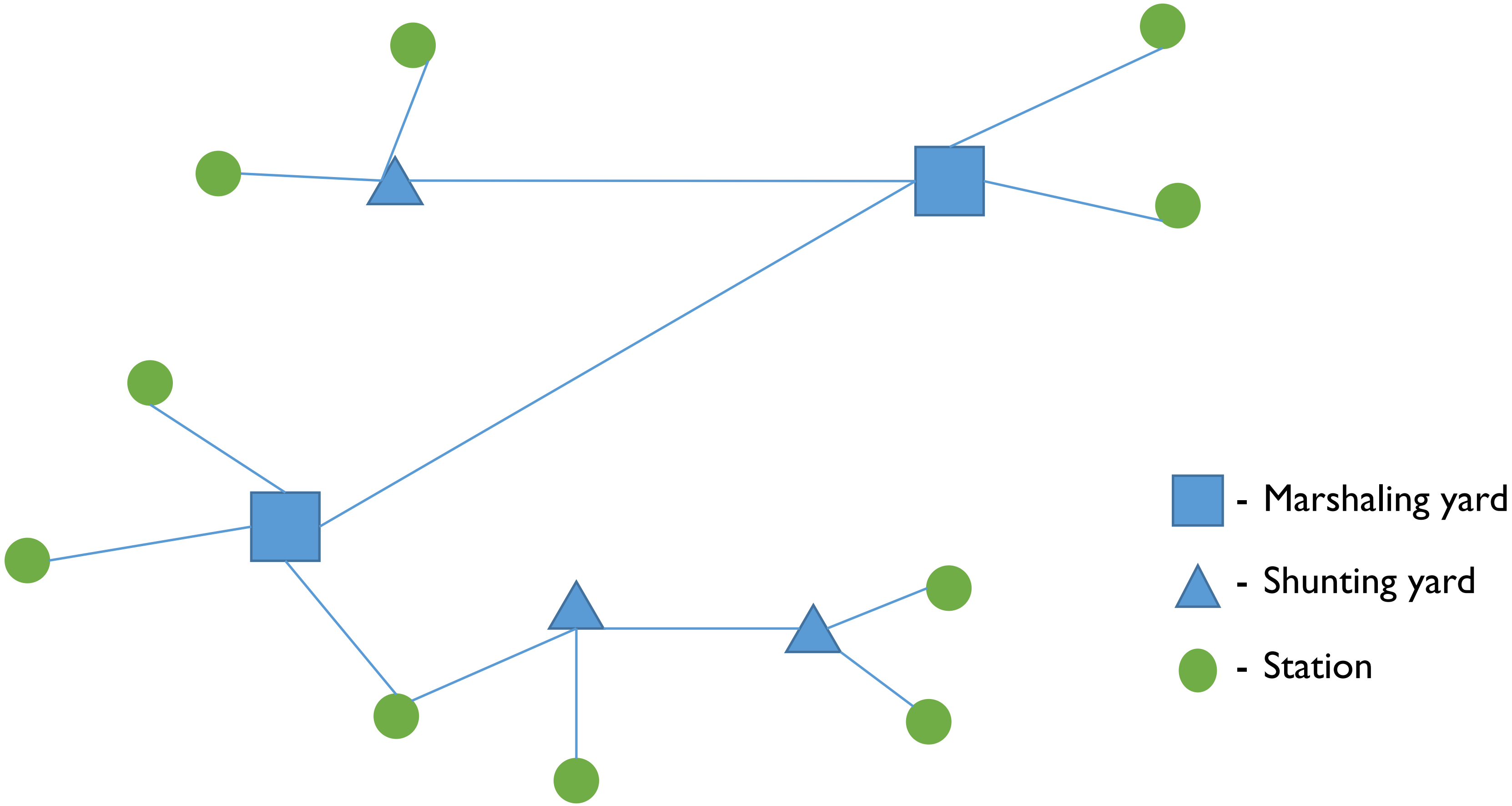
October 25, 2018

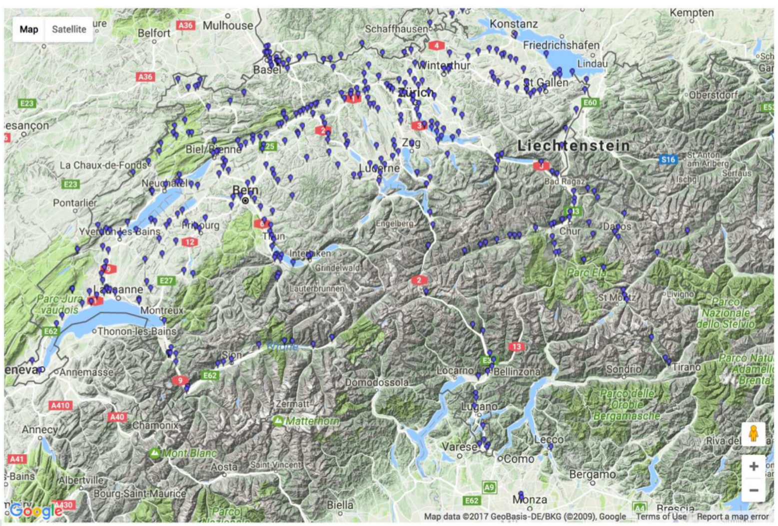
Marshaling and shunting yards

- Bundling different commodities with close origins and close destinations



Problem setting

- Existing SBB Cargo network
  - 2 inner marshaling yards
  - 3 border marshaling yards
  - Approx. 70 shunting yards – 50 can be changed
- Solution should provide:
  - Optimal number and locations of marshaling and shunting yards
  - Set of used trains
  - Assignment of commodities to trains



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SBB CFF FFS Cargo

Problem definition

- Combination and extension of the Hub Location (HLP) and Multicommodity Network Design (MNDP) Problems
- Objective function:

$$\min C_{ct} + C_{ls} + C_{cs}$$

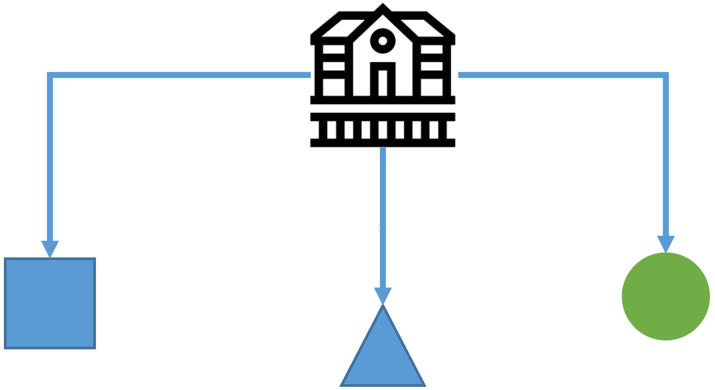
Commodity transport costs

Locomotive and staff costs

Commodity shunting costs

Problem definition *(cont.)*

- Constraints from MNDP:
  - Flow conservation constraints for trains
  - Arc capacity constrains
- Constraints from HLP:
  - Hub capacity constraints
  - Maximal number of hubs
- Node type constraints:



$$r_i + s_i + m_i = 1, \qquad \forall i \in N$$

Problem definition *(cont.)*

- Trains modelling
  - Commodity assignment constraints
  - Flow conservation constraints for commodities
  - Train capacity constraints

$$f_{pq}^{k} \leq s_{p}^{k} + m_{p}^{k} + o_{kp}, \qquad \forall p, q \in N, \forall k \in K$$

$$f_{pq}^{k} \leq s_{q}^{k} + m_{q}^{k} + d_{kq}, \qquad \forall p, q \in N, \forall k \in K$$

$$\sum_{k \in K} f_{pq}^{k} v^{k} l^{k} \leq L_{t} n_{pq}, \qquad \forall p, q \in N$$

Data collection

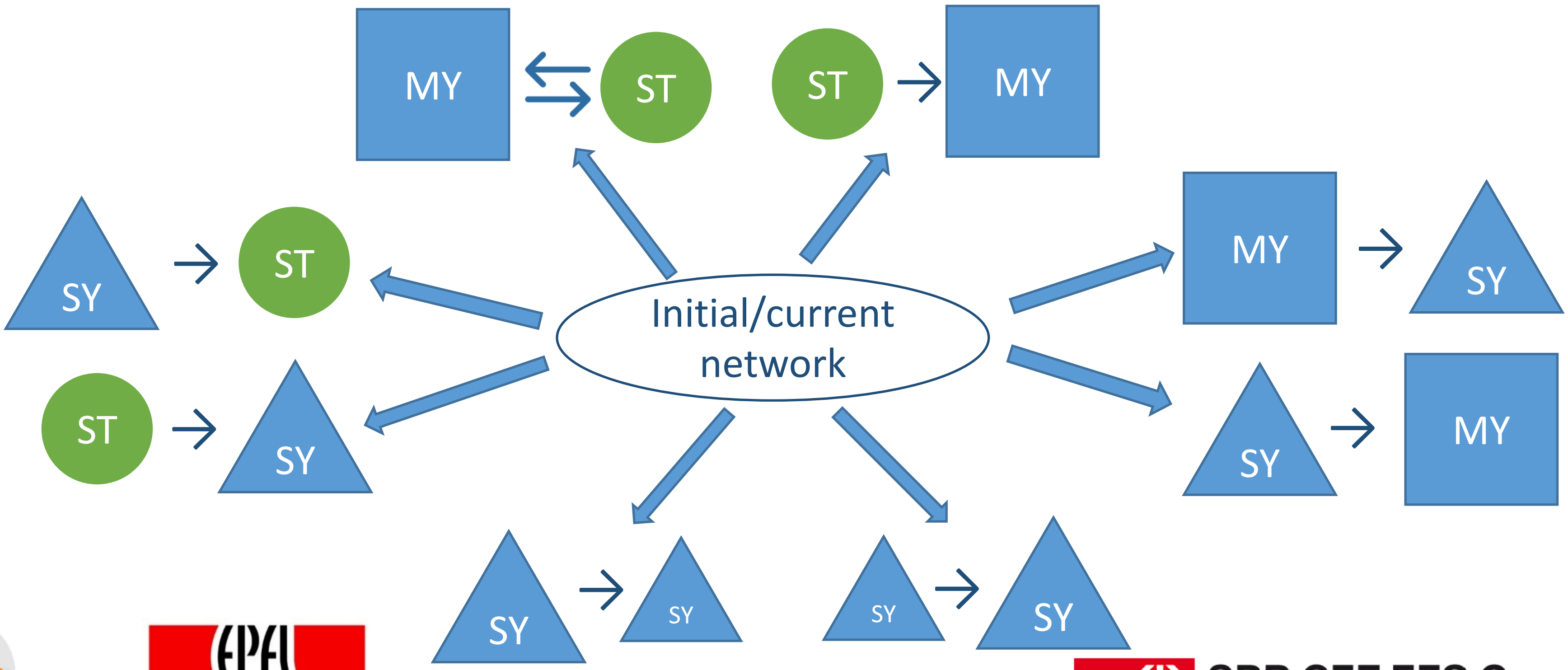
- Close collaboration with Vincent J. Baeriswyl
- Received initial data set from SBB Cargo:
  - infrastructure, cost, and demand data (OD pairs)
- Additional data supplied when the requirement is identified

Heuristic algorithm

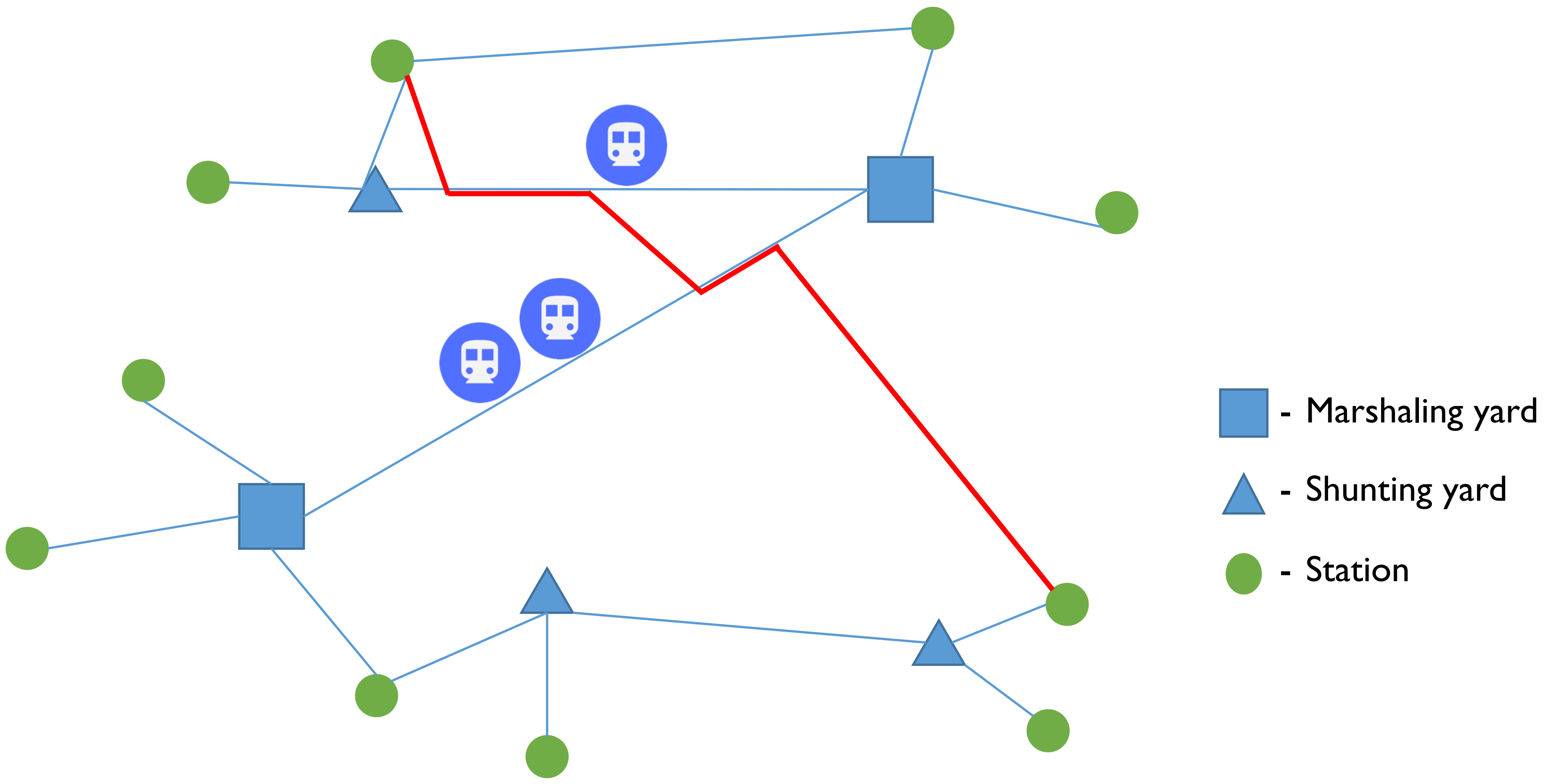
- Size of the SBB Cargo network: approx. 2100 stations, 2500 direct links, over 65000 commodities
  - Yearly demand, scaled to daily average
- Heuristic algorithm composed of 4 stages:
  - Yard location and sizing
  - Initial train generation
  - Commodity assignment (routing)
  - Train number reduction

Heuristic algorithm – Yard location and sizing

- Yard location:
  - Adaptive large neighborhood search (ALNS)
  - Variable neighborhood search (VNS)

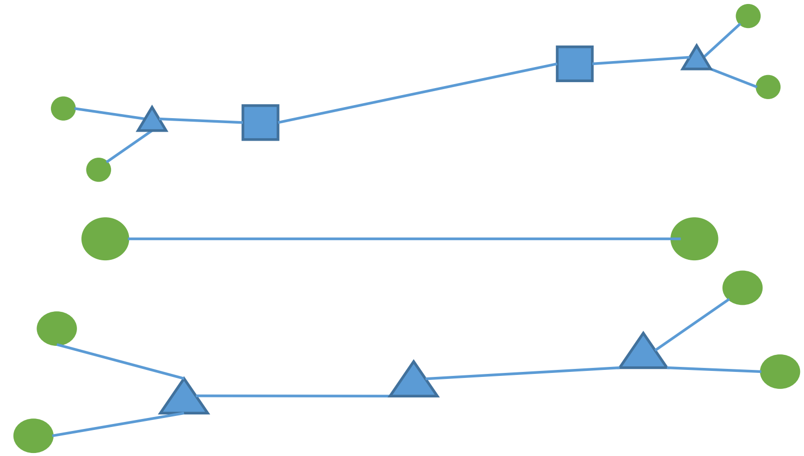


Heuristic algorithm – Initial trains generation



Heuristic algorithm – Commodity assignment

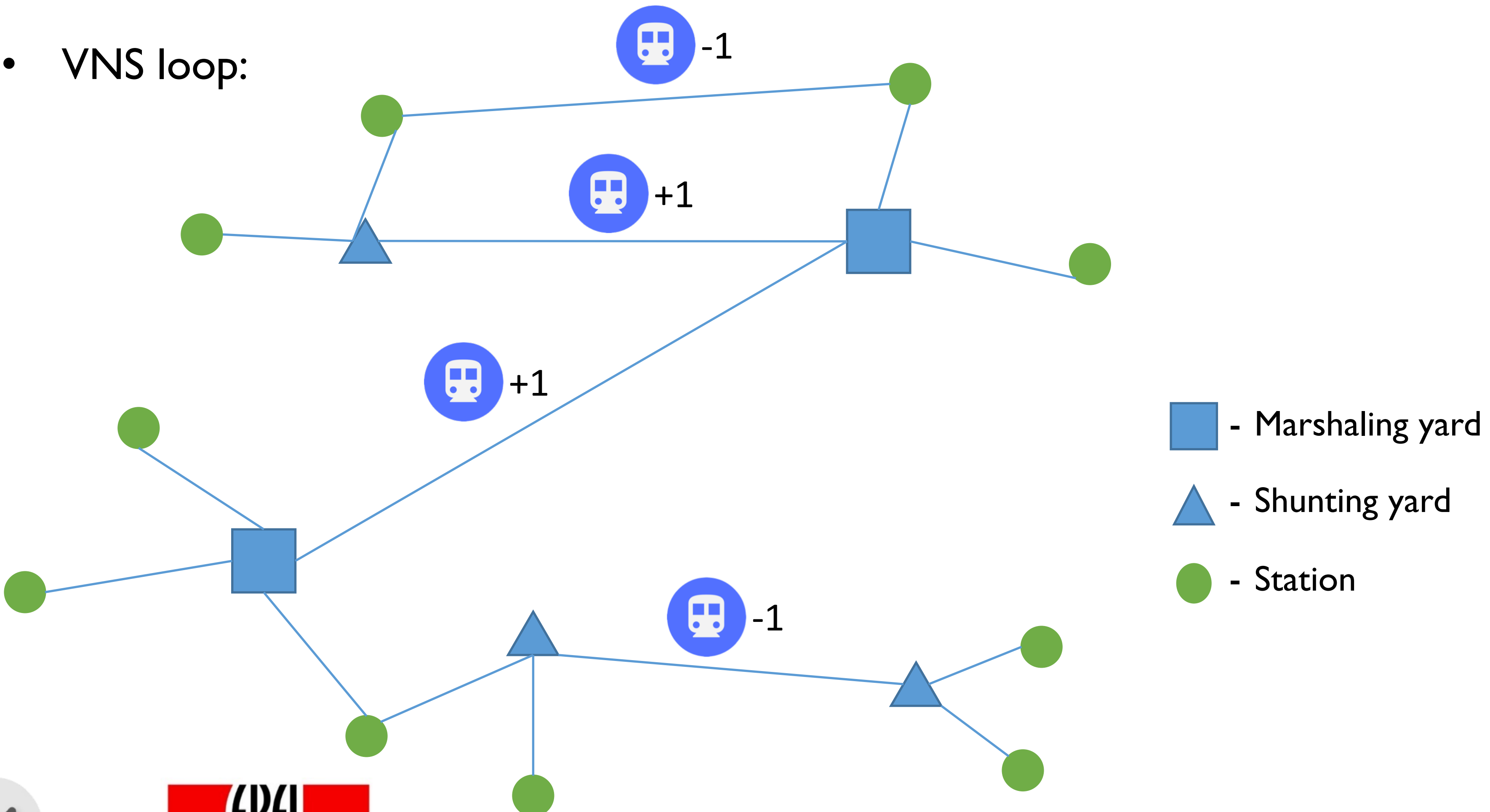
- Commodity routing:
  - Prioritized assignment algorithm



Select commodity by priority	
Path alternatives test	Via marshaling and shunting yards, shunting yards only, or direct train.
Path selection	Cheapest estimated, available path
Add necessary trains	If none of the paths is feasible

Heuristic algorithm – Reduction of train number

- Remove all unused trains
- VNS loop:



Heuristic algorithm – development details

- Developed algorithm is very flexible:
  - Easily extendable with additional neighborhood operators, i.e. network transformations
  - Easy definition of specific initial network states, e.g. all marshaling yards closed, several additional marshaling yards open, etc.
- Algorithm modes:
  - Daily average demand
  - Peak demand

Algorithm results

- Two usage strategies:
  - S1: allowing increase in the number of marshaling yards
  - S2: limiting the number of marshaling yards to the current one
- Initial network state
  - The current network state
  - Changed number and locations of the marshaling and shunting yard

Algorithm results

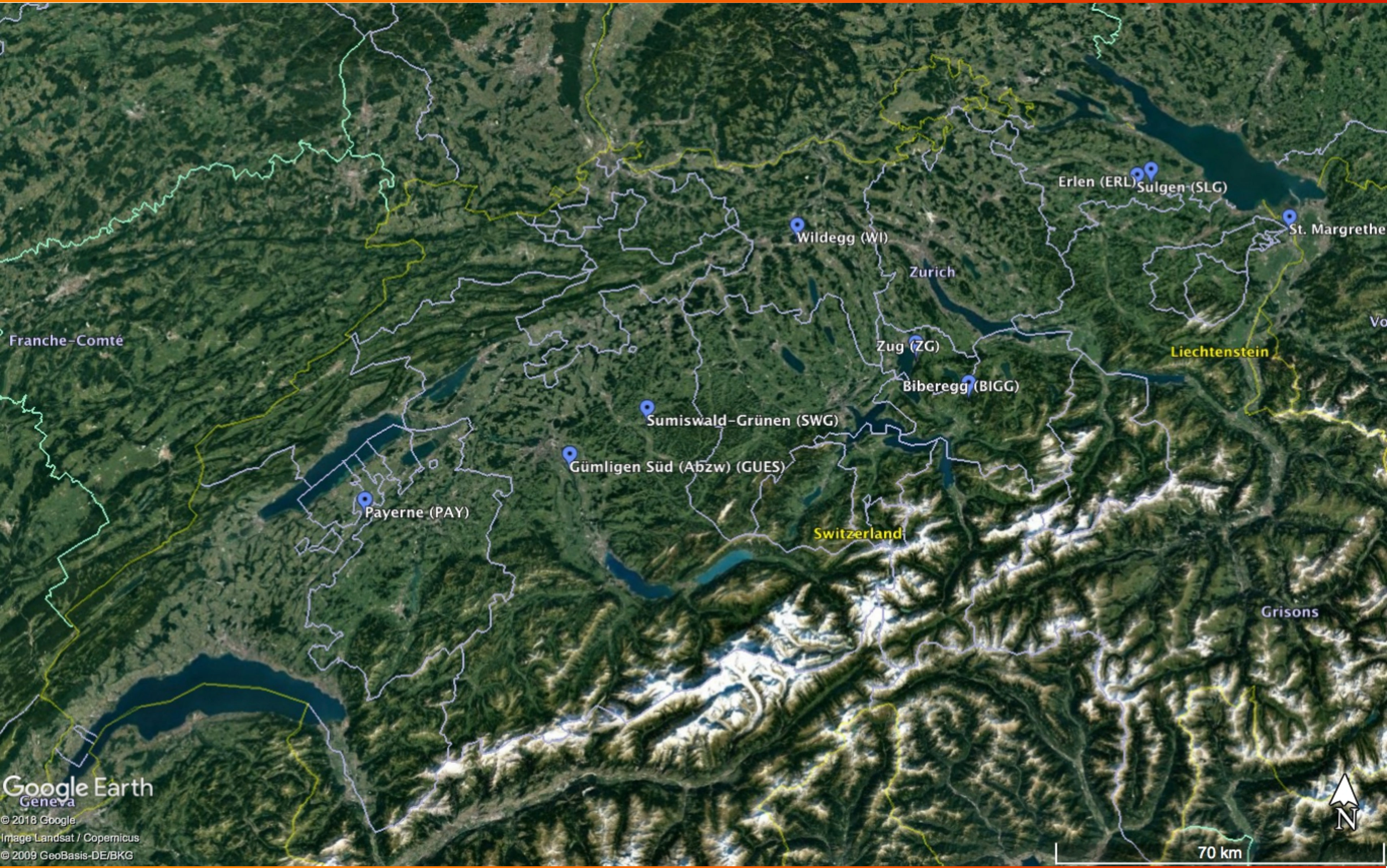
- Best resulting networks obtained from the current network state

Strat.	New MY	Rem. MY	New SY	Rem. SY	Algor.	Run. time	Cost reduct.
S1	6	1	2	2	VNS	2h	**10.01%**
S2	1	2	5	49	ALNS	17h	**16%**

- S1 should in theory yield a better result, but the investigation in this direction was shorter due to a business decision

Algorithm results – Marshaling yards

Algorithm results – Shunting yards



Results analysis

- Locomotive and personnel (distance-dependent) costs are dominant over weight-dependent commodity transportation costs
- Costs of yard opening and maintenance are not taken into account
  - Potentially would further reduce the number of yards and their size
  - Could be included in another case study
- New yards can be near the existing ones
  - The objective function has been extended to penalize this situation

Results analysis - Routing

Conclusions

- Developed algorithm explores various network changes, their combinations and their influence to the transportation costs
    - Flexible, easily extendable algorithm
- The algorithm identified network changes resulting in **transportation cost reduction**
- The objective function should be extended with the real **costs of maintenance** of the marshaling and shunting yards
- Algorithm parallelization – performance improvement

Possible future collaborations

- Development of the exact solution method (on the whole set or subset of input data)
  - Also to benchmark the heuristic results
- Algorithm for daily cargo management
  - Train routing
  - Track allocation
  - Staff allocation
  - Demand prediction

Thank you!

Questions?

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