

Reengineering of Forest Road Networks

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- Mathematical Model
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Problem

- Forest Roads constructed mainly between 1950 and 1980
- Today:
  - different requirements and harvesting technology
  - Budget restrictions
- Question: How to adapt forest road networks for actual requirements?

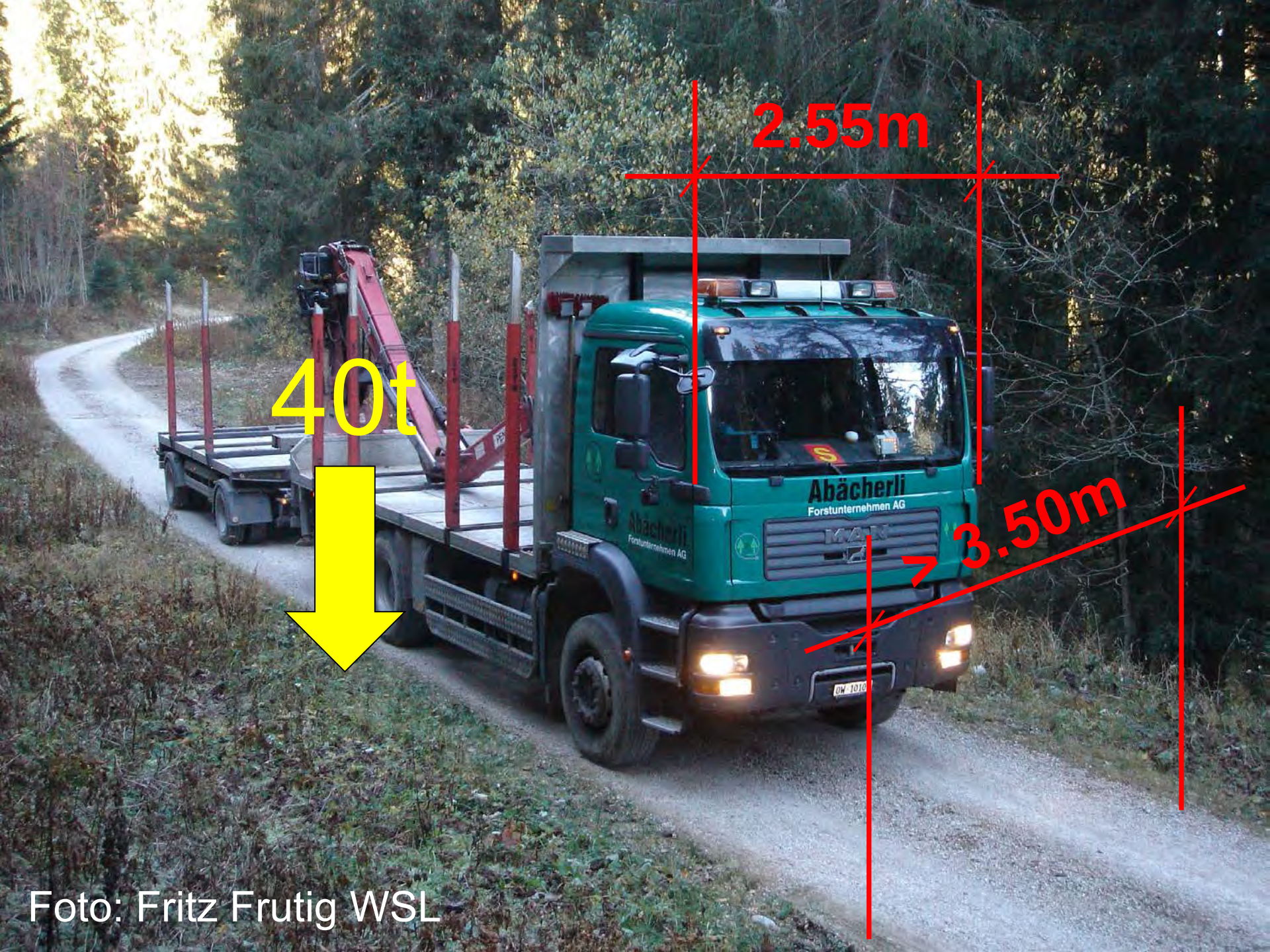

Foto: Fritz Frutig WSL

Foto: Gian Cla Feuerstein

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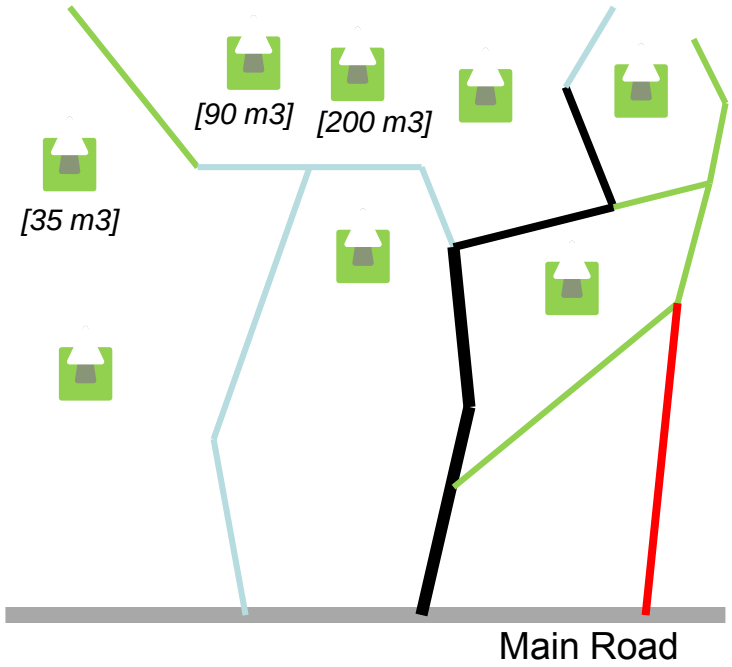
Problem

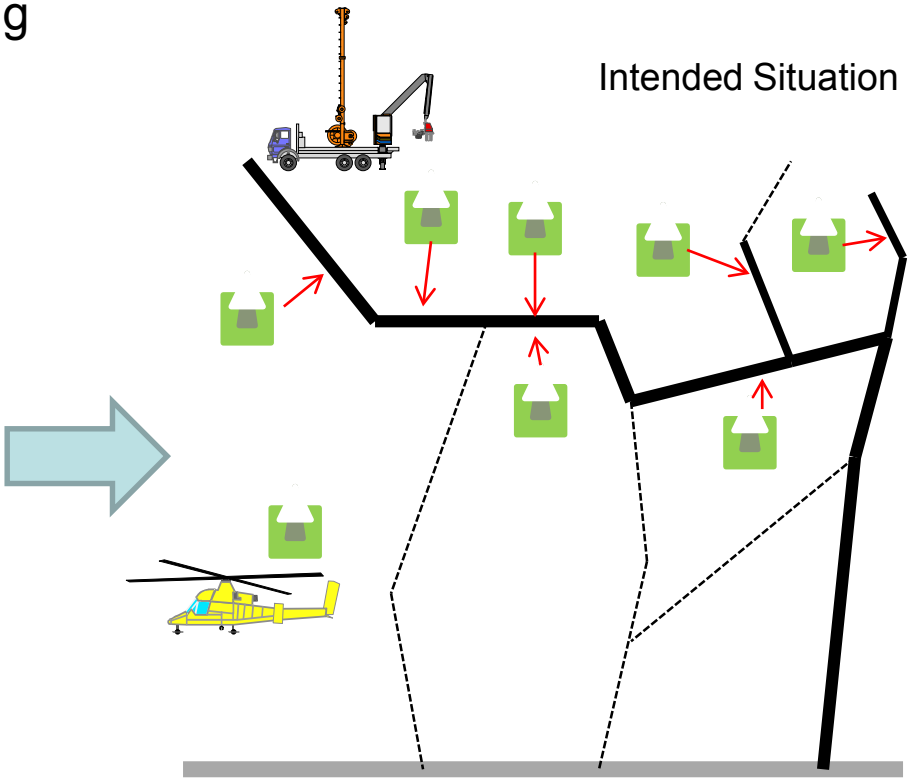
Minimize Life Cycle Cost

- Road Network
- Harvesting
- Hauling

Actual Situation



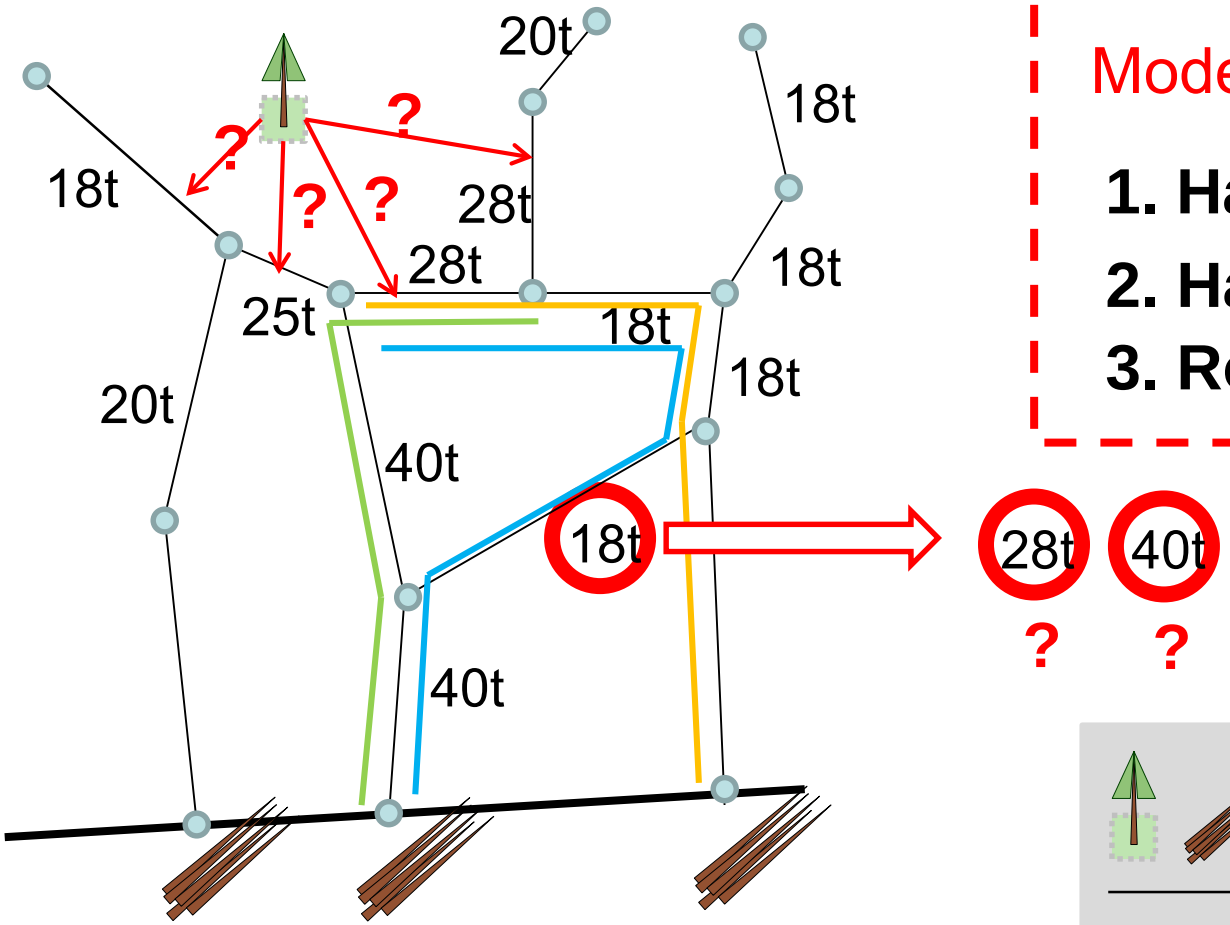
Intended Situation



18t
20-25t
28 - 40t
Existing Roads
Possible constr. (Expert defined)
Timber parcel
Volume [m3]

28 - 40t
Not used anymore
Timber parcel

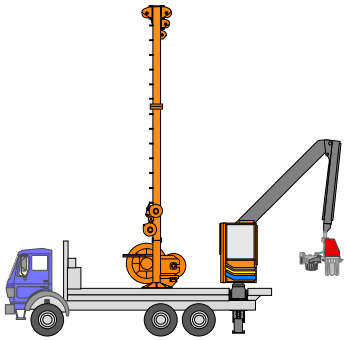
Decisions

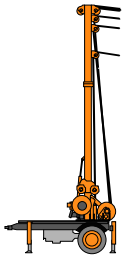


Model Components

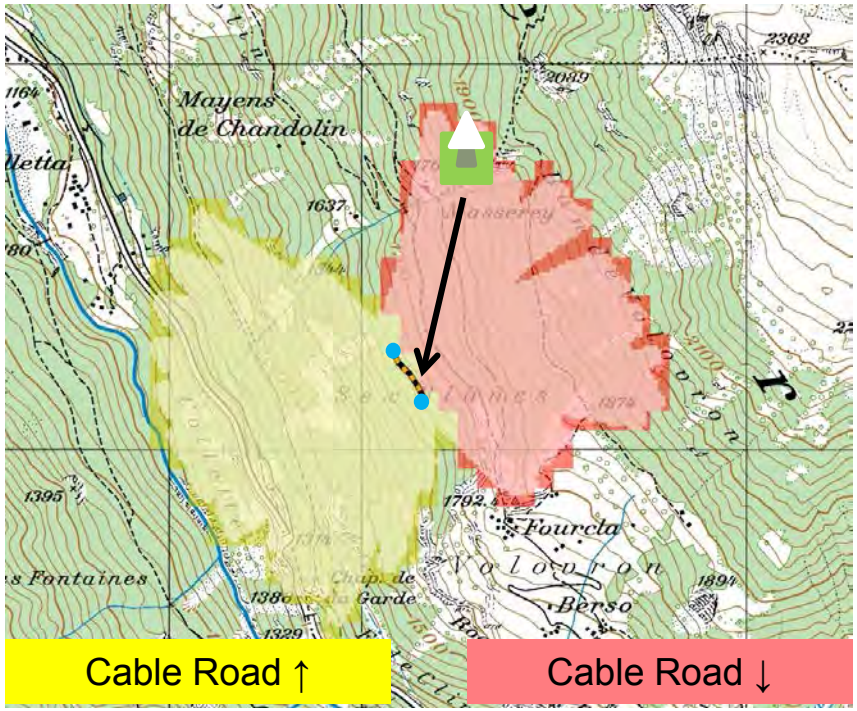
1. **Harvesting System**
2. **Hauling Path**
3. **Road Standard**

Harvesting system

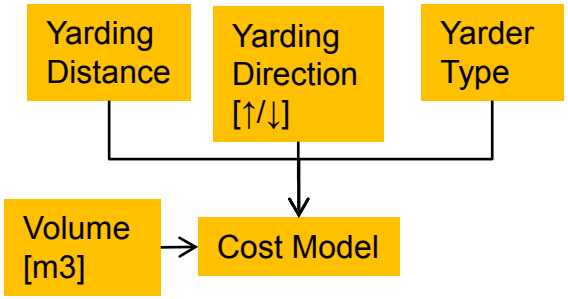




Terrain Analysis



Cost Model



Harvesting Alternative / Dummy Exit

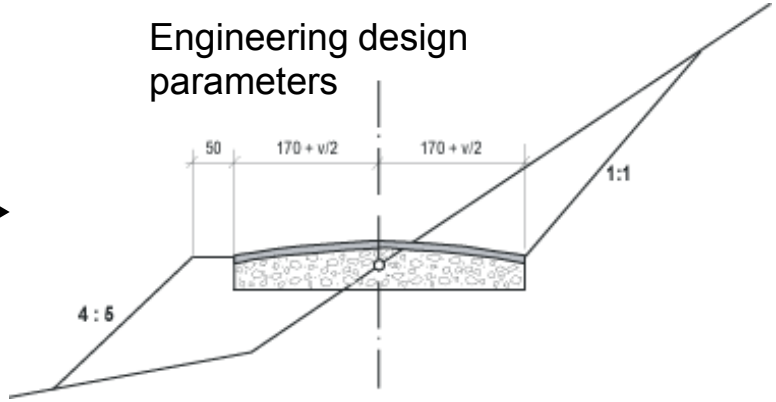
Road Standard / Cost

New Road

Terrain (DEM)

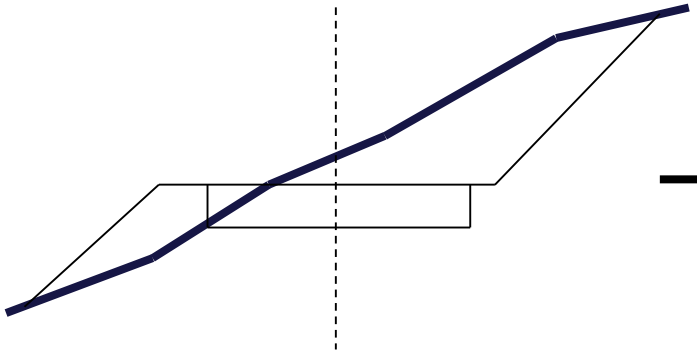
Geological Layer

Engineering design parameters

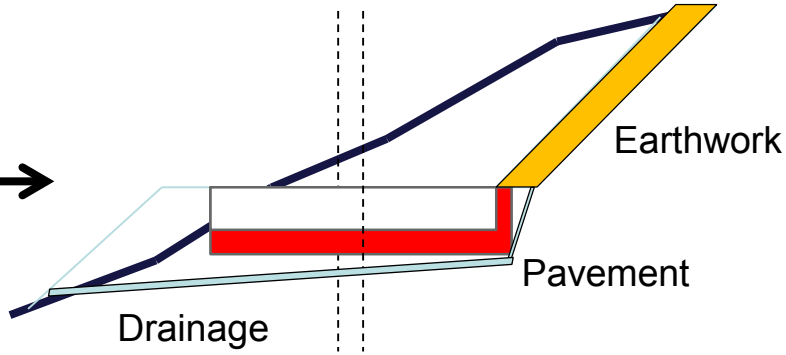


Upgrade

Actual State



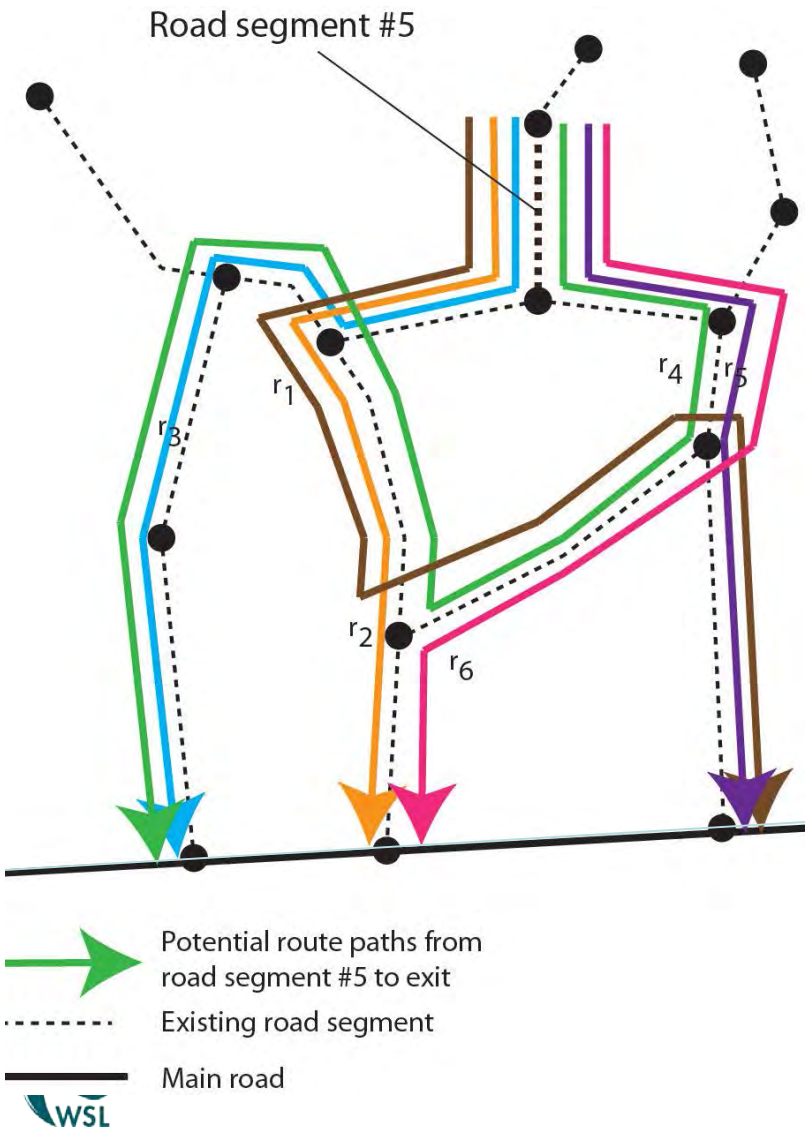
Upgrade State



Maintenance

Flat Cost
[no model available]

Hauling Paths & Costs



Design Standard [t]	Hauling Cost [CHF/m3/km]
18	1.28
28	0.8
40	0.54

Hauling Cost [CHF/m3]

Path	Design Standard [t]		
	18	28	40
r1	1.9	1.2	0.8
r2	2.6	1.6	1.1
r3	1.3	0.8	0.5
r4	1.5	1	0.6

Objective Function

Minimize Life Cycle Cost (over 40 years)
- Road Network (New Construction, Upgrade, Maintenance)
- Harvesting
- Hauling

Constraints:
- Harvest all Timber Parcels

Frame conditions:
- Men Transportation is not considered

Mathematical model

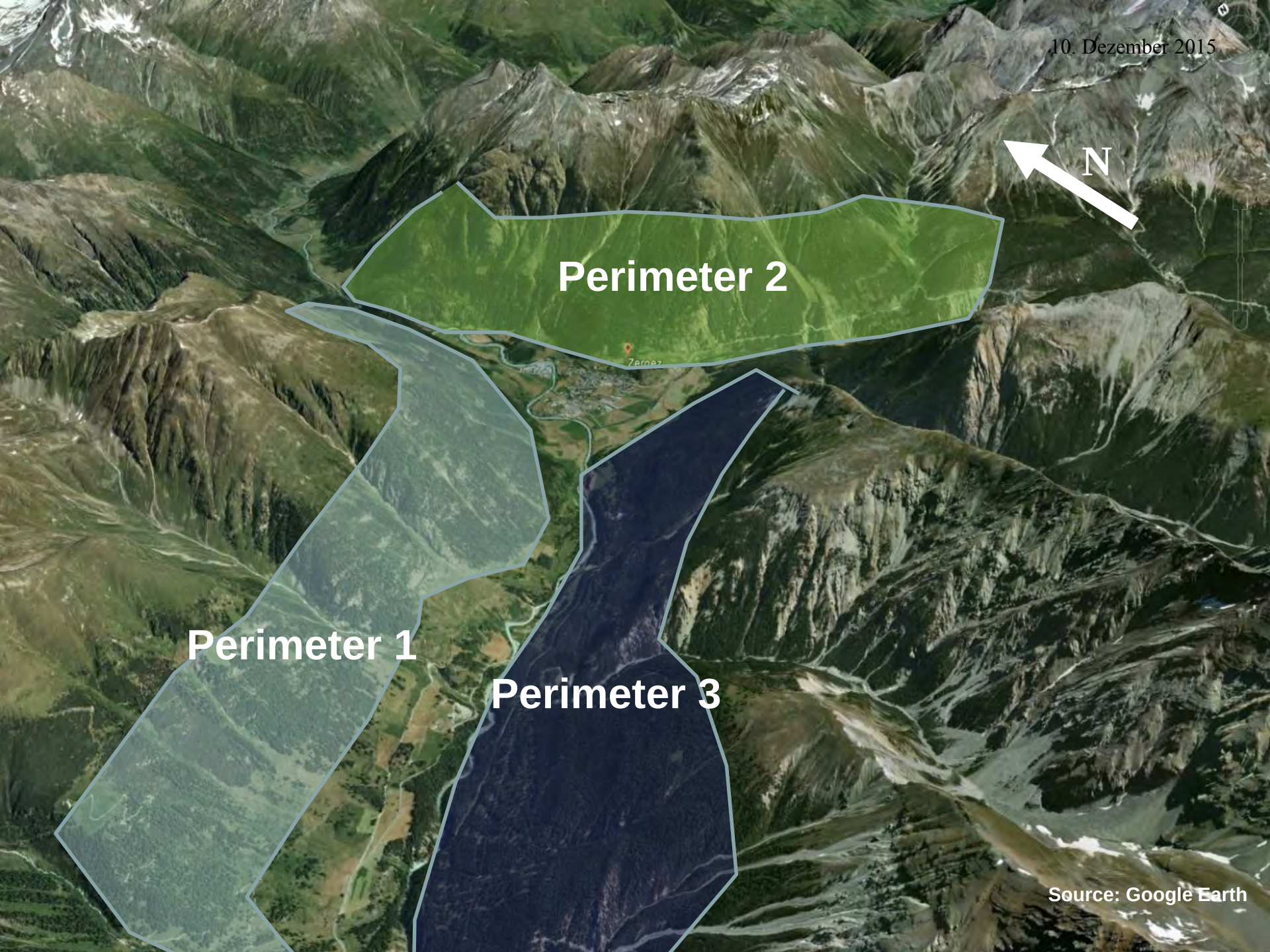
Combinatorial Problem

e.g. 10’000 Variables => 100 Millions Combinations

Mixed Integer Linear Programming

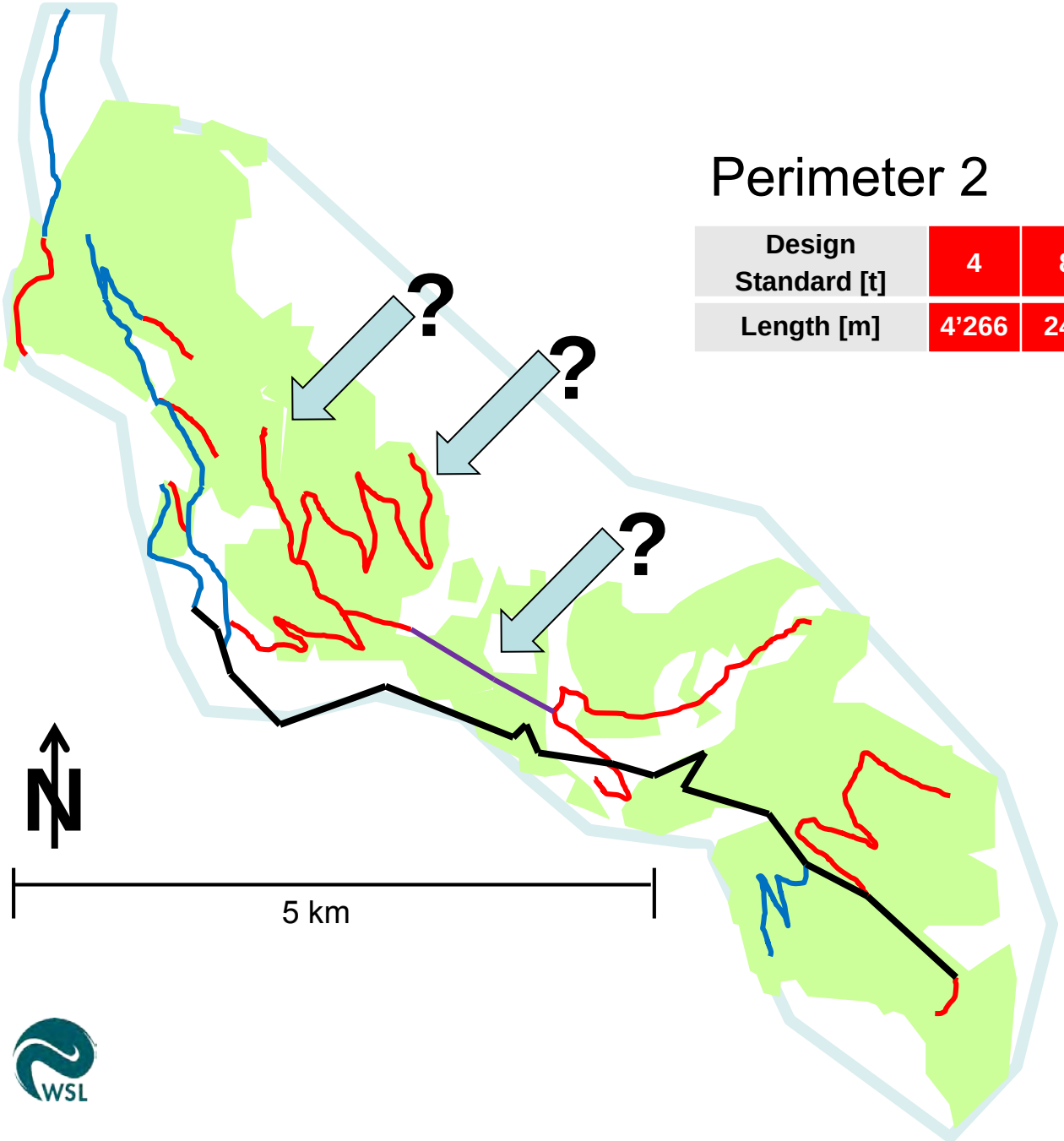
Application

Source: Swisstopo

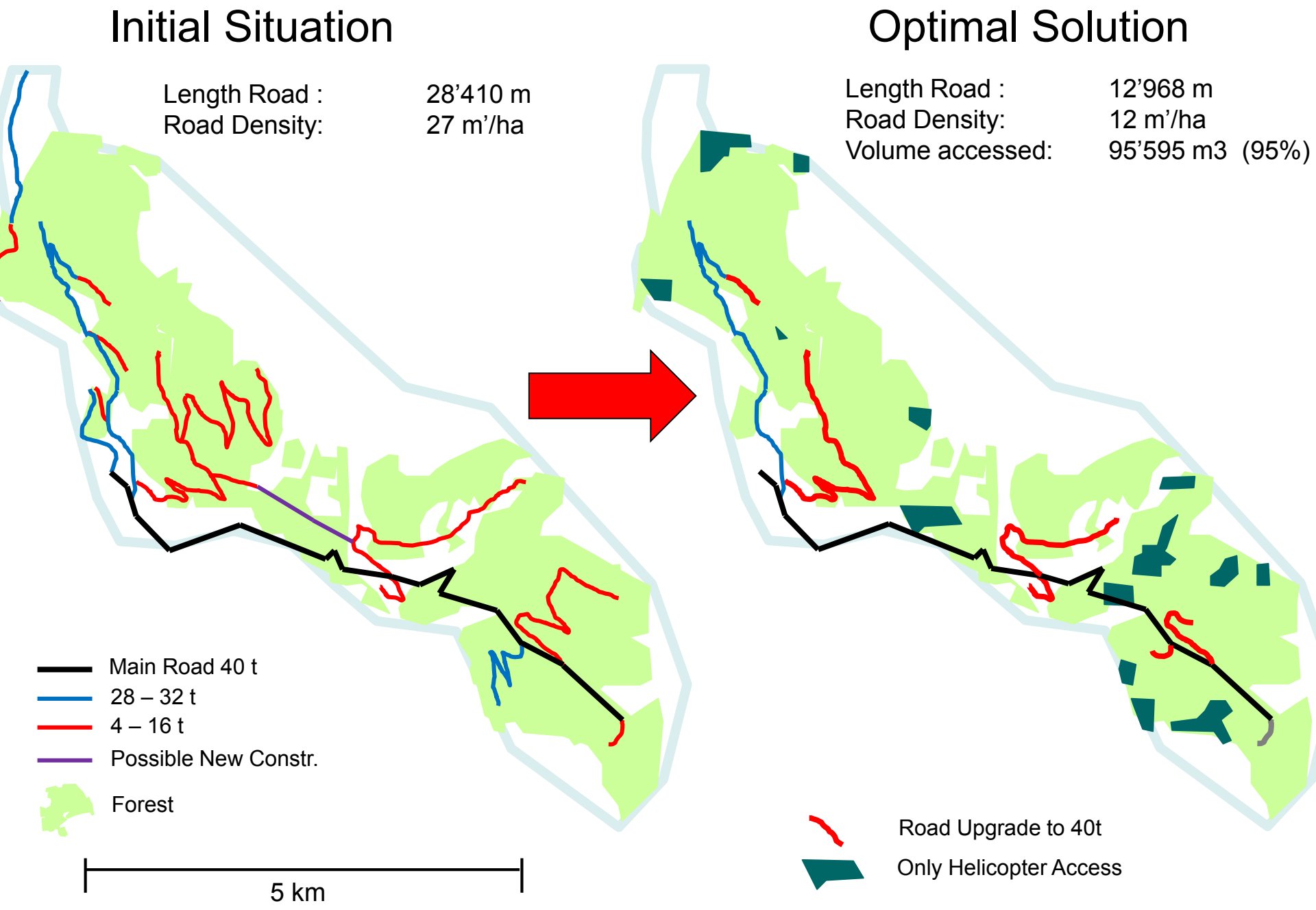

10. Dezember 2015
N
Perimeter 2
Perimeter 1
Perimeter 3
Source: Google Earth

Perimeter 2

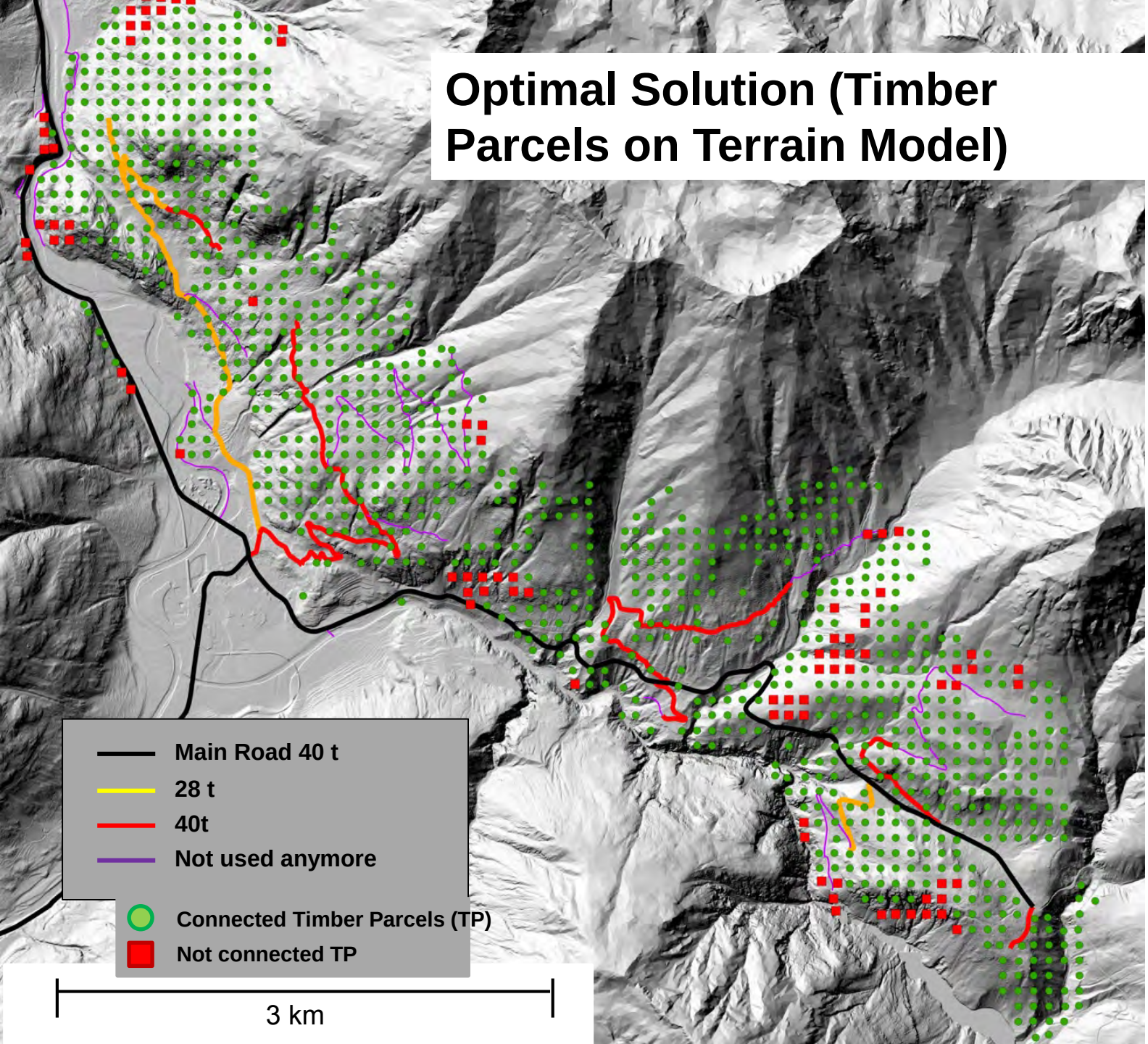
Design Standard [t]	4	8	10	16	28	40
Length [m]	4’266	246	9’708	3’930	10’203	57



Main Road 40 t
28 – 32 t
4 – 16 t
Possible New Constr.


Initial Situation
Length Road : 28’410 m
Road Density: 27 m’/ha
Optimal Solution
Length Road : 12’968 m
Road Density: 12 m’/ha
Volume accessed: 95’595 m3 (95%)
Main Road 40 t
28 – 32 t
4 – 16 t
Possible New Constr.
Forest
5 km
Road Upgrade to 40t
Only Helicopter Access

Optimal Solution (Timber Parcels on Terrain Model)



Computation Time

Problem Size:
5000 – 10’000 Variables
10’000 – 100’000 Constraints

Perimeter	**1**	**2**	**3**
Computation Time	15 – 20h	5 – 10 min	17h

Conclusions

Scientific

- First spatial explicit optimization method
- Detects mathematical optimal solution
- Applicable for areas up to 50 km2

Practical

Recommendation Gian Cla Feuerstein, District Forest Officer Zernez

“Check all «old» Road Networks, especially if some investments will be done”

“Without Optimization Tools, this will not be possible for large areas under objective criteria”