Mathematical Optimization of Harvesting and Transportation Processes in Steep Terrain and Big Data

Leo Bont, WSL, Switzerland

NB Nord Workshop

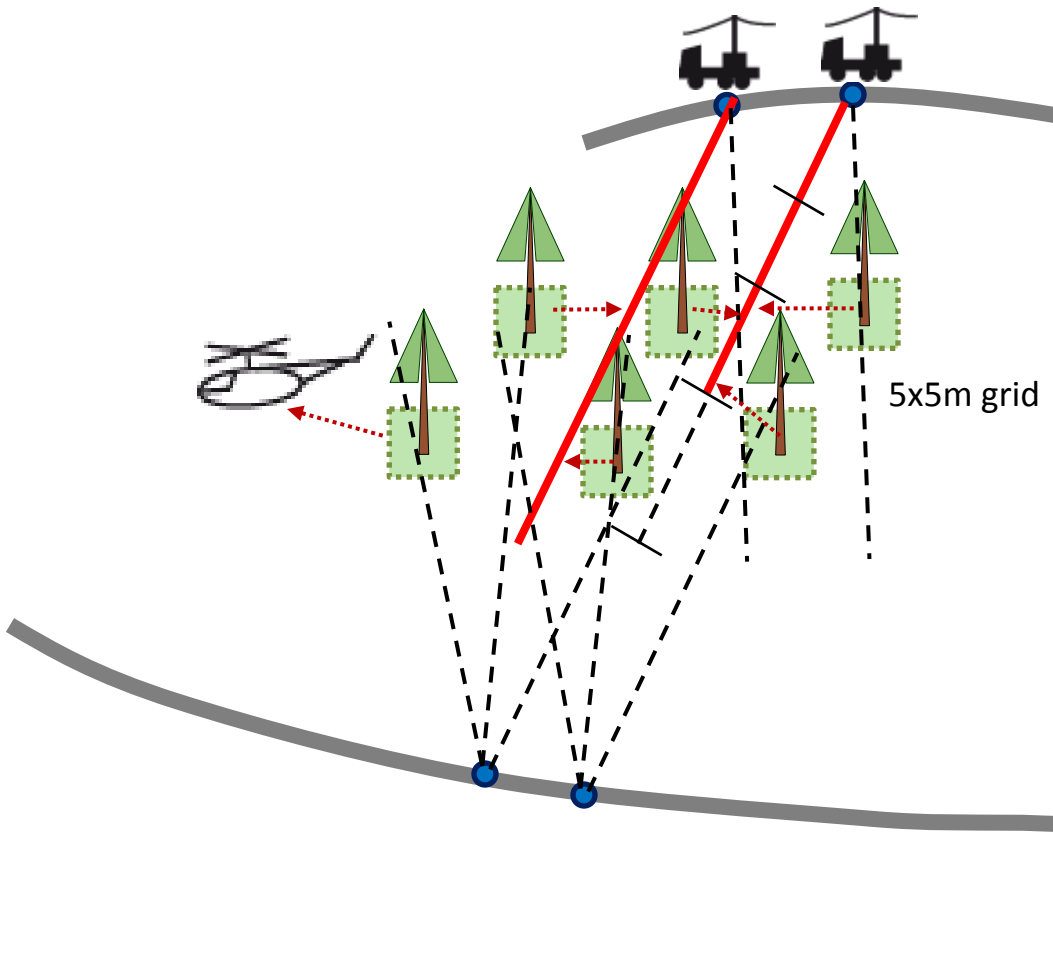
19. / 20. June 2018

Content

- Harvesting Layout in Steep Terrain
- Road Upgrading
- Potential of Having Big Data available

HARVESTING LAYOUT IN STEEP TERRAIN

Optimize Harvesting Layout in Steep Terrain



Decisions :
- Harvesting system
- Cable road section
- Landing

Objectives: Minimize…
- Harvesting Cost
- Environmental Impact (Stand Damages)

Constraint:
- Harvest each Parcel

Multi objective optimization

$$MIN \qquad Z^{overall} = \lambda_C Z^{C} + \lambda_{EI} Z^{EI}$$

Cost *Environmental Impact*

λ_X	weight
Z^X	objective function (standardized)
C	cost
EI	environmental impact

example.:

$\lambda_C = 1$

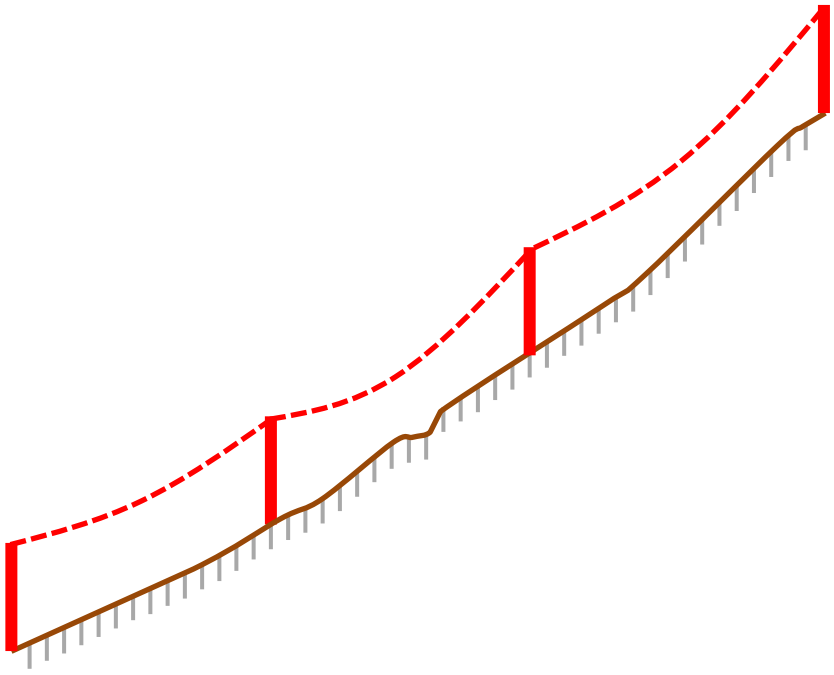
$\lambda_{EI} = 0$

$$\lambda_C + \lambda_{EI} = 1$$

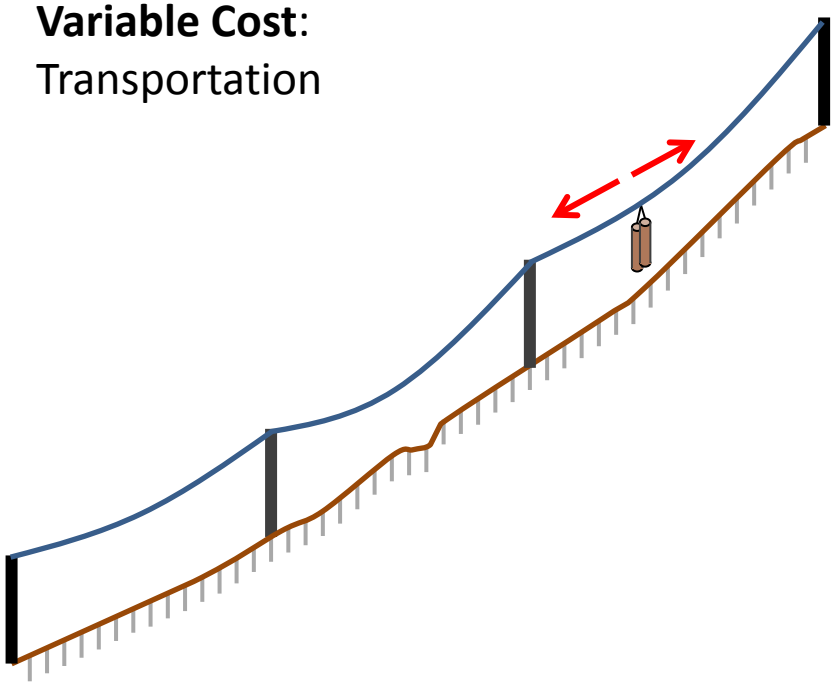
Objective: Cost

Minimize wood extraction cost [CHF]

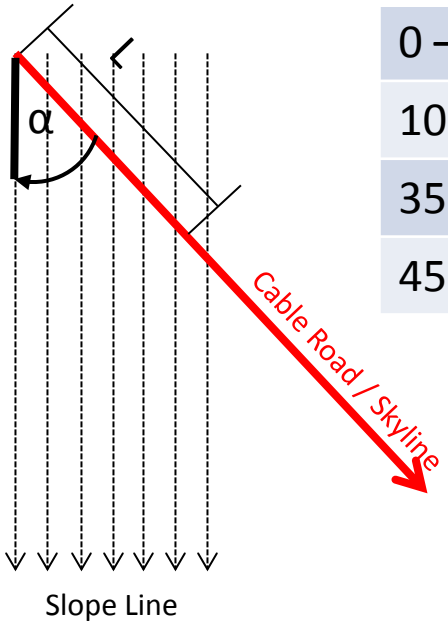
Fixed Cost:
Set Up- and Dismantling



Variable Cost:
Transportation



Environmental Impact: Penalty for angle between skyline and slope line

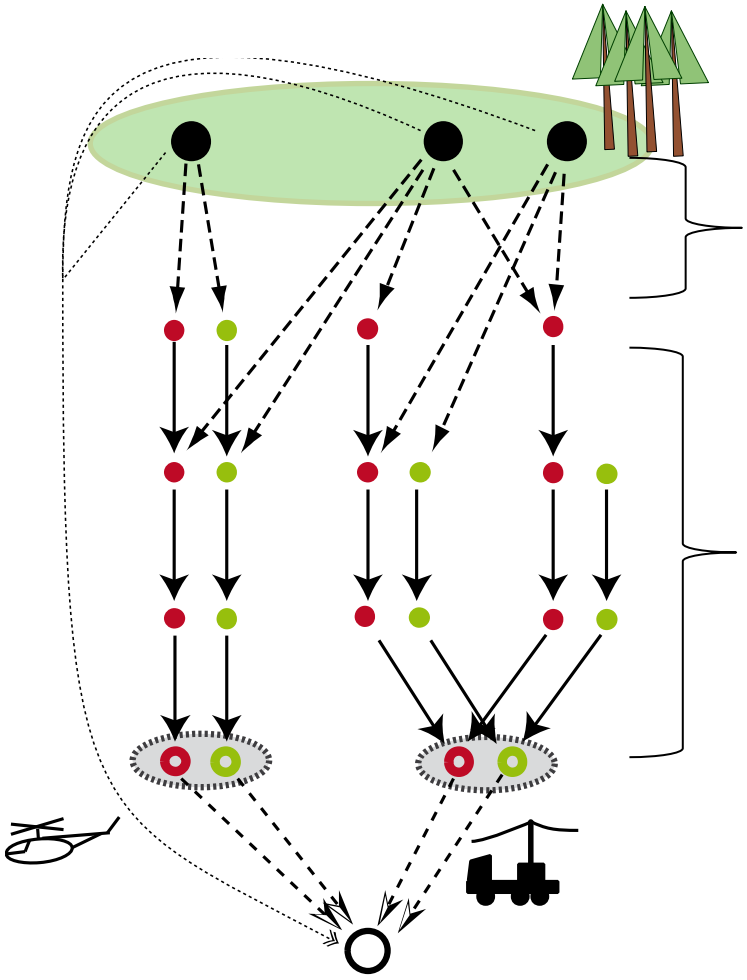


Angle (α)	Penalty
0 – 10°	L * 0.5
10 – 35°	0
35 – 45°	L * 0.5
45 – 90°	L * 2

Lateral Yarding

Nightmare for workers &

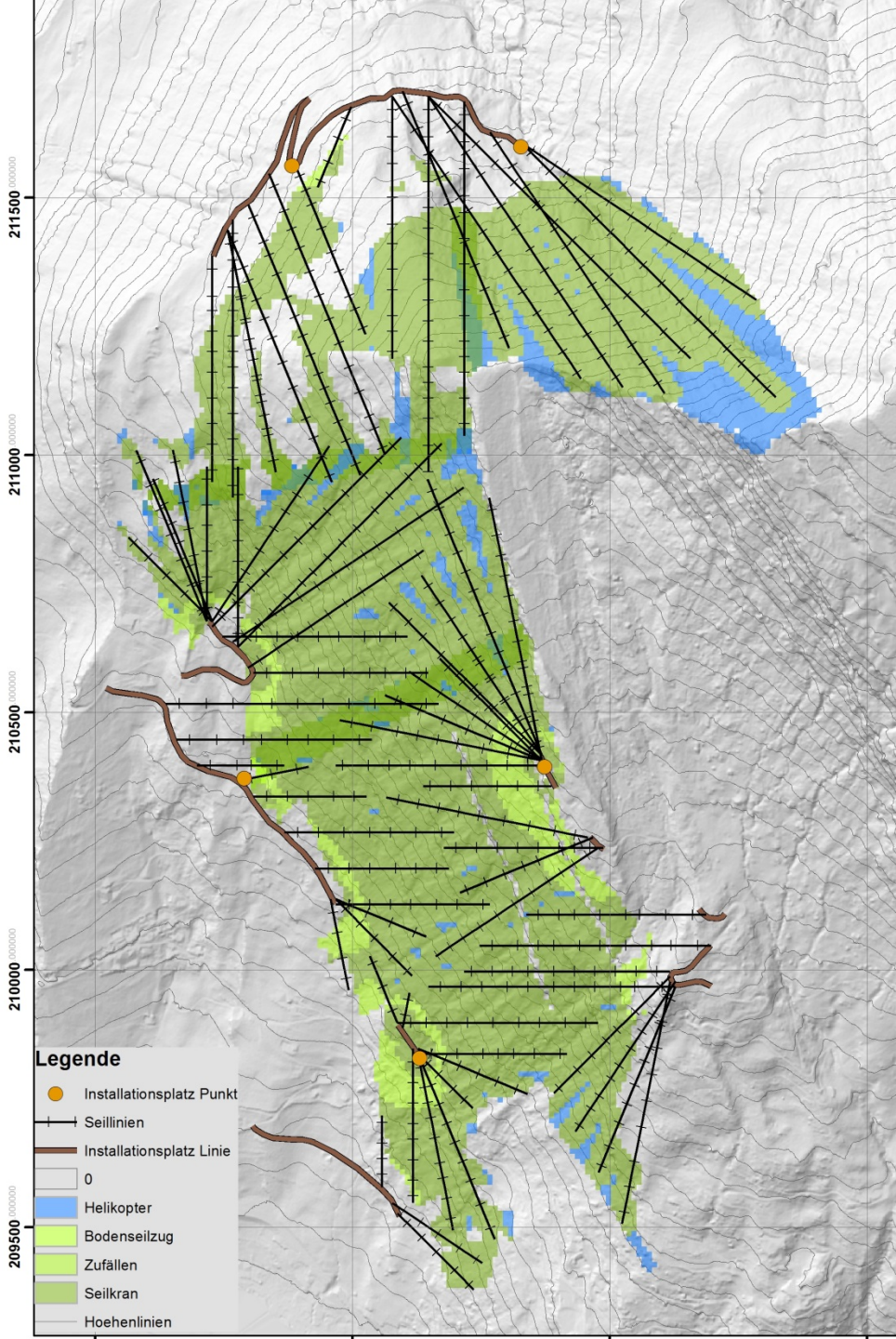
Optimization technique



Arc	Arc Weight
Timber P. - Cable Road	Variable Cost
Cable road section	Fix Cost / Environmental Impact

Mixed Integer Linear Programming:
10m grid resolution, 35 ha
about 300'000 variables → Time = 8 min.
Application Rigi: Between 1 min. and 1 hour

Chosen Solution



ROAD UPGRADING

Foto: Gian Cla Feuerstein

Foto: Gian Cla Feuerstein

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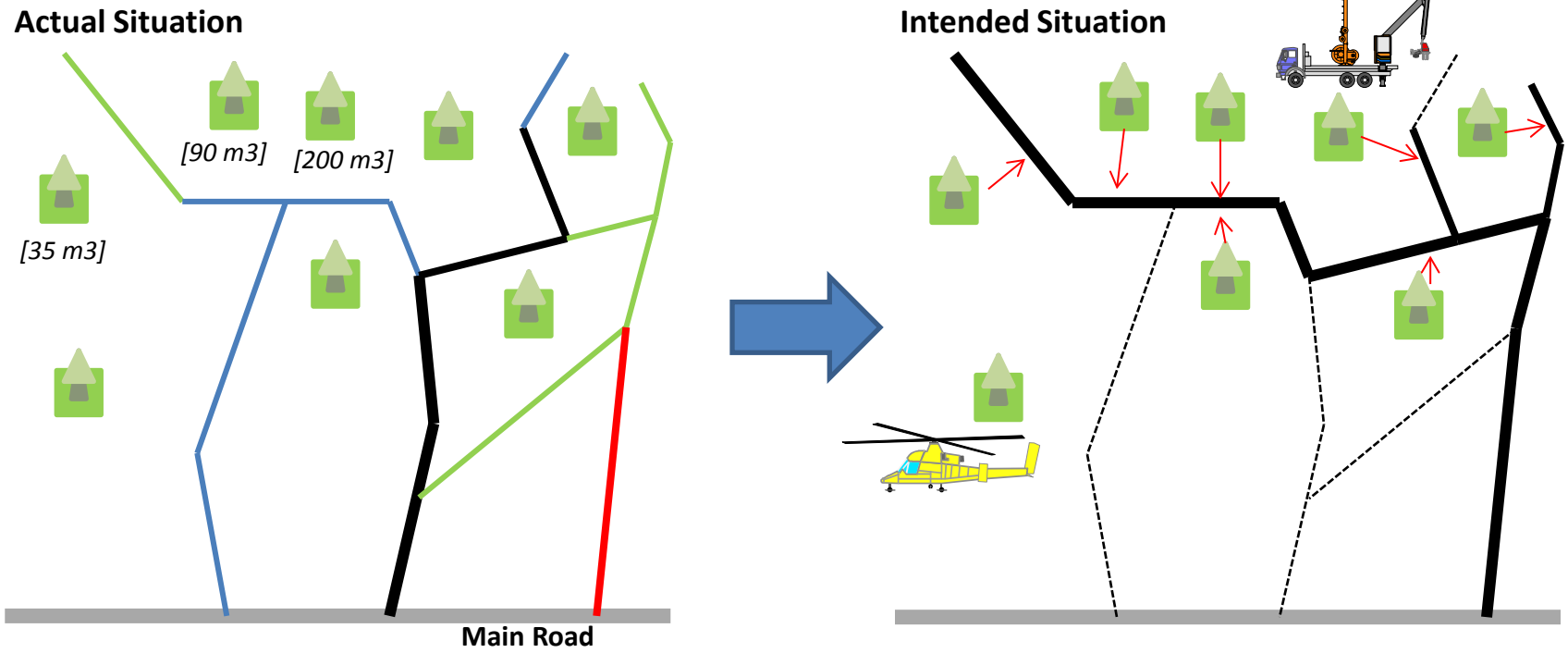
Problem – spatial explicit model



Road standard

- 18t
- 20-25t
- 28 - 40t

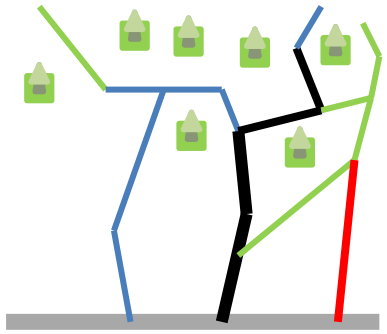
Existing Roads

- Possible constr. (Expert defined)
- Timber parcel
  Volume [m3]

Road standard

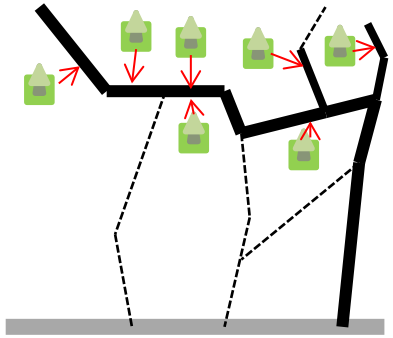
- 28 - 40t
- Not used anymore
- Timber parcel

Model Components



Actual Situation

Optimization Model



Result

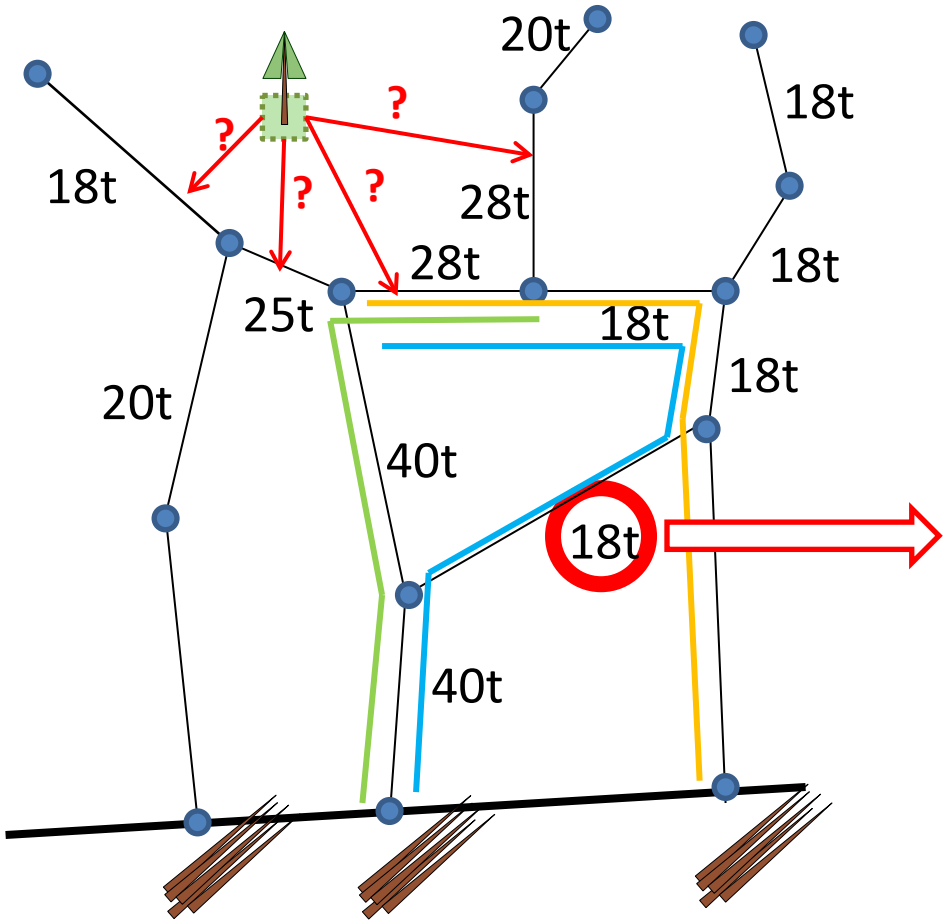
Harvesting system

Road Cost (Life Cycle)

Hauling Paths

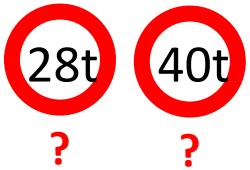
Model Components

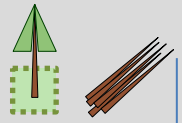
Decisions



Model Components

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



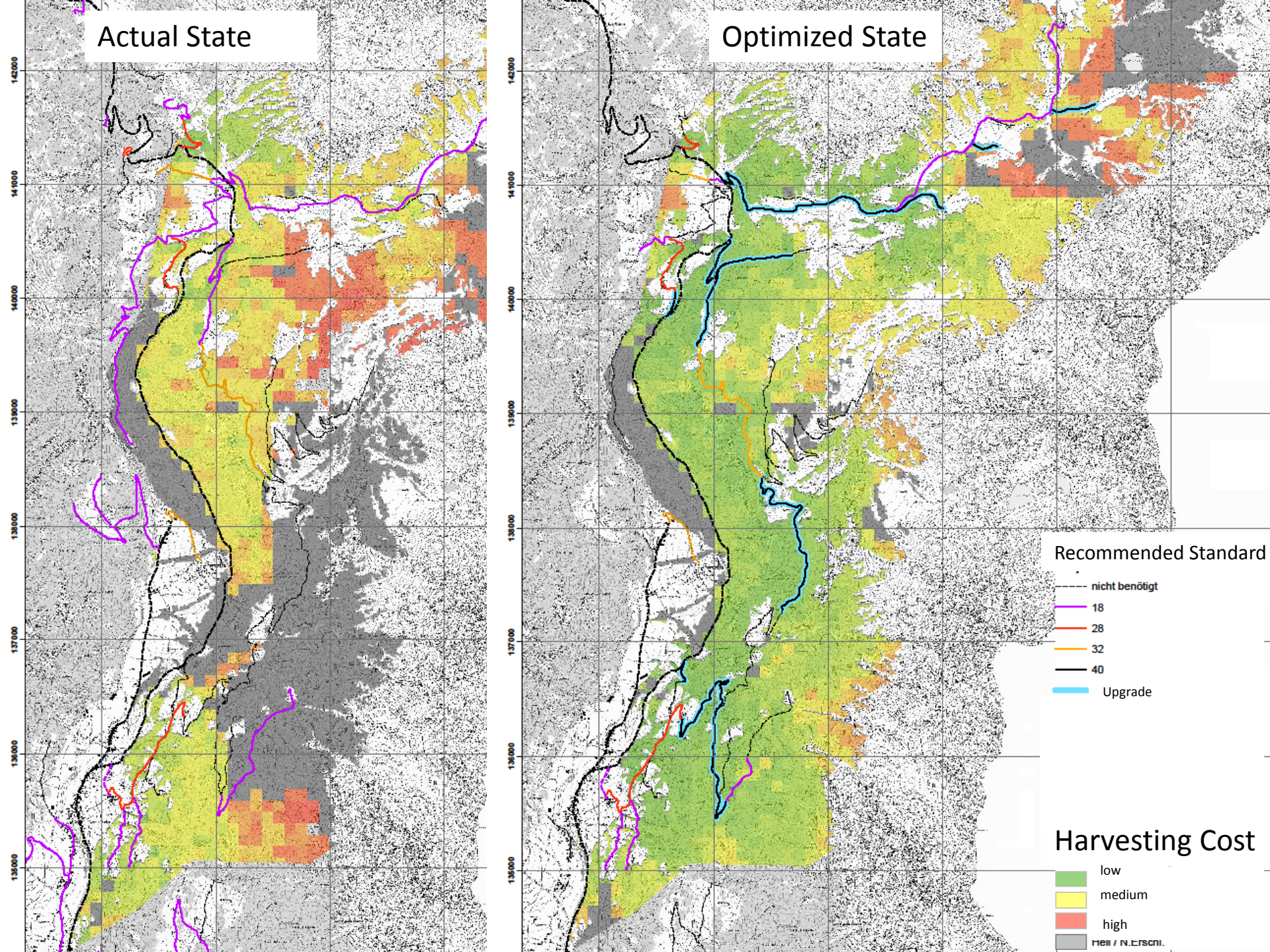


Timber parcel, Timber Pile

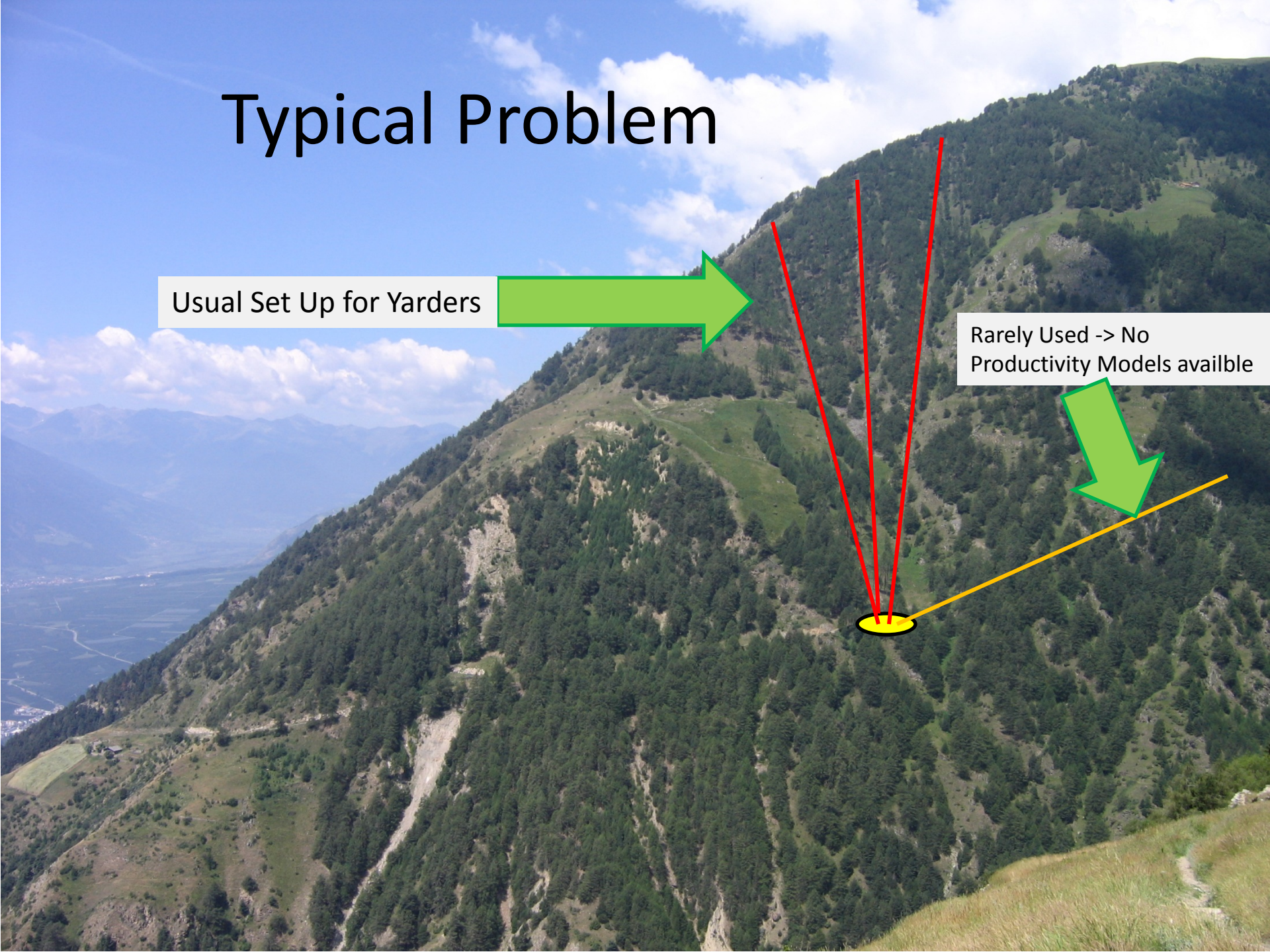
Forest Road

Main Road

20t Weight Limitation


Actual State
Optimized State
Recommended Standard
nicht benötigt
18
28
32
40
Upgrade
Harvesting Cost
low
medium
high

Typical Problem



General Problems

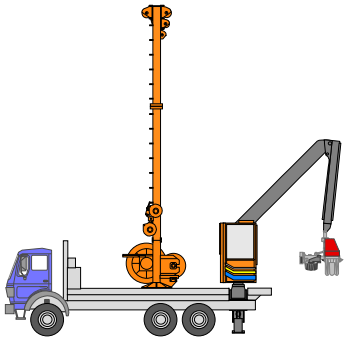
- Productivity models are usually created to answer very specific research questions.
- Geometry of existing roads not described accurately
- Volume prediction

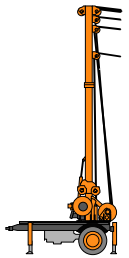
Benefit of «Big Data»

- Algorithms are working well, however, quality of the results is just as good as the quality of the input datas
- Here, better Inputs would be a benefit:
  - Volume prediction
  - Road Upgrade Cost Estimation
  - Productivity models, in particular for unfavorable conditions

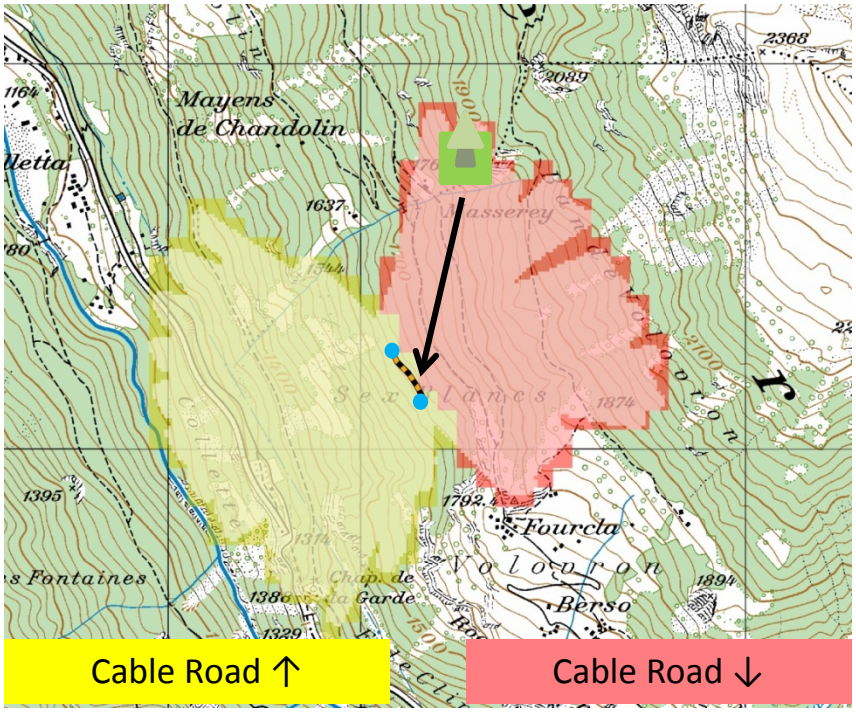
Thank you

Harvesting system

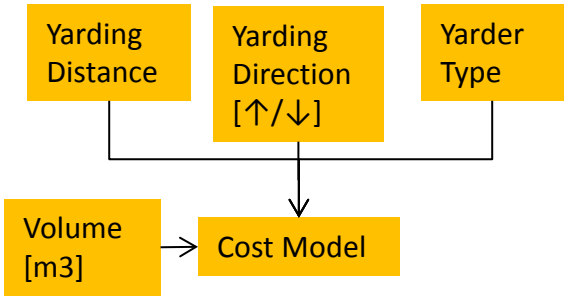




Terrain Analysis



Cost Model



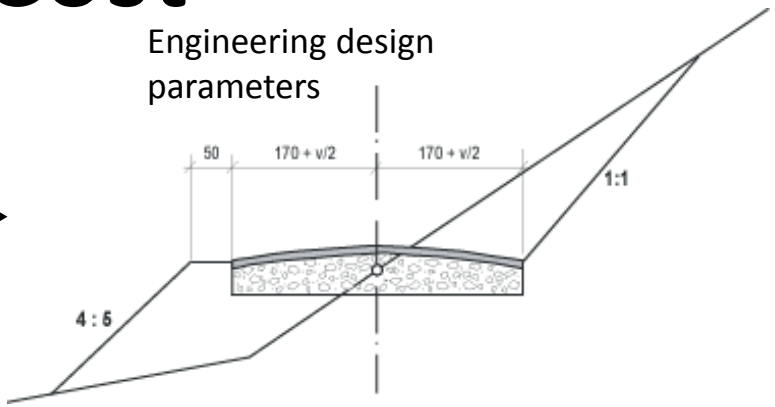
Harvesting Alternative / Dummy Exit

Road Cost

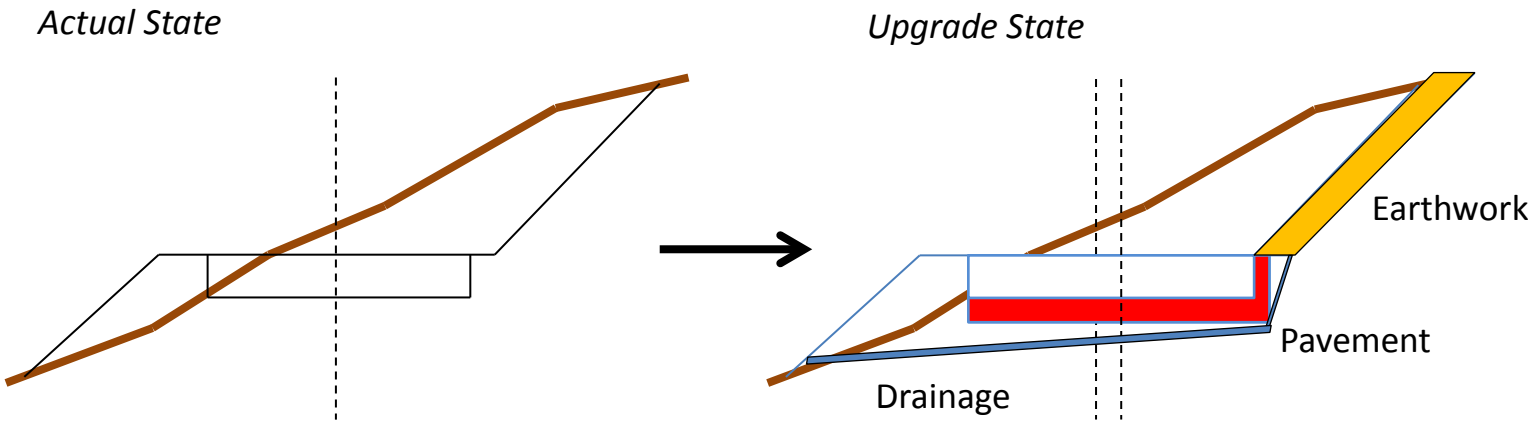
New Road

Terrain (DEM)

Geological Layer



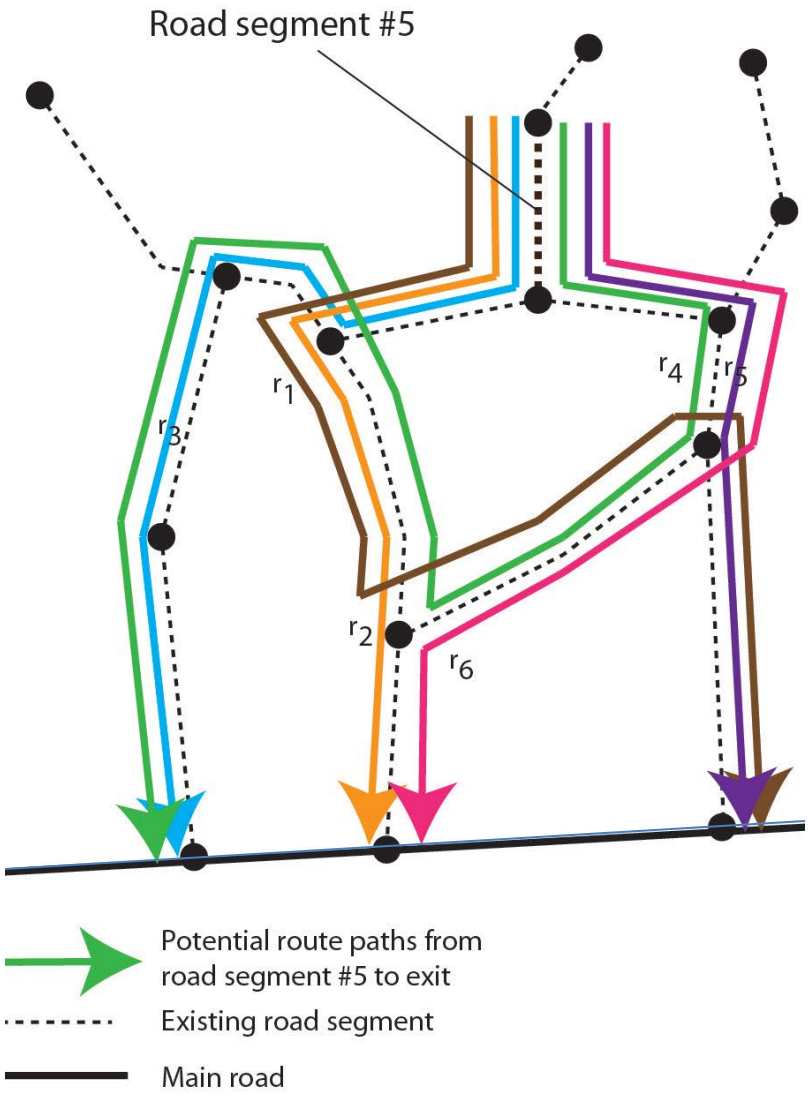
Upgrade



Maintenance

Flat Cost

Hauling Paths & Costs



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

Hauling Cost [CHF/m3]

		Design Standard [t]		
		18	28	40
Path	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