UPDATE ON MATERIAL LOGISTIC CONCEPT

Simulation assumptions, processes and parameters. Preliminary results

FIML project team: Gerd Kuhlmann, Benedikt Oliver Müller, Christian Prasse, Dr. Michael Schmidt, Lucas Schreiber, Frederic Veit

Fraunhofer IML

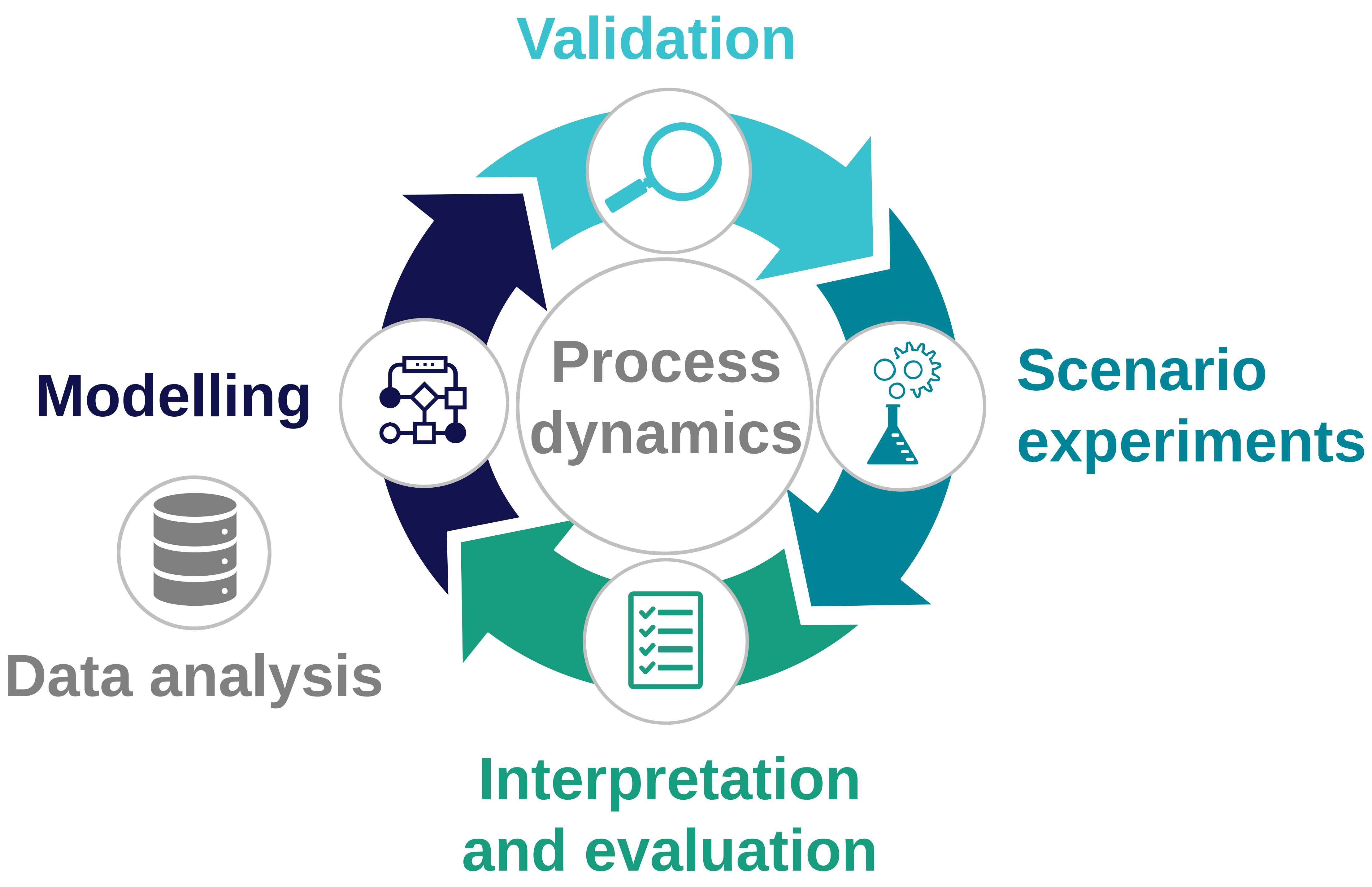
Content

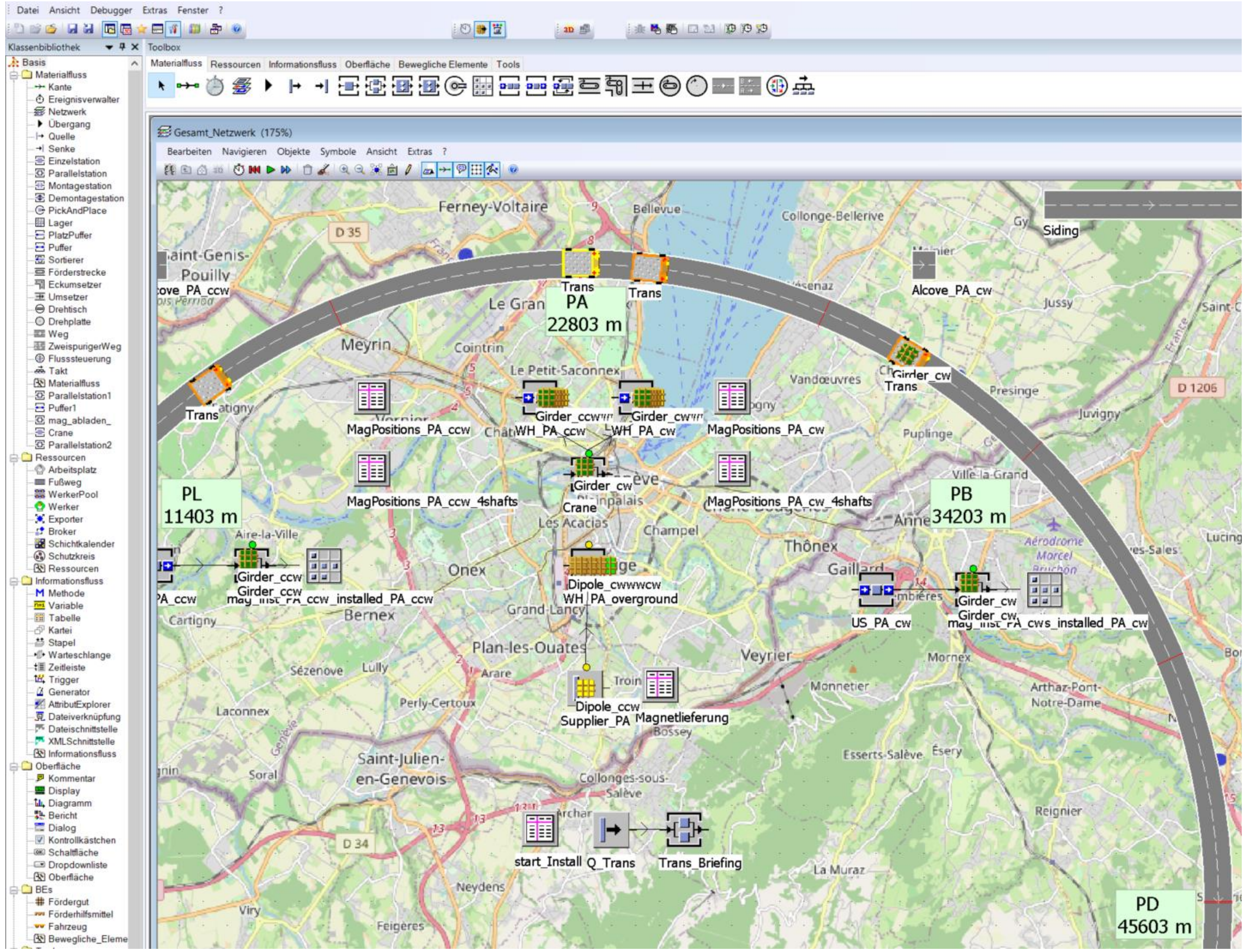
Topics for today

Material flow simulation with Plant Simulation

Simulation procedure and simulation tool

Procedure of a material flow simulation study





Screenshot from Tecnomatix Plant Simulation 11

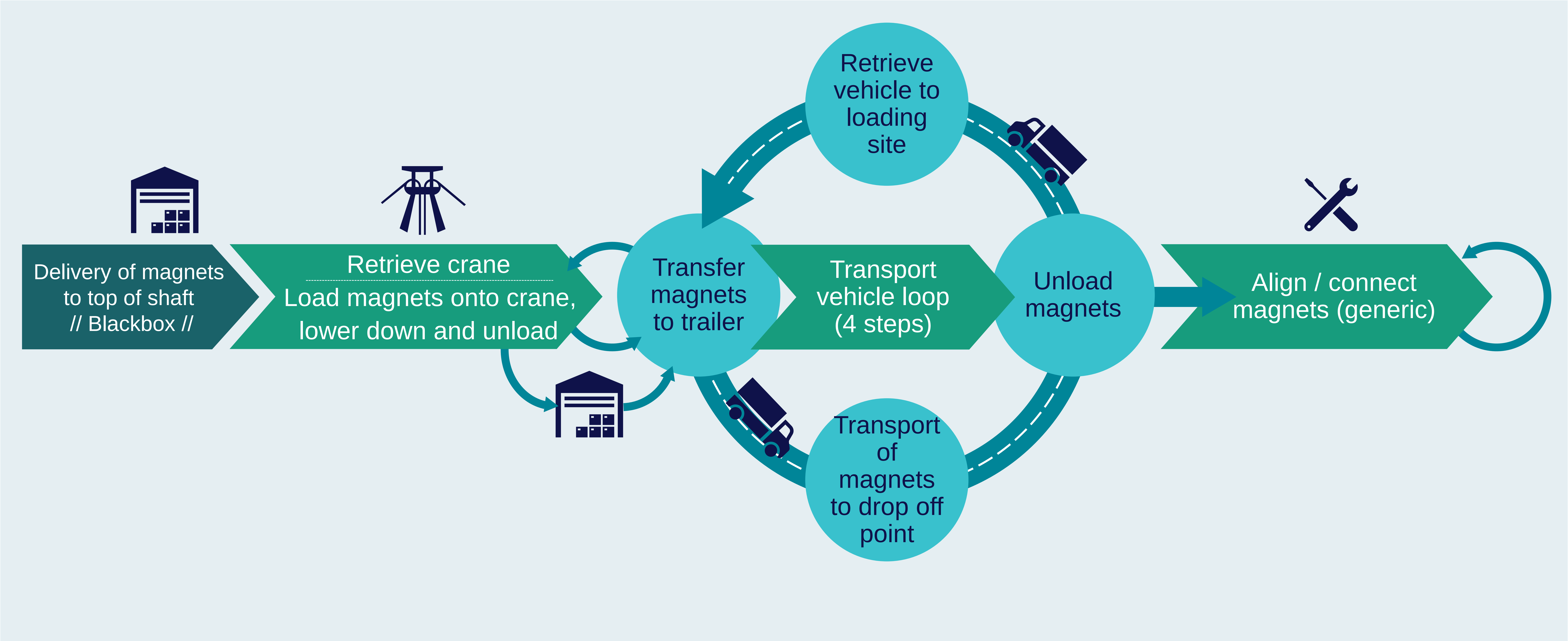
Assumptions for the simulation study

What are the circumstances for the simulation? (non-exhaustive list)

General	Tunnel is handed over from civil engineering in a completed state	Technical infrastructure is installed → ready to transport and install magnets	During the time of magnet transport and installation there is no other traffic in the tunnel	Each shaft for magnet transport is a separated system and not influenced by the other shafts
Infra-structure	For each magnet shaft there is an overground storage area nearby to load the crane	A limited number (tbd) of magnets can be stored at the bottom of the shaft	Magnet transports access the installation front from the front and instalment teams from the back	There is a limited number of enlargements in the tunnel so that vehicles can pass each other
Process	Magnet transports are not allowed to pass positions where installation teams are working	Collider ring and booster ring can be installed simultaneously	Dipoles arrive in transport units of three	Quadrupoles and sixtupoles arrive preinstalled on a girder as a transport unit

Process for the simulation study

Which process steps are considered in the simulation?



Parameters for the simulation study

What information is the simulation based on?

Parameter	Value	Information maturity
Length of tunnel	91200 m	Given by CERN
Enlargements for transport passing	16 overall (8 shafts + 8 enlargements)	Given by CERN
No. of magnets overall	8832 (2944 half cells with 2 dipoles + 1 girder)	Given by CERN
Load crane, lower down magnet and retrieve crane	90 min	Rough guess by CERN
Magnet transfer time from crane to vehicle and enter tunnel	50 min	Estimated by IML
Unloading time vehicle	23 min	Estimated by IML
Vehicle driving velocity loaded	10 km/h	Estimate by IML / design value
Vehicle driving velocity unloaded	20 km/h	Estimate by IML / design value
Aligning and connecting time per magnet / girder	4 h	Rough guess by IML
No. of installation teams per magnet shaft	4 teams	Variable in further experiments
Underground buffer capacity for magnets at shaft	2 transport units	Variable in further experiments
No. of shafts for magnet transport	2 or 4 shafts	Variable
No. of vehicles operating per shaft	2 or 4 vehicles	Variable

Result overview

Key data at a glance

Summary	Scenario	2s2v	2s4v	4s2v	4s4v
	KPI	Value	Value	Value	Value
General	Overall simulation time [h]	5928*	5496*	2760*	2760*
Magnet transport	Transport time [h]	5424	4584	2304	2280
	Magnets transported per day and shaft	20	23	23	23
Magnet aligning and connecting	Aligning and connecting time [h]	5904*	5472*	2736*	2736*
	Magnets aligned and connected per day and shaft	18*	19*	19*	19*
Transporters waiting at shaft for crane with magnet	No. of times waiting for magnet	865	2440	865	1223
	Accumulated total waiting for crane time [hh:mm:ss]	735:21:59	3149:32:22	741:48:04	1734:48:20
	Avg waiting for crane time [hh:mm:ss]	0:51:00	1:17:27	0:51:27	1:25:07
Transporter waiting for other transporters to pass by	No. of encounters	0	2449	0	1221
	Accumulated total encounter waiting time [hh:mm:ss]	0:00:00	2664:00:52	0:00:00	1866:18:18
	Avg encounter waiting time [hh:mm:ss]	0:00:00	1:05:21	0:00:00	1:31:56

s = shafts

v = vehicles per shaft

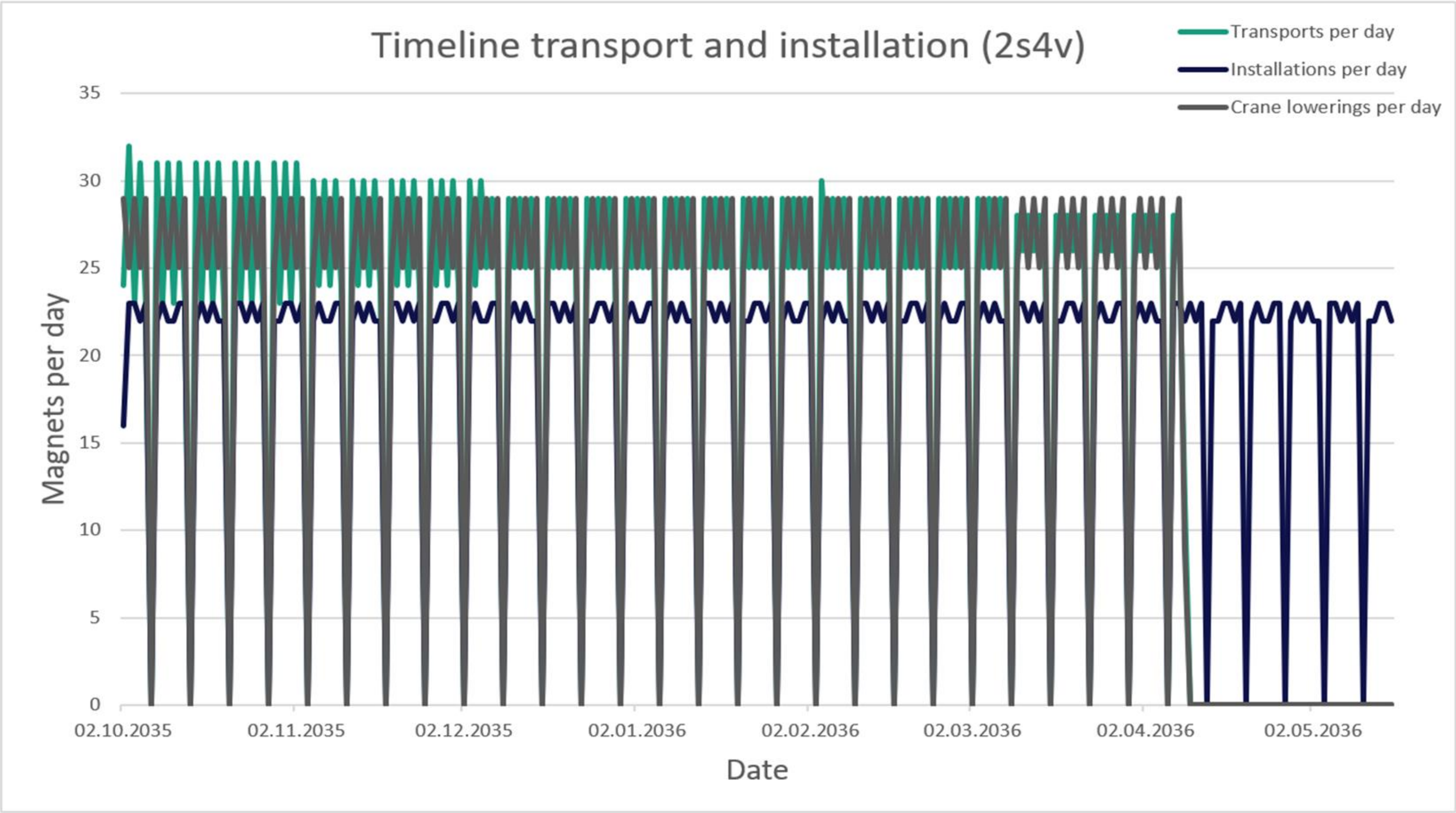
Important notes

- The results are pure absolute values and don’t include a contingency margin.
- Data basis and therefore results for magnet alignment and connecting time are not sufficient yet (marked with *)

Result key learnings

Scenario similarities

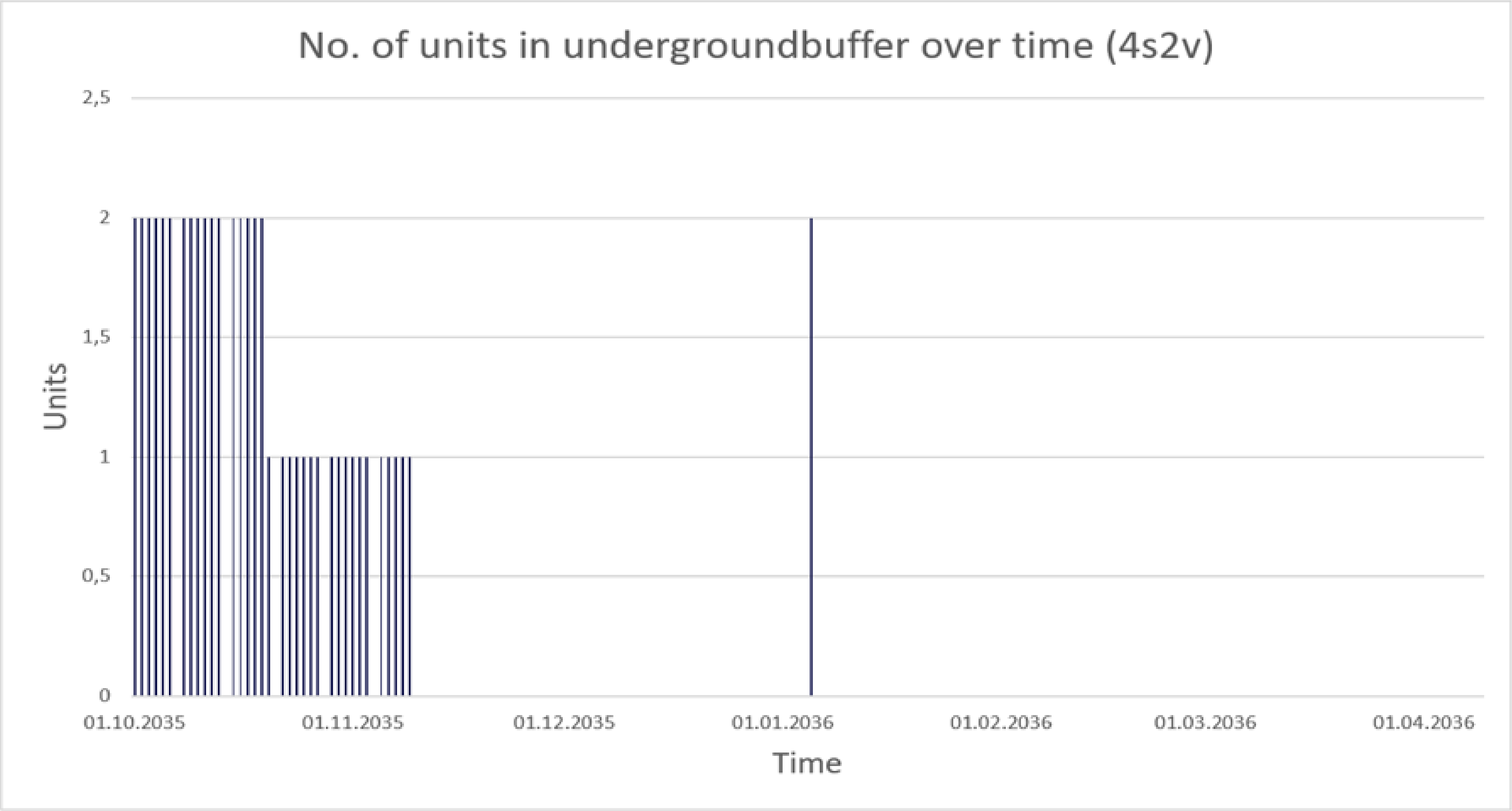
- For all scenarios, lowering down the magnets into the shaft via crane is the bottle neck of the process, to be seen in:
  - High waiting time of transporters at the shaft
  - Magnet transport frequency is as high as magnet lowering frequency
  - Low underground buffer utilization
- Underground buffer is only needed in the beginning



Result key learnings

Scenario differences - focus on 2s4v and 4s2v

- In terms of magnet transport frequency 2s4v and 4s2v are equal, however, due to twice as much magnet access shafts, 4s2v (2760 hours) is twice as fast as 2s4v (5496 hours)
  → about 4 months
- In 4s2v, transporters have a higher utilization due to less waiting time for magnets and other transporters
  → about a third of the waiting time in 2s4v
- Using more than 2 vehicles in a 4-shaft setting has no effect due to the crane already working on its limit
- 4s2v is more resilient to crane failure



Recommendations

What actions do we recommend

1	Trade-off between time and resilience vs. costs to decide whether to use 2 magnet shafts or 4	Is it worth preparing two additional shafts for lowering the magnets and doubling the number of vehicles to halve the total transport time and be more resilient to crane failure?
2	Validate crane times and explore possibilities to increase the frequency of lowering down the magnets into the shaft	Being the bottleneck, reducing the crane time can have a significant effect on the overall transport time (to be tested)
3	Reserve space for a small magnet buffer (2–4 units) at the bottom of the shaft	This might be even more important, if it is possible to increase the crane speed (to be tested)

Further experiments

Next potential steps for exploration (non-exhaustive list)

Set the number of alignment and connection teams

Include mature information on magnet alignment and connection

Quantify the potential of improvement for faster crane time

Add transport of further material (technical infrastructure etc.) to simulation

Check how crane failure affects the overall duration

Fine tune parameters and do further experiments with different parameters (in general)

Review the importance of the underground buffer with different crane times

…

Thank you for your attention

Fraunhofer IML

Benedikt Oliver Müller, M.Sc.
Research associate
Supply Chain Engineering
Team Supply Chain Management

Fraunhofer-Institut für Materialfluss und Logistik IML
Joseph-von-Fraunhofer-Str. 2-4
D-44227 Dortmund, Deutschland

Telefon: +49 (0) 231 9743-559
E-Mail: benedikt.oliver.mueller@iml.fraunhofer.de

Appendix A

Full list of assumptions for the simulation study

- Tunnel is handed over from civil engineering in a completed state
- Technical infrastructure is installed → ready to transport and install magnets
  - Cooling and ventilation
  - Marking
  - Cabling
  - Alignment jacks and supporting structure / racks
- Quadrupoles and sixtupoles arrive preinstalled and aligned on a girder and represent one transport unit
- One girder at a time can be transported (crane and vehicle)
- Three dipoles at a time can be transported as one unit (on crane and vehicle) → three dipoles = dipole pack
- Handling, loading and transferring times of girder and dipole pack don‘t differ
- Dipole pack will be unloaded by one dipole at a time, resulting in three times the unloading time for a dipole pack in comparison to the girder
- During the time of transport and installation of the magnets there is no other traffic in the tunnel
- A limited number (tbd) of dipole packs and girders can be stored underground at the bottom of the shaft to keep the crane running
- 2 or 4 shafts are access points for magnets
- All 8 shafts are access points for people
- Magnet transports are not allowed to pass positions where installation teams are working on aligning and connecting the magnets
- Magnet transport and people transports can drive next to installed collider and booster ring
- Girder and dipole packs can be transported with the same type of trailer
- Loaded transporters have the right of way -> good assumption? Maybe adjust simulation
- Collider ring and booster ring can be installed simultaneously
- For each shaft there is a overground storage area nearby to directly load the crane from there
- Each shaft for magnet transport is a separated system and not influenced by the transporters of other shafts