AP4 - BIM för produktionsstyrning av platsgjutna betongkonstruktioner i kallt klimat

AP4 - Planning and construction of cast-on-site concrete buildings in cold climate

Smarta plan-, bygg- och förvaltningsprocesser över hela livscykeln

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Tim Johansson, LTU
Mats Emborg Betongindustri/LTU

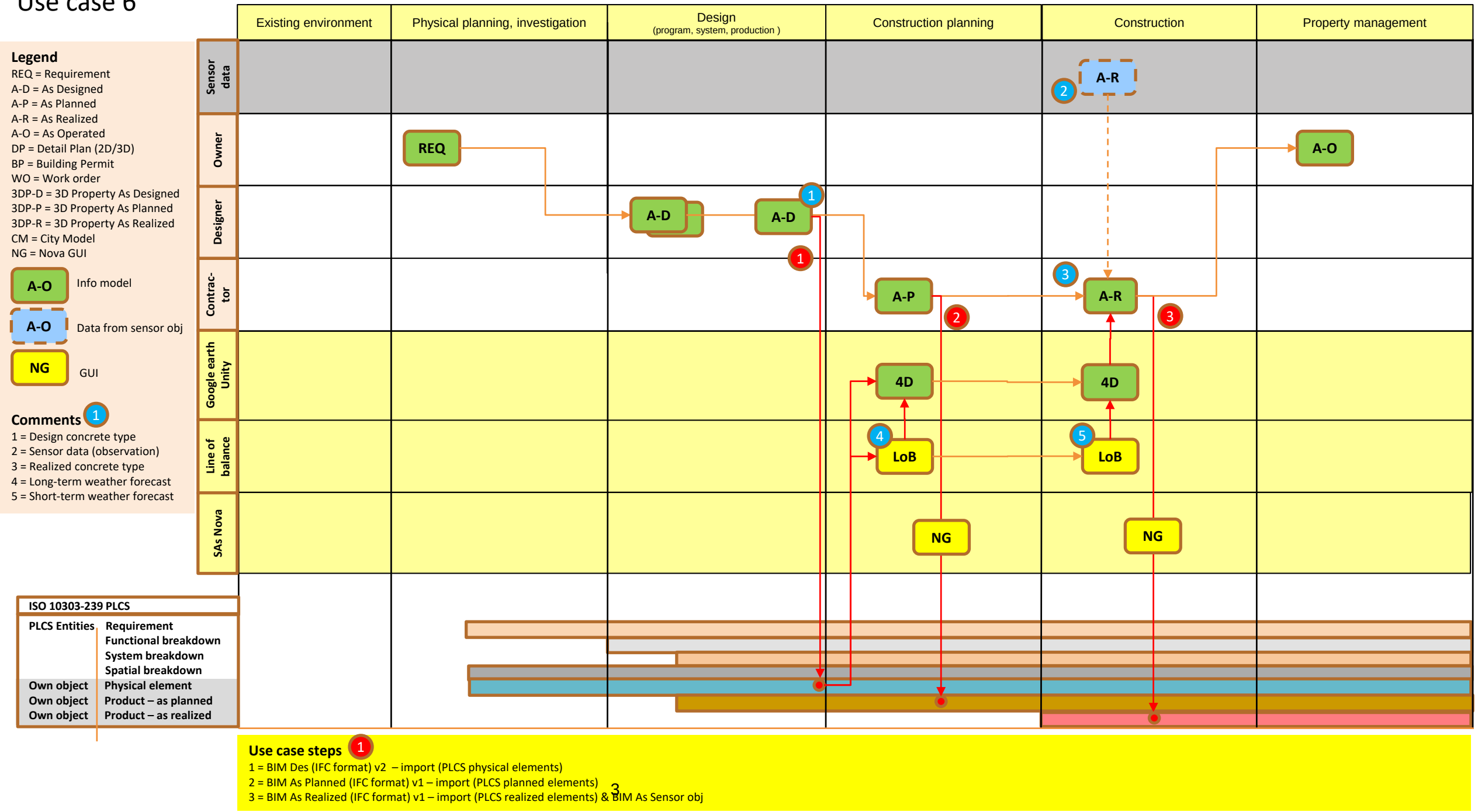
SMART BUILT ENVIRONMENT

Testbed Use Cases

1. Linking Municipality planning & Building Design process
2. Moving from Architectural design model to (planned and) as_realized models
3. Linking City model building to Building
4. Linking 3D real estates and the individual elements to the BIM model in Nova
5. Linking Sensor data to Realized objects (and then linking to their designed objects for requirement values?)
6. **Planning and construction of cast-on-site concrete buildings (from product as planned to product as realized)**

SMART BUILT ENVIRONMENT

Use case 6


Existing environment
Physical planning, investigation
Design
(program, system, production)
Construction planning
Construction
Property management
Sensor data
Owner
Designer
Contrac-tor
Google earth Unity
Line of balance
SAs Nova
REQ
A-D
A-D
A-P
A-R
A-R
A-O
4D
4D
LoB
LoB
NG
NG
1
2
3
4
5
Legend
REQ = Requirement
A-D = As Designed
A-P = As Planned
A-R = As Realized
A-O = As Operated
DP = Detail Plan (2D/3D)
BP = Building Permit
WO = Work order
3DP-D = 3D Property As Designed
3DP-P = 3D Property As Planned
3DP-R = 3D Property As Realized
CM = City Model
NG = Nova GUI
A-O Info model
A-O Data from sensor obj
NG GUI
Comments
1 = Design concrete type
2 = Sensor data (observation)
3 = Realized concrete type
4 = Long-term weather forecast
5 = Short-term weather forecast
ISO 10303-239 PLCS
PLCS Entities
Requirement
Functional breakdown
System breakdown
Spatial breakdown
Own object
Physical element
Own object
Product – as planned
Own object
Product – as realized
Use case steps
1 = BIM Des (IFC format) v2 – import (PLCS physical elements)
2 = BIM As Planned (IFC format) v1 – import (PLCS planned elements)
3 = BIM As Realized (IFC format) v1 – import (PLCS realized elements) & BIM As Sensor obj

Background

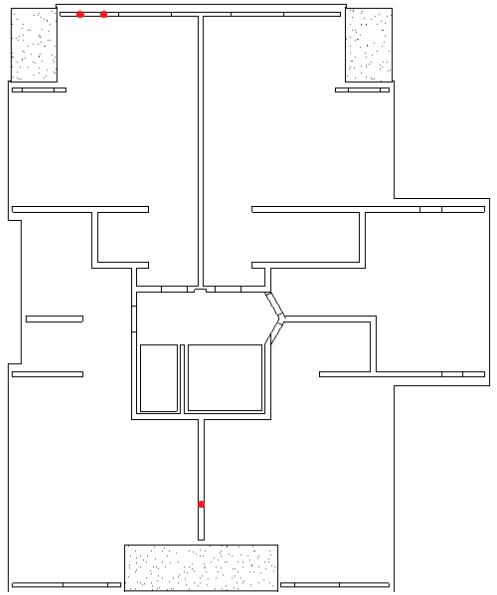
- Concrete hardening is dependent on the temperature
- Type of concrete hardening measures need to be selected according to weahter conditions
- The concrete mix is cooling during transport, casting and hardening.
- Measure how much!

- Concrete hardening measures:
  - Cover and insulate
  - Increase the temperature of the ready mixed concrete ”hot concrete”
  - Heat the surrounding air and/or surrounding building parts
  - Use heating cables in the concrete mix
  - Select a concrete recipe with higher strenght and faster hardening process

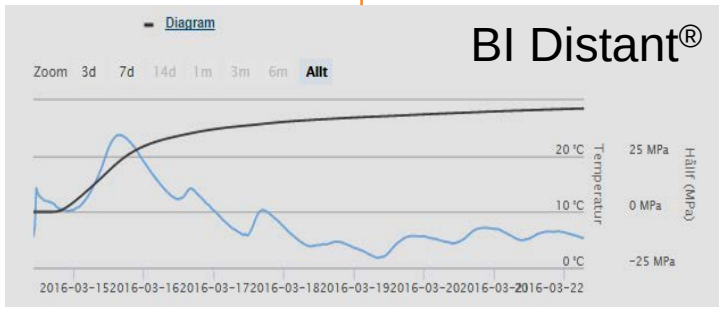
SMART BUILT ENVIRONMENT

Case: NCCs Folkboende koncept

- Project in Nordmaling



- Cast-on-site concrete framework
  - Casting of slab - removal of formwork ~15 days, requirement 70% of design concrete strength.
  - Casting of walls (removal of formwork 16-18 hours req. concrete strength >5 MPa



BI Distant®

- Planning and follow-up of curing using temperature sensors

Possible planning and follow-up tools

- BIM modell
- Planning using Line of balance
- PPB – Swedish software for planning of production of cast-on-site constructions
- BI – distant logging of measurements

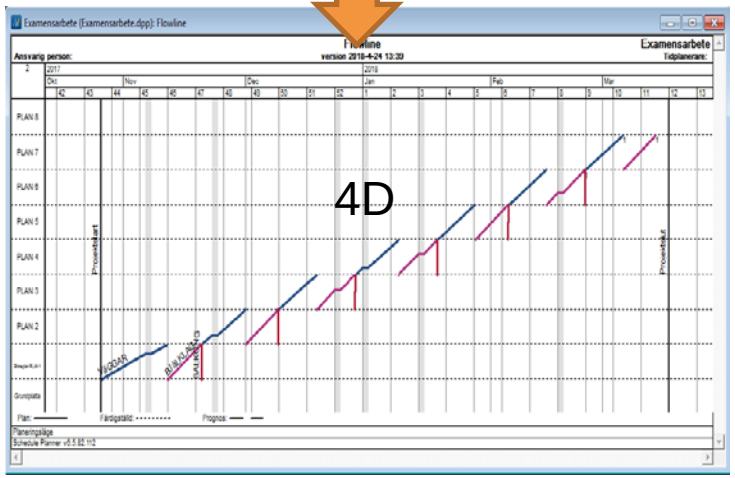
BI Distant®

SMART BUILT ENVIRONMENT

Current workflow

RVT

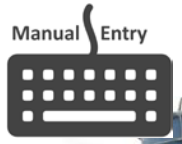
VICO OFFICE



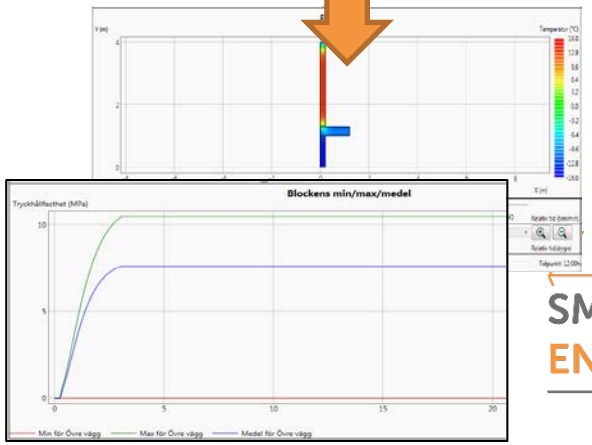
- hardening
- insulation
- heating
- How is the production affected?

SMHI

Forecast



Forecast Measurement



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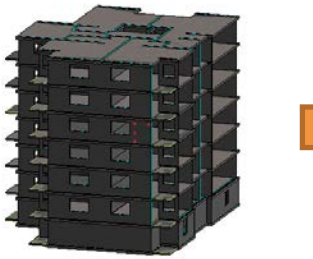
Prototype I - workflow

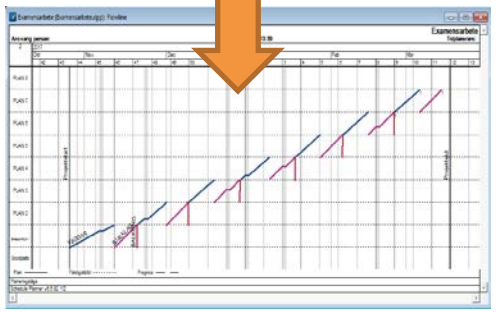


RVT

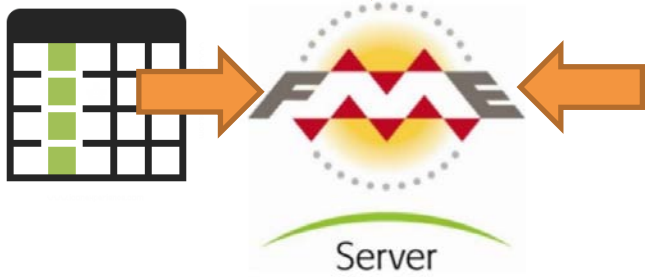
IFC

Nova
ShareAspace

VICO OFFICE



IFC



Server

KMZ

CityPlanner

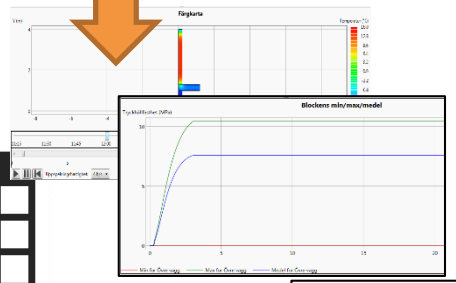
4D

SMHI

Manual Entry

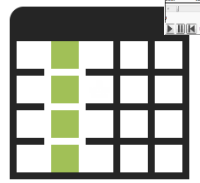
Prognos

Produktionsplanering Betong

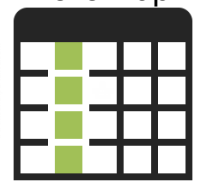


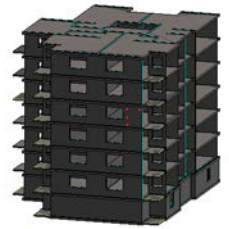
Manual Entry

Prognos



Follow-up

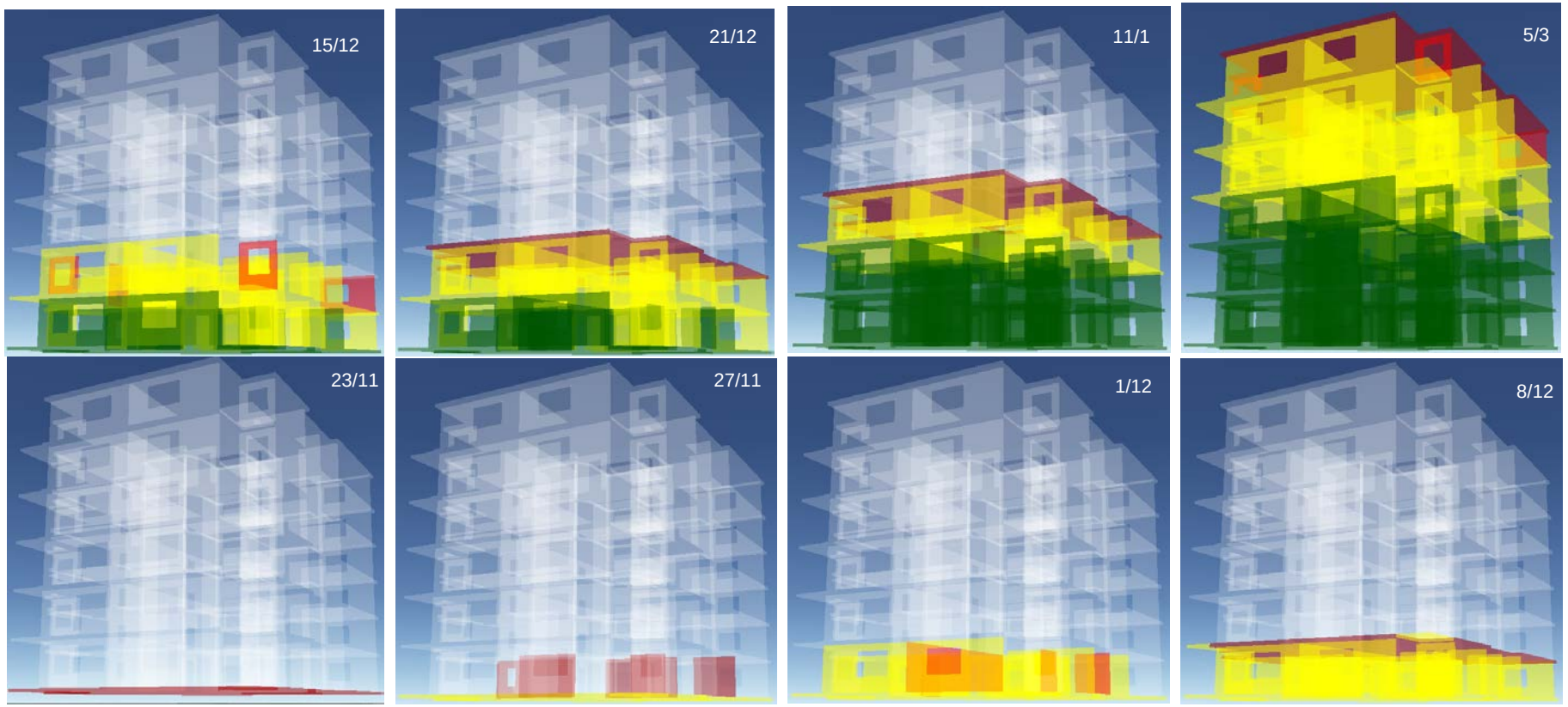




- Hardening?
- insulated formwork?
- Heating?
- Time of removal of formwork?

SMART BUILT ENVIRONMENT

Prototyp I – 4D



Ok to remove wall formwork

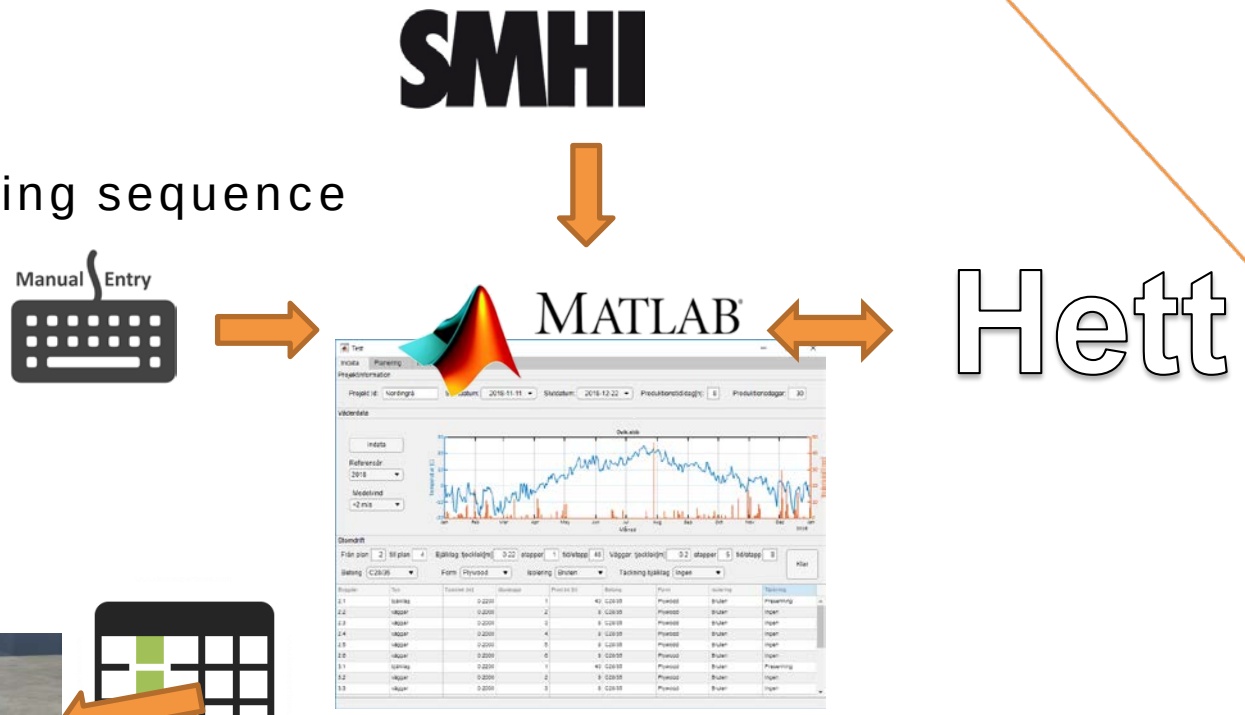
Color codes
- Red < 0-5 Mpa
- Yellow < 25 MPa
- Grön > 25 MPa (70%)

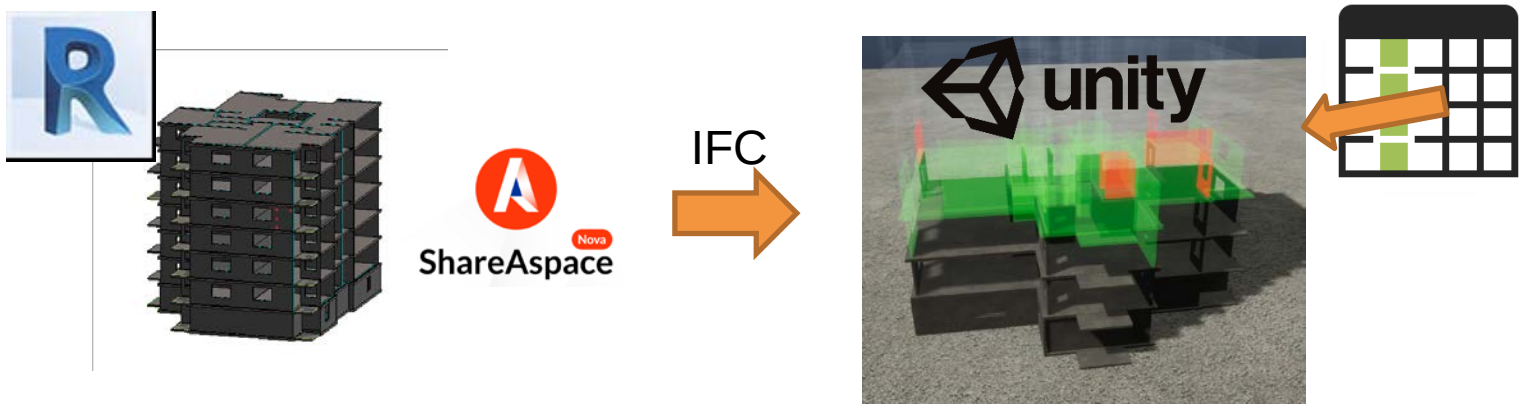
Ok to remove slab formwork

SMART BUILT ENVIRONMENT

Prototyp II – workflow

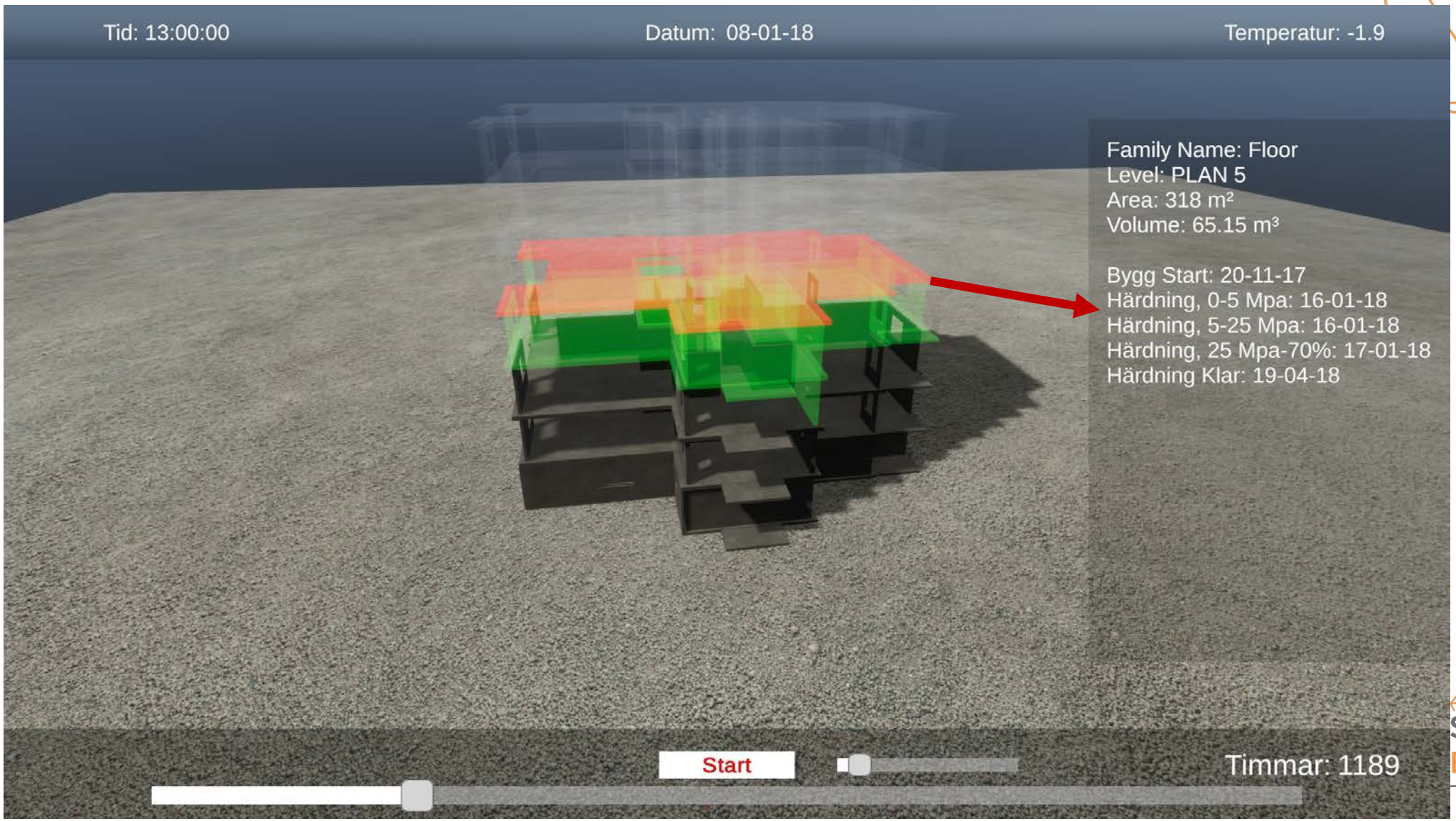
- Integration planning, weather forecast and curing measures
  - Casting sequence
  - Curing measures
  - Import of SMHI data
- 4D visualisation using UNITY





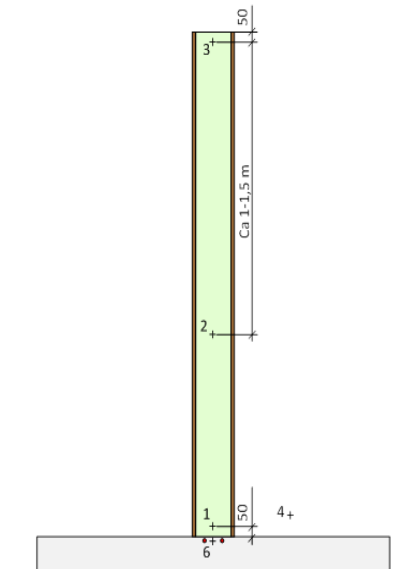
SMART BUILT ENVIRONMENT

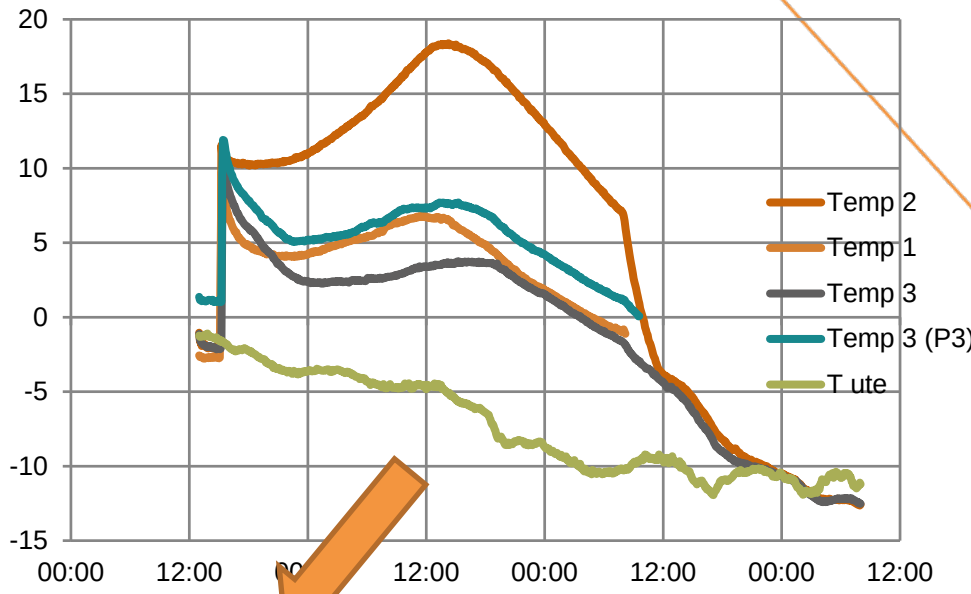
Prototype II -4D

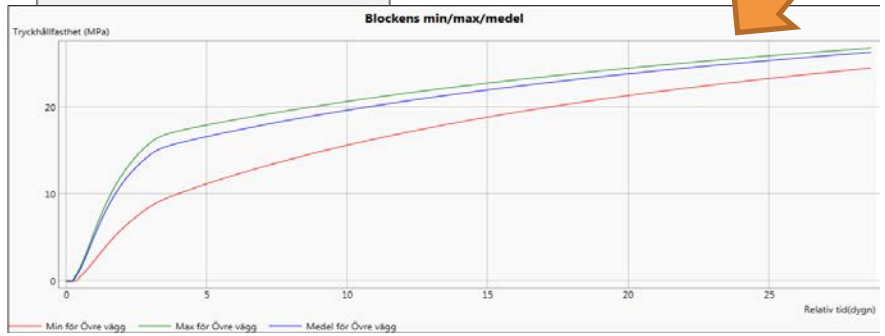


SMART BUILT ENVIRONMENT

Example – temperature measurements



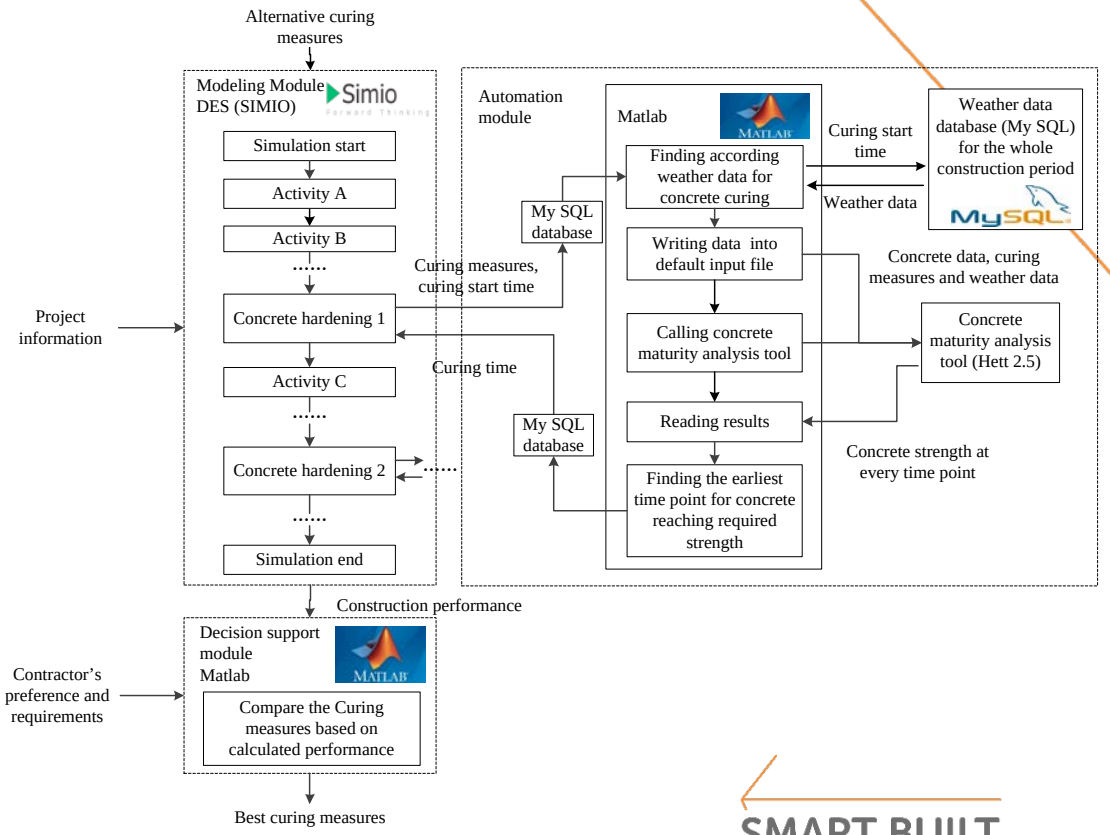




SMART BUILT ENVIRONMENT

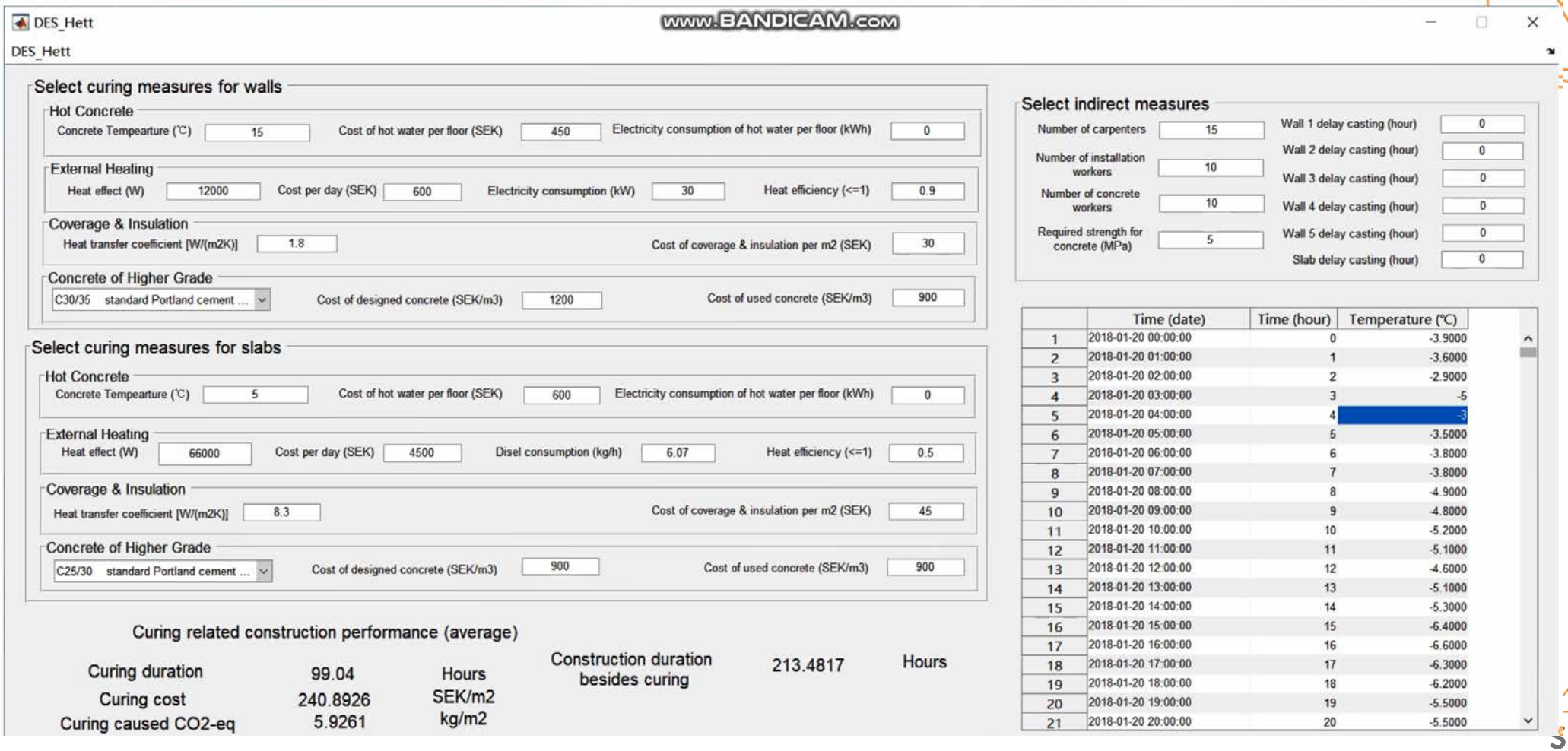
Prototyp III – Optimization of curing measures

- How choice of curing measures affect production cost, time and CO_{2eq}
- Simulating work and curing process using Discrete Event Simulation and Hett
- The evaluation is based on the concrete materials used, the energy and time used for production of the walls and slabs



SMART BUILT ENVIRONMENT

Prototyp III – Optimization of curing measures



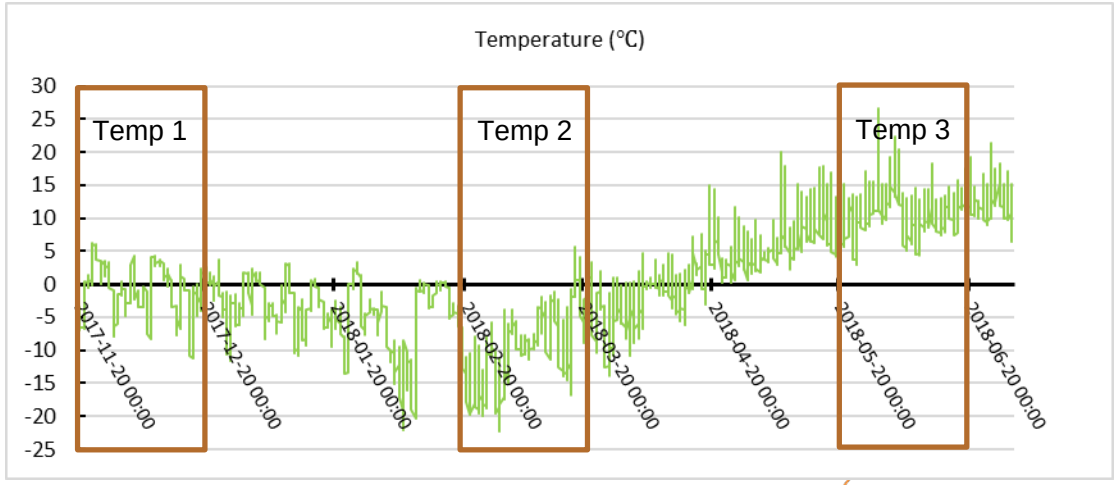
SMART BUILT ENVIRONMENT

Prototyp III – Optimization of curing measures

Curing measure Walls	Details
Hot concrete	Concrete temperature when curing starts: 5℃
	Concrete temperature when curing starts: 25℃
Heating	Heating cables, heat effect: 12 kW
	Heating cables, heat effect: 6 kW
Coverage & insulation	12mm plywood formwork with insulation, heat transfer coefficient: 1.8 W/(m^2 K) (when wind speed is lower than 2m/s)
	12mm plywood formwork without insulation, heat transfer coefficient: 5.4 W/(m^2 K) (when wind speed is lower than 2m/s)
Concrete of higher grade	C25/30, standard Portland cement
	C28/35, standard Portland cement

Curing measure Slabs	Details
Hot concrete	Concrete temperature when curing starts: 5℃
	Concrete temperature when curing starts: 25℃
Heating	Steam heating, heat effect: 48 kW; diesel consumption: 4.4 kg/h
	Steam heating, heat effect: 66 kW; diesel consumption: 6.07 kg/h
Coverage & insulation	Slab cover, normal tarps, heat transfer coefficient: 8.3 W/(m^2 K) (when wind speed is lower than 2m/s)
	Slab cover, insulated tarps, heat transfer coefficient: 2.7 W/(m^2 K) (when wind speed is lower than 2m/s)
Concrete of higher grade	C25/30, standard Portland cement
	C28/35, standard Portland cement

Curing measure Walls & Slab	Details
Changing number of workers	Carpenters: 10; Concrete workers: 10; Installation workers: 10.
	Carpenters: 15; Concrete workers: 15; Installation workers: 15.
Changing wall casting delay	No delay
	Delay 15 hours for each wall casting
Changing slab casting delay	No delay
	Delay 15 hours



A total of 228 variants have been calculated for Temp 1 2 and 3

SMART BUILT ENVIRONMENT

Prototyp III - Optimization of curing measures

- The combination of curing measures combines external heating, insulation and warmer concrete mix

- During certain conditions (temperature/cementtype/energy mix) it is better to select a higher strength concrete mix compared with external heating

Best combinations compared to reference scenario A1

Construction start time	Shortest curing duration	Lowest curing caused CO_2 emissions	Least curing cost	Pareto solutions
Nov 20th 2017	A40 -56%	A18 -66%	A26 -15%	A2, A4, A10, A18, A26, A34, A36, A38, A40, A42, A44, A50, A52, A54, A56, A58, A62
Feb 20th 2018	A40 -60%	A18 -70%	A58 -18%	A2, A4, A18, A34, A36, A38, A40, A42, A50, A52, A54, A58, A62
May 20th 2018	A40 -53%	A26 -54%	A26 -4%	A2, A4, A10, A12, A26, A34, A36, A40, A42, A44, A46, A52, A56, A58, A62, A64

SMART BUILT ENVIRONMENT

Further research and development

- Include drying out time of concrete slabs
- Better integration of sensors positions and historical result (machine learning) in the planning GUI
- 3D BIM > calculations > vizualisation