Automatic Generation of 4D-Schedules for reliable Construction Management
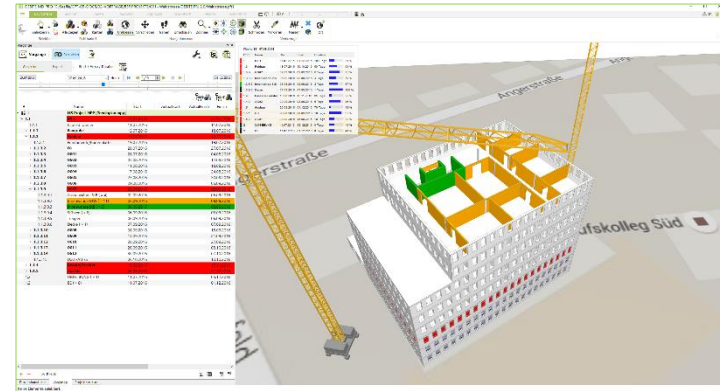
Dr.-Ing. Jochen Hanff
Geschäftsführer
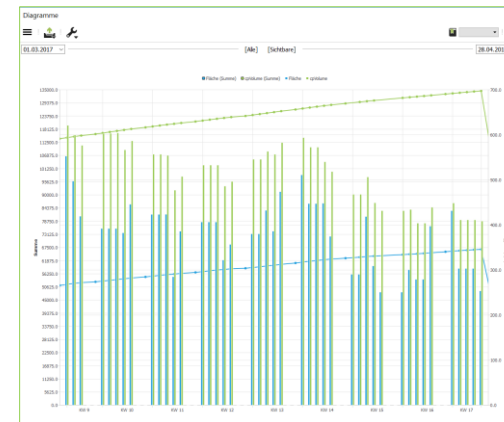ceapoint aec technologies GmbH

Dipl.-Ing. (FH), MBA Jürgen Melzner
Zentrale Kalkulation Hochbau/
modellbasierte Projektkalkulation
W. Markgraf GmbH & Co KG
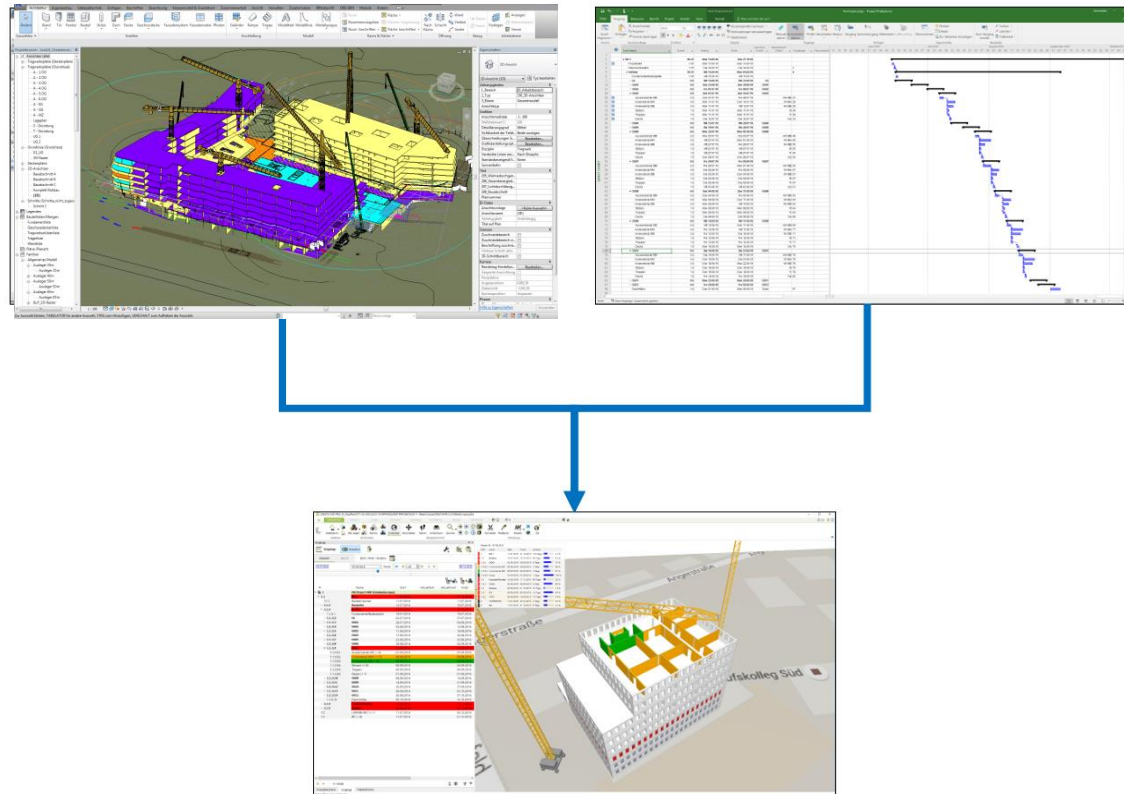
4D-Simulation – Benefits

Visualisation /
Improved communication
between stakeholders

Evaluation of Quantities / Costs

4D-Simulation – Current Situation

Automatic Generation of 4D-Simulations – New Approach

- The time schedule should be generated from the model.
  Including quantities and dependencies between activities.

- Production rates and dependencies between activities should be stored
  in a database for reuse in other projects.

- Visualisation options should be taken into account.

- Variations should be calculated easily.

- The structure of the time schedule should be controlled by the
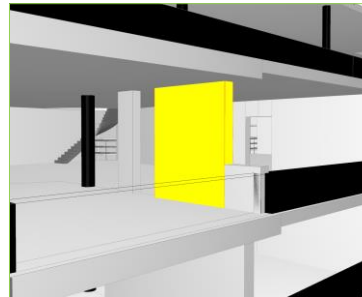 scheduler.

Approach

Process Components

and

Building Structure

Approach

Process Components
How to build

Building Structure
Where to build

Automatic Generation of 4D-Schedules for reliable Construction Management

Process Components

Process Components define activities to build a specific object
such as a column, a wall, a window as well as all other activities in a time schedule.

A Process Component can contain other Process Components.

The Level of Detail used for creating the time schedule can be chosen by the user.

Process Components define:

- Quantity and a Unit of Measurement (UoM)
- Production rate
- Resources value
- Dependencies to other process components (Finish-Start, Start-Start, …)

Process Components

#	Name	Quantity	UoM	ProductionRate	Predecessors	Ressource
∨ ■ 1	**Rohbau**	0,0000		1,0000		1,0000
∨ 1.1	**Stahlbeton**	0,0000		0,0000		1,0000
1.1.1	Bodenplatte/Fundamente herstellen (» 83)	= [[cpVolume##xs:double##geometry]]	m3	0,2000		1,0000
1.1.2	Stb. Wände herstellen (» 2693)	= [[cpVolume##xs:double##geometry]]	m3	1,4000		1,0000
1.1.3	Stb. Stützen herstellen (» 897)	= [[cpVolume##xs:double##geometry]]	m3	1,4000	0SS1.1.2;	1,0000
1.1.4	Unterzüge herstellen (» 177)	= [[cpVolume##xs:double##geometry]]	m3	0,9000		1,0000
1.1.5	Stb. Decken herstellen (» 199)	= [[cpBaseArea##xs:double##geometry]]	m2	0,1100		1,0000
∨ 1.1.6	**Stb. Wände**	0,0000		1,0000		1,0000
1.1.6.1	Einschalen	= [[Fläche##xs:double##geometry]]		1,0000		1,0000
1.1.6.2	Bewehren	= [[Fläche##xs:double##geometry]]		1,0000		1,0000
1.1.6.3	Betonieren	= [[cpVolume##xs:double##geometry]]		1,0000		1,0000
1.1.6.4	Ausschalen	= [[Fläche##xs:double##geometry]]		1,0000		1,0000
> 1.2	**Mauerwerk**	0,0000		1,0000		1,0000
> ■ 2	**Ausbau**	0,0000		1,0000		1,0000
> ■ 3	**Fassade**	0,0000		1,0000		1,0000

Catalogue

Level of Detail

Quantity

Dependencies

Building Structure

The Elements of the **Building Structure** define the location where a linked object such as a column, a wall, a window should be built.

The Elements of the Building Structure contain dependencies to other elements in the Building Structure (Finish-Start, Start-Start, …)
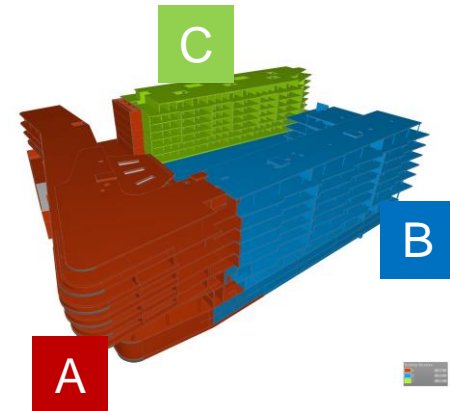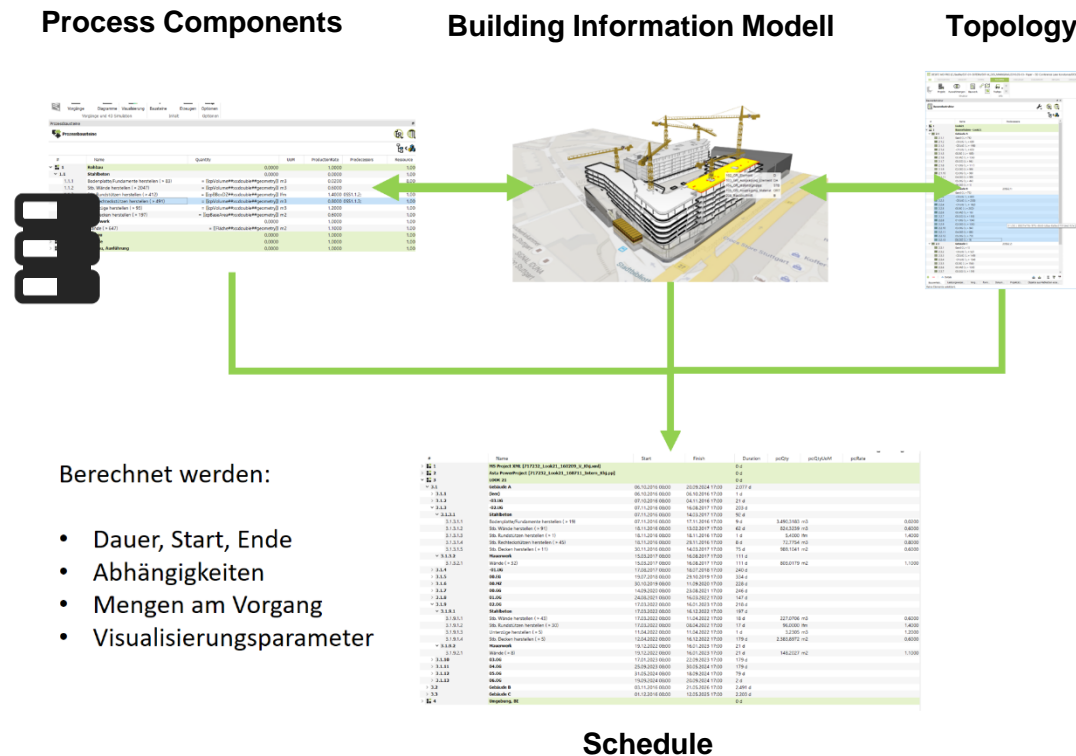
Building Structure

Hierarchy

Dependencies

"Building B starts
1 month after Building A"

Automatic Generation of 4D-Simulations – New Approach

Process Components   **Building Information Modell**   **Topology**

Berechnet werden:

- Dauer, Start, Ende
- Abhängigkeiten
- Mengen am Vorgang
- Visualisierungsparameter

Schedule

Resulting Time Schedule – Control the Hierarchy

Process Component / Activities

Building Structure / Location

PC ‚OrderFlag' = true

PC ‚OrderFlag' = false

3	**Baustelleneinrichtung**	0 d
4	**Rohbau**	0 d
4.1	**Building Structure**	2.225 d
4.1.1	**Building A**	709 d
4.1.1.1	**-03.UG**	55 d
4.1.1.2	**-02.UG**	222 d
4.1.1.3	**-01.UG**	43 d
4.1.1.4	**00.EG**	109 d
4.1.1.5	**00.MZ**	46 d
4.1.1.6	**00.GG**	52 d
4.1.1.7	**01.OG**	50 d
4.1.1.8	**02.OG**	40 d
4.1.1.8.1	**Stahlbeton**	40 d
4.1.1.8.1.1	Stb. Wände herstellen (» 43)	40 d	227,0706 m3
4.1.1.8.1.2	Stb. Stützen herstellen (» 30)	2 d	10,0941 m3
4.1.1.8.1.3	Unterzüge herstellen (» 13)	1 d	3,2305 m3
4.1.1.8.1.4	Stb. Decken herstellen (» 5)	33 d	2.383,8972 m2
4.1.1.9	**03.OG**	38 d
4.1.1.10	**04.OG**	38 d
4.1.1.11	**05.OG**	15 d
4.1.1.12	**06.OG**	1 d
4.1.2	**Building B**	660 d
4.1.3	**Building C**	856 d

AS-IS Production Rates

Actual Production Rate

4.1.1.3.1.2	Stb. Stützen herstellen (» 2)	1 d	1,4000 0	0,0000	1,0454 m3
4.1.1.3.1.3	Stb. Decken herstellen (» 10)	42 d	0,1100 0	0,0000	2.985,8241 m2
⌄ 4.1.1.4	00.EG	109 d	0	nan	
⌄ 4.1.1.4.1	Stahlbeton	109 d	0	nan	
4.1.1.4.1.1	Stb. Wände herstellen (» 92)	109 d	1,4000 48000	1,2881	621,0823 m3
4.1.1.4.1.2	Stb. Stützen herstellen (» 37)	6 d	1,4000 2400	1,2602	31,7420 m3
4.1.1.4.1.3	Stb. Decken herstellen (» 6)	49 d	0,1100 14400	0,0683	3.514,7223 m2
› 4.1.1.5	00.MZ	46 d	0	nan	
› 4.1.1.6	00.GG	52 d	0	nan	
› 4.1.1.7	01.OG	50 d	0	nan	

Actual Duration [min]

Case study
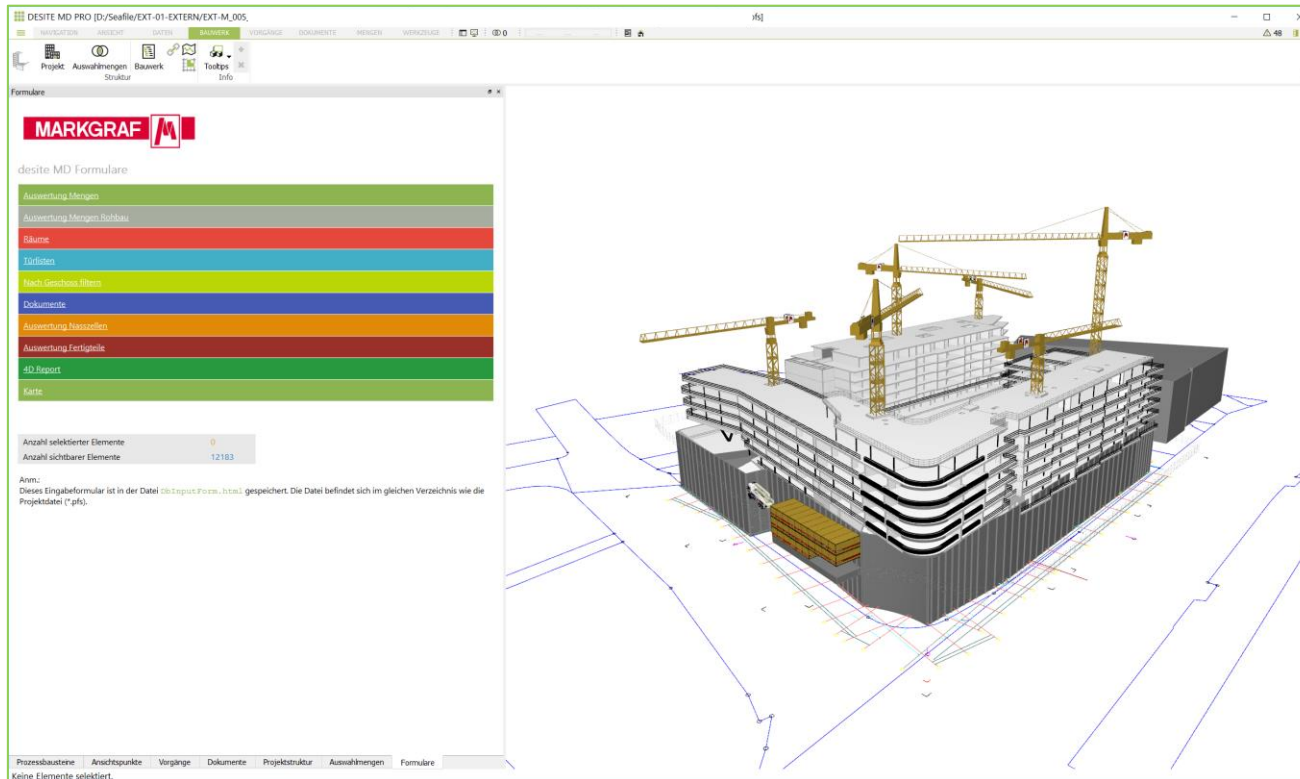
Case study - Software environment

Modelling
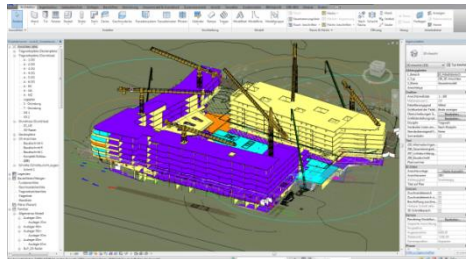
Model Management / Scheduling
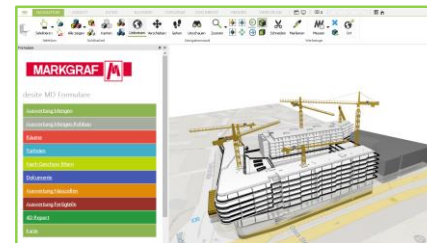
VR
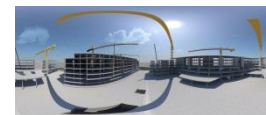
Case study - Preparatory work
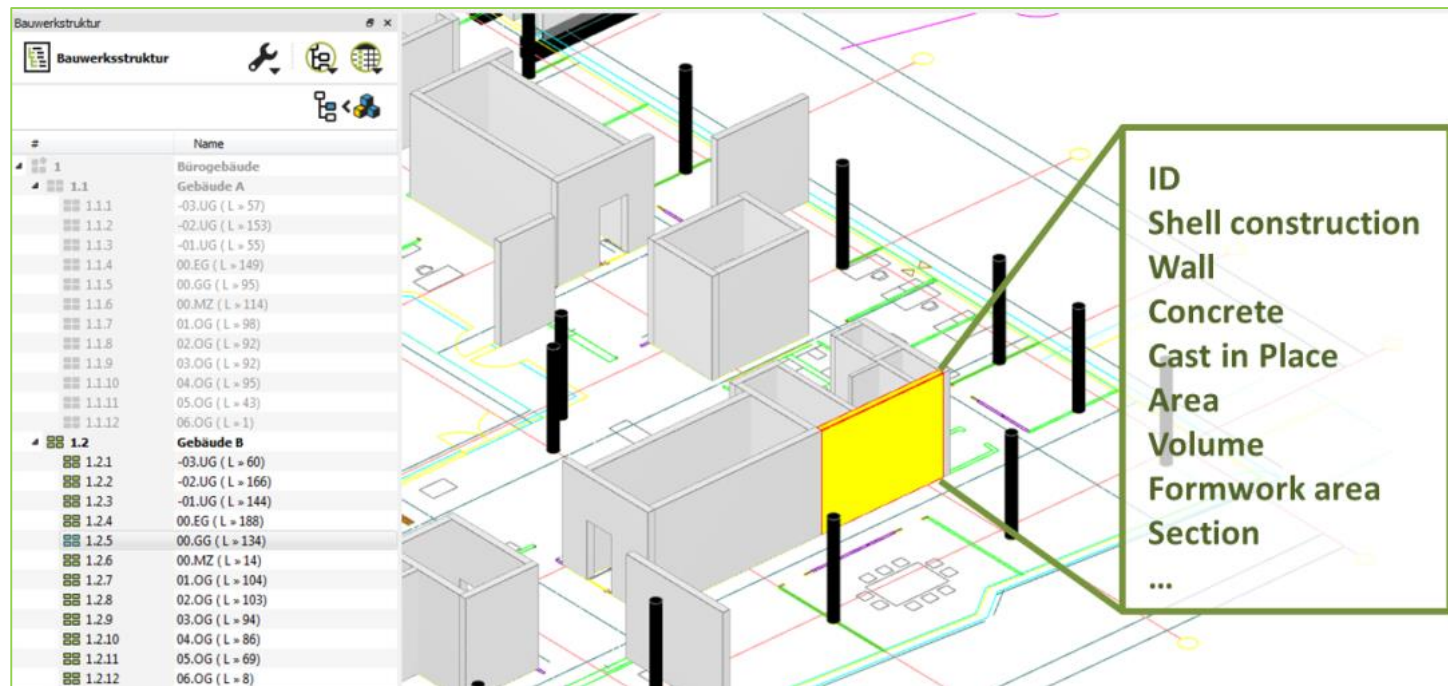
Define Building Structure - Building Section
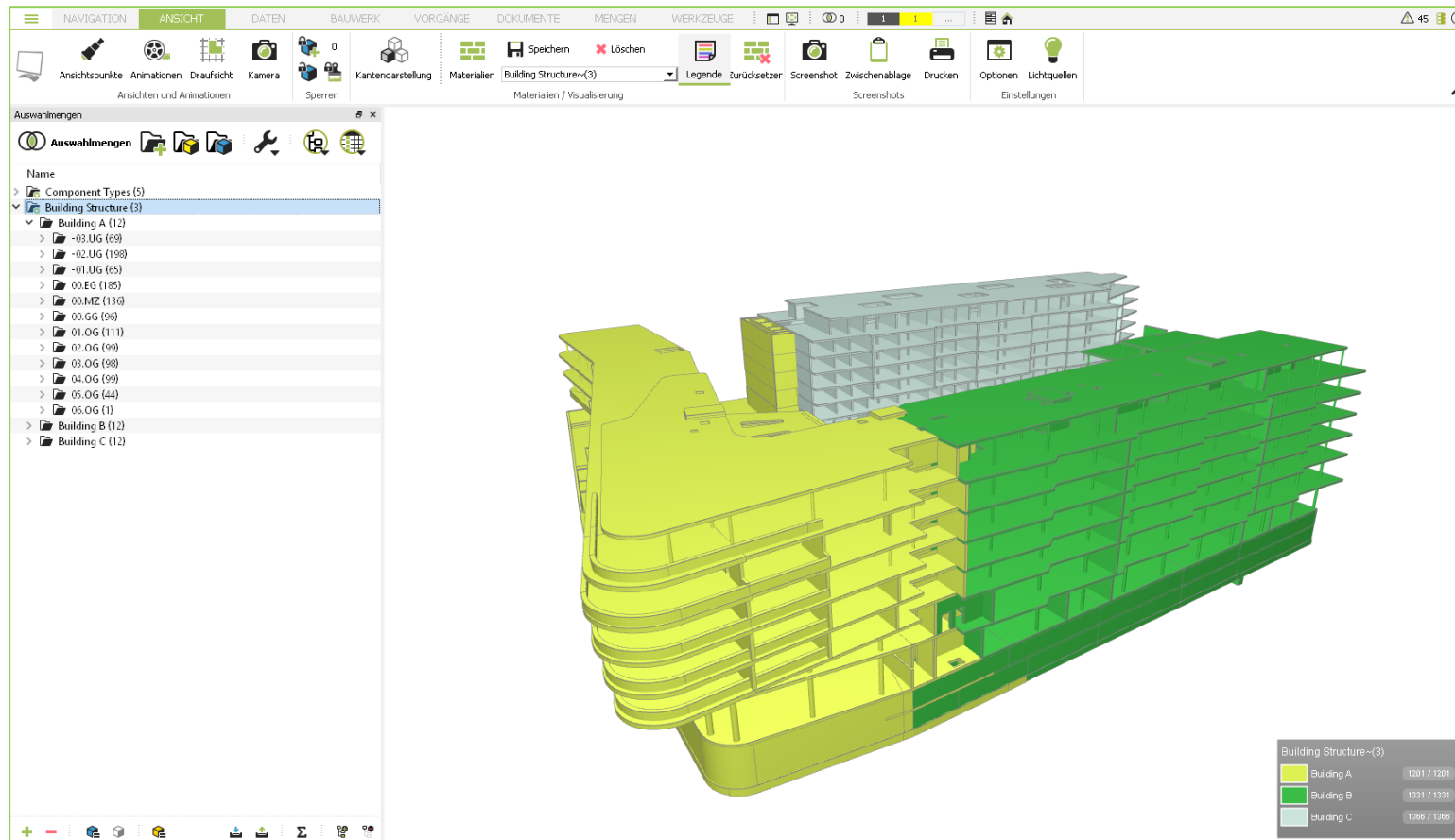
Define Building Structure - Floors
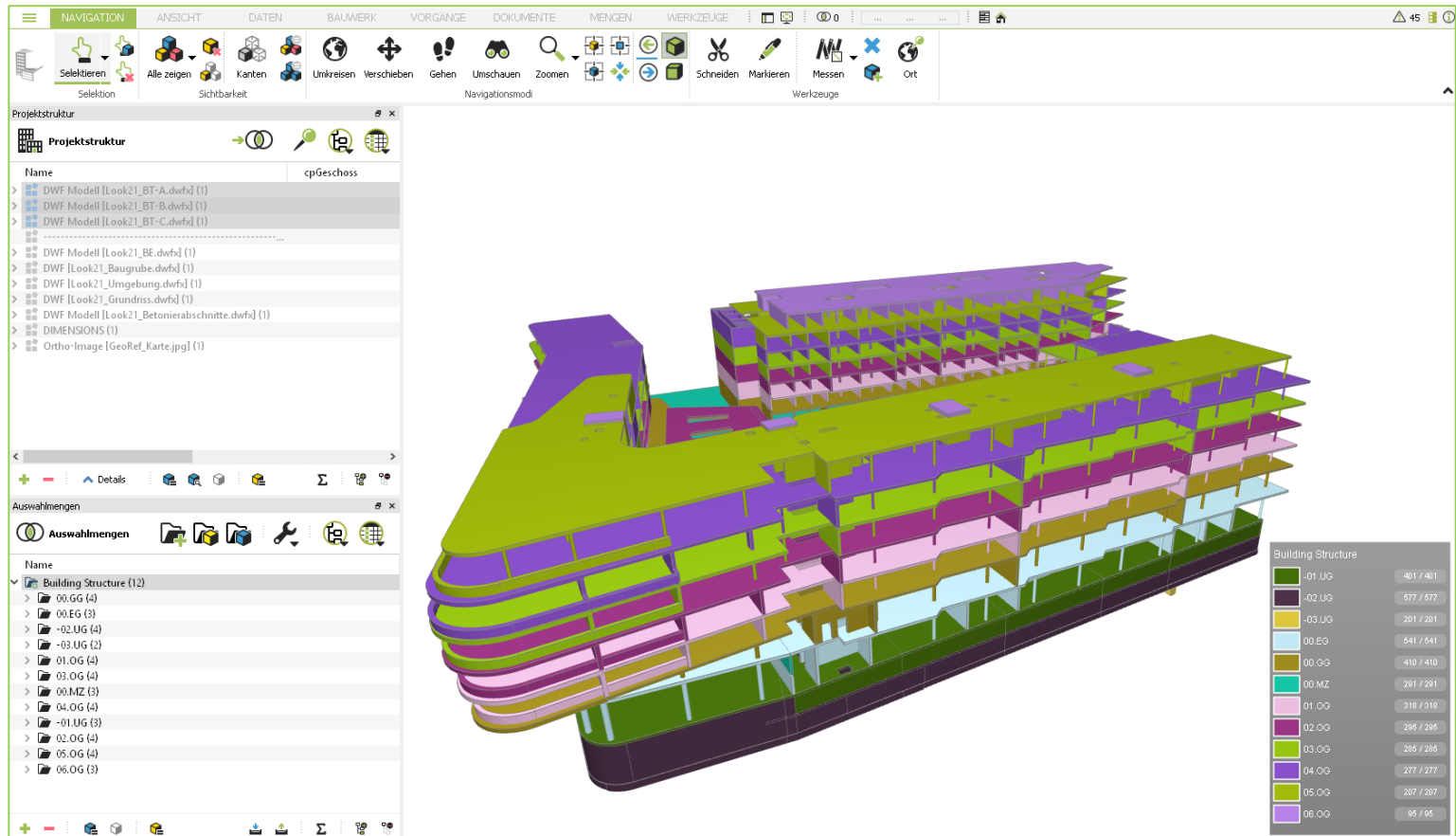
Define Building Structure - Component Types
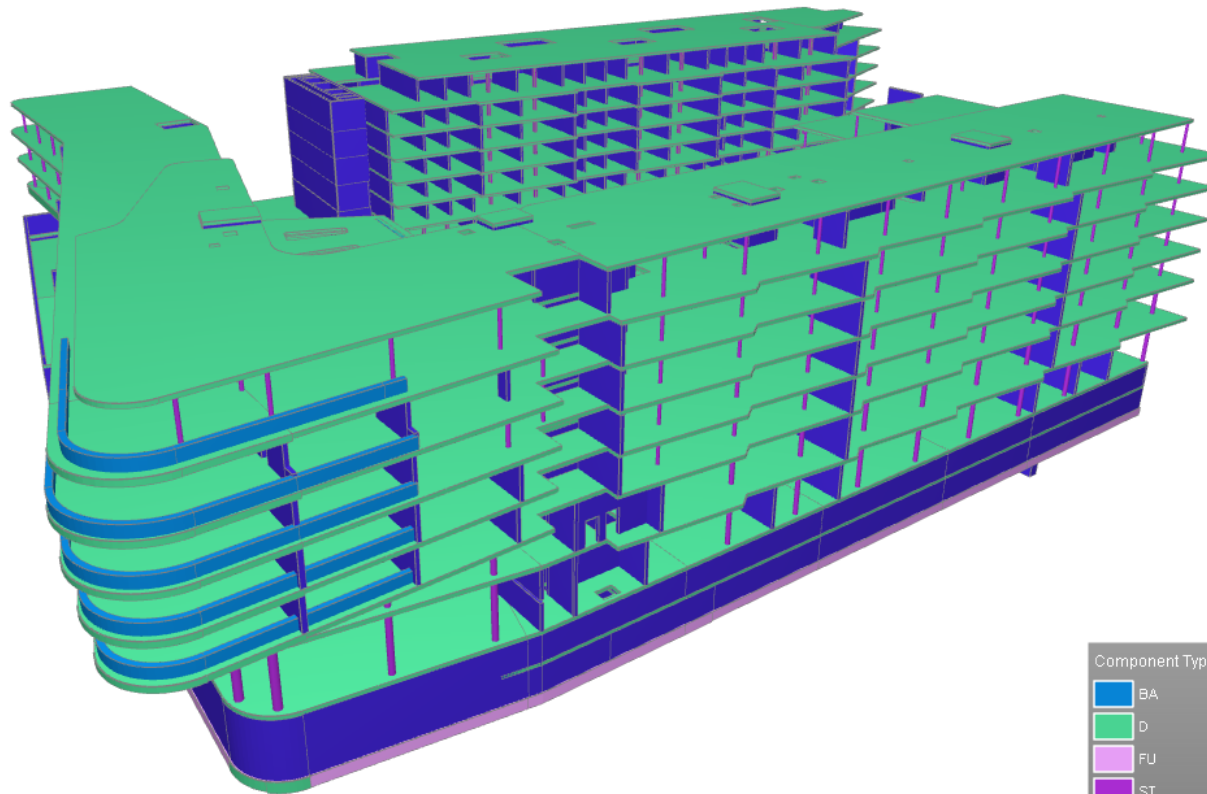
Component Types~(2)

BA	92 / 92	
D	199 / 199	
FU	83 / 83	
ST	897 / 897	
W	2693 / 2693	

Create Building Structure for Scheduling

Process Components

#	Name	ProductionRate	Quantity	UoM	Ress	TaskVisua	Predeces:	Trade	102_Bauteil
∨ 1	Rohbau	1,0000	0,0000		1,0000				
∨ 1.1	Stahlbeton	0,0000	0,0000		1,0000				
1.1.1	Bodenplatte/Fundamente herstellen	0,0200	= [[cpVolume##xs:double##geometry]]	m3	1,0000	Rohbau		Rohbau	FU
1.1.2	Stb. Wände herstellen	0,6000	= [[cpVolume##xs:double##geometry]]	m3	1,0000	Wände		Rohbau	W
1.1.3	Stb. Stützen herstellen	1,4000	= [[cpBBoxDZ##xs:double##geometry]]	lfm	1,0000	Wände	0SS1.1.2;	Rohbau	ST
1.1.4	Unterzüge herstellen	1,2000	= [[cpVolume##xs:double##geometry]]	m3	1,0000	Decken		Rohbau	BA
1.1.5	Stb. Decken herstellen	0,2000	= [[cpBaseArea##xs:double##geometry]]	m2	1,0000	Decken		Rohbau	D
> 1.2	Mauerwerk	1,0000	0,0000		1,0000	MW			
> 2	Ausbau	1,0000	0,0000		1,0000				
> 3	Fassade	1,0000	0,0000		1,0000				

Process Components → Building Elements

Create Schedule

Automatic Generation of 4D-Schedules for reliable Construction Management
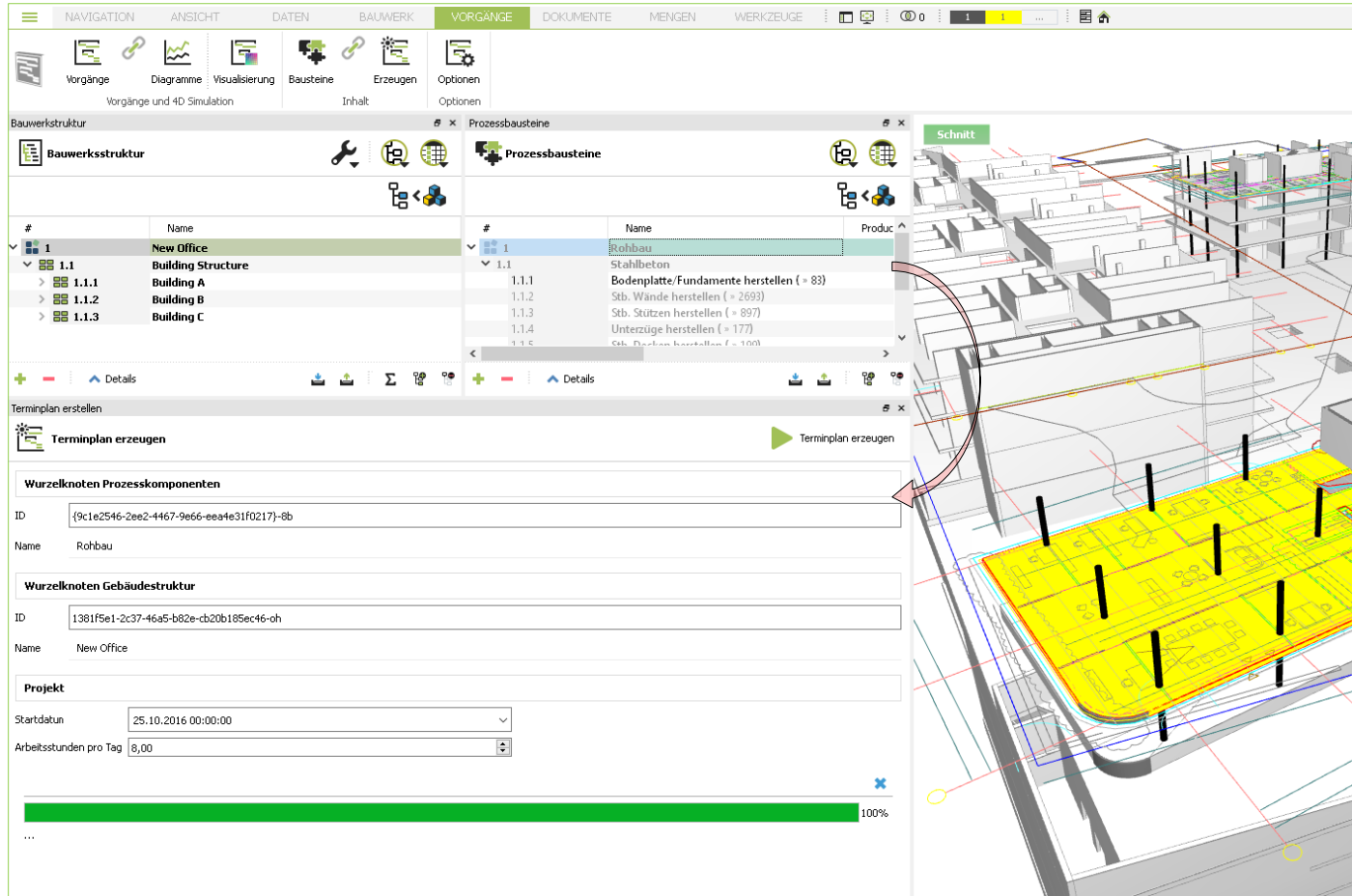
Schedule calculation and customisation

Create Schedule

4D-Simulation

4D-Simulation

Variants

Prozessbausteine

Prozessbausteine

#	Name	Quant
1	**Rohbau**	
1.1	**Stahlbeton**	
1.1.1	Bodenplatte/Fundamente herstellen (» 83)	
1.1.2	Stb. Wände herstellen	
1.1.3	**Stb. Wände (» 2693)**	
1.1.3.1	Einschalen	
1.1.3.2	Bewehren	
1.1.3.3	Betonieren	
1.1.3.4	Ausschalen	
1.1.4	Stb. Stützen herstellen (» 897)	
1.1.5	Unterzüge herstellen (» 177)	
1.1.6	Stb. Decken herstellen (» 199)	
1.2	**Mauerwerk**	
2	**Ausbau**	
3	**Fassade**	

+ − ∧ Details

V1

4	Rohbau	0 d	
4.1	Building Structure	2.225 d	
4.1.1	Building A	709 d	
4.1.1.1	-03.UG	55 d	
4.1.1.2	-02.UG	222 d	
4.1.1.3	-01.UG	43 d	
4.1.1.4	00.EG	109 d	
4.1.1.4.1	Stahlbeton	109 d	
4.1.1.4.1.1	Stb. Wände herstellen (» 92)	109 d	621,082
4.1.1.4.1.2	Stb. Stützen herstellen (» 37)	6 d	31,742
4.1.1.4.1.3	Stb. Decken herstellen (» 6)	49 d	3.514,722
4.1.1.5	00.MZ	46 d	
4.1.1.6	00.GG	52 d	
4.1.1.7	01.OG	50 d	
4.1.1.8	02.OG	40 d	
4.1.1.9	03.OG	38 d	

V2

4.1.3	Building C	856 d	
5	Rohbau	0 d	
5.1	Building Structure	2.139 d	
5.1.1	Building A	651 d	
5.1.1.1	-03.UG	60 d	
5.1.1.2	-02.UG	196 d	
5.1.1.3	-01.UG	43 d	
5.1.1.4	00.EG	97 d	
5.1.1.4.1	Stahlbeton	97 d	
5.1.1.4.1.1	Stb. Wände	97 d	
5.1.1.4.1.1.1	Einschalen (» 92)	29 d	2.317,
5.1.1.4.1.1.2	Bewehren (» 92)	29 d	2.317,
5.1.1.4.1.1.3	Betonieren (» 92)	10 d	621,
5.1.1.4.1.1.4	Ausschalen (» 92)	29 d	2.317,
5.1.1.4.1.2	Stb. Stützen herstellen (» 37)	6 d	31,
5.1.1.4.1.3	Stb. Decken herstellen (» 6)	49 d	3.514,
5.1.1.5	00.MZ	47 d	
5.1.1.6	00.GG	44 d	
5.1.1.7	01.OG	44 d	

4D-Simulation

VIDEO
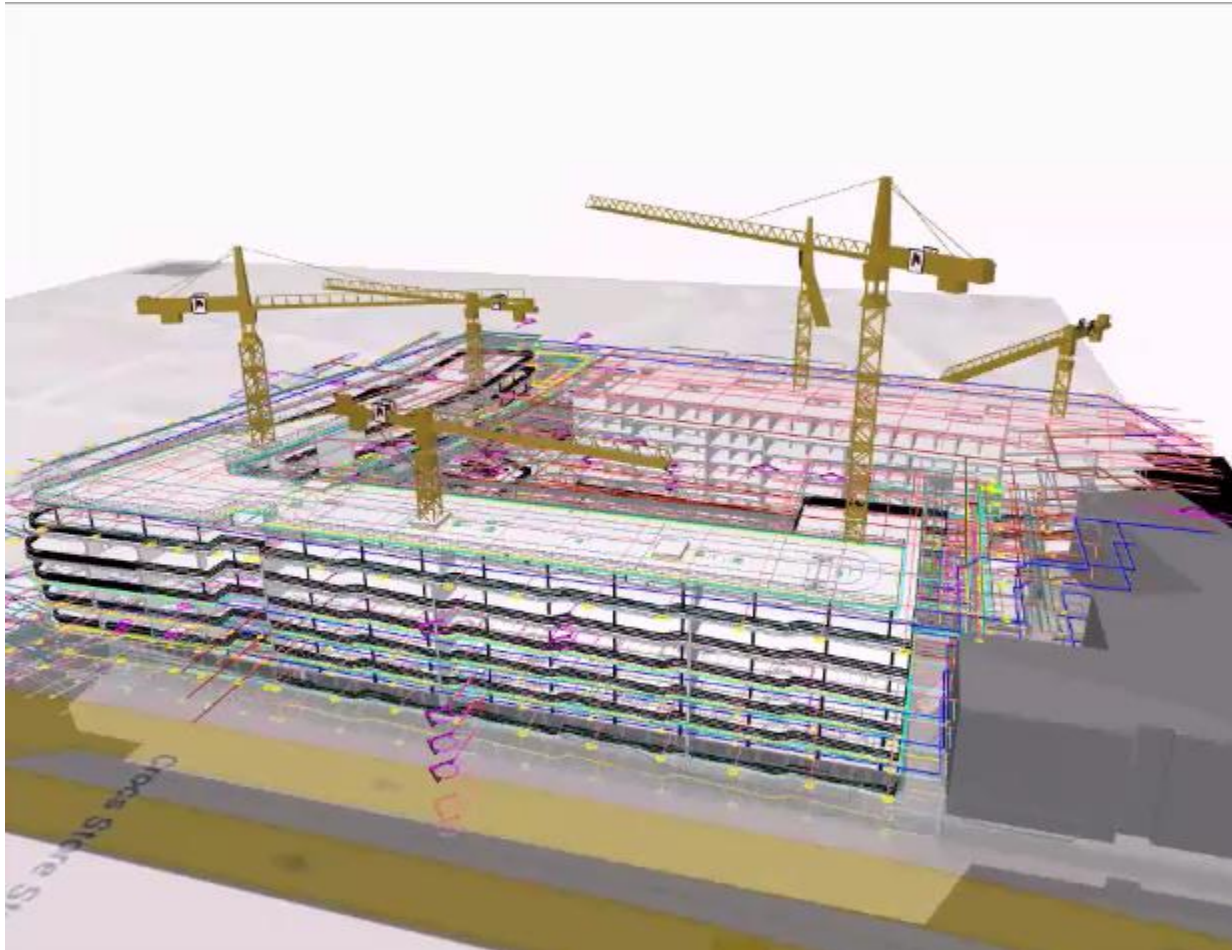
Conclusion

The presented approach allows the model-based construction scheduling …

- by consideration of the **Building Structure**
- by defining **Process Components**
- by determining the element **Quantities**
- on different **Levels of Detail**

- increases the **Transparency** in construction processes planning
- improves the workflow and **Quality** of construction planning
- reduces **Time and Effort** for creating a 4D-model

Automatic Generation of 4D-Schedules for reliable Construction Management

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