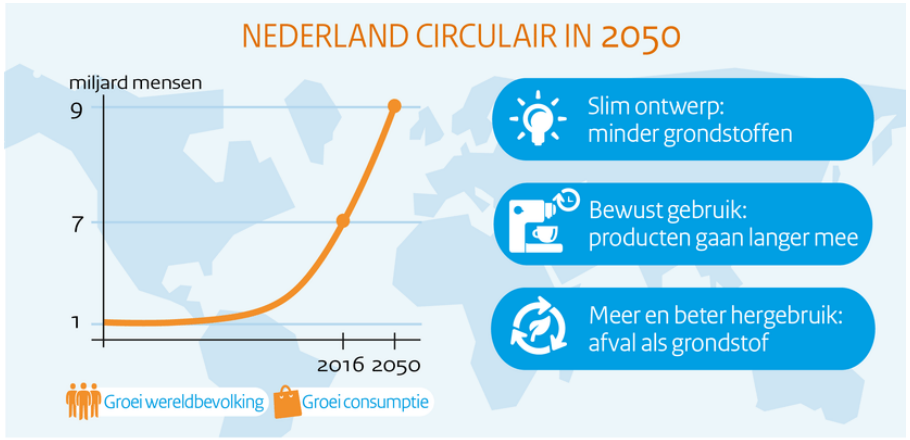
STRUCTURAL STEEL REUSE ANALYSIS

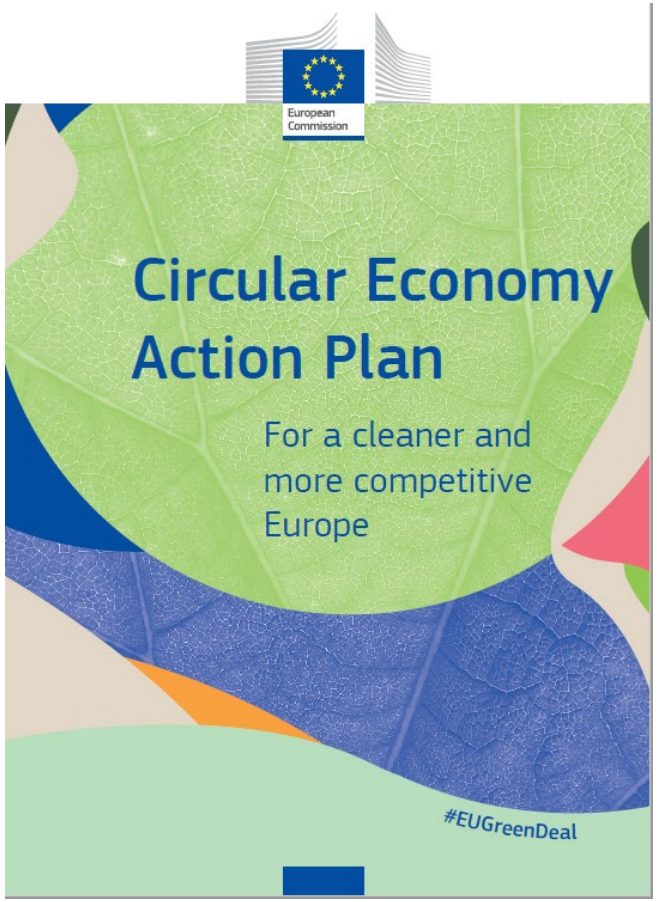
P5 Presentation

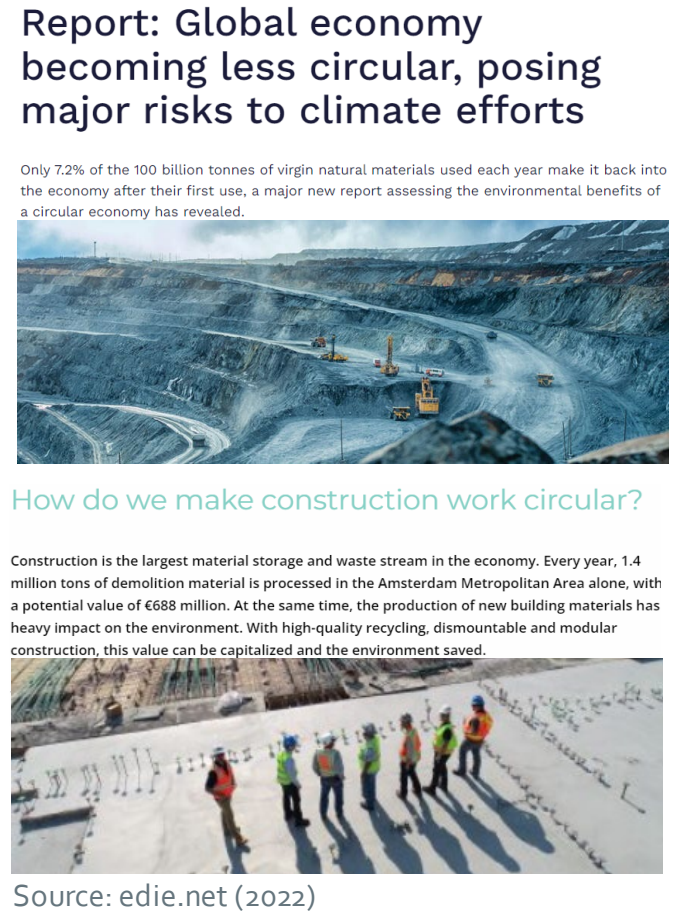
Jelle ten Hove
4854136

CIRCULAR AMBITIONS



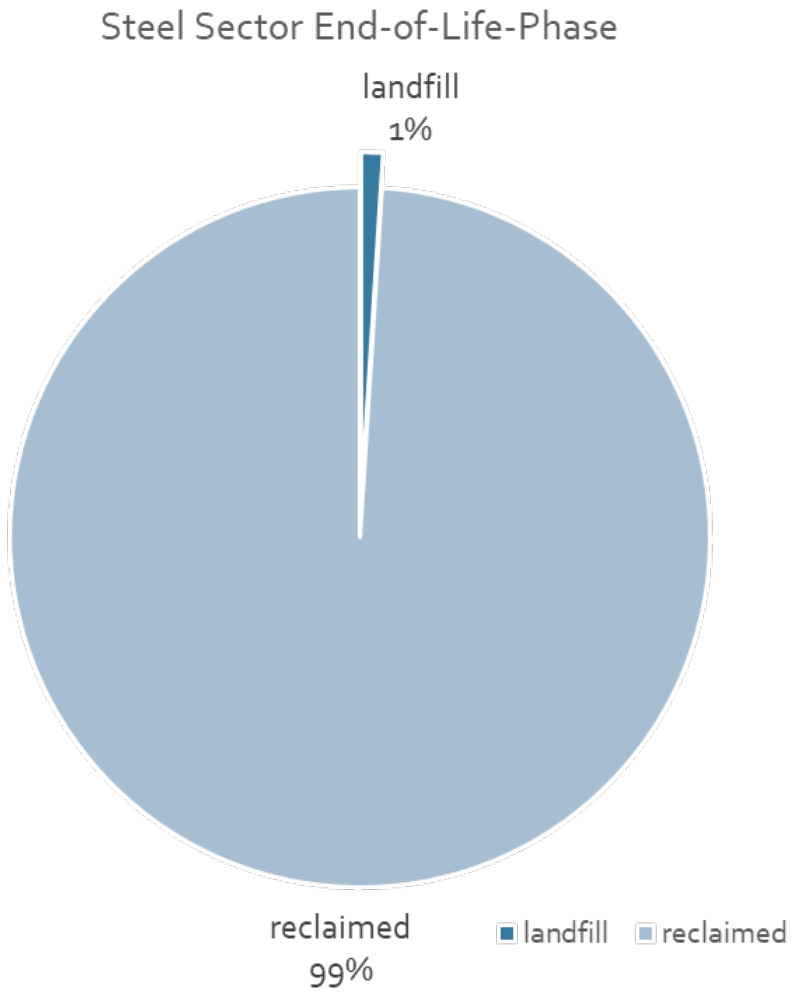
Source: Nweurope.com (2015), Rijksoverheid (2016)

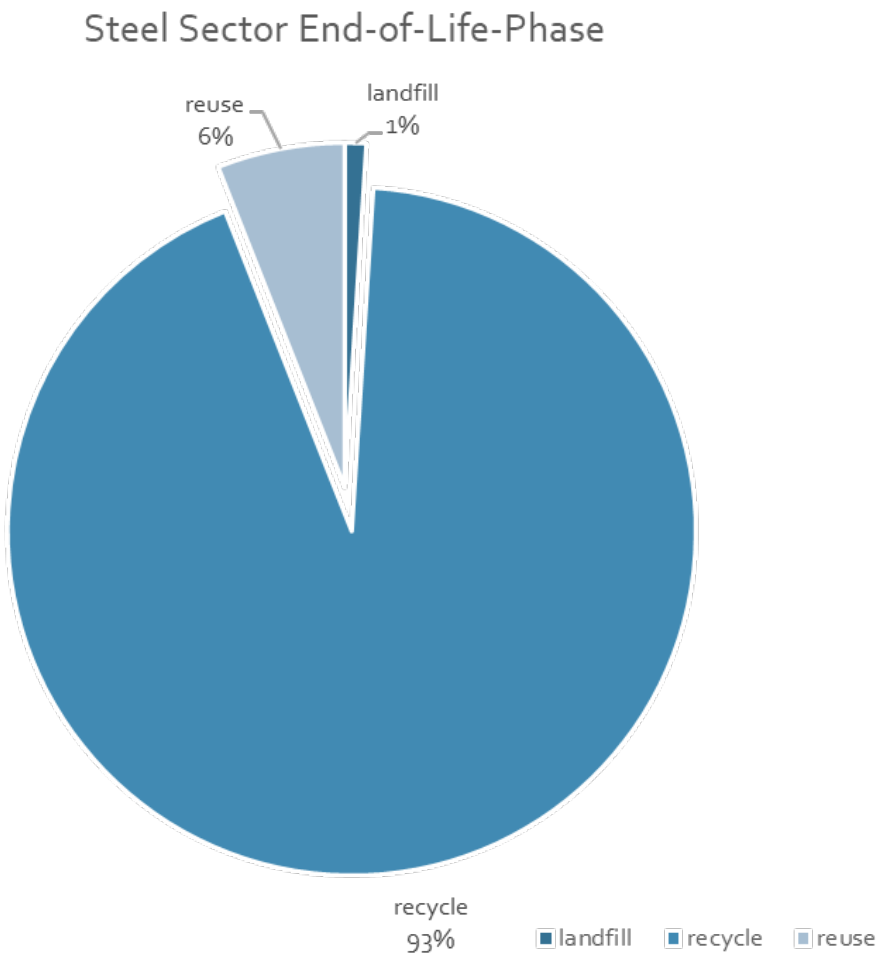




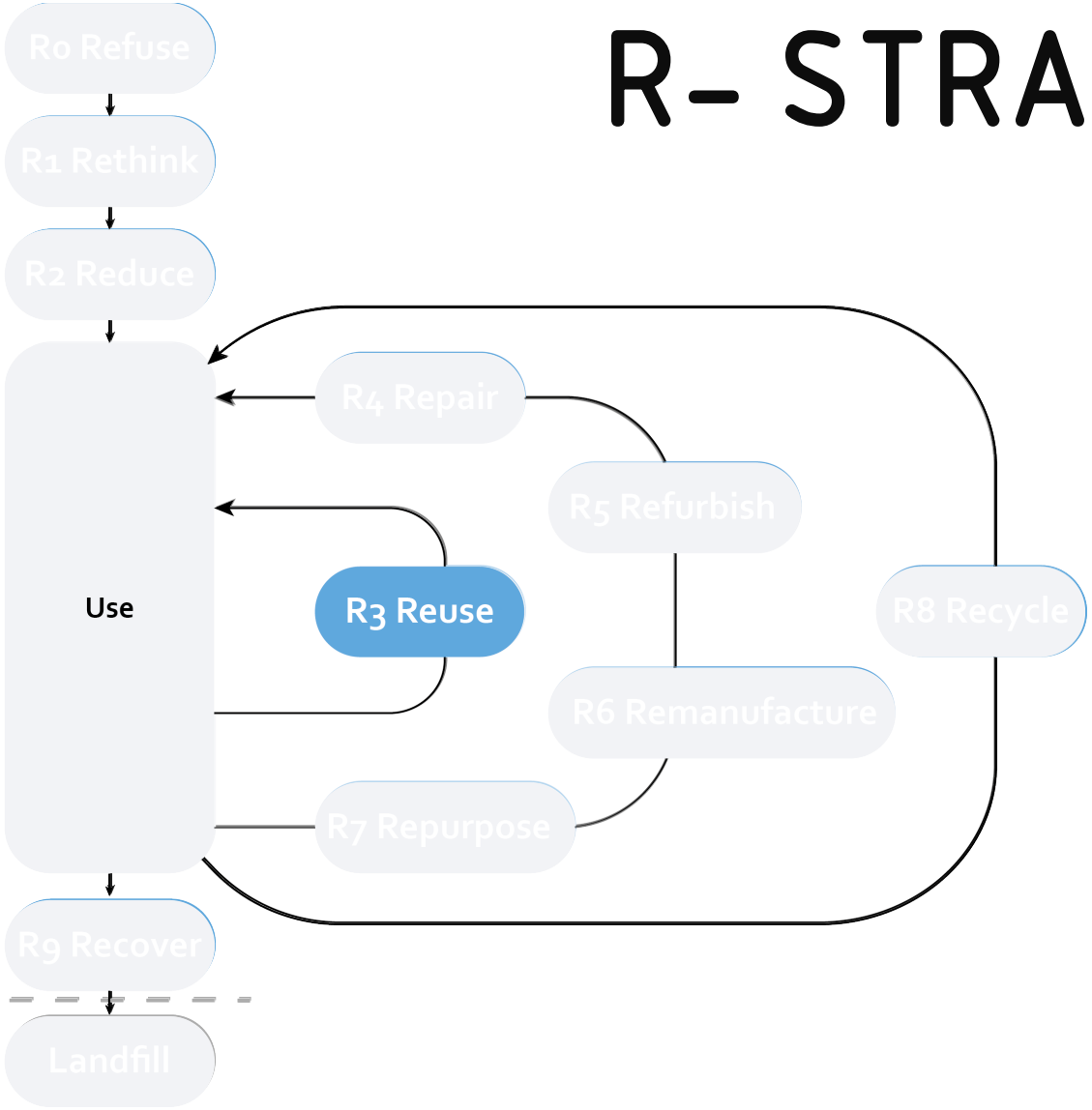
Source: edie.net (2022)

STEEL SECTOR



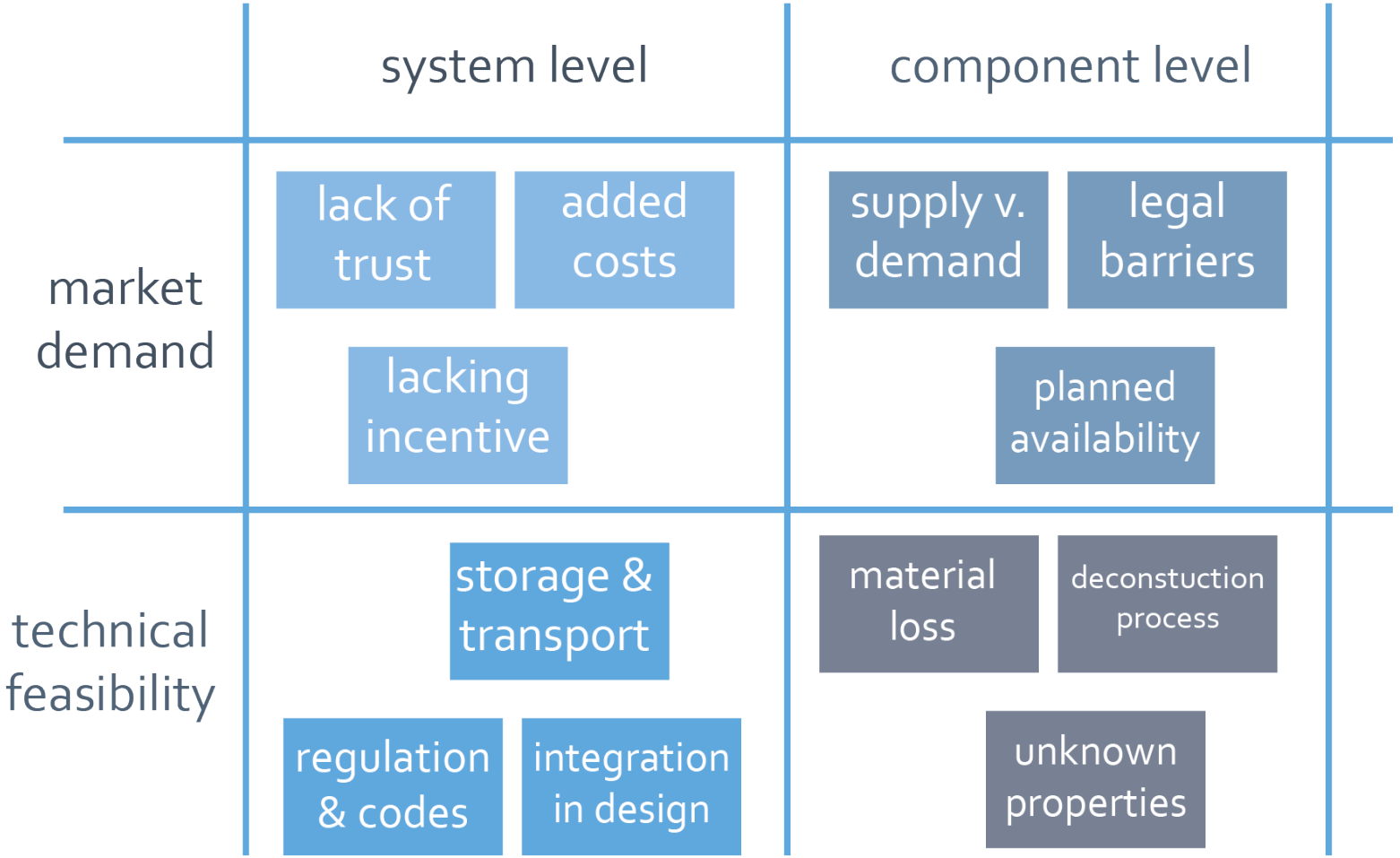


R- STRATEGIES

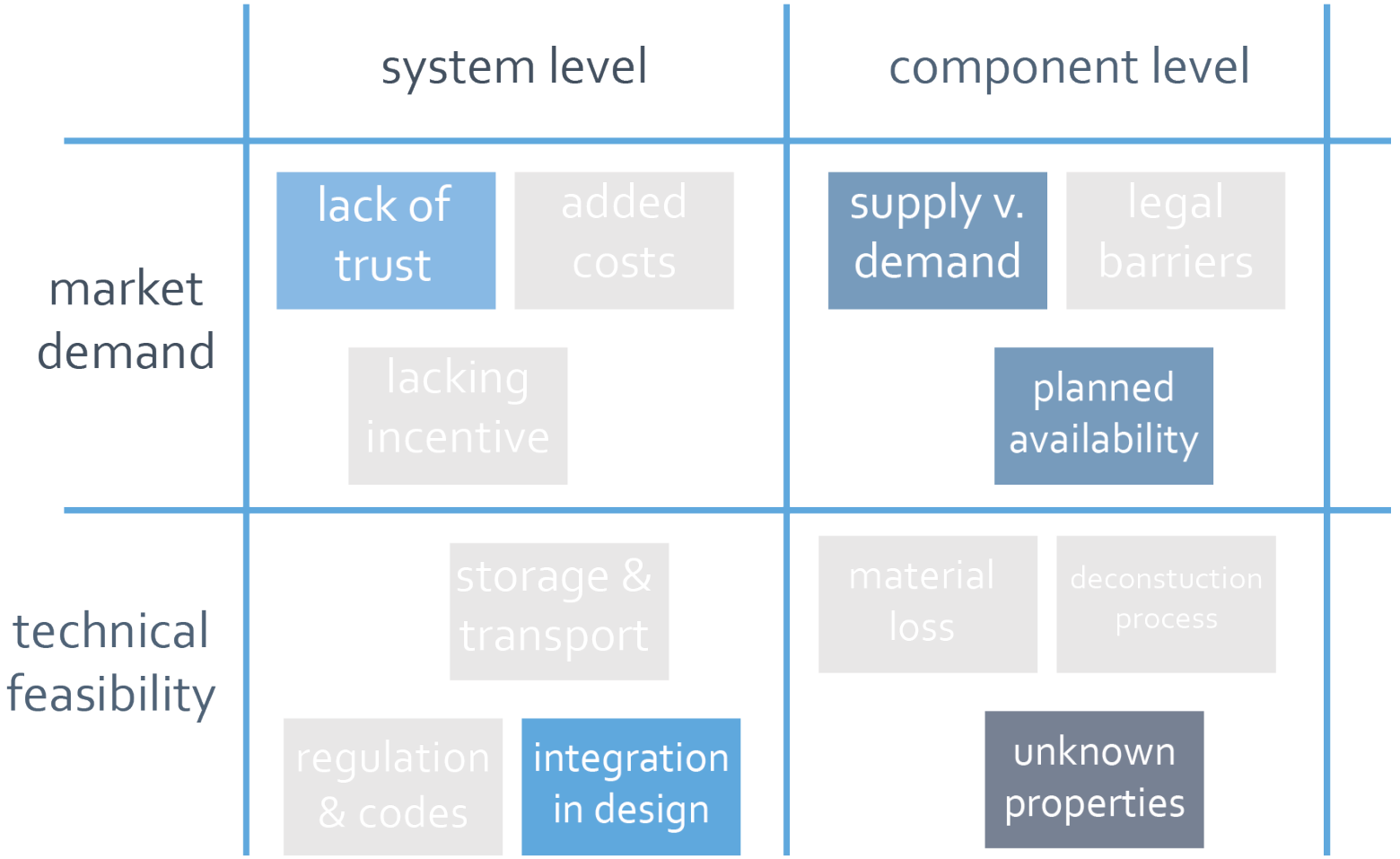


Item			Stainless Steel
Energy	MJ	Electricity	7.18
		Natural gas	2.6
Emission	Kg	SO_2	4.28×10^{-4}
		NOx	5.27×10^{-6}
		CO_2	4.41×10^{-1}
		CO	1.01×10^{-2}
		PM2.5	6.71×10^{-2}
		PM10	8.46×10^{-4}

BARRIERS


system level
component level
market demand
technical feasibility
lack of trust
added costs
lacking incentive
supply v. demand
legal barriers
planned availability
storage & transport
regulation & codes
integration in design
material loss
deconstuction process
unknown properties

BARRIERS


system level
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market demand
technical feasibility
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added costs
supply v. demand
legal barriers
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planned availability
storage & transport
material loss
deconstuction process
regulation & codes
integration in design
unknown properties

RESEARCH QUESTION

*'How can **structural steel elements** be analysed and mapped out in order to be introduced in a **circular context**?'*

NITROGEN CRISIS

The New York Times

Dairy Farmers in the Netherlands Are Up in Arms Over Emission Cuts

Goals of cutting nitrogen emissions in half by 2030 have caused an uproar in the Netherlands. Climate activists say the cuts are necessary to preserve nature.

Stikstofcrisis

NOS Nieuws • Woensdag 5 oktober, 11:55 • Aangepast woensdag 5 oktober, 14:20

Remkes: binnen een jaar 500 tot 600 grote uitstoters stikstof uitkopen

Rutte over 'onvermijdelijk' besluit stikstof: 'De sector gaat er anders uitzien'

Kabinet noemt één jaar voor wegwerken 500 tot 600 piekbelasters 'ambitieus'

14 oktober 2022 14:41 • Aangepast 14 oktober 2022 22:10

Net binnen

22:11 PSV beëindigt slechte reeks

22:04 Sparta nestelt Cambuur stev

20:41 PSV-aanvoerd hoofdblessure

20:32 Depay debute Madrid

20:22 Kat knuffelen? katvriendelijk

Meer

NEWS | CLIMATE

Nitrogen crisis from jam-packed livestock operations has 'paralyzed' Dutch economy

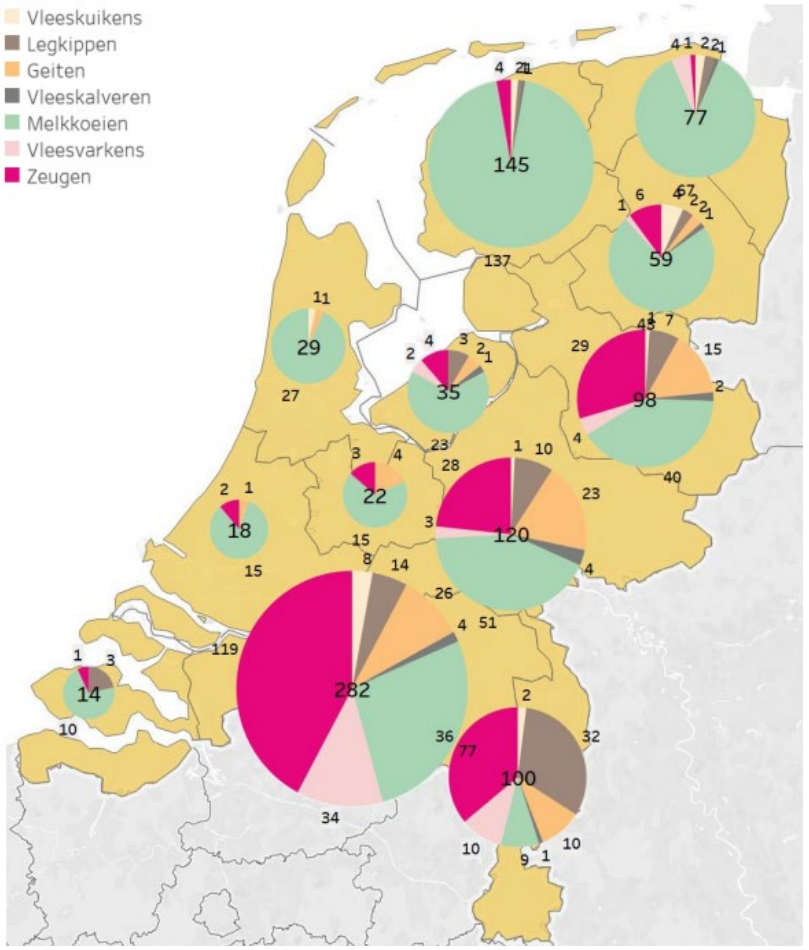
Ecological damage from manure fumes triggers calls for drastic change to agriculture

4 DEC 2019 • BY ERIK STOKSTAD

MEGABARNS

Source: AD.nl (2022)

Source: De Stentor (2022)



Source: WakkerDier (2022)

Aantal megastallen in tien jaar tijd verdubbeld

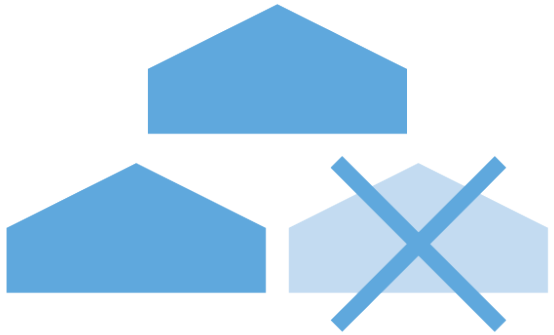
Nieuws · 29-06-2022 · leestijd 2 minuten · 2633 keer bekeken · bewaren

Nederland telt duizend megastallen

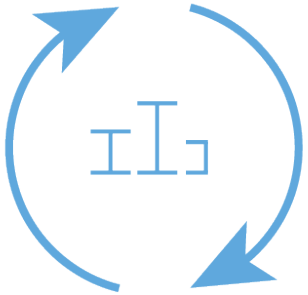
Nieuws · 30-06-2022 · leestijd 2 minuten · 169 keer bekeken · bewaren

Source: BNNVARA (2022)

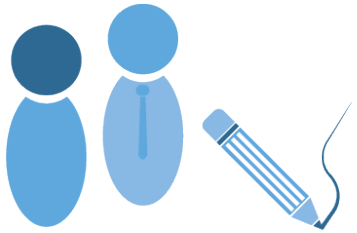
OPPORTUNITY



agrarian halls
out of business



desire to reuse steel
instead of recycle



lack of available data
for designers

500-600

peak-emitters
bought out

~21kg/m2

structural steel
components

10.000m2 or more

of agrarian hall
per mega-farm

~121.000 tonnes

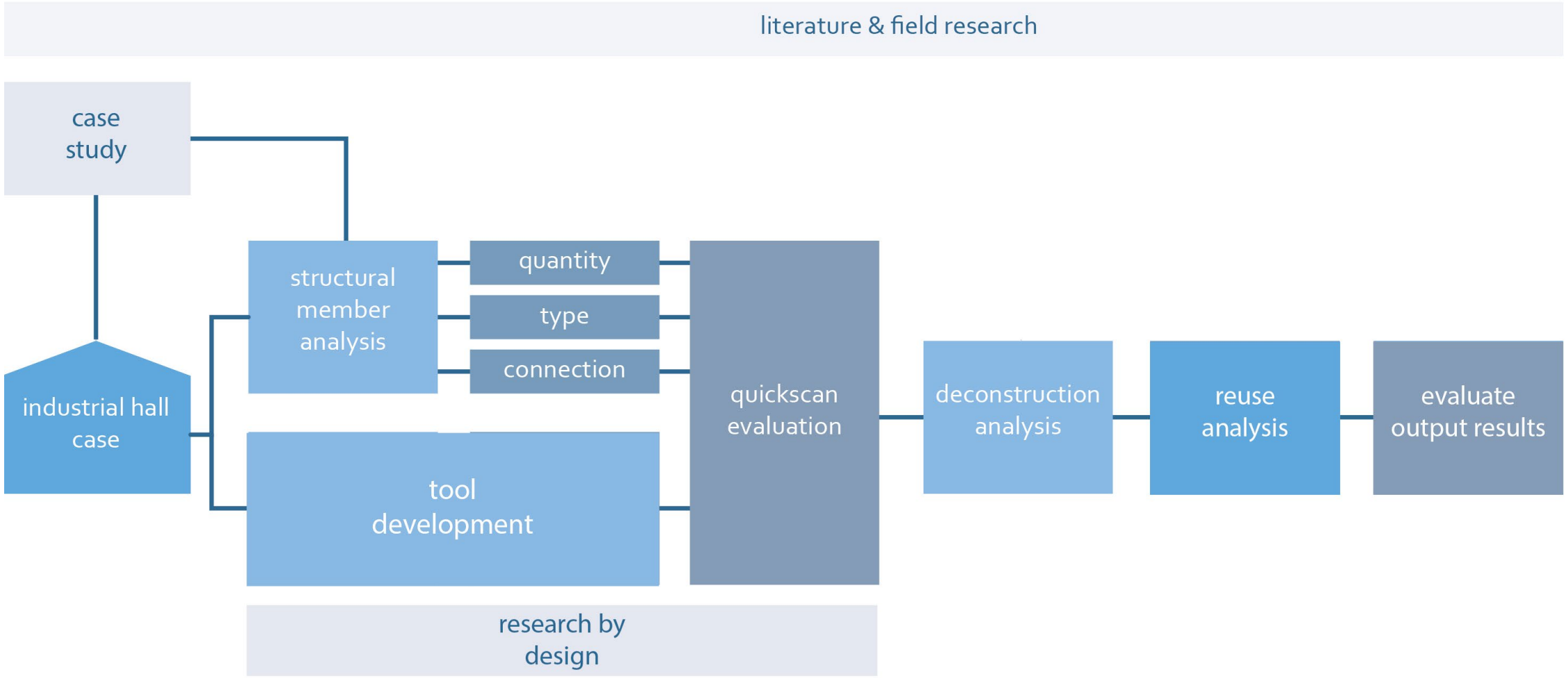
structural steel
components in total

1.800km of
eq. IPE300 profile

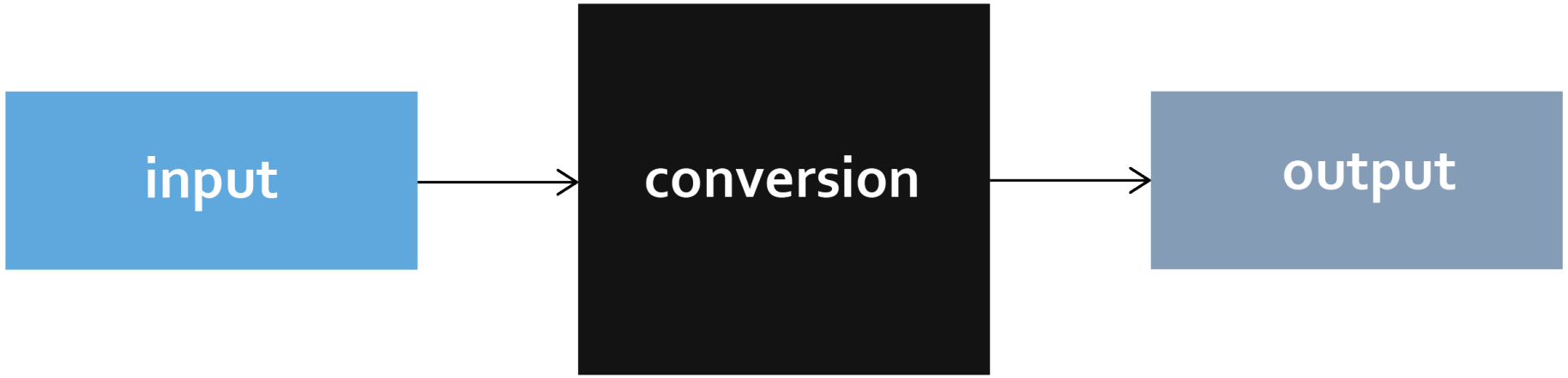
RESEARCH QUESTION

*'How can **structural steel elements** of **industrial buildings** be analysed and mapped out in order to be introduced in a **circular context**?'*

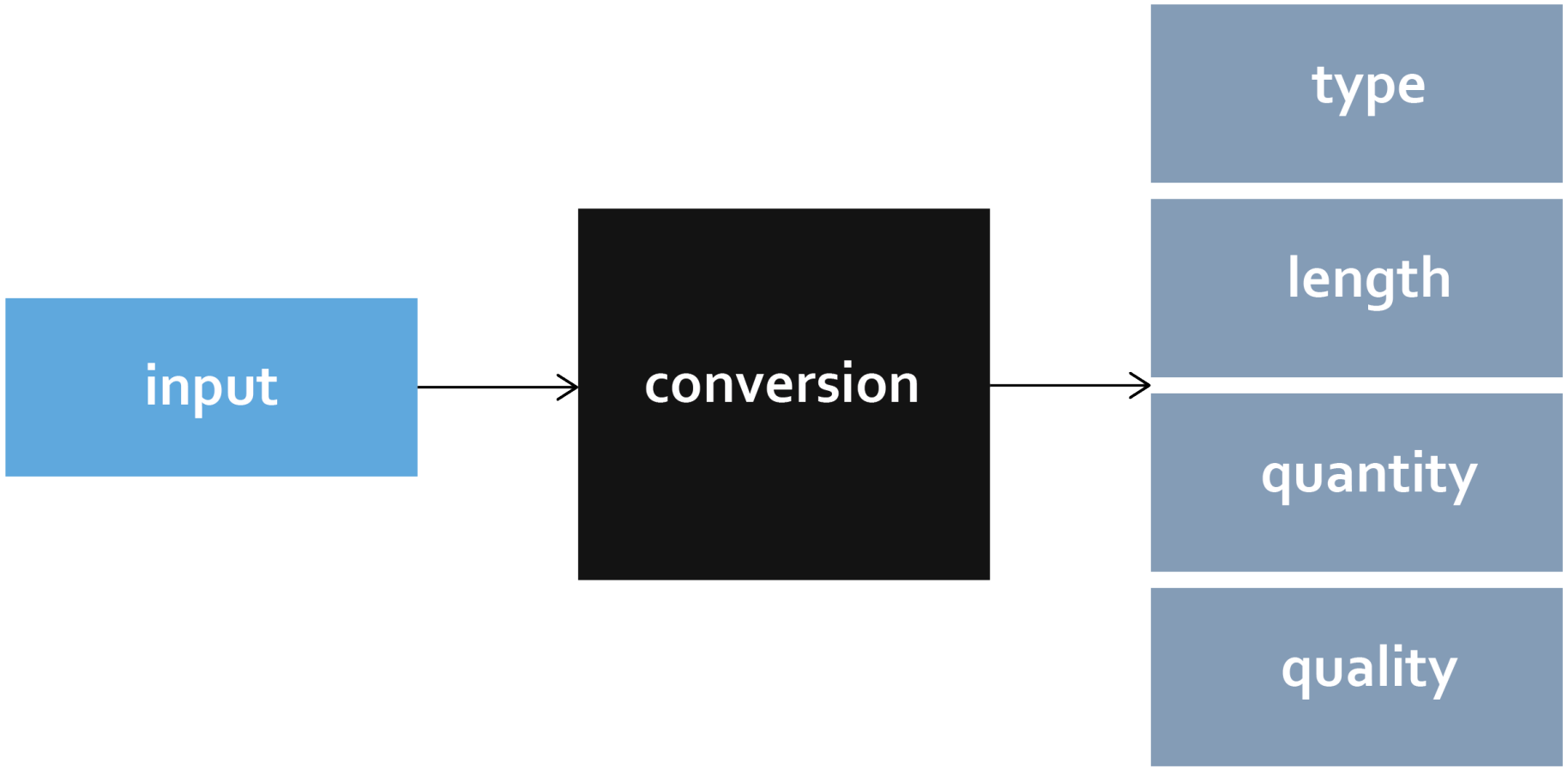
RESEARCH SETUP



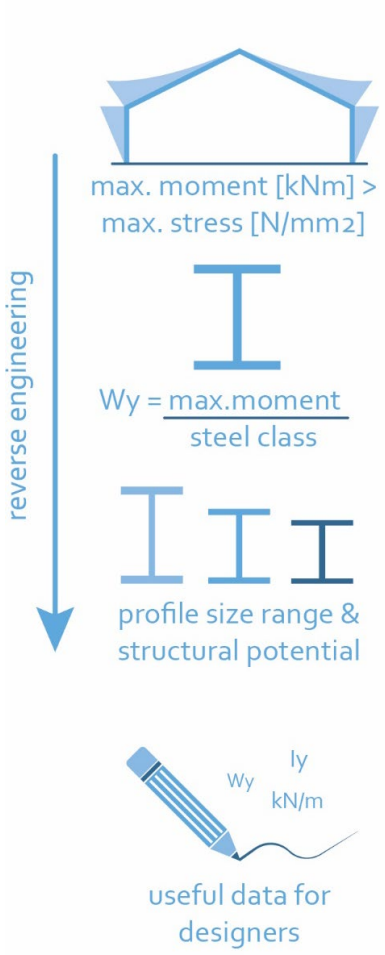
QUICKSCAN TOOL

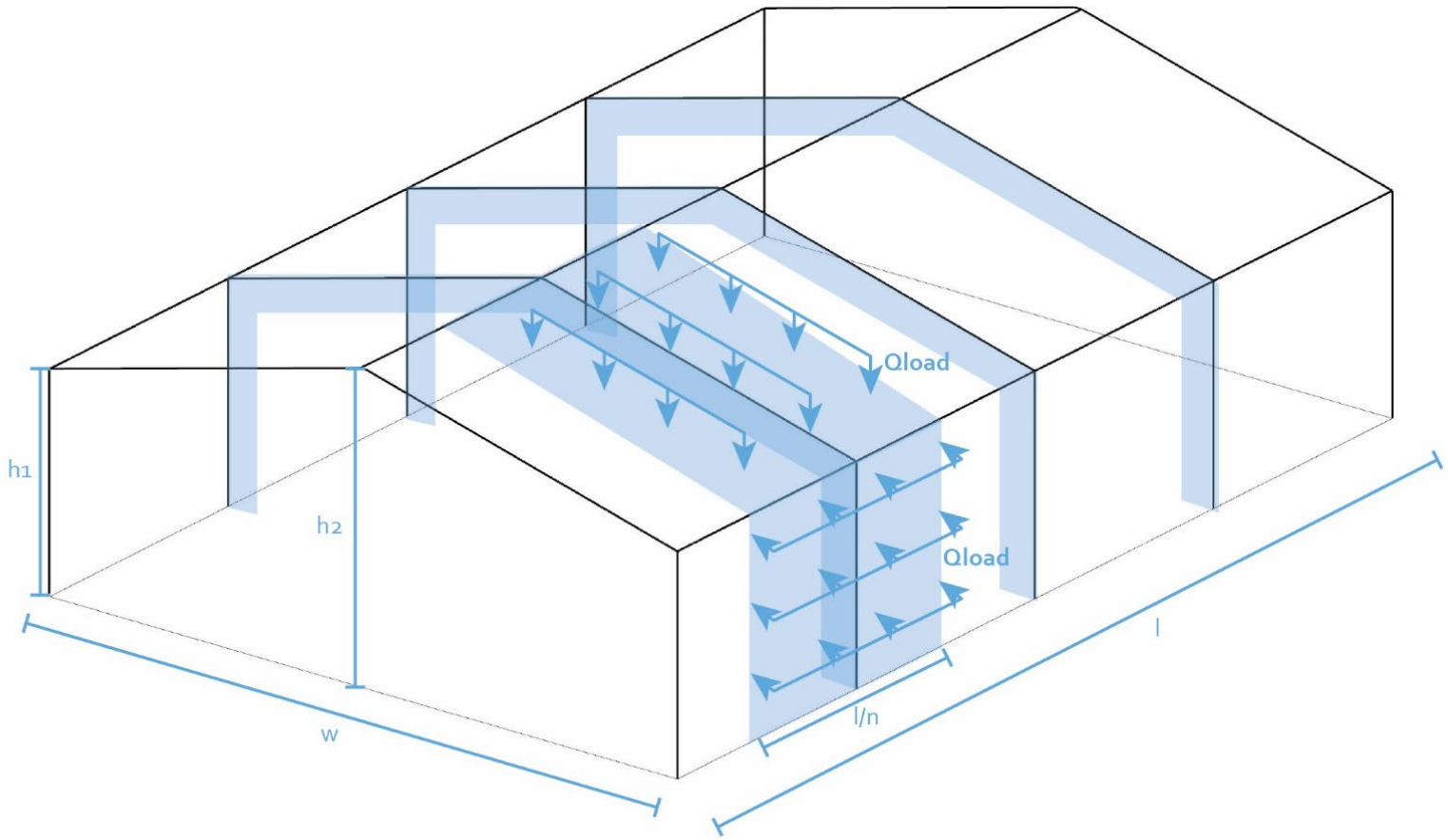


QUICKSCAN TOOL

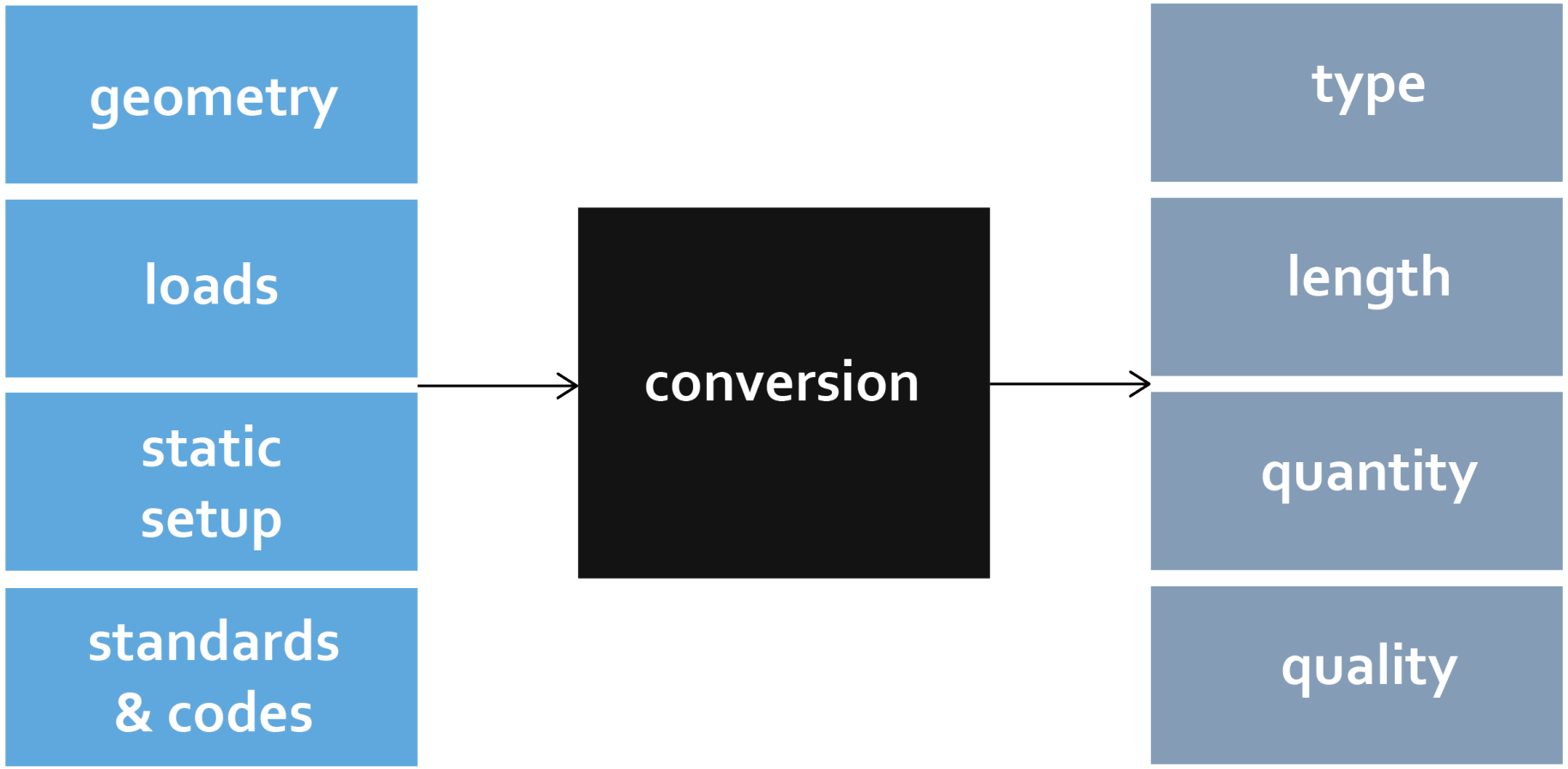


REVERSE-ENGINEERING

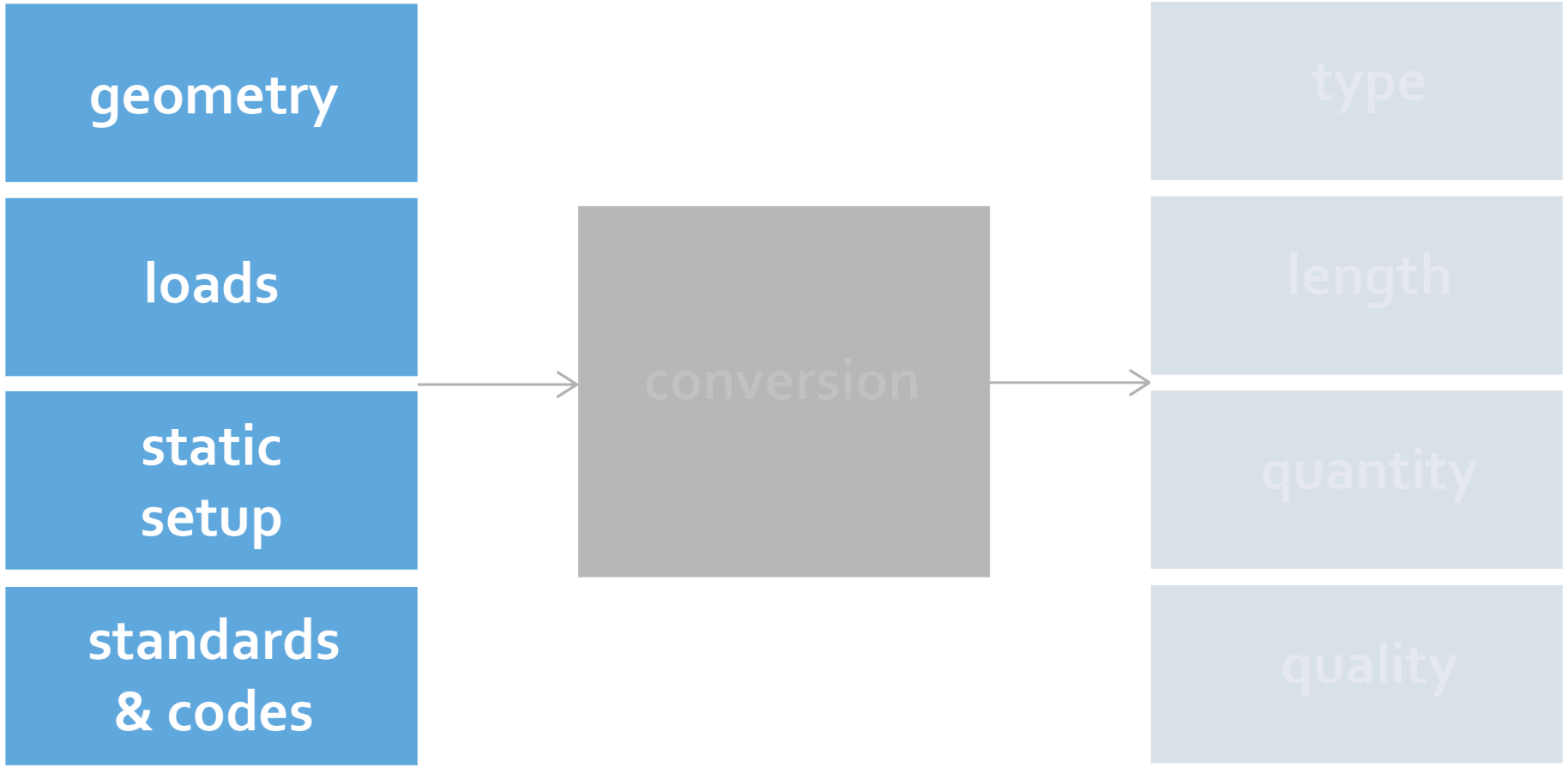




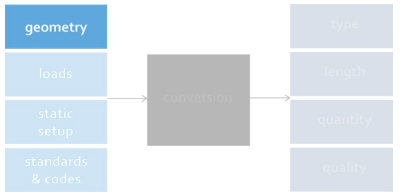
QUICKSCAN TOOL

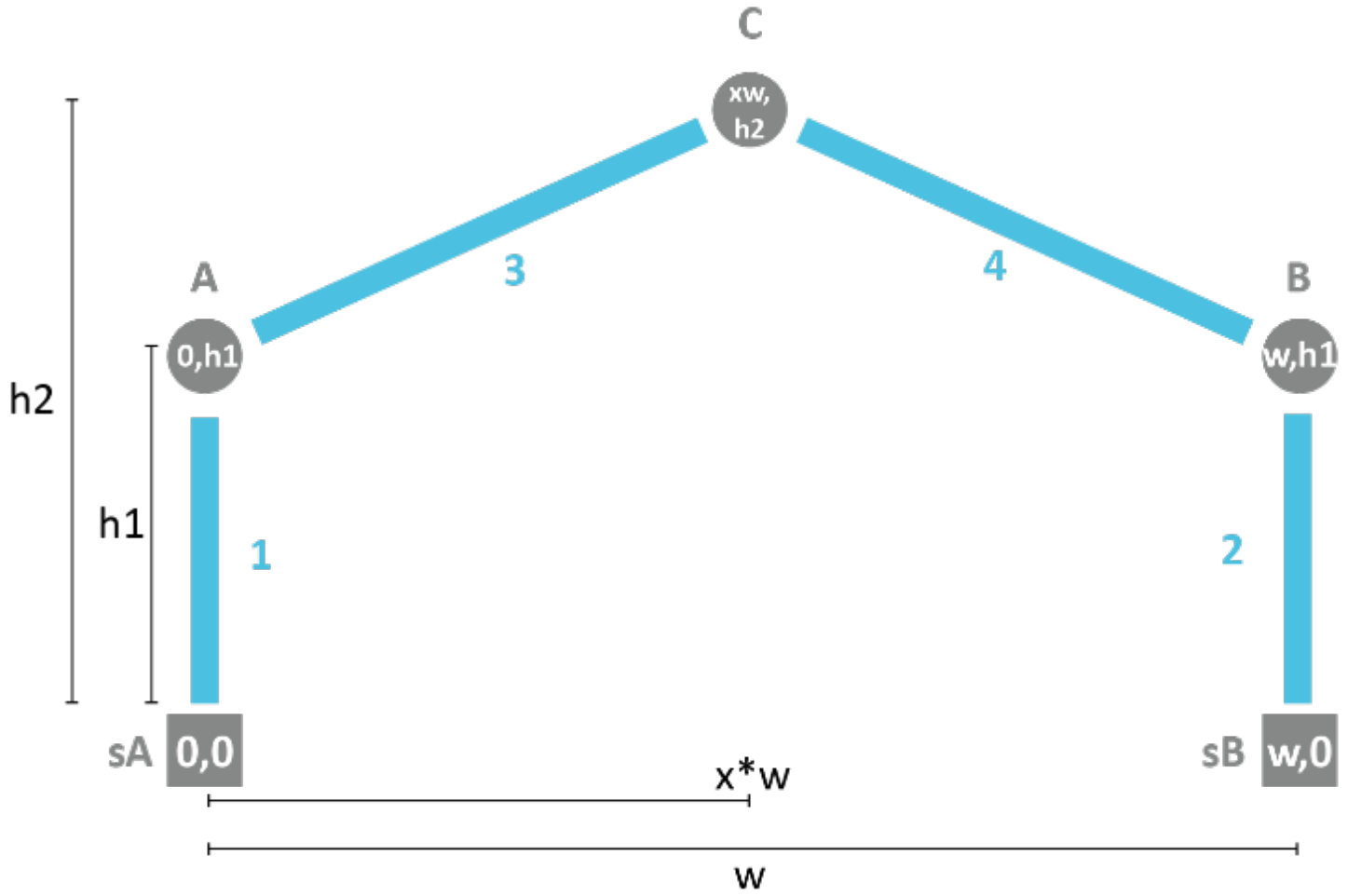


INPUT


geometry
loads
static setup
standards & codes
conversion
type
length
quantity
quality

PORTAL DEFINITION

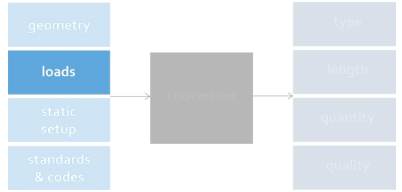


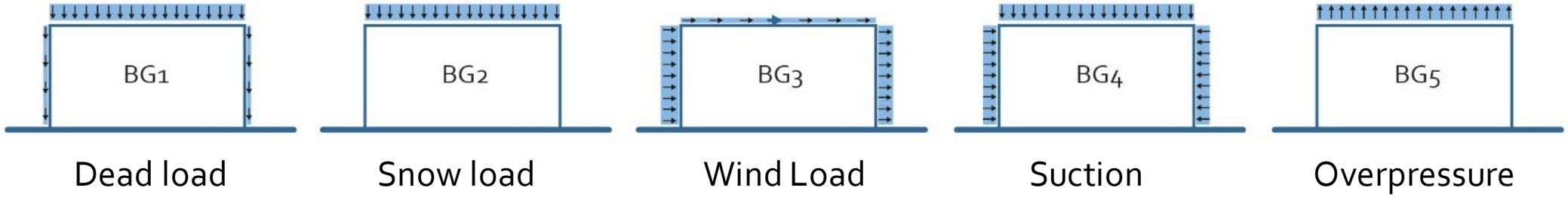


Line	Beam
1	Id1
2	Id2
3	Id3
4	Id4

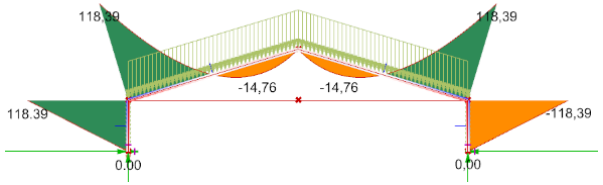
Point	Type
sA	Support
sB	Support
A	Connection
B	Connection
C	Connection

LOADS

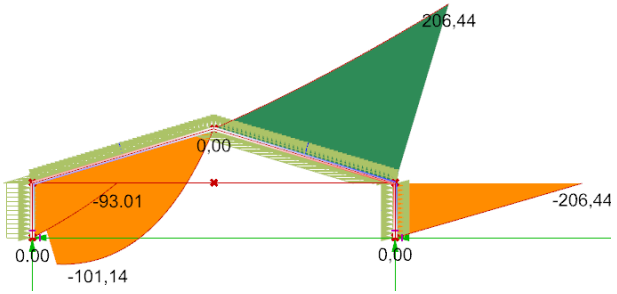




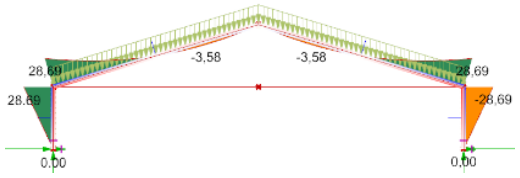
LOAD COMBINATIONS



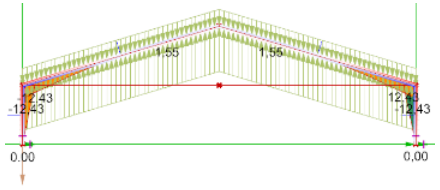
LC1: BG1 + BG2



Lc2: BG1 + BG3 + BG4

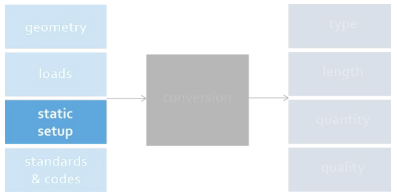


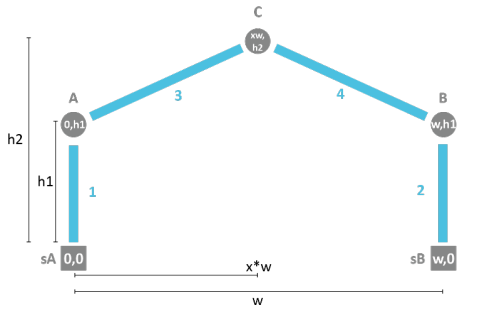
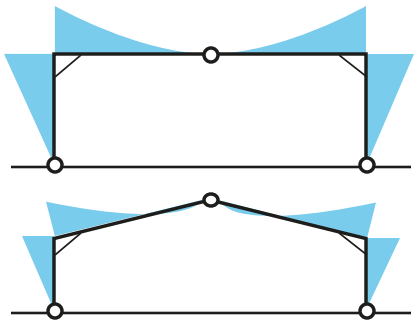
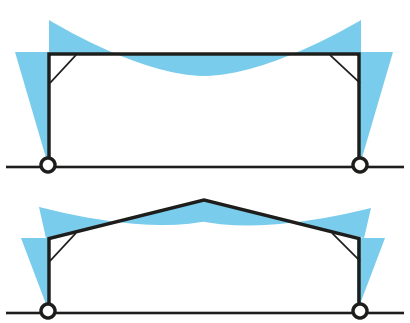
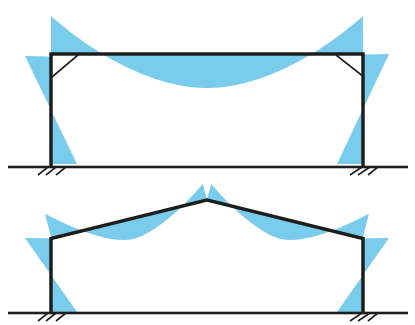
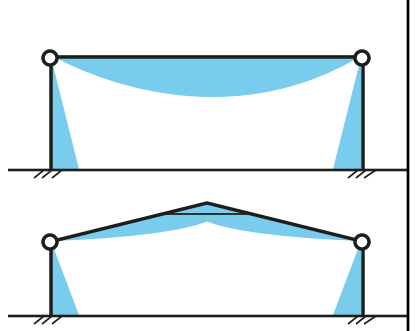
LC3: BG1



LC4: BG1 + BG5

STATIC SETUP



Portal Setup	Three-pinned	Semi-rigid frame	Rigid frame	Hinged Girder
				

Point	Type
sA	Support
sB	Support
A	Connection
B	Connection
C	Connection

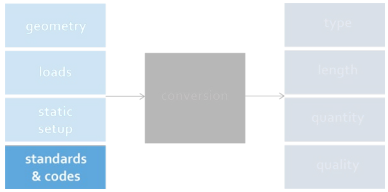
Point	Type
sA	Pin
sB	Pin
A	Rigid
B	Rigid
C	Flexible

Point	Type
sA	Pin
sB	Pin
A	Rigid
B	Rigid
C	Rigid

Point	Type
sA	Rigid
sB	Rigid
A	Rigid
B	Rigid
C	Rigid

Point	Type
sA	Rigid
sB	Rigid
A	Pin
B	Pin
C	Rigid

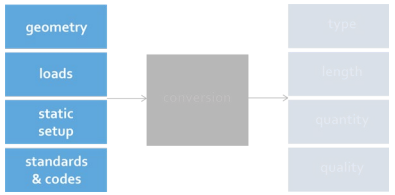
SAFETY FACTORS



Loadcase Scenario	Lc1	Lc2	Lc3	Lc4
BG1	1,1	1,1	1,35	1,1
BG2	1,3	0	0	0
BG3	0	1,3	0	0
BG4	0	1,3	0	0
BG5	0	0	0	0,9

Source: Hollander & Eldik (2007)

ADDITIONAL VARIABLES



Cladding weight

Scenario	Load [kN/m2]
Light	0.10
Medium	0.20
Heavy	0.30

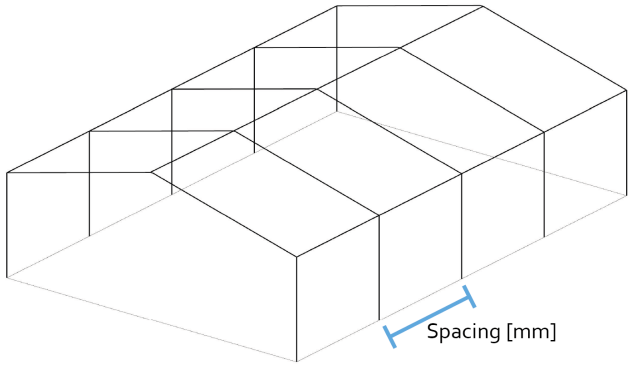
Based on: SCI (2008)

Impact on BG1

Based on case studies & literature:

Avg. 0.20 kN/m2

Portal Spacing



Impact on loads and *n* portals

Based on case studies & literature:

Avg. +- 5000mm

Open/closed walls

Scenario	coefficient
All walls open	0,8
L-wall open	0,55
R-wall open	0,55
No walls open	0,3

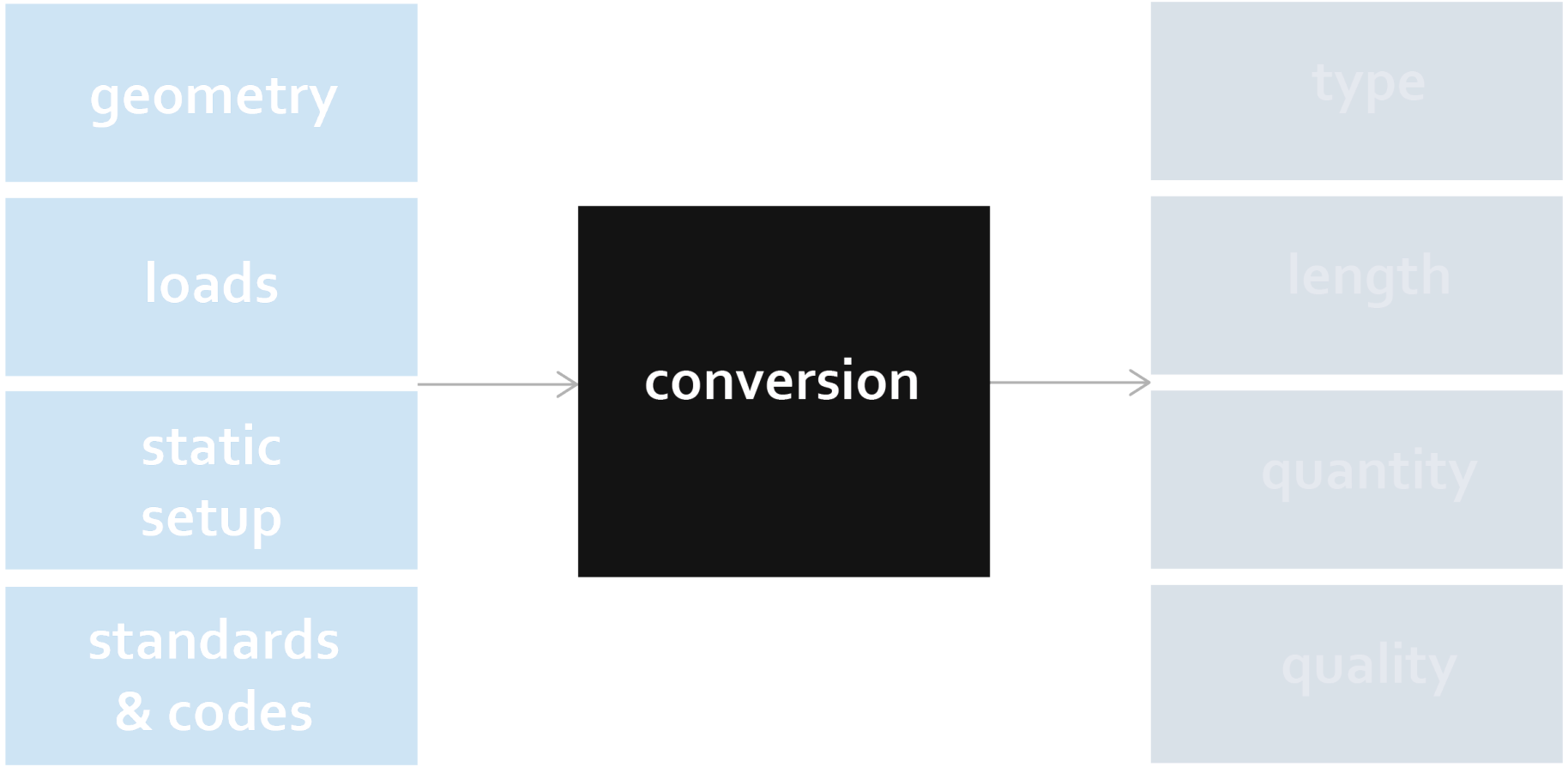
Based on: TNO (1992)

Impact on BG1, BG3, BG4, BG5

Based on case studies & literature:

Closed is the norm (0,3)

CONVERSION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standards & codes
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quantity
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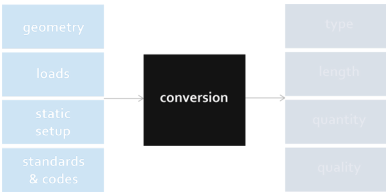
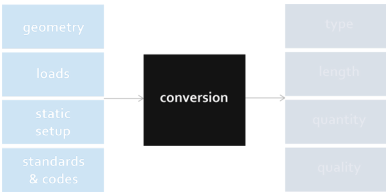
SOFTWARE

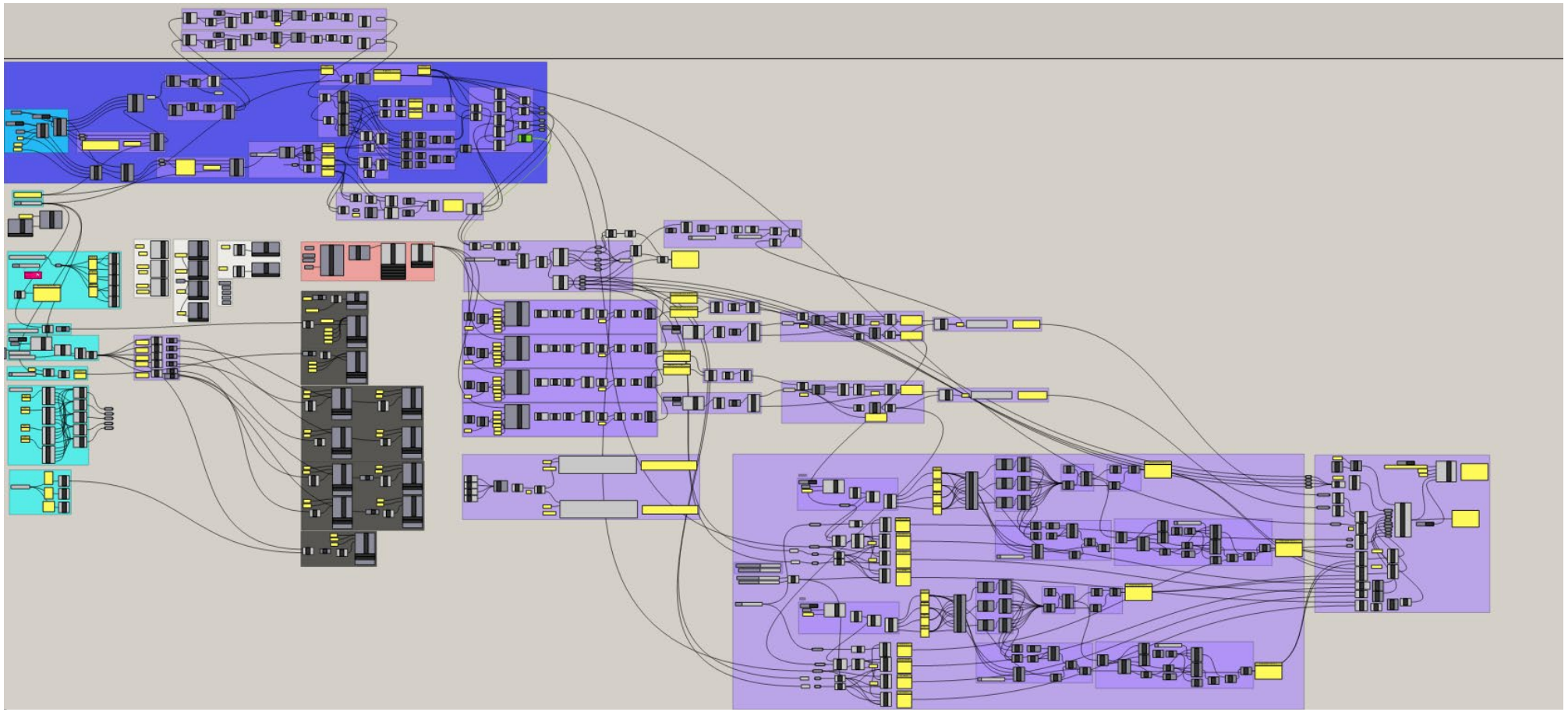


Rhinoceros

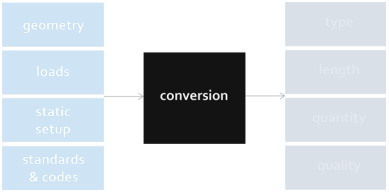
Karamba 3D
parametric engineering

GRASSHOPPER SCRIPT





WORKFLOW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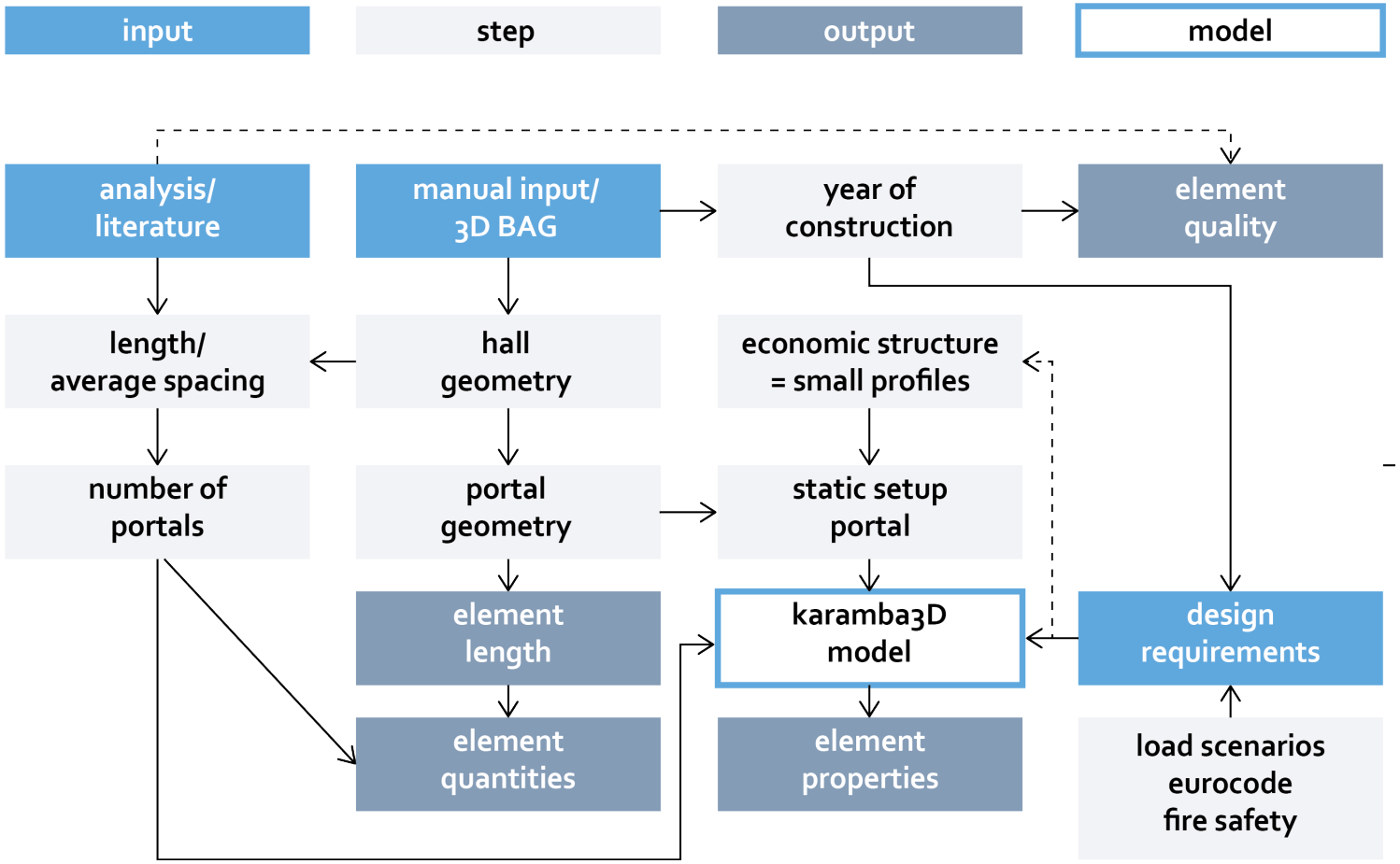
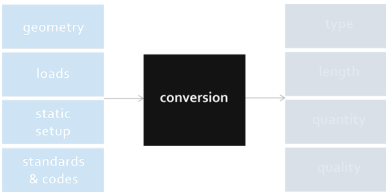

input
step
output
model
analysis/ literature
manual input/ 3D BAG
year of construction
element quality
length/ average spacing
hall geometry
economic structure = small profiles
number of portals
portal geometry
static setup portal
element length
karamba3D model
design requirements
element quantities
element properties
load scenarios eurocode fire safety

WORKFLOW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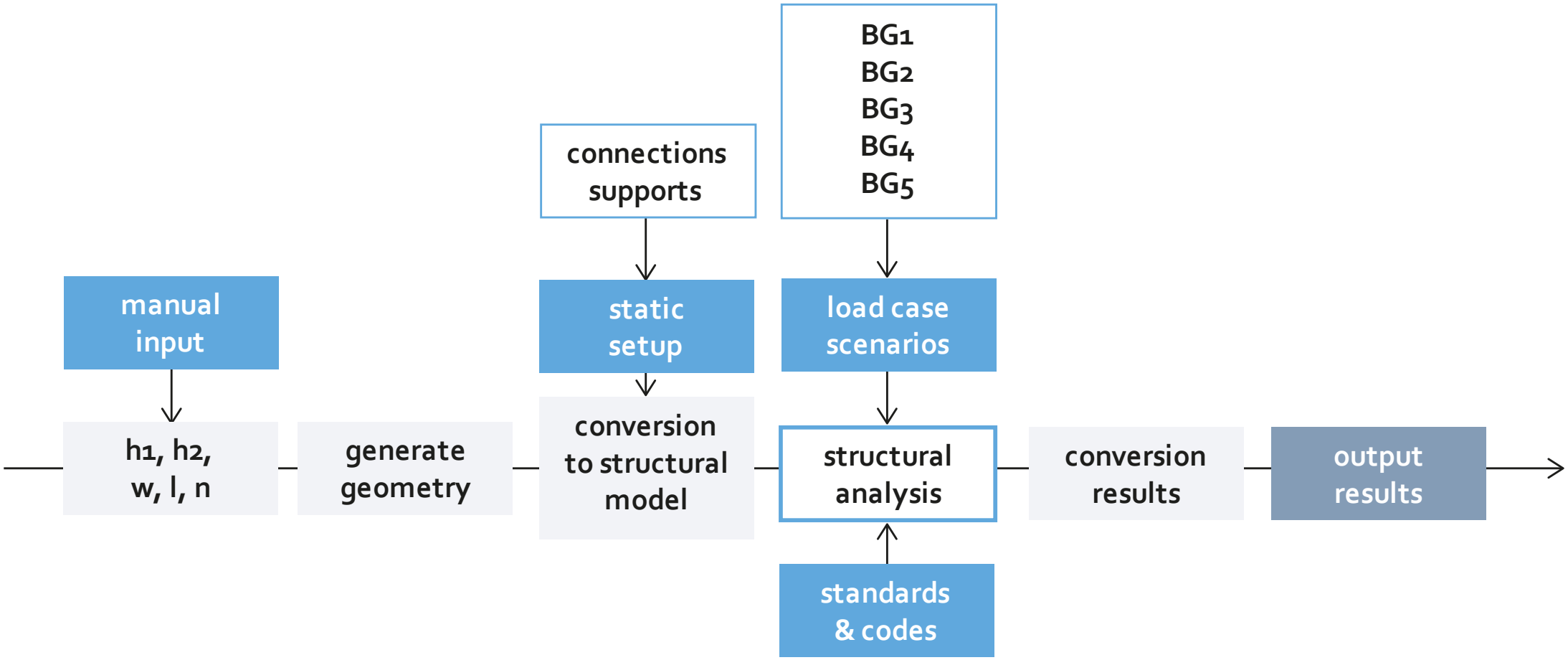
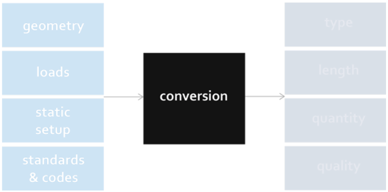
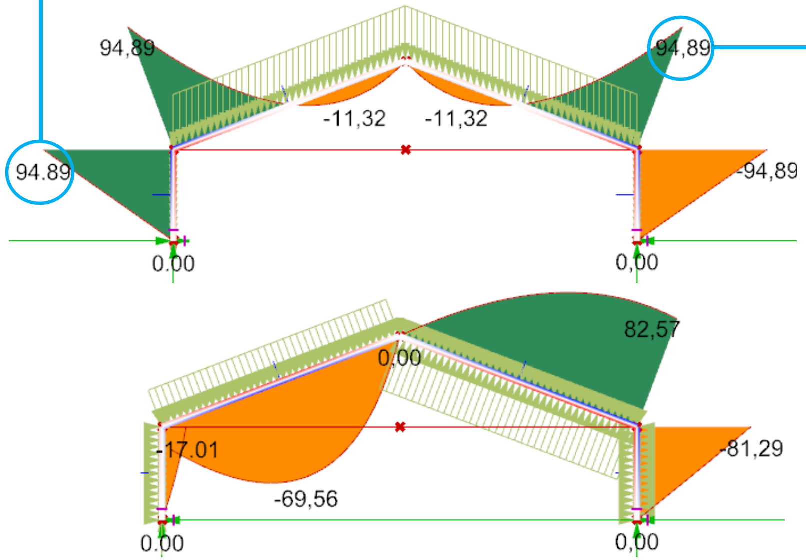

BG1
BG2
BG3
BG4
BG5
connections supports
manual input
static setup
load case scenarios
h1, h2, w, l, n
generate geometry
conversion to structural model
structural analysis
conversion results
output results
standards & codes

STRUCTURAL ANALYSIS



Mmax/235 = 94.890.000/235 = 404 * 10^3 mm3



Nearest ceiling in list

A_L m²/m	I_y x10⁴ mm⁴	$W_{y;el}$ x10³ mm³	I_z x10⁴ mm⁴	$W_{z;el}$ x10³ mm³	profiel nr.
0,328	80,1	20,0	8,49	3,69	80
0,400	171	34,2	15,9	5,79	100
0,475	318	53,0	27,7	8,65	120
0,551	541	77,3	44,9	12,3	140
0,623	869	109	68,3	16,7	160
0,698	1317	146	101	22,2	180
0,768	1943	194	142	28,5	200
0,848	2772	252	205	37,3	220
0,922	3892	324	284	47,3	240
1,04	5790	429	420	62,2	270
1,16	8356	557	604	80,5	300
1,25	11767	713	788	98,5	330
1,35	16266	904	1043	123	360
1,47	23128	1156	1318	146	400
1,61	33743	1500	1676	176	450
1,74	48199	1928	2142	214	500
1,88	67117	2441	2668	254	550
2,01	92083	3069	3387	308	600

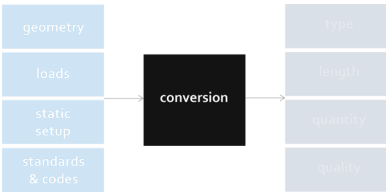
Nearest ceiling in list

A_L m²/m	I_y x10⁴ mm⁴	$W_{y;el}$ x10³ mm³	I_z x10⁴ mm⁴	$W_{z;el}$ x10³ mm³	profiel nr.
0,561	349	72,8	134	26,8	100
0,677	606	106	231	38,5	120
0,794	1033	155	389	55,6	140
0,906	1673	220	616	76,9	160
1,02	2510	294	925	103	180
1,14	3692	389	1336	134	200
1,26	5410	515	1955	178	220
1,37	7763	675	2769	231	240
1,48	10455	836	3668	282	260
1,60	13673	1013	4763	340	280
1,72	18263	1260	6310	421	300
1,76	22929	1479	6985	466	320
1,79	27693	1678	7436	496	340
1,83	33090	1891	7887	526	360
1,91	45069	2311	8564	571	400
2,01	63722	2896	9465	631	450
2,11	86975	3550	10367	691	500
2,21	111932	4146	10819	721	550
2,31	141208	4787	11271	751	600
2,41	175178	5474	11724	782	650
2,50	215301	6241	12179	812	700

Max. moment → req. Resistance [10^3 mm^3] = $M_{max}/235$

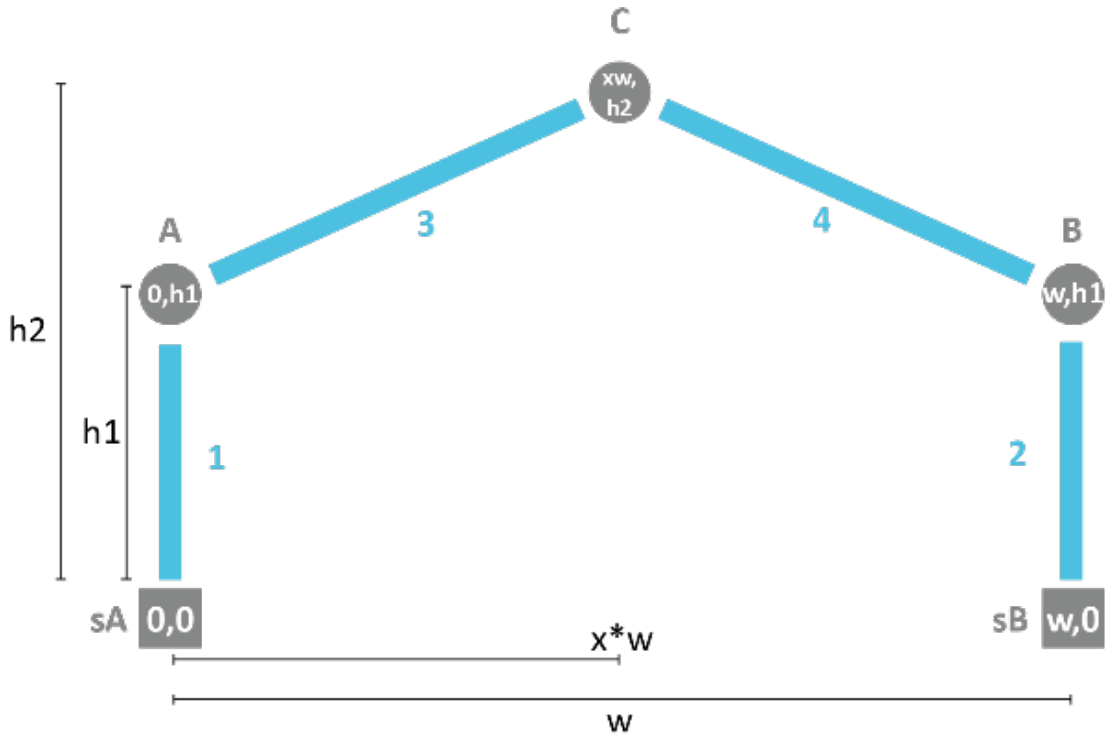
Column: HEA220 = Beam → IPE270

SENSITIVITY ANALYSIS

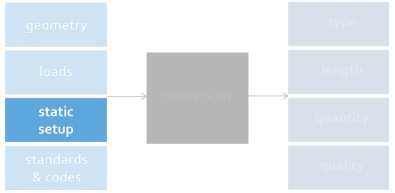


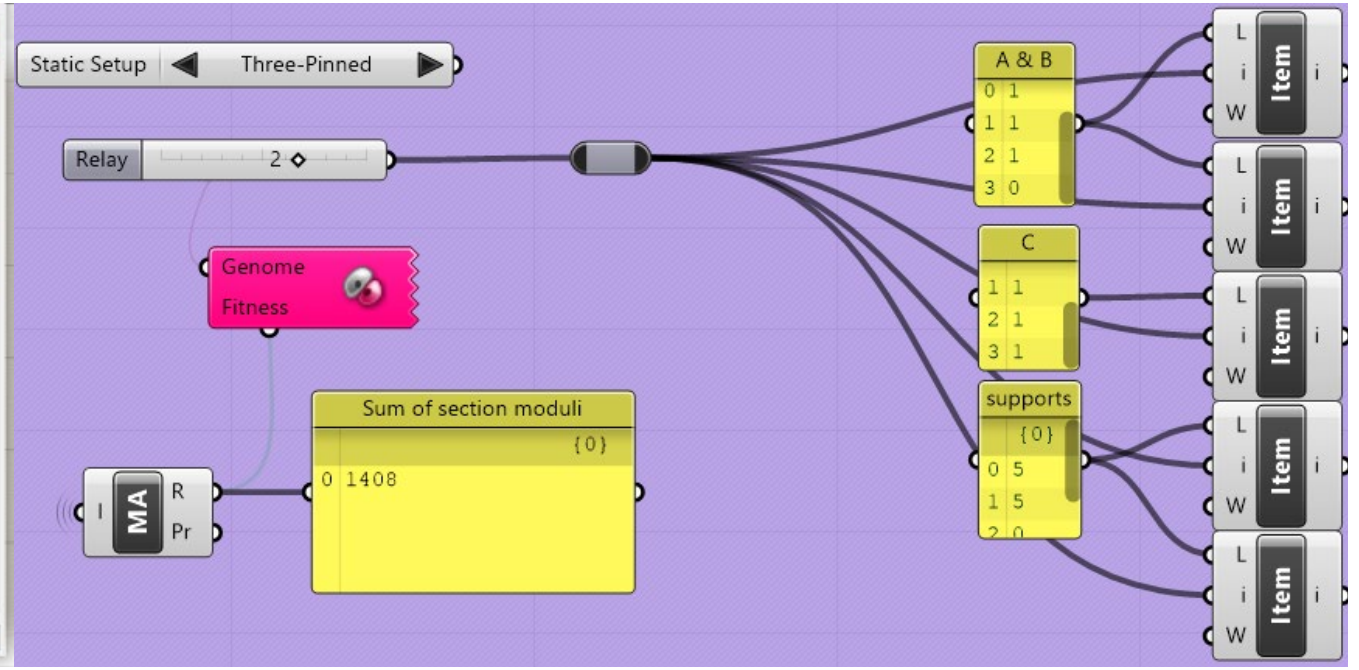
Uncertainty of input values:

- Preset profiles
- Cladding weight
- Portal spacing
- Static setup



STATIC SELECTOR



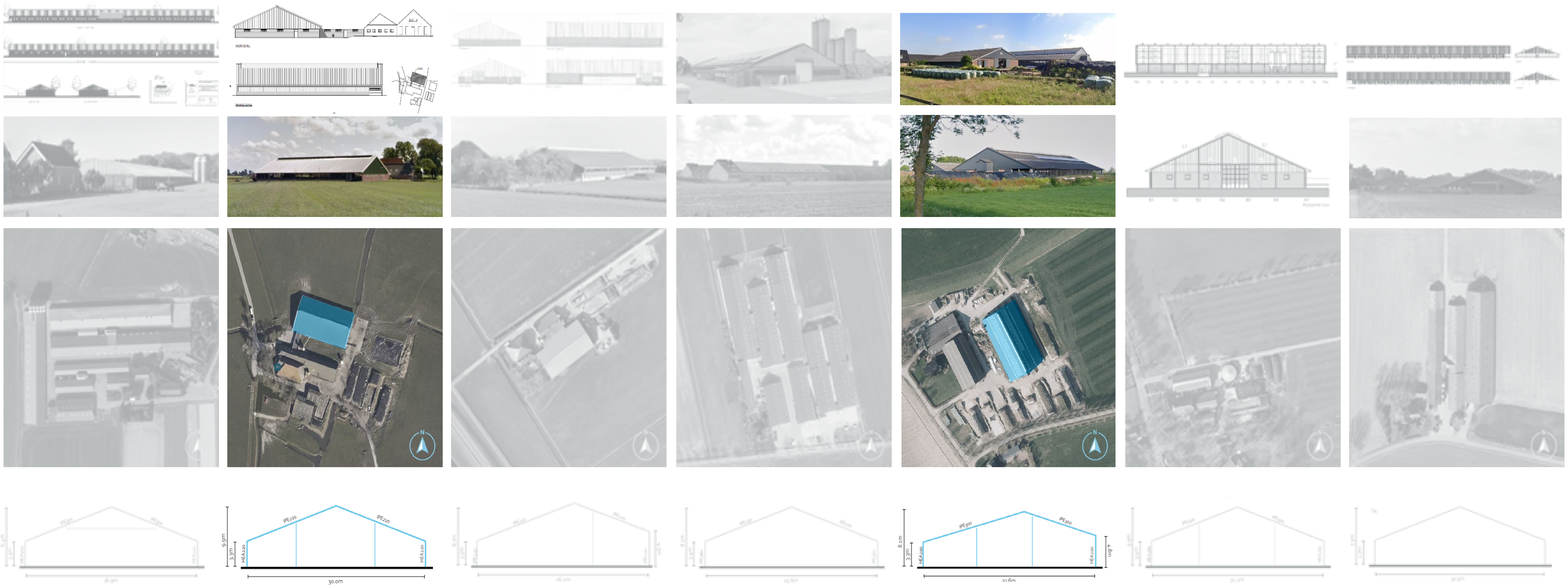


CASES

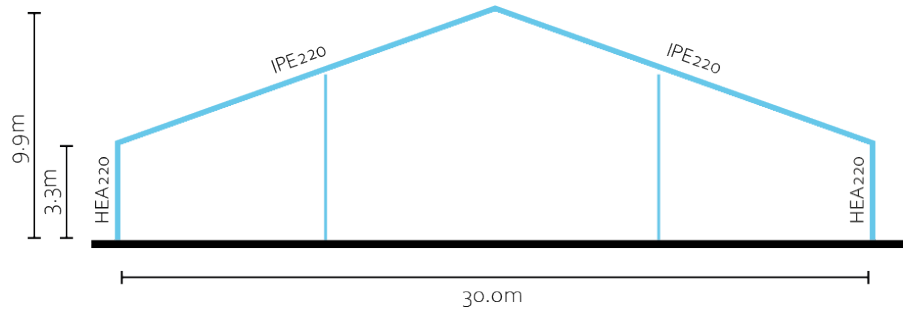
A | B | C | D | E | F | G

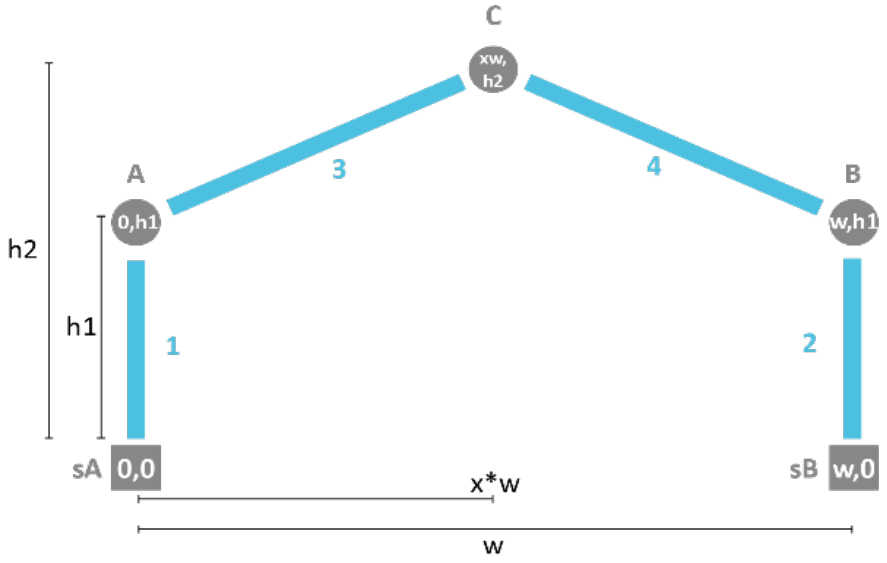
CASES

A B C D E F G



CASE B

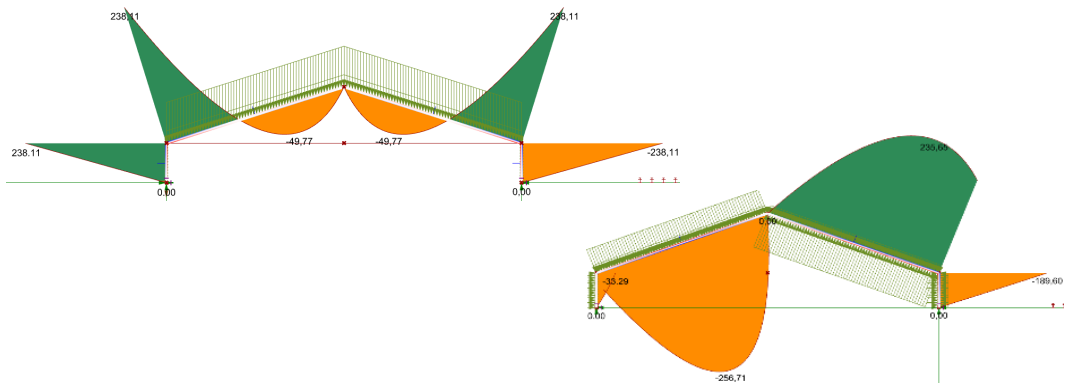




case	element type	length [m]	quantity
B	HEA220	3.3	20
	IPE220	15.6	20

Portal properties	Value
w	30m
h1	3.3m
h2	9.9m
x	0.5
spacing	4.8m
cladding	medium
wind area	II-open
mechanical setup	three-pinned

CASE B - RESULTS



case	element type	length [m]	quantity
B	HEA400	3.2	20
	IPE360	15.7	20

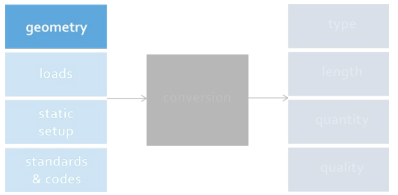
1. Error in input values
2. Static setup of the portal
3. Secondary supporting elements

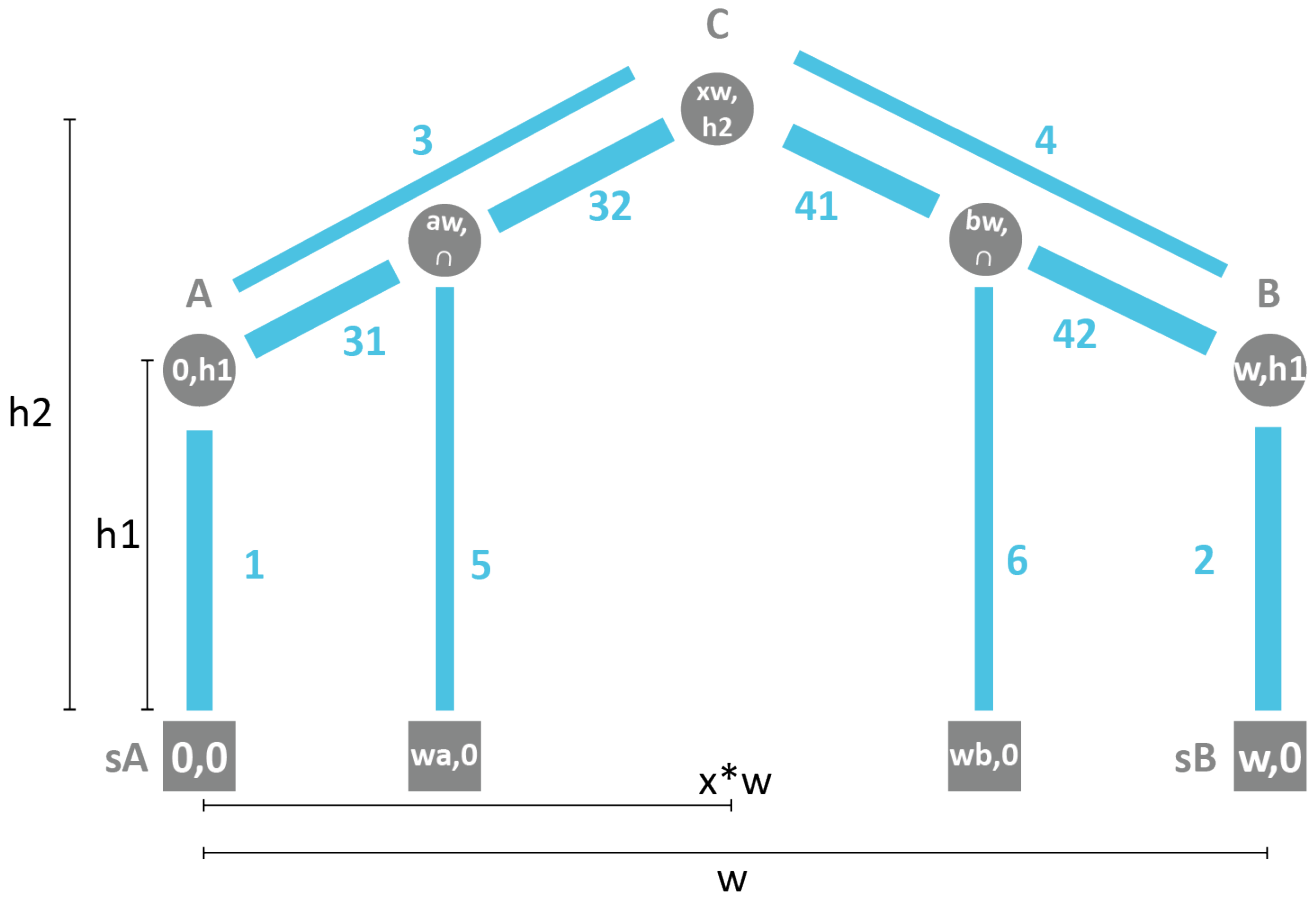
→ Checked - no errors

→ Checked - no improvement in result

→ Requires script to be reworked…

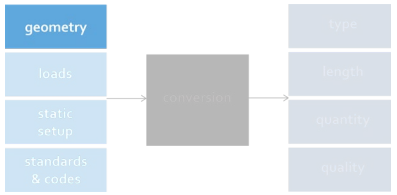
PORTAL DEFINITION V2

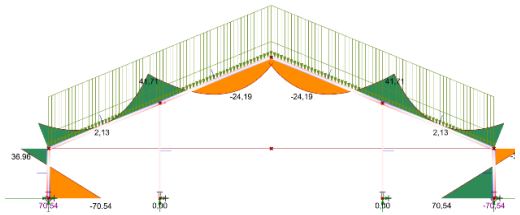


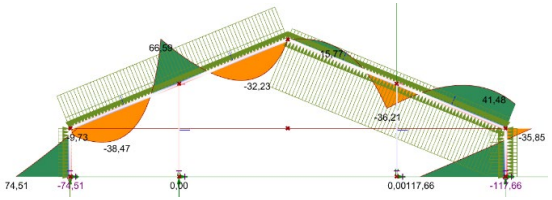


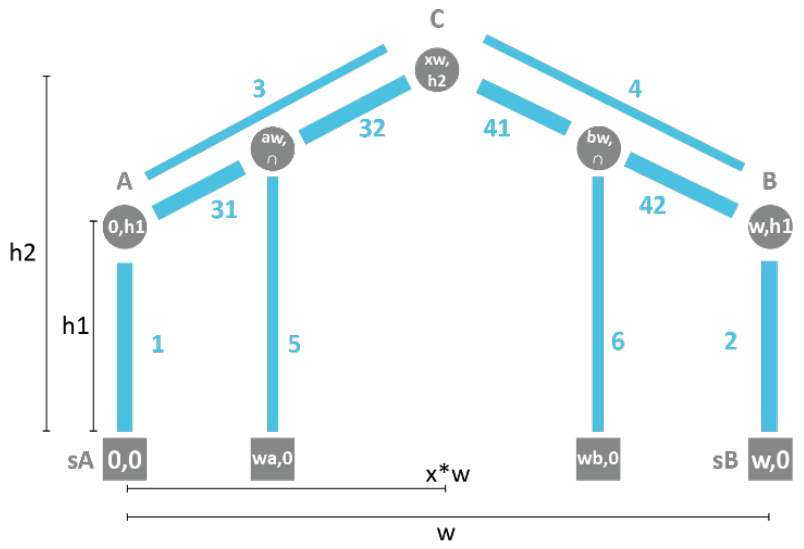
Point	Coordinate
sA	(0,0)
sB	(w1+w2,0)
A	(0,h1.1)
B	(w1+w2,h1.2)
C	(w1,h2)
s'A	(wa,0)
s'B	(wb,0)
ac	∩ (A-C;wa)
bc	∩ (B-C;wb)

CASE B – RESULTS V2





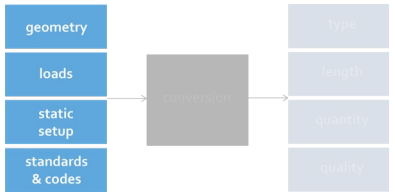


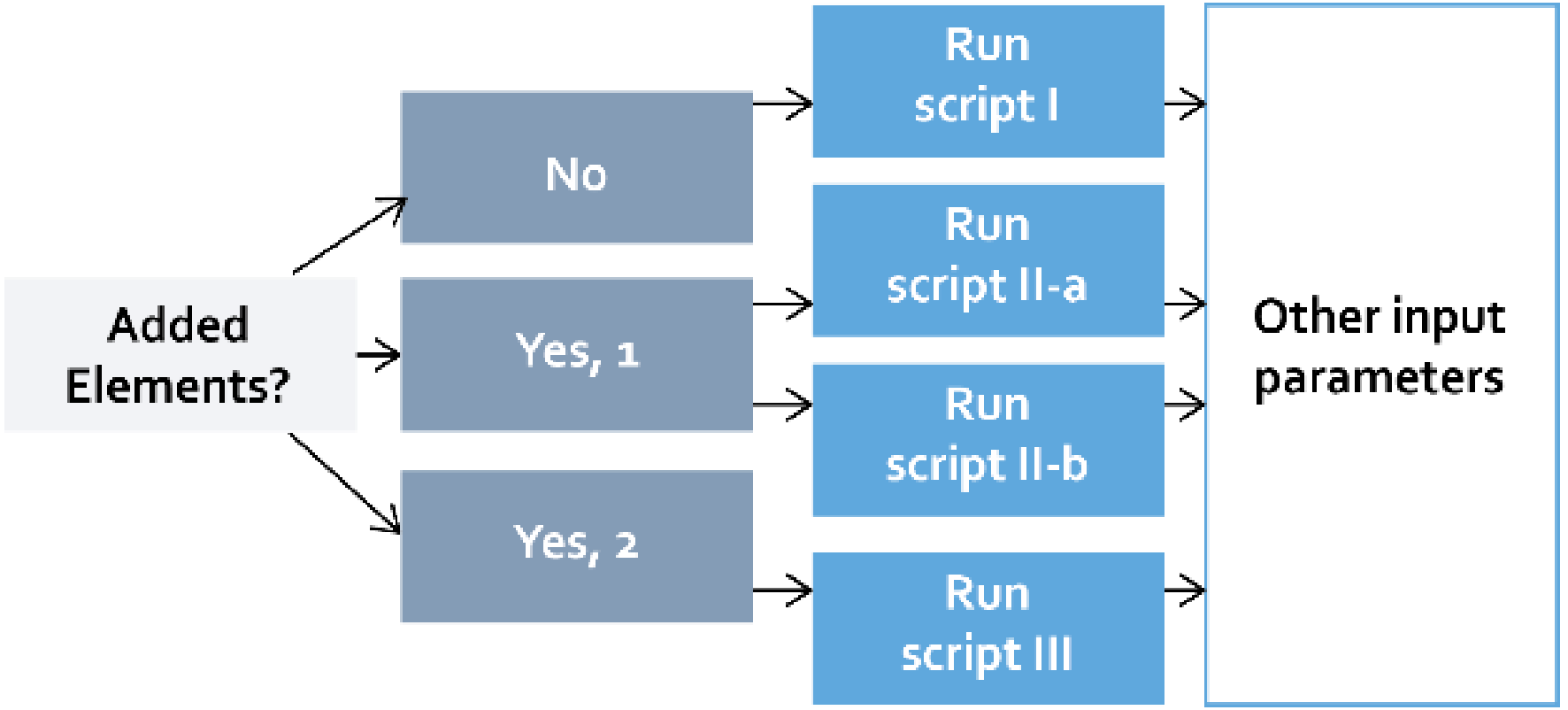


case	element type	length [m]	quantity
B	HEA220	3.2	20
	IPE240	15.7	20

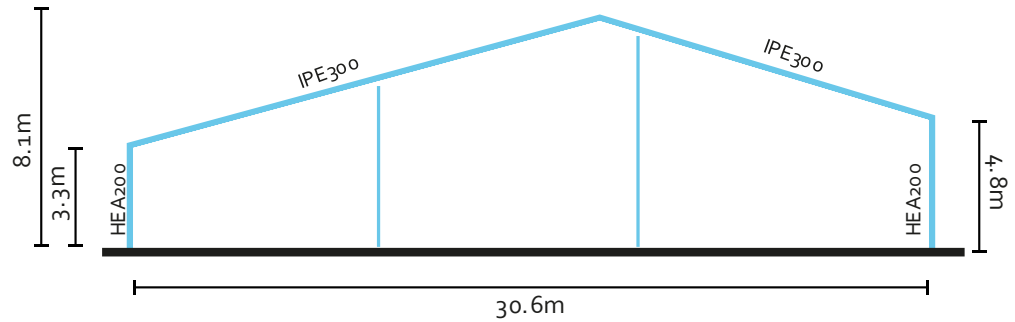
Portal properties	Value
w	30m
h1	3.3m
h2	9.9m
x	0.5
spacing	4.8m
cladding	medium
wind area	II-open
mechanical setup	rigid frame

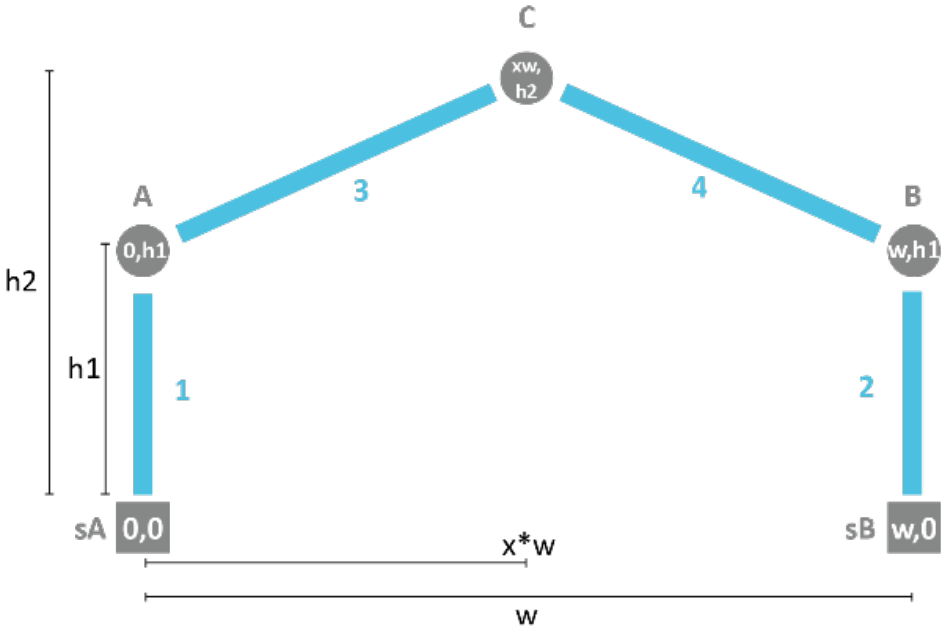
SCRIPT SELECTION





CASE E

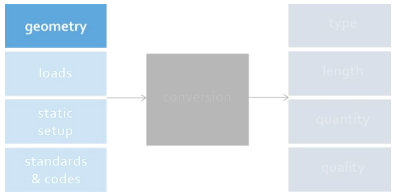


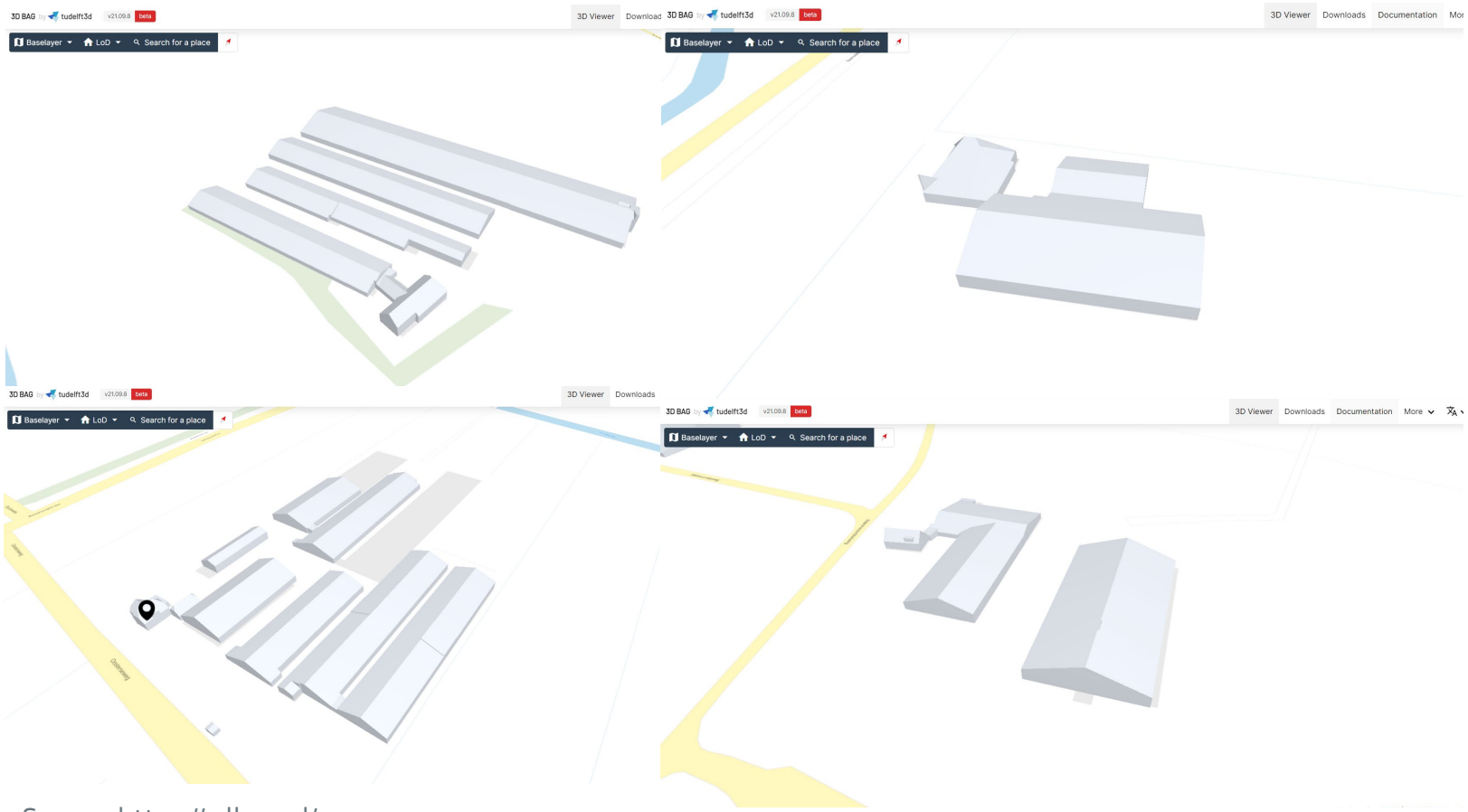


case	element type	length [m]	quantity
E	HEA200	3.3	17
	HEA200	4.8	17
	IPE300	17.4	17
	IPE300	15.0	17

Portal properties	Value
w	30.6m
h1.1	3.3m
h1.2	4.8m
h2	9.9m
x	0.58
spacing	5 m
cladding	medium
wind area	III-open
mechanical setup	three-pinned

3DBAG GEOMETRY

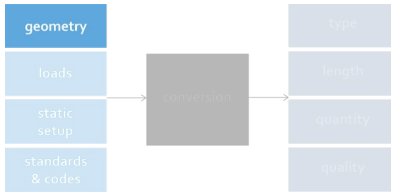




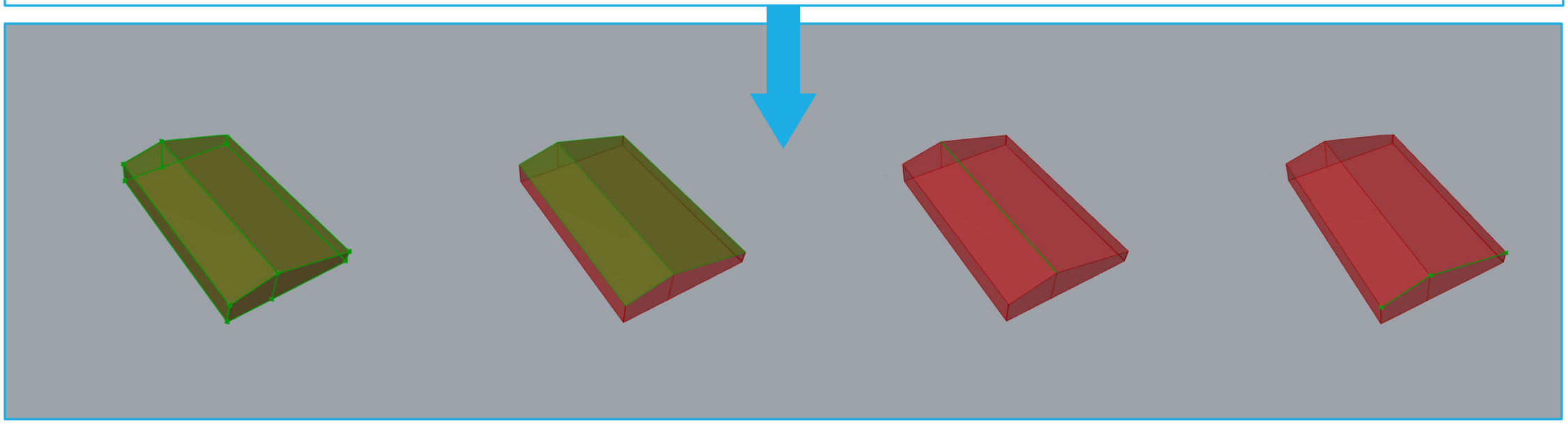
Source: https://3dbag.nl/

dak_type	slanted
data_area	17.892.801.513.671.800
data_coverage	0.9234398603439331
documentnummer	20080045-M
geconstateerd	false
gid	5107108
h_dak_50p	7.578.999.996.185.300
h_dak_70p	8.717.000.007.629.390
h_dak_max	10.739.999.771.118.100
h_dak_min	463.700.008.392.334
h_maaiveld	0.5419999957084656
identificatie	**NL.IMBAG.Pand.0140100000179936**
kas_warenhuis	false
lod11_replace	false
ondergronds_type	above ground
oorspronkelijkbouwjaar	2010
pw_actueel	yes
pw_bron	ahn3
reconstructie_methode	tudelft3d-geoflow
reconstruction_skipped	false
rmse_lod12	2.016.771.078.109.740
rmse_lod13	2.047.823.905.944.820
rmse_lod22	0.031802497804164886
rn	1
status	Pand in gebruik
t_run	5.758.410.034.179.680

GEOMETRY SELECTION

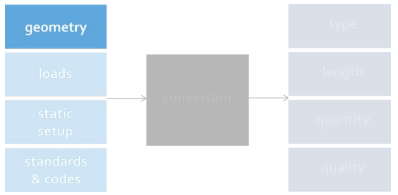


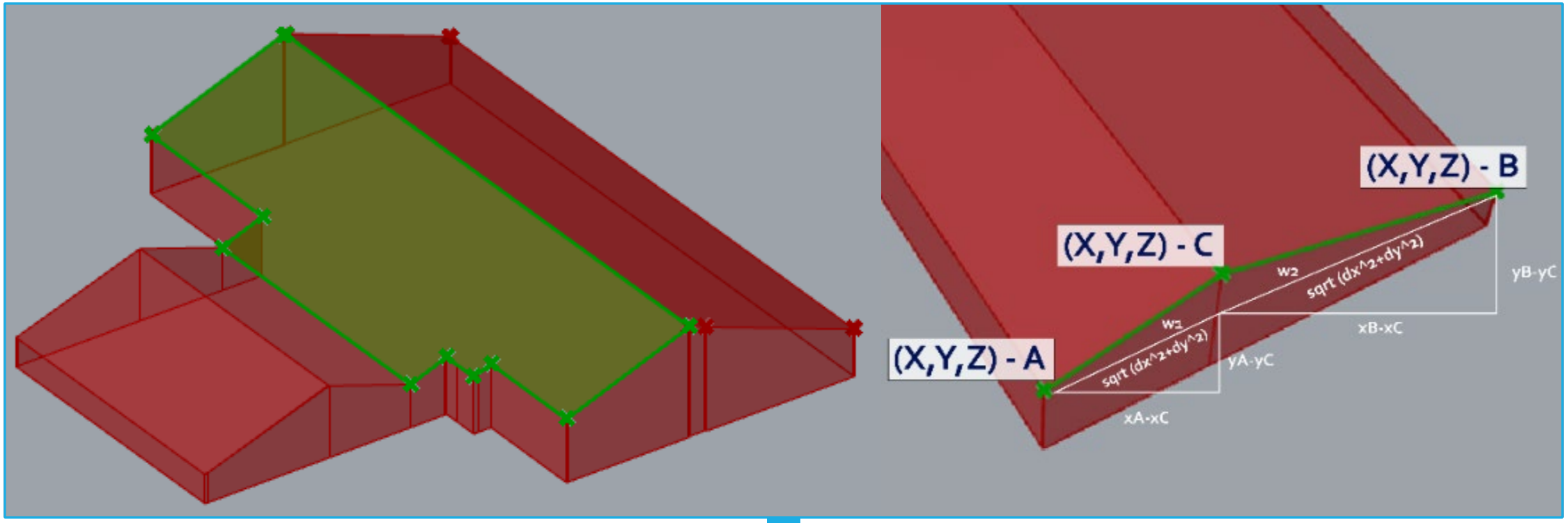
Explode faces > define rules based on mathmatical properties > select faces > select edges



1. Explode Geometry
2. Roof Selection
3. Ridge Selection
4. Slope Selection

CHALLENGES



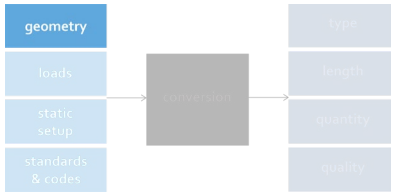


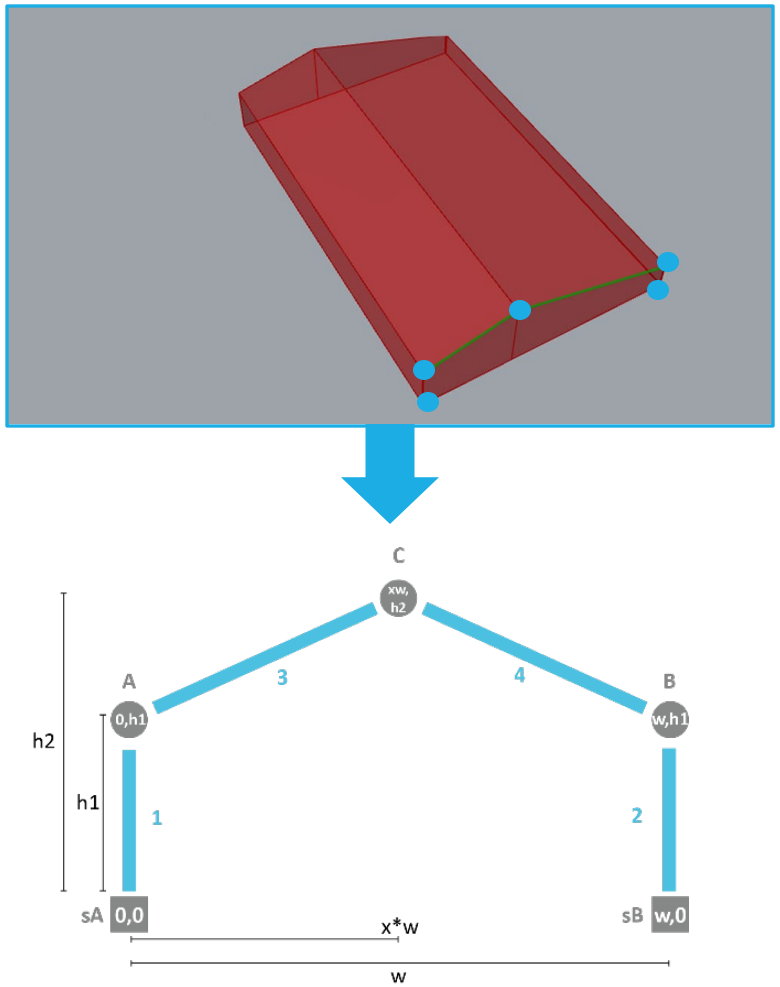
Complex surfaces

Relative positioning

Revise mathmatical rules & approach

PANDCODE > GEOMETRY





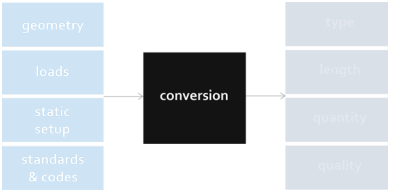
3D BAG → pand code

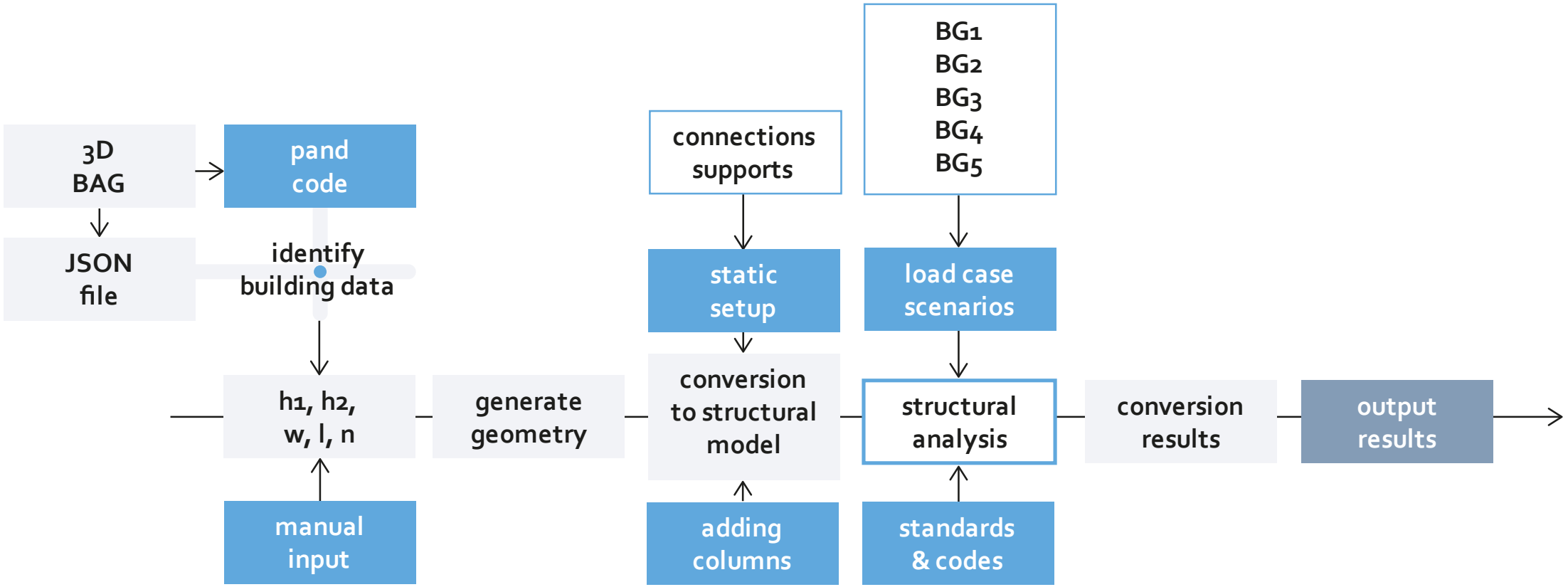
JSON file

identify building data

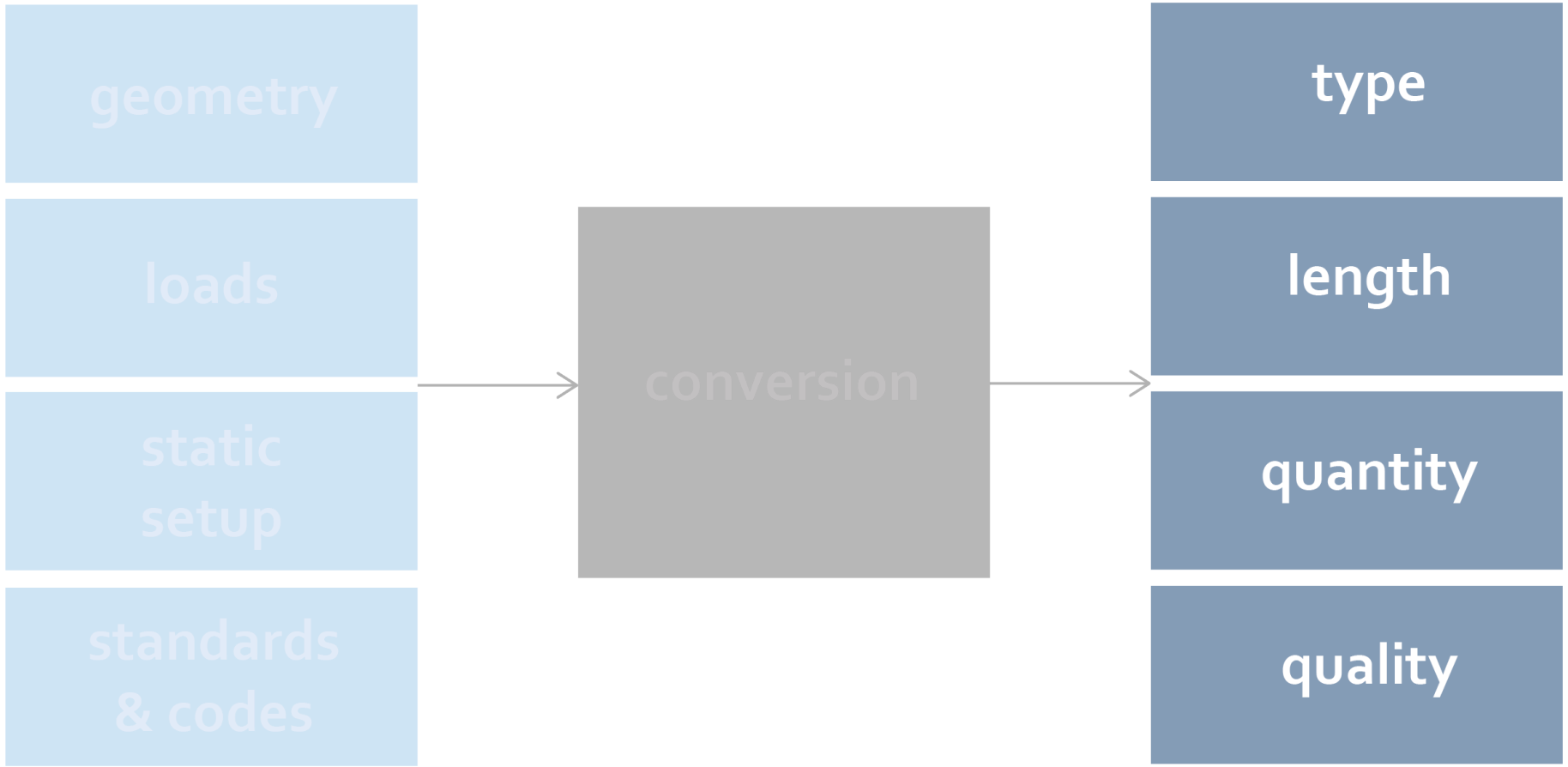
h1, h2, w, l, n

EXTENDED WORKFLOW

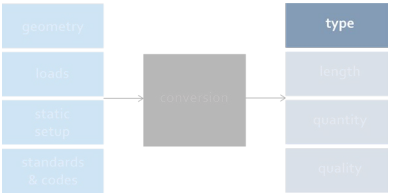




OUTPUT


geometry
loads
static setup
standards & codes
conversion
type
length
quantity
quality

OUTPUT RESULTS

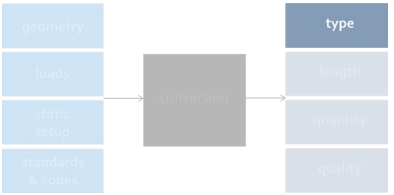


- Results expressed as profile deviation
- Underestimation < Overestimation

	A	B	C	D	E	F	G	Average
Id1;id2	+1	0	+3	0	+1	+1	+2	+1,15
Id3;id4	0	+1	+5	+2	0	0	0	+1,15

	A	B	C (lc1)	D	E	F	G	Average
Id1;id2	+1	0	-1	0	+1	+1	+2	+0,57
Id3;id4	0	+1	0	+2	0	0	0	+0,43

CORRECTION FACTOR

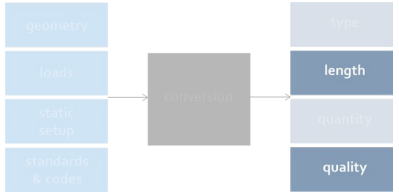


- Half a profile class = half range mm3 between 2 profiles
- Tool indicative rather than exact

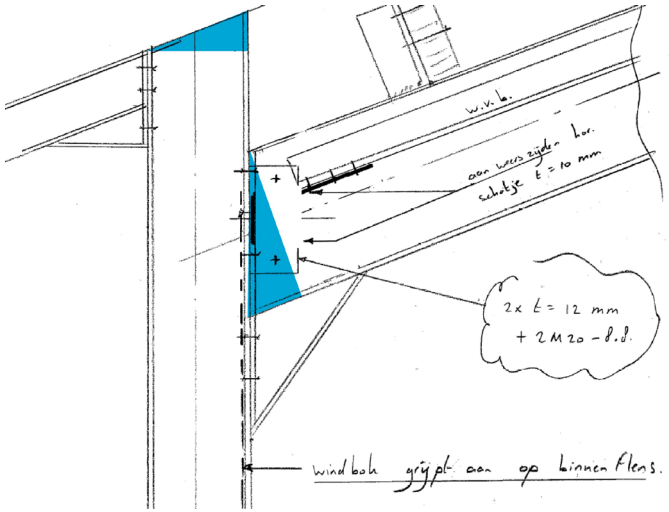
	A	B	C (lc1)	D	E	F	G	Average
Id1;id2	+1	0	-1	0	+1	+1	+2	+0,57
Id3;id4	0	+1	0	+2	0	0	0	+0,43

	A	B	C (lc1)	D	E	F	G	Average
Id1;id2	0	0	-1	0	0	+1	+1	+0,14
Id3;id4	0	+1	0	+1	-1	0	0	+0,14

LOSS & DEGRADATION



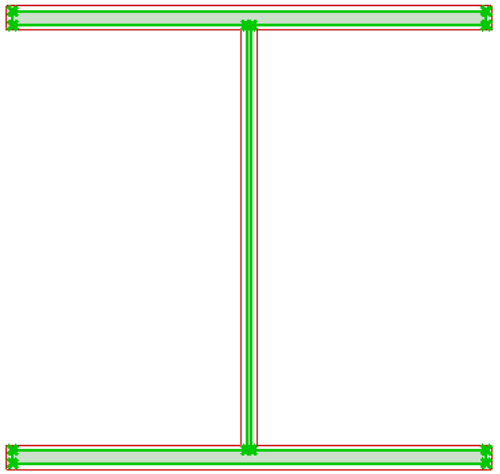
Length loss due to deconstruction



Length lost [m] =

*2 * tan (x) * profile height [m]*

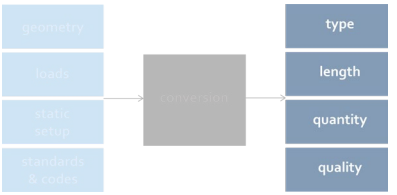
Performance loss due to degradation



Degradation rate * n years

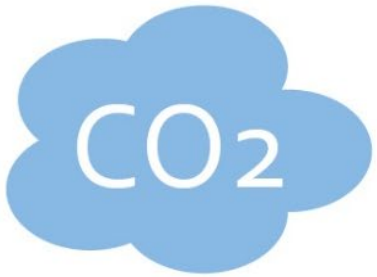
Performance = Syc / Syc+n

SAVINGS ANALYSIS



energetic

MJ/kg steel



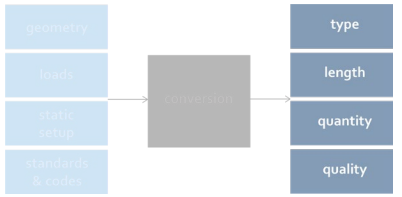
environmental

Kg CO2/kg steel

economic

€/kg steel

QUICKSCAN OUTPUT

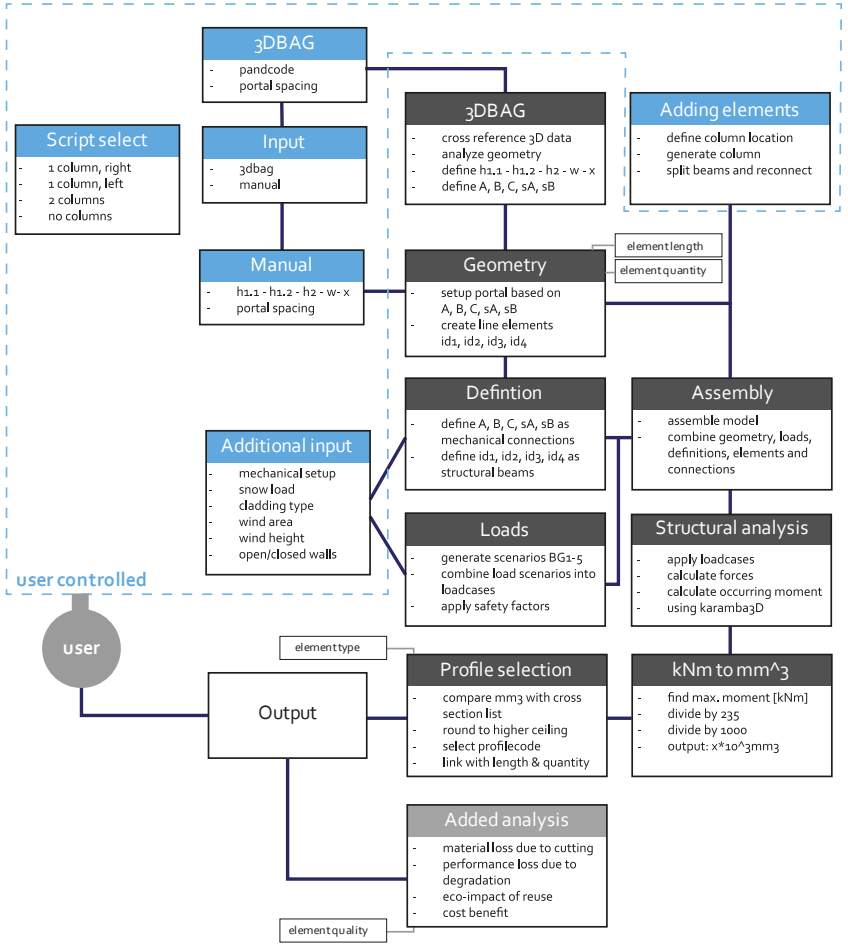


Element	Length [m]	Type	Quantity	Performance S	Performance A	CO_2 savings [kg]	Energy savings [MJ]	Cost benefit [euro]
id_1	3,3	HEA240	16	0,944	0,937	3.698	51.937	1413,98
id_2	6,6	HEA240	16	0,944	0,937	5.379	75.544	2056,7
id_3	17,4	IPE300	16	0,939	0,932	16.011	224.855	6121,71
id_4	14,5	IPE300	16	0,939	0,932	13.801	193.821	5276,8

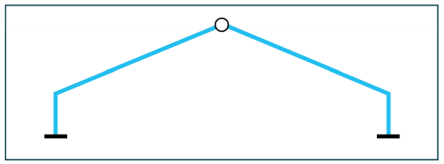
CO_2 savings [T]	Emb. energy Saved [GJ]	Euro saved salvaging
43,1	605,2	€ 16.476,45

USER PERSPECTIVE

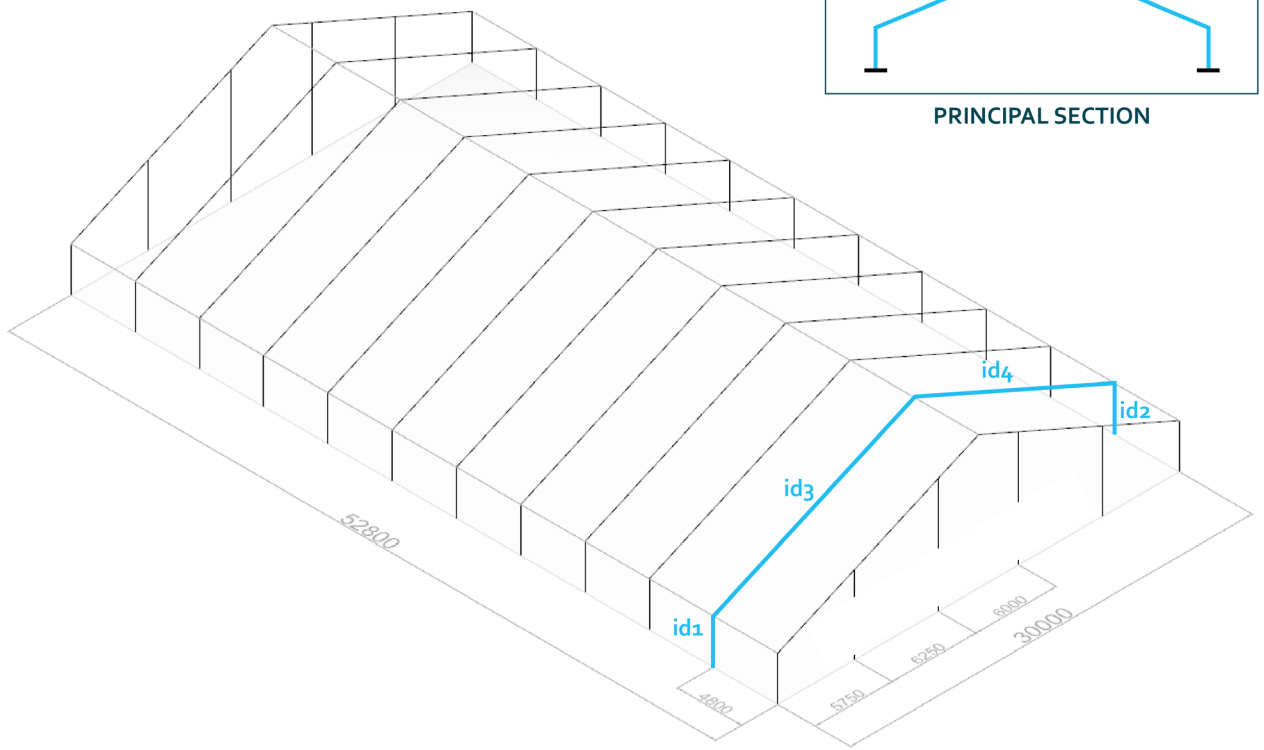
Step	Input
1.	Extra supporting elements? – Yes, 2 – Yes 1, right – Yes, 1 left – No
2.	3DBAG input available? – Yes – No
	Script version selection
3.	3DBAG / Geometrical input
4.	Cladding type
5.	Wind area
6.	Open/closed sides
7.	Static setup (if needed: optimization)
8.	Price/kg new steel beam
9.	Price/kg reused beam
10.	In case of no 3DBAG: year of construction
11.	Button to export to excel sheet



UI-HALL INPUT



PRINCIPAL SECTION



SUPPORTING ELEMENTS

(•) None ( ) One-L
( ) Two ( ) One-R

PANDCODE

NL.IMBAG.0476100000003241

WIND AREA: II-Open

CLADDING: Medium

OPEN SIDES

(•) None ( ) One-L
( ) Two ( ) One-R

STATIC SETUP: Semi-rigid

OPTIMIZATION: RUN

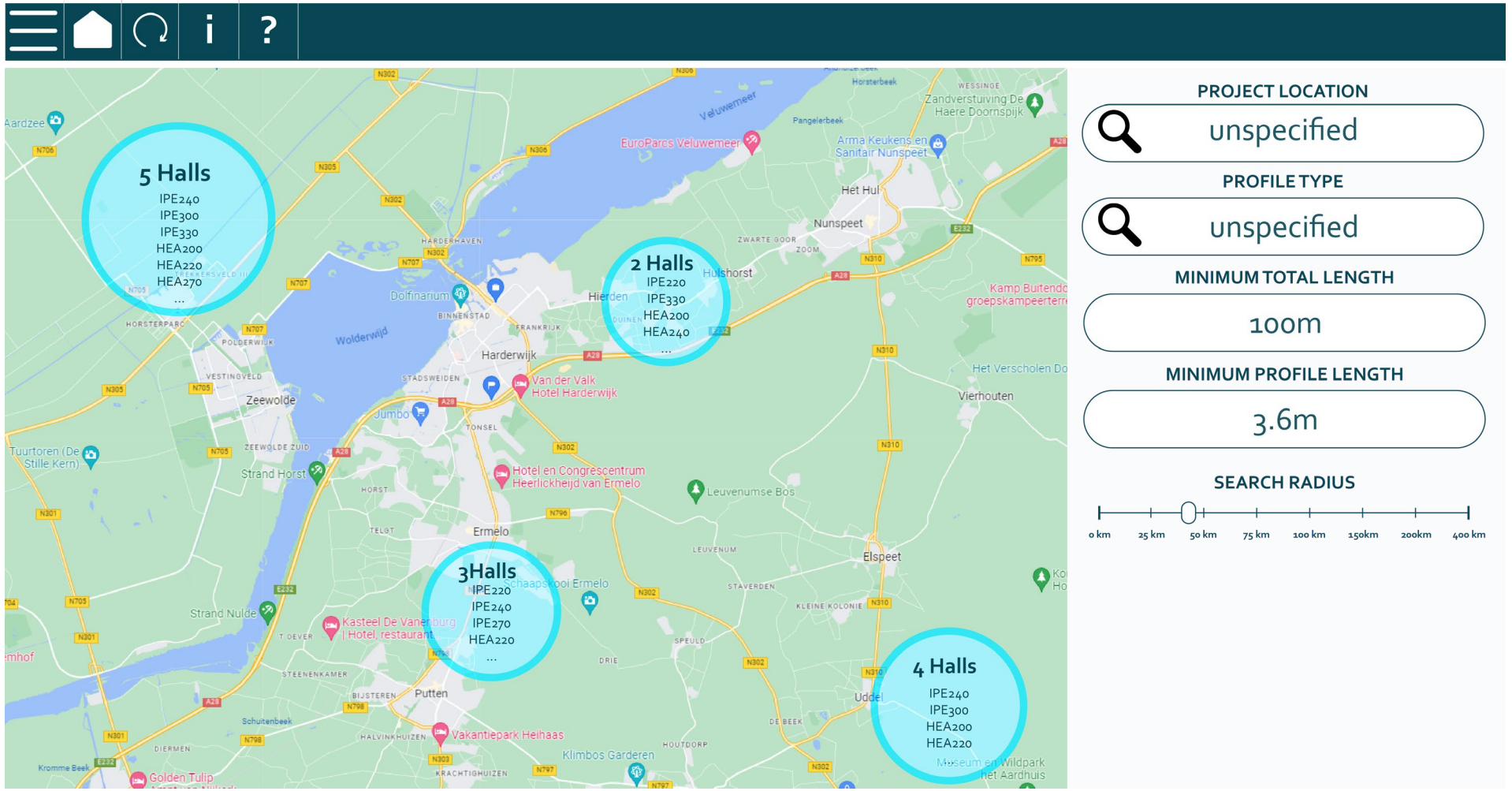
OUTPUT RESULTS

Export to MS Excel

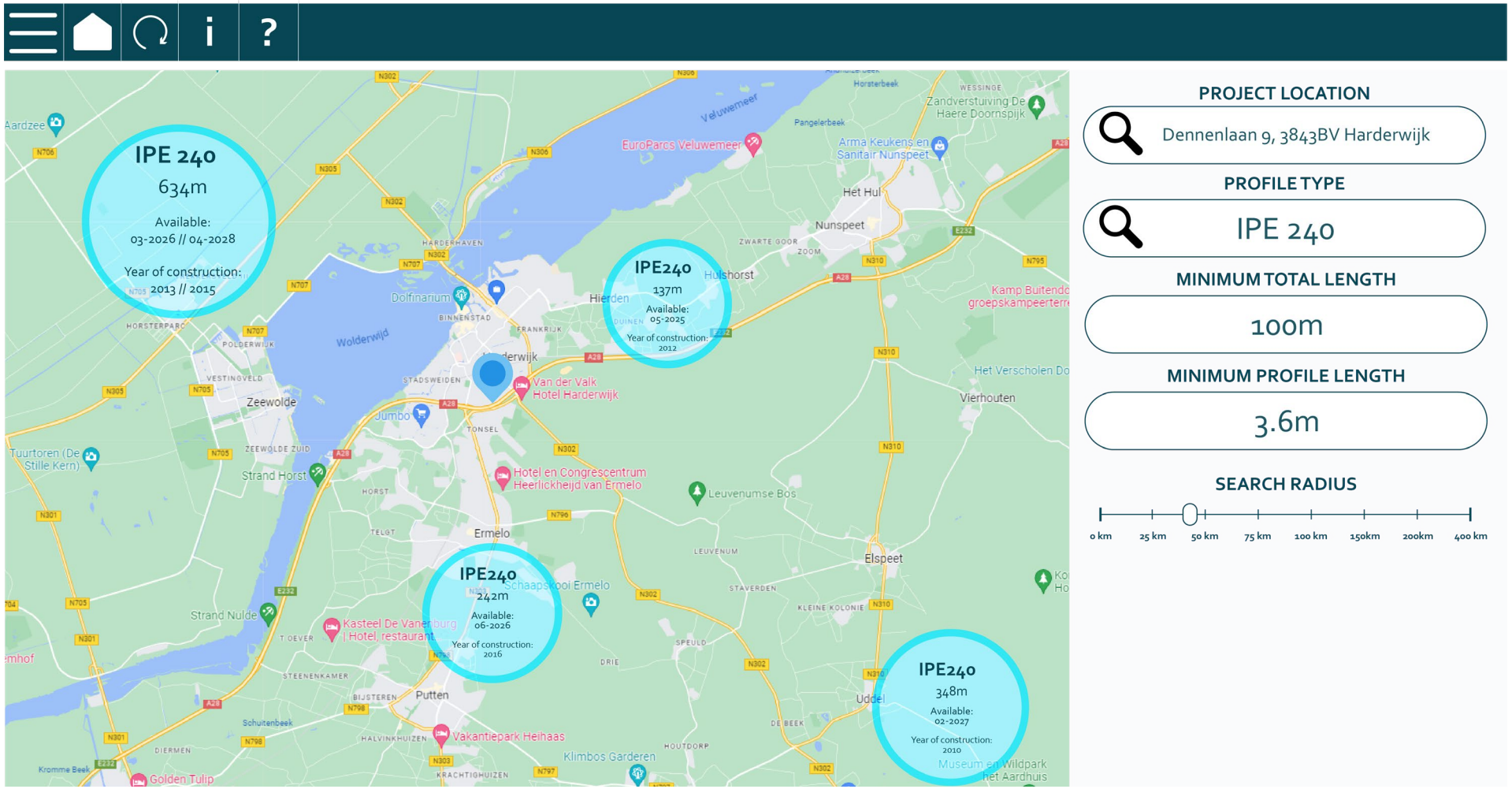
FILE NAME

0476100000003241.xlsx

UI-DESIGNER


5 Halls
IPE240
IPE300
IPE330
HEA200
HEA220
HEA270
...
2 Halls
IPE220
IPE330
HEA200
HEA240
...
3Halls
IPE220
IPE240
IPE270
HEA220
...
4 Halls
IPE240
IPE300
HEA200
HEA220
...
PROJECT LOCATION
unspecified
PROFILE TYPE
unspecified
MINIMUM TOTAL LENGTH
100m
MINIMUM PROFILE LENGTH
3.6m
SEARCH RADIUS
0 km
25 km
50 km
75 km
100 km
150km
200km
400 km

UI-DESIGNER


IPE 240
634m
Available:
03-2026 // 04-2028
Year of construction:
2013 // 2015
IPE240
137m
Available:
05-2025
Year of construction:
2012
IPE240
242m
Available:
06-2026
Year of construction:
2016
IPE240
348m
Available:
02-2027
Year of construction:
2010
PROJECT LOCATION
Dennenlaan 9, 3843BV Harderwijk
PROFILE TYPE
IPE 240
MINIMUM TOTAL LENGTH
100m
MINIMUM PROFILE LENGTH
3.6m
SEARCH RADIUS
0 km
25 km
50 km
75 km
100 km
150km
200km
400 km

LIMITATIONS

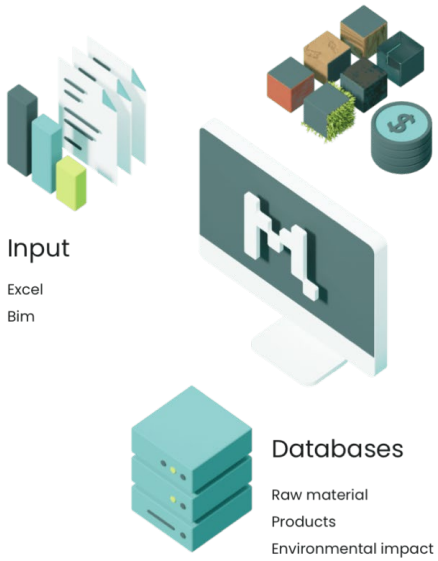
- Limited wind direction
- Front and end portal
- Combined beams & complex solutions
- Suggestive - no guarantee

OPPORTUNITIES & FUTURE RESEARCH

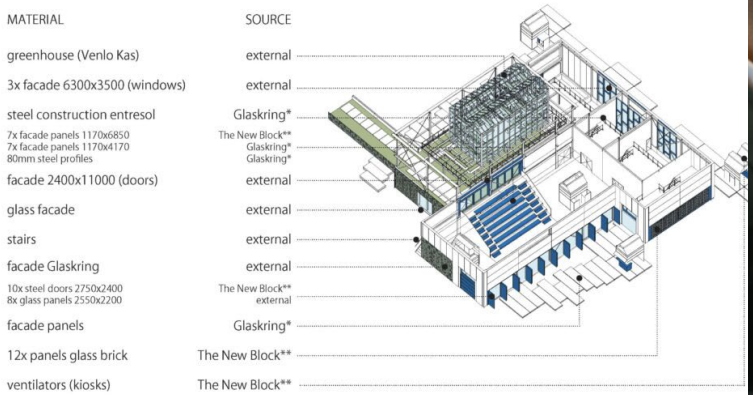
- Economic perspective
- Linking with computational tools
- Batch process & online database
- Evaluating tool with other materials
- Second order element inclusion

PLACING IN CONTEXT

Part of the process of urban mining



Source: Madaster, 2023



Source: The Exploded View, n.d.

Source: Lidarnews.com, 2020

THANK YOU FOR YOUR ATTENTION!

P5 Presentation
Jelle ten Hove
4854136