

Graduation Presentation

Y.U.S.F.

-Your Urban Structural Forestry-

‘A computational framework for urban roundwood stock to supply the loadbearing structure of an architectural design’

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22-1-2026
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TU-DELFT
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- Methodology
- Results
- Conclusion



Figure 1: Felling of urban tree (Source: Tom van der Put, <https://shorturl.at/bE3QF>)

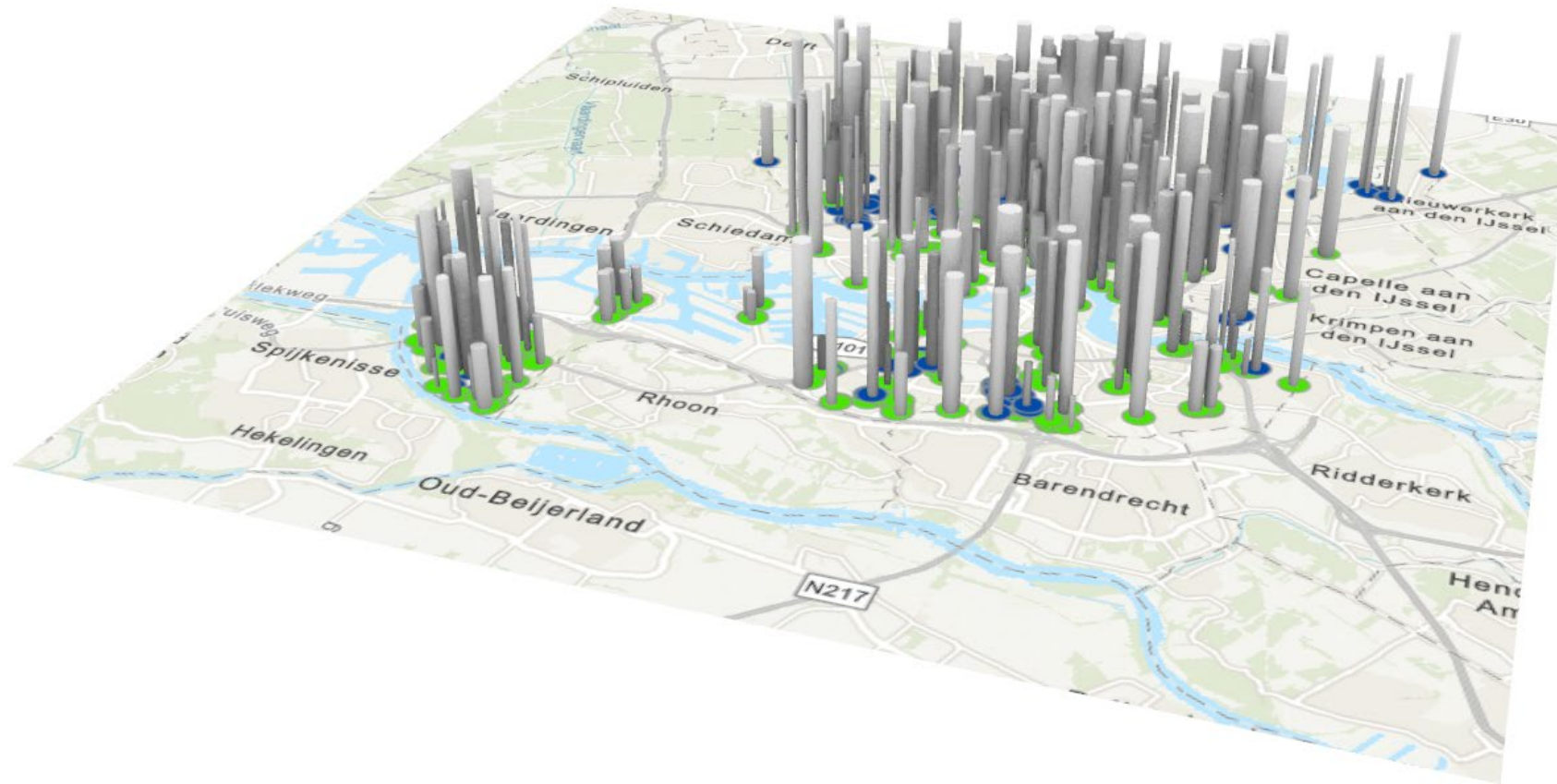
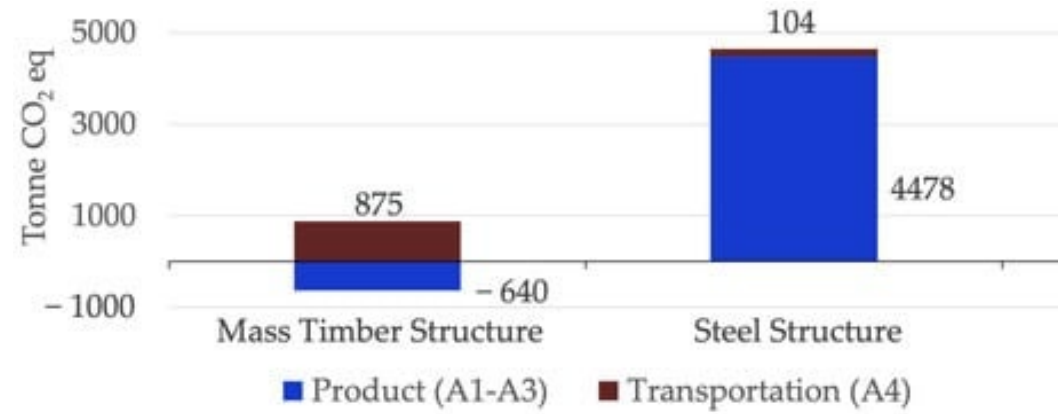


Figure 2:
Overview urban trees Rotterdam
(Source: Author)



Figure 3:
Zoom-in on a Rotterdam urban tree
(Self-made & Rotterdam Municipality, <https://shorturl.at/8l3DL>)



Graph displaying carbon footprint A1 to A4
Timber structure vs Steel Structure

Figure 4:
Graph displaying carbon footprint A1 to A4 Timber structure vs Steel Structure
(Source: Hemmati et al., 2024)

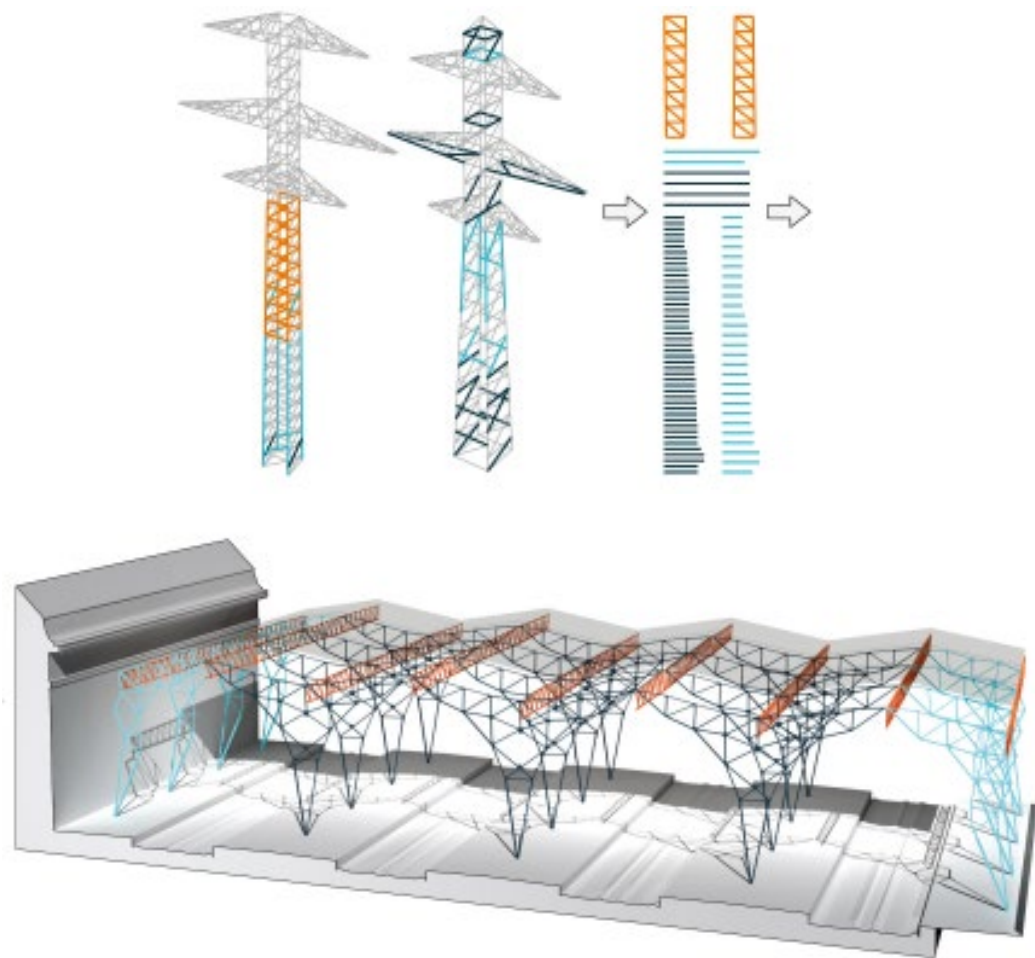


Figure 5:
The reuse of load-bearing components
(Brütting et al., 2019)



Figure 6:
Tree fork truss
(Zachary & Martin, 2016)

Research Question

“How can felled **urban trees** be processed into **taylor-made** load-bearing **architectural elements** using **computational optimization**?”

Methodology

Overview Methodology

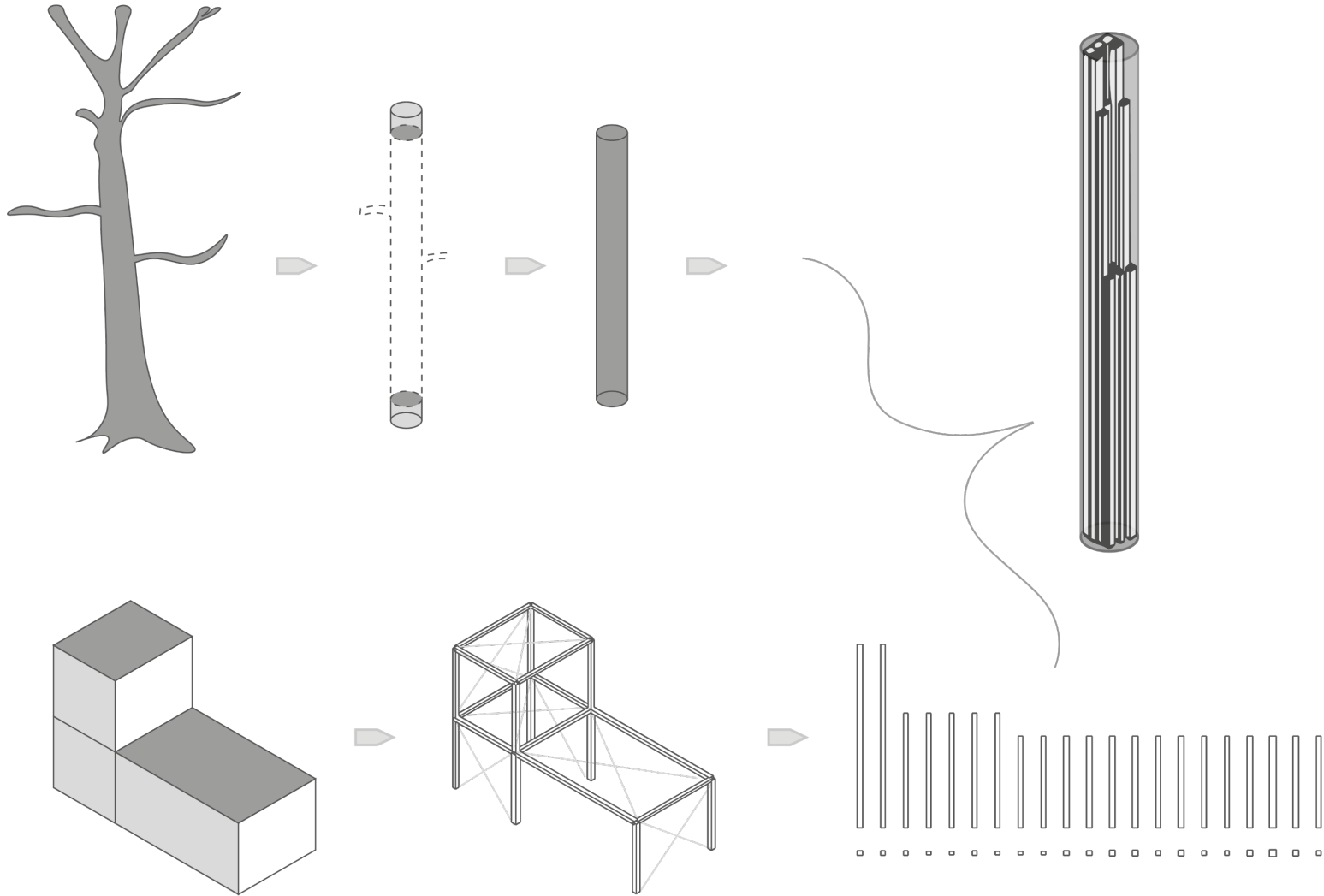


Figure 7:
Overview methodology
(Source: Author)

Urban wood stock

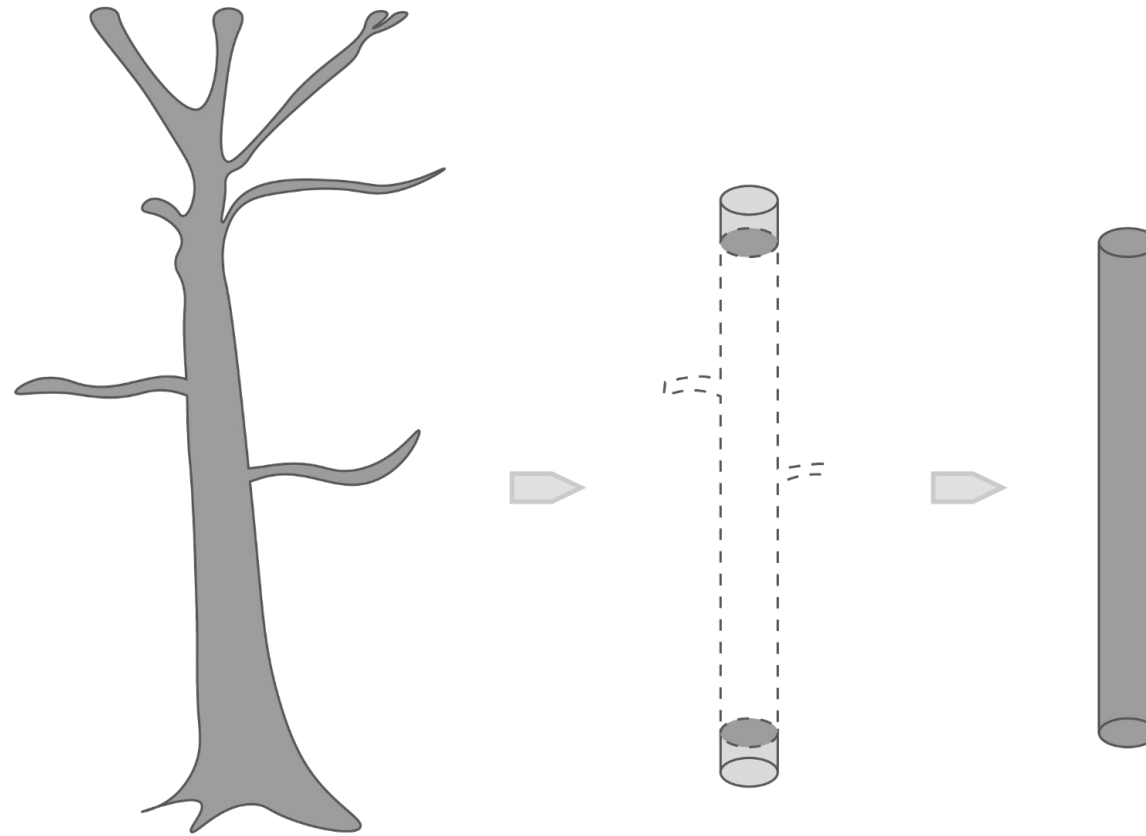


Figure 7:
Overview methodology
(Source: Author)

Overview marked trees Rotterdam

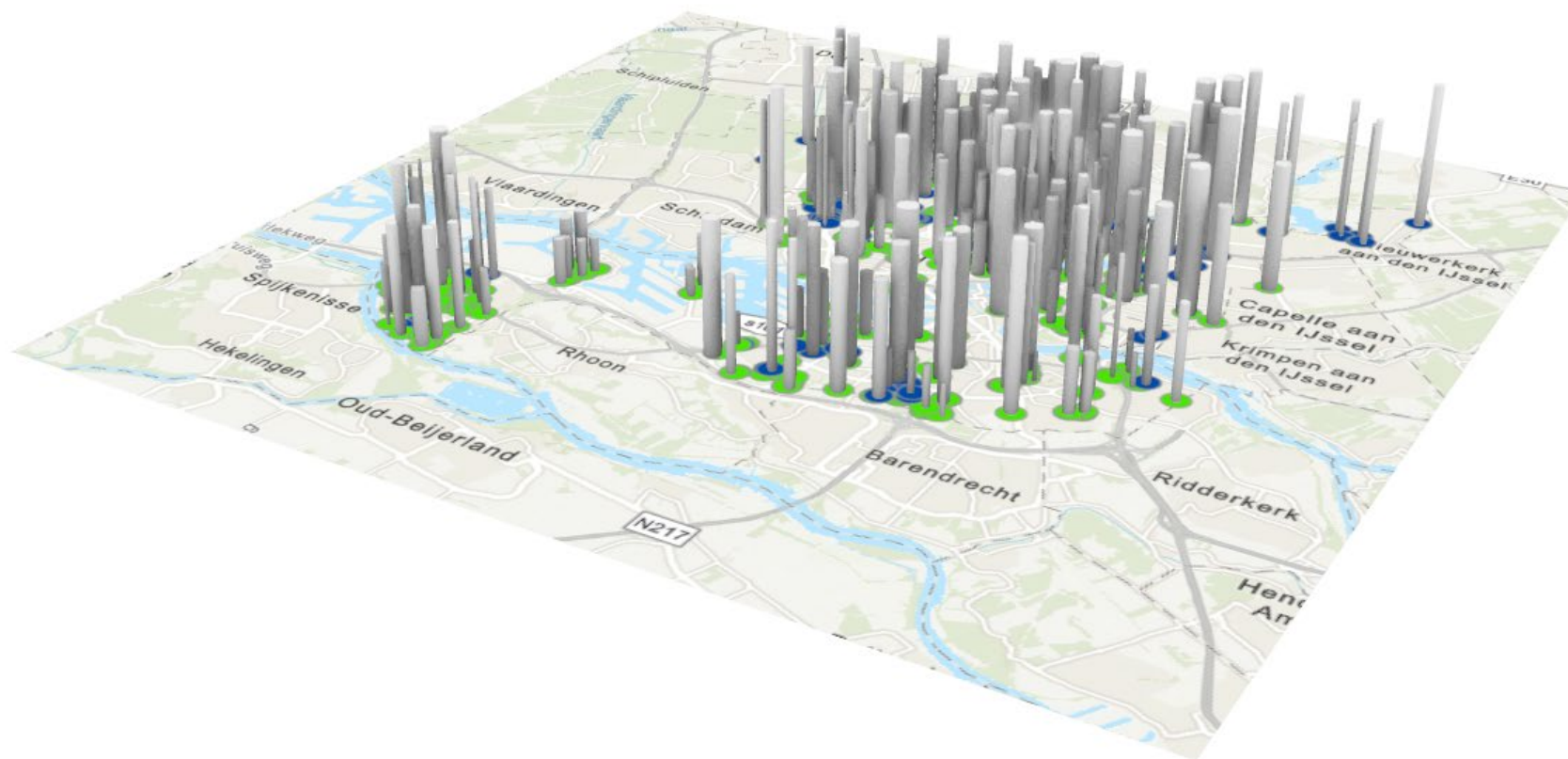


Figure 8:
Overview trees Rotterdam
(Source: Author)

Urban wood stock

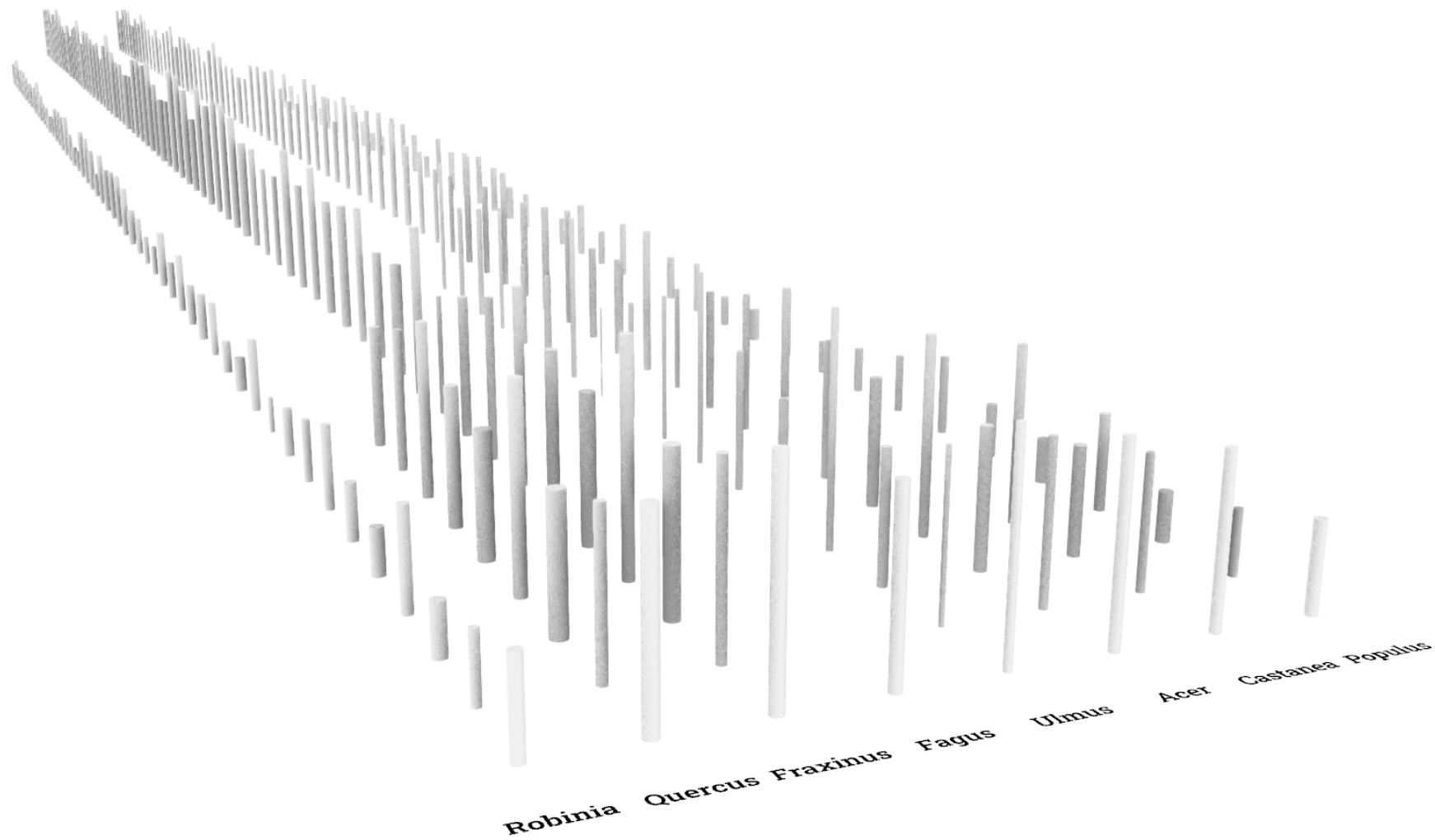


Figure 9:
Overview 3D Rotterdam, species
(Source: Author)

Species	Amount
Robinia	56
Quercus	9
Fraxinus	68
Fagus	1
Ulmus	17
Acer	70
Castanea	4
Populus	45
Total	270

Table 1:
Overview total trees by species
(Source: Author & 'Gemeente Rotterdam')

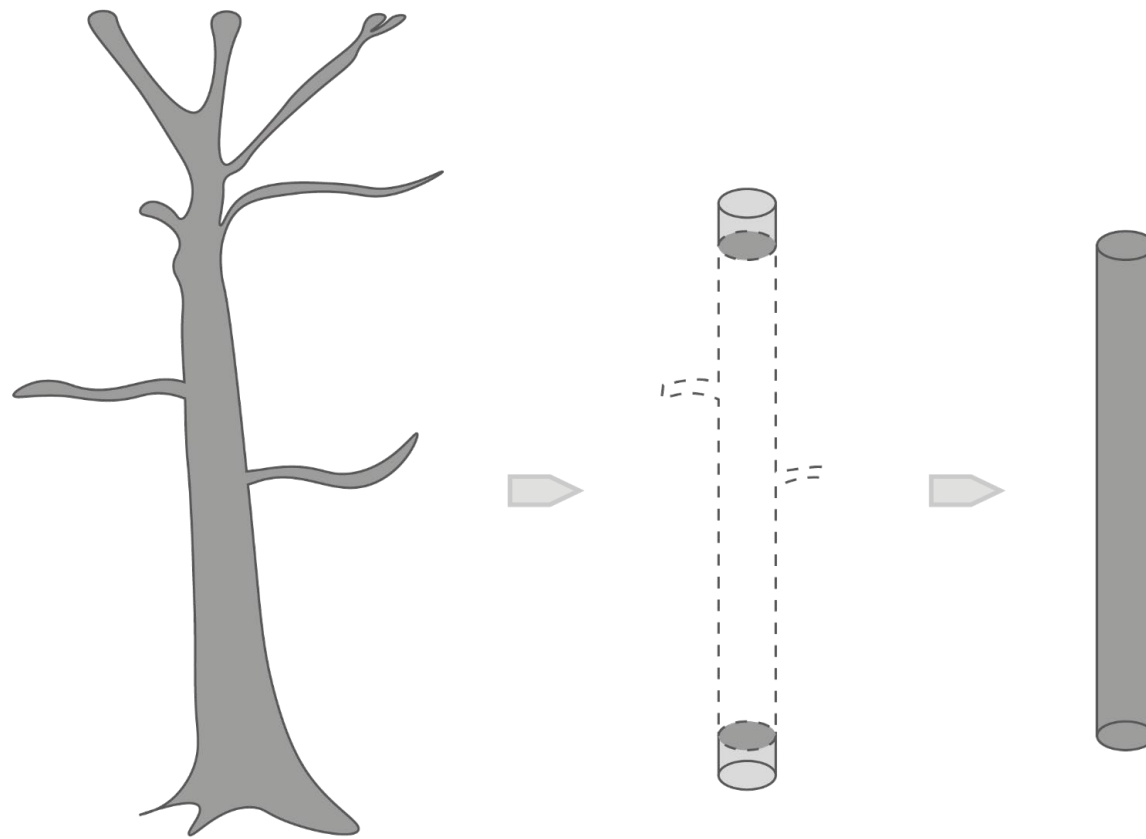


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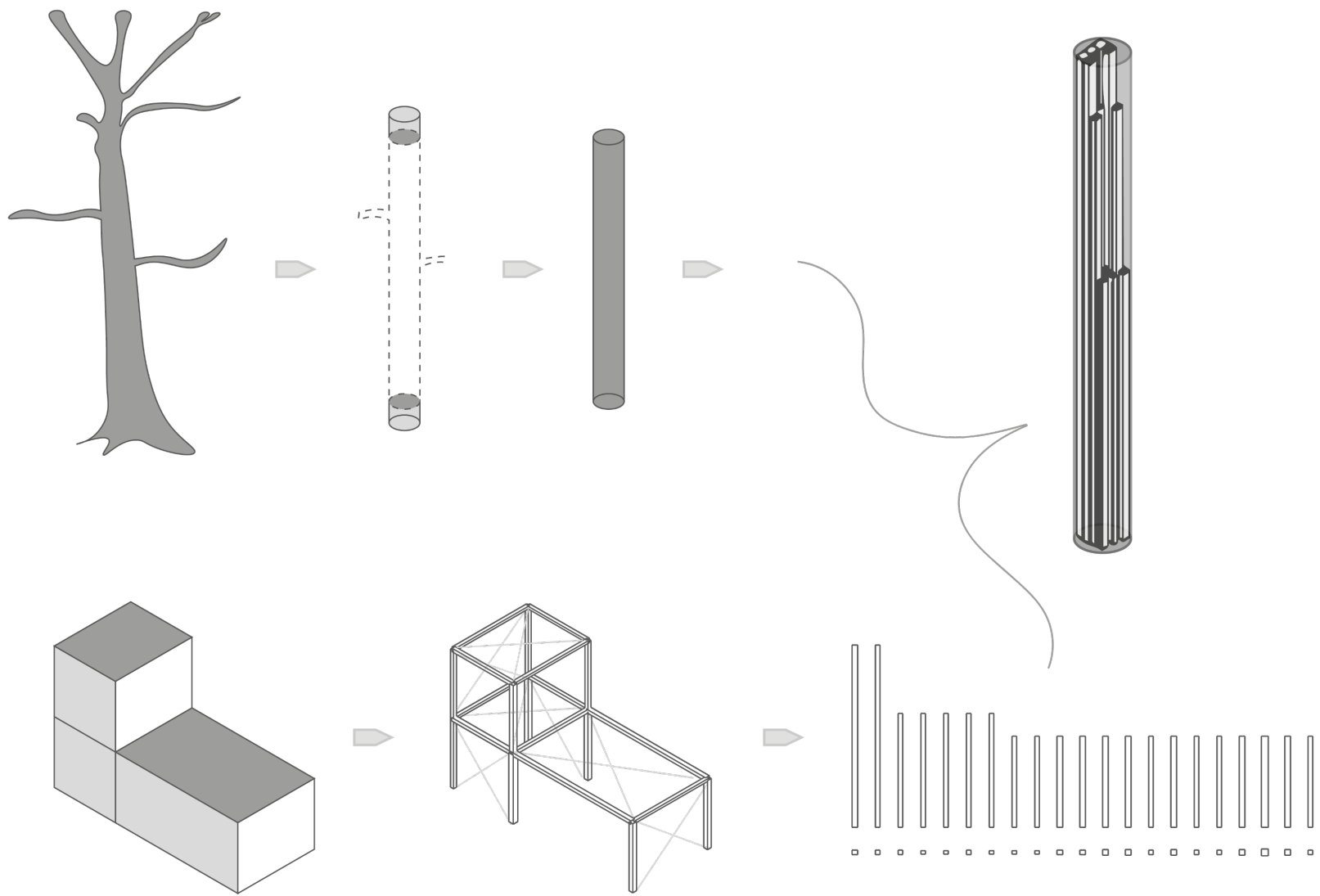


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 Overview methodology
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Element dimensioning

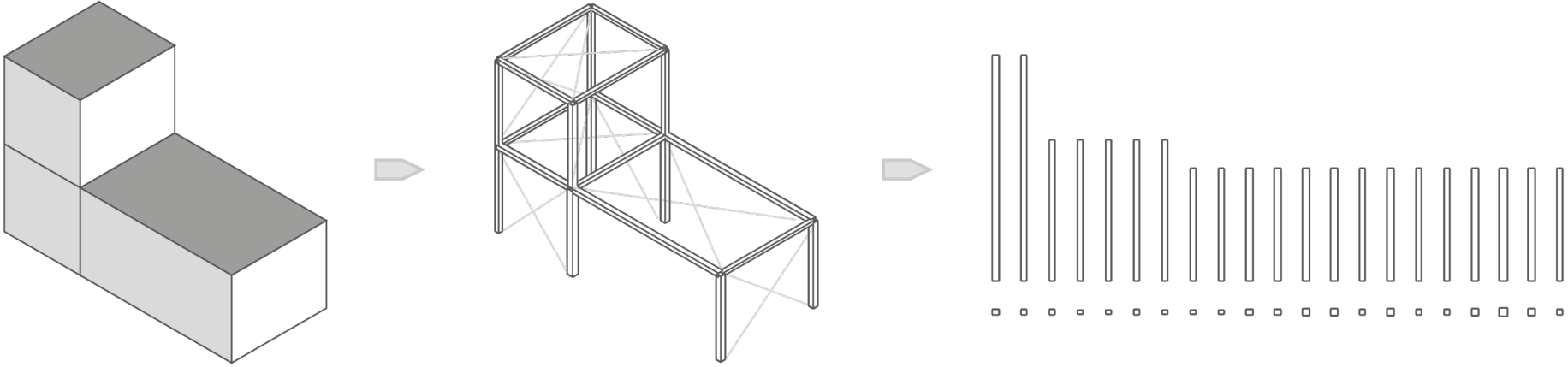


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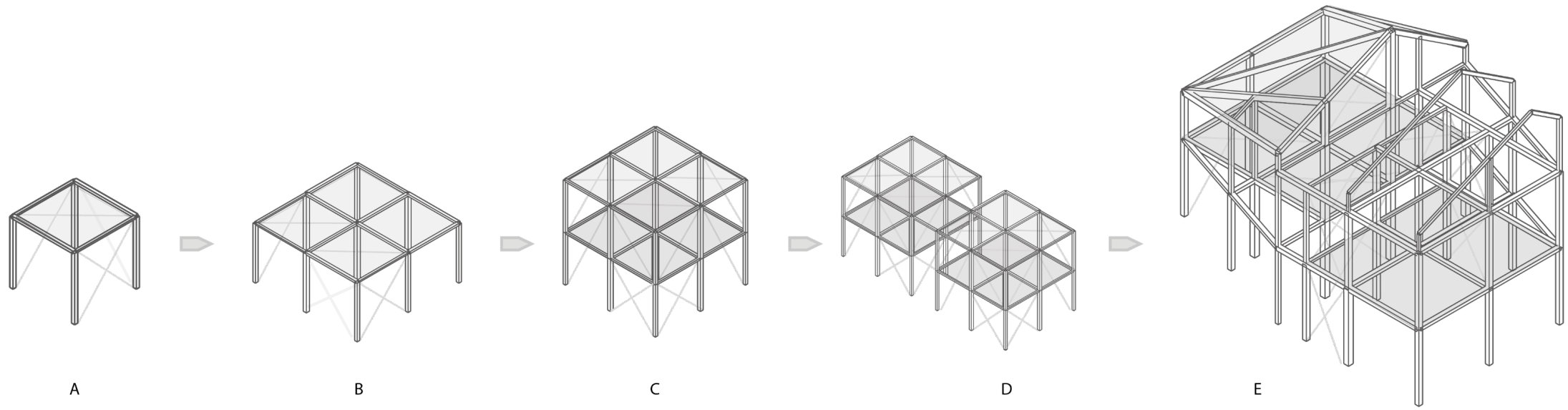
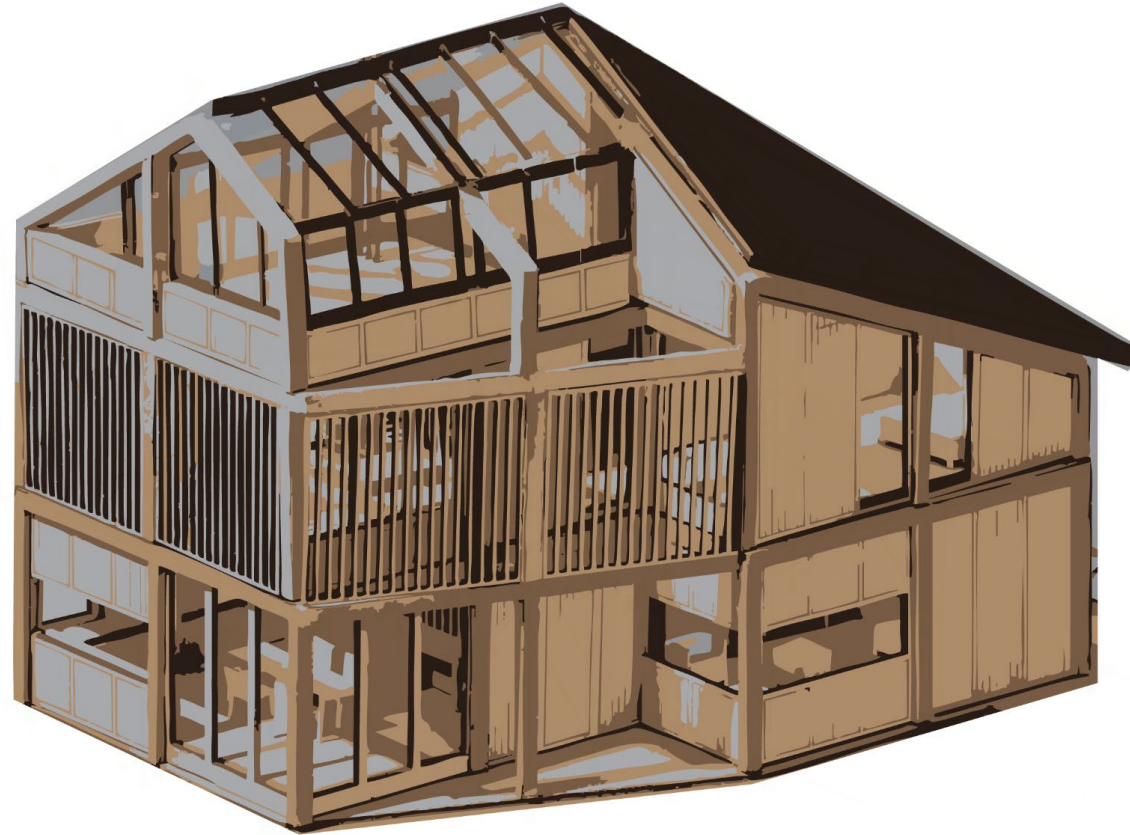


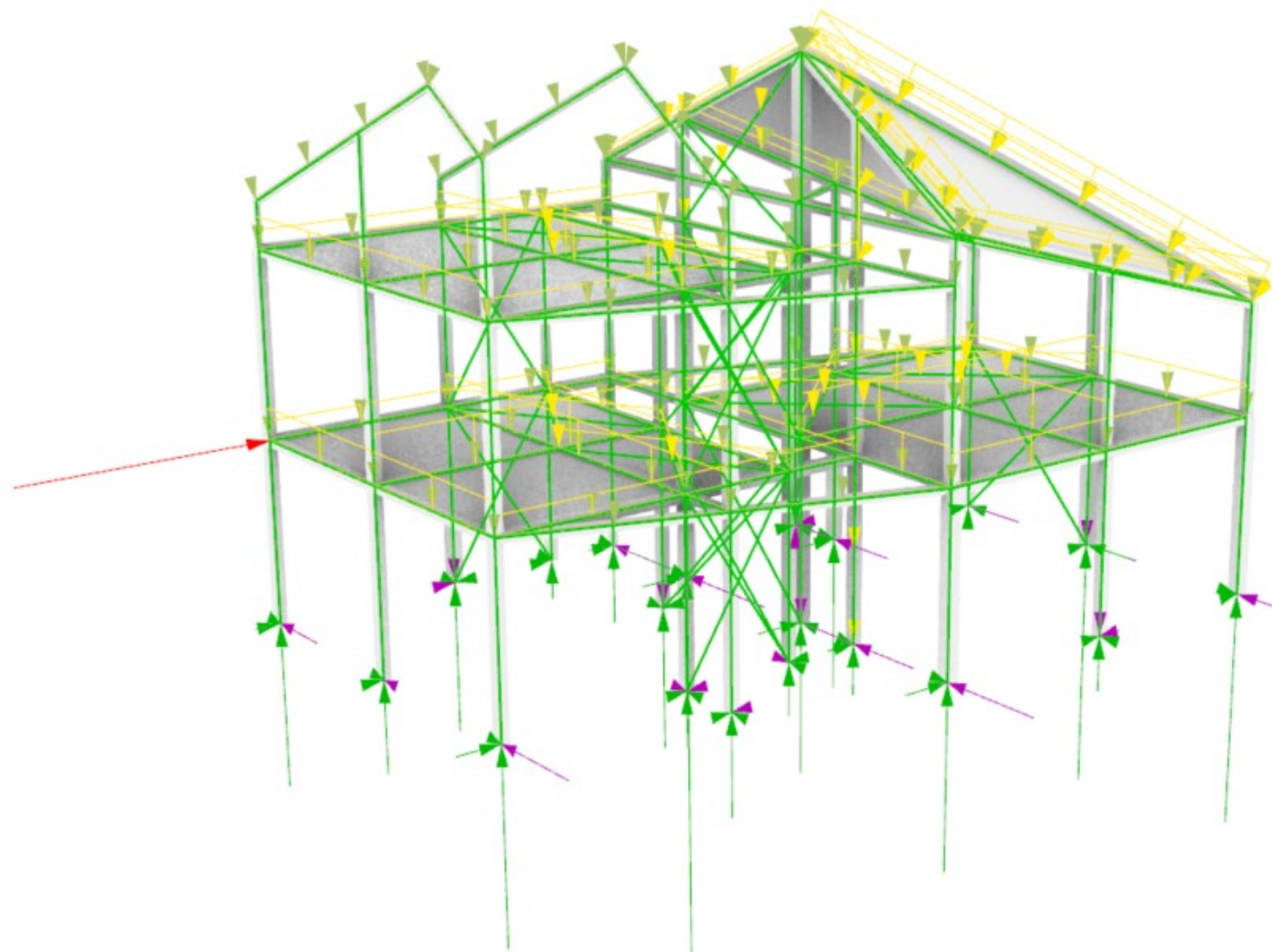
Figure 10:
Reference structures used for results
(Source: Author)

Reference structures



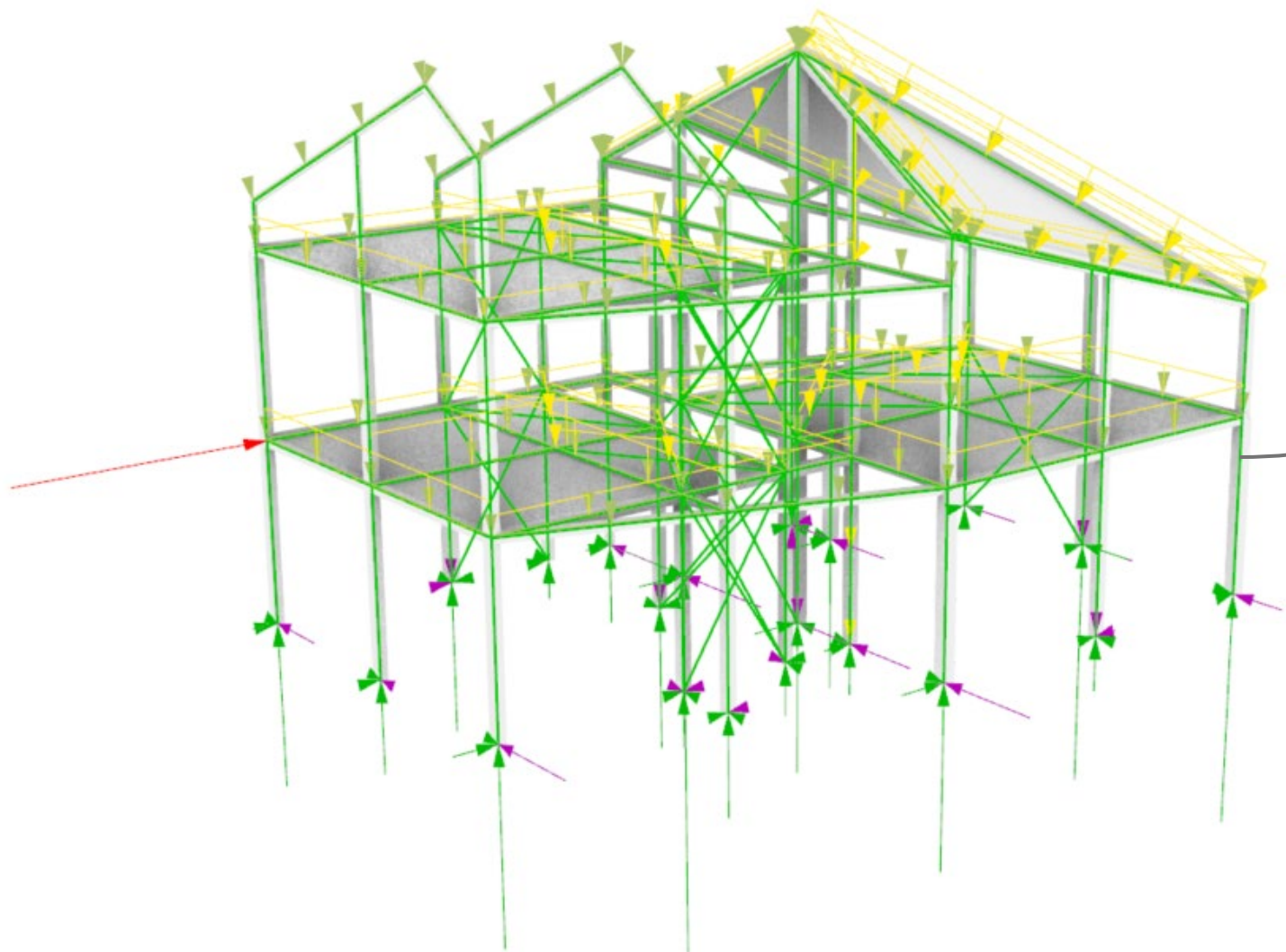
Model of *Woonhuis Muiden*

Figure 11:
Impression of *Woonhuis Muiden*
(Source: *MOKE ARCHITECTS*, edited by Author)



Load distribution *Woonhuis Muiden*

Figure 12:
Visualisation of load distribution *Woonhuis Muiden*
(Source: Author)

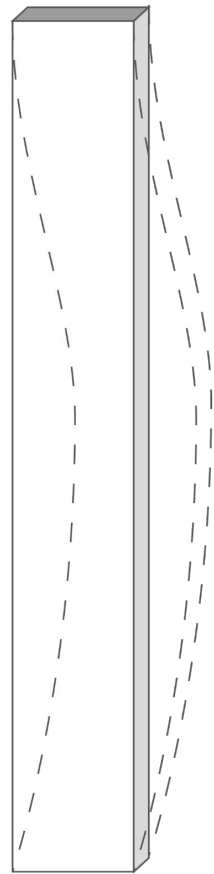


Resulting forces	
Normal Forces	[kN]
Shear Force V_y	[kN]
Shear Force V_z	[kN]
Bending moment M_y	[kNm]
Bending moment M_y	[kNm]

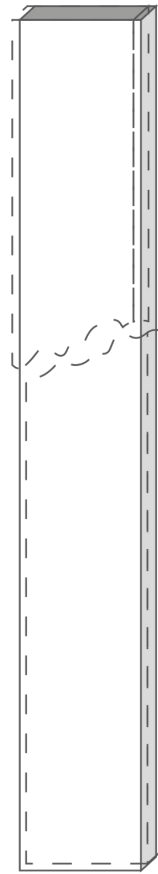
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Load distribution *Woonhuis Muiden*

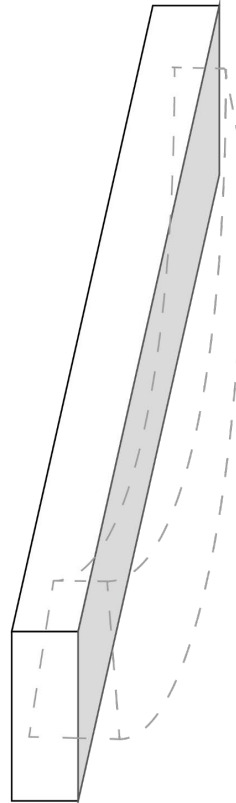
Element dimensioning
Structural design principles



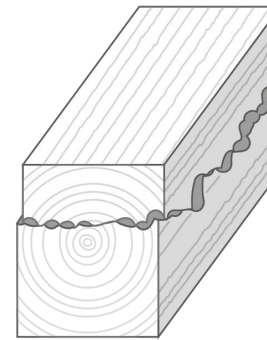
(A) Buckling



(B) Compression



(C) Bending Moment

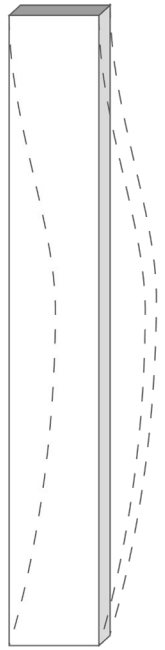


(D) Longitudinal shear

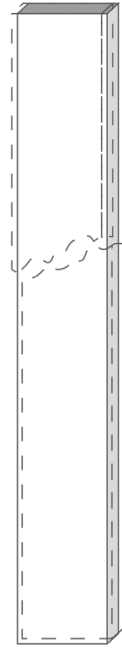


(E) Charring layer

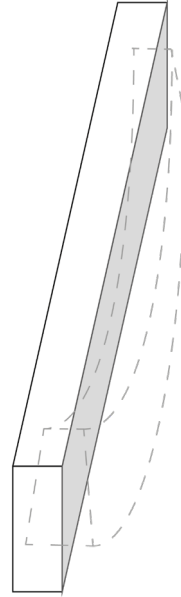
Figure 13:
Visualisation of 5 structural design principles
(Source: Author)



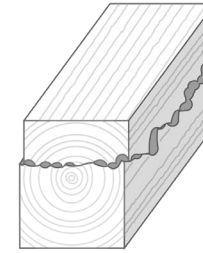
(A) Buckling



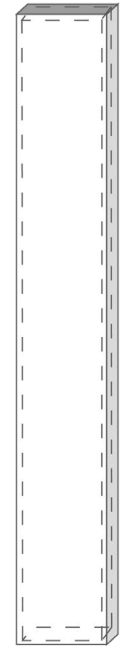
(B) Compression



(C) Bending Moment



(D) Longitudinal shear



(E) Charring layer

$$P_{crit} = \frac{(\pi^2 EI)}{(Le)^2}$$

$$b = \sqrt[4]{\frac{60P_{crit} (Le)^2}{xE\pi^2}}$$

$$\sigma_c = \frac{F}{A} \leq f_{c,0,d}$$

$$b = \sqrt[2]{\frac{FA}{xf_{c,0,d}}}$$

$$\sigma_m = \frac{M}{W} \leq f_{m,d}$$

$$h = \sqrt[3]{\frac{6xM}{\sigma_m}}$$

$$\tau = \frac{S A_c \bar{y}}{I b}$$

$$b \geq \sqrt[2]{\frac{3S}{2f_{v,k}x}}$$

$$h = h_{eff} + a_{eff}$$

$$b = b_{eff} + 2a_{eff}$$

$$h = h_{eff} + 2a_{eff}$$

$$b = b_{eff} + 2a_{eff}$$

Element dimensioning
Different ratios and wood-species

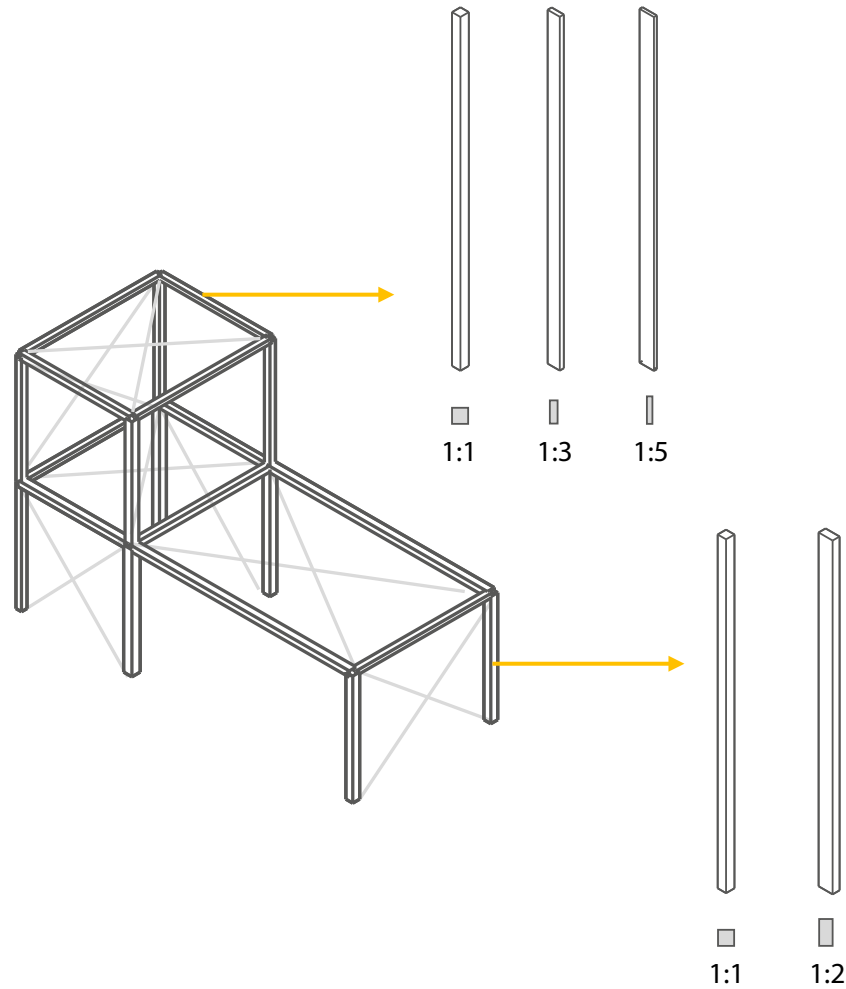


Figure 14:
Visualisation of different possible ratio's
(Source: Author)

Element dimensioning
Different ratios and wood-species

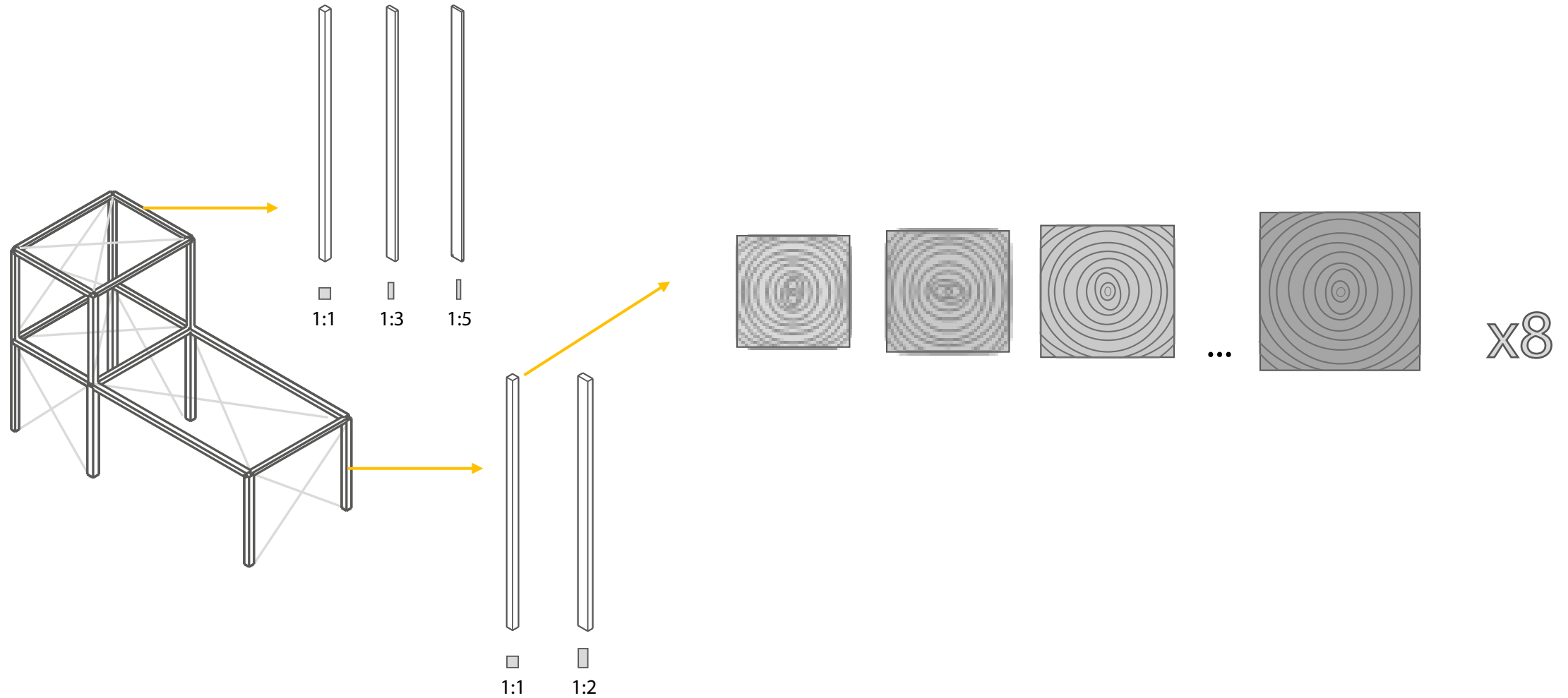


Figure 14:
Visualisation of different possible ratio's
(Source: Author)

Element dimensioning
Different ratios and wood-species

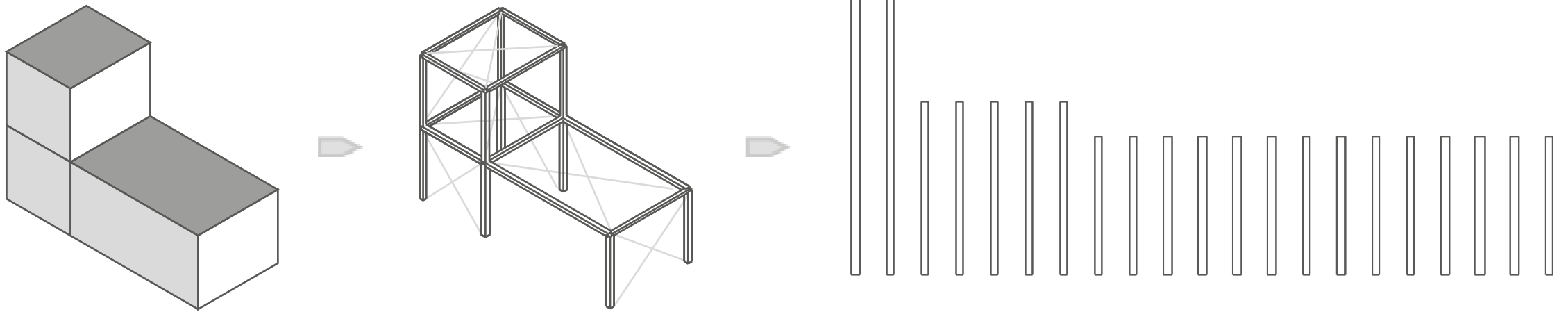


Figure 15:
Effect different possible ratio's & wood species
(Source: Author)

Element dimensioning
Different ratios and wood-species

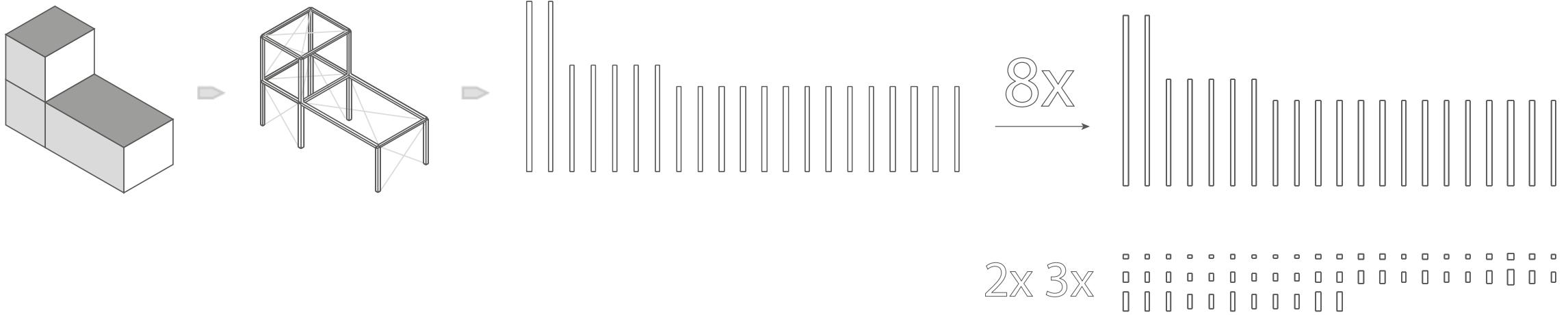


Figure 15:
Effect different possible ratio's & wood species
(Source: Author)

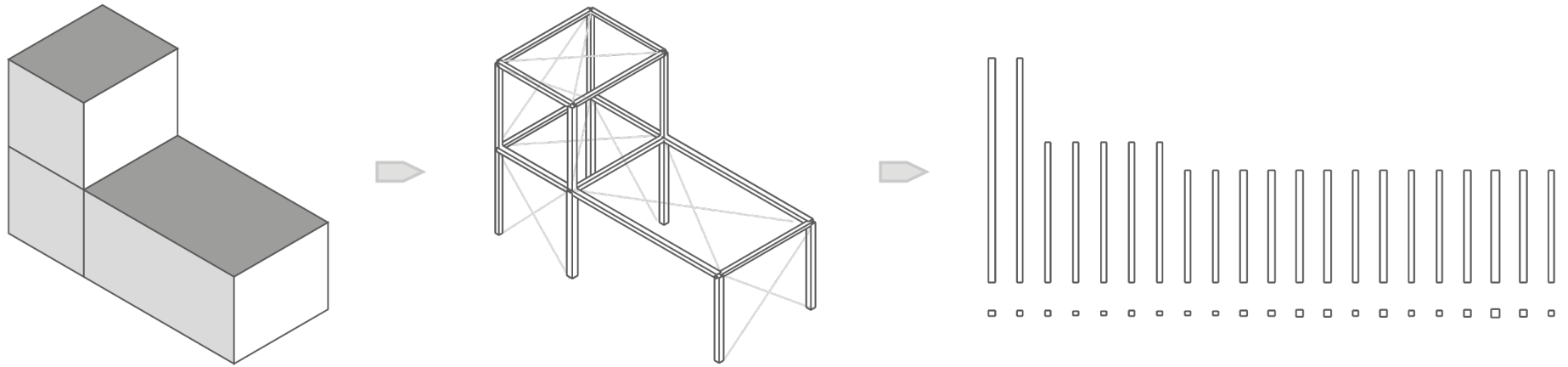


Figure 7:
Overview methodology
(Source: Author)

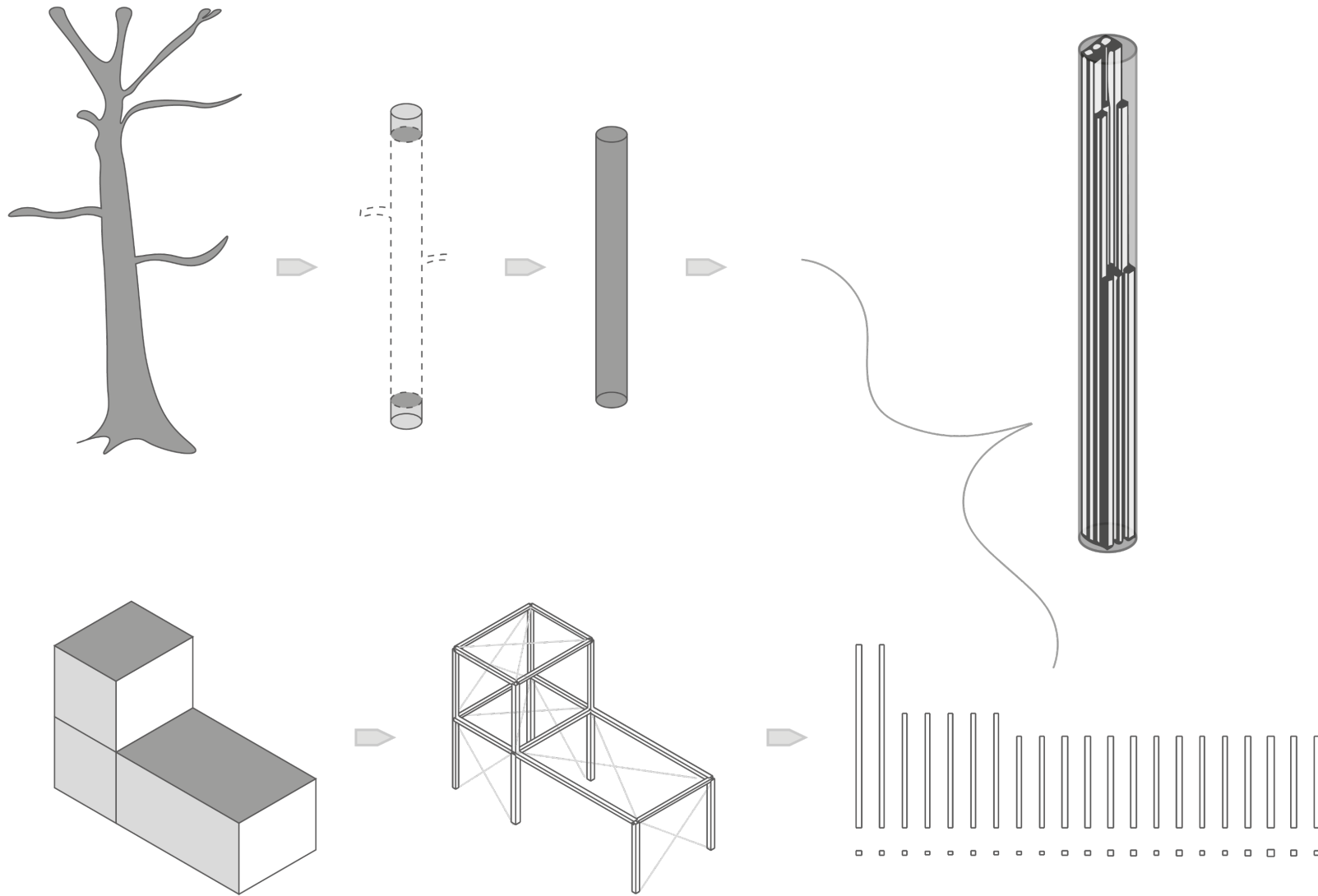
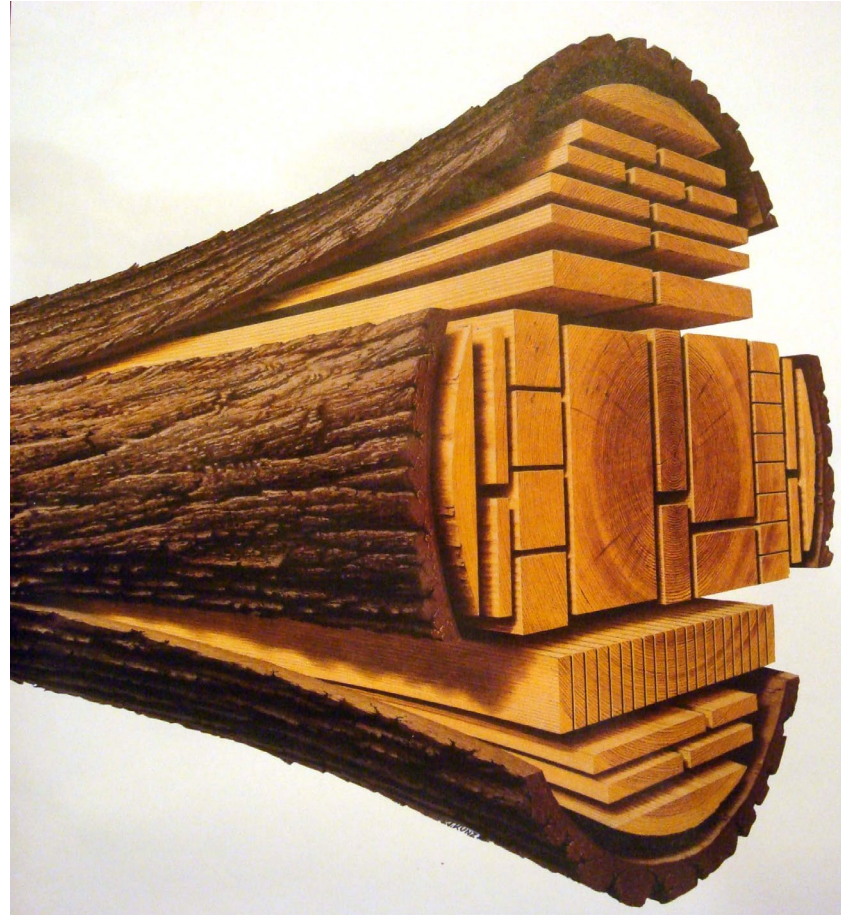


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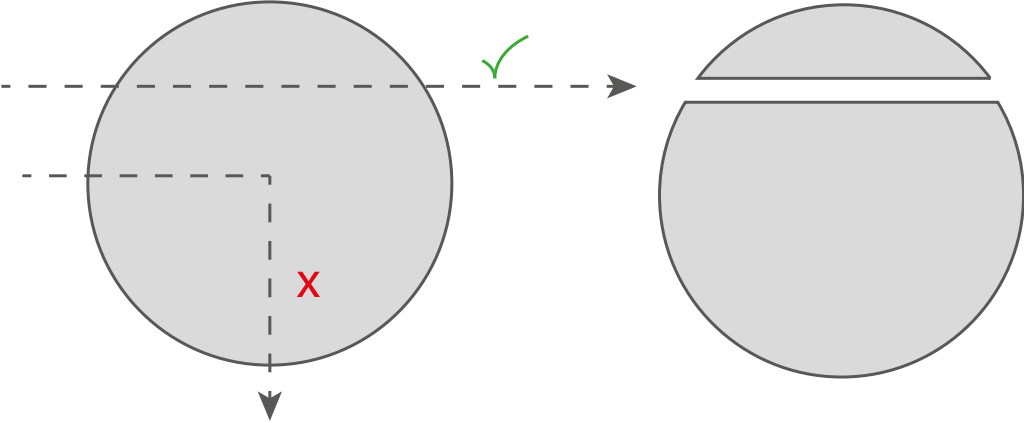
3D bin-packing



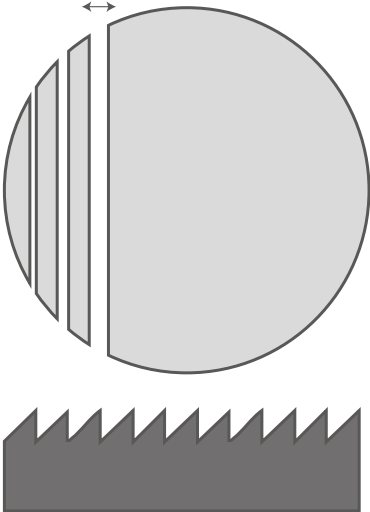
Fictional image of a tightly packed sawing pattern for a log, as an impression for bin-packing

Figure 16:
Impression of bin-packing elements in log
(Source: *Reddit*, tinyurl.com/44rjcu fz)

Restrictions



Guillotine cutting



Kerf size

Figure 17:
Visualisation of restrictions
(Source: Author)

Heuristic logic

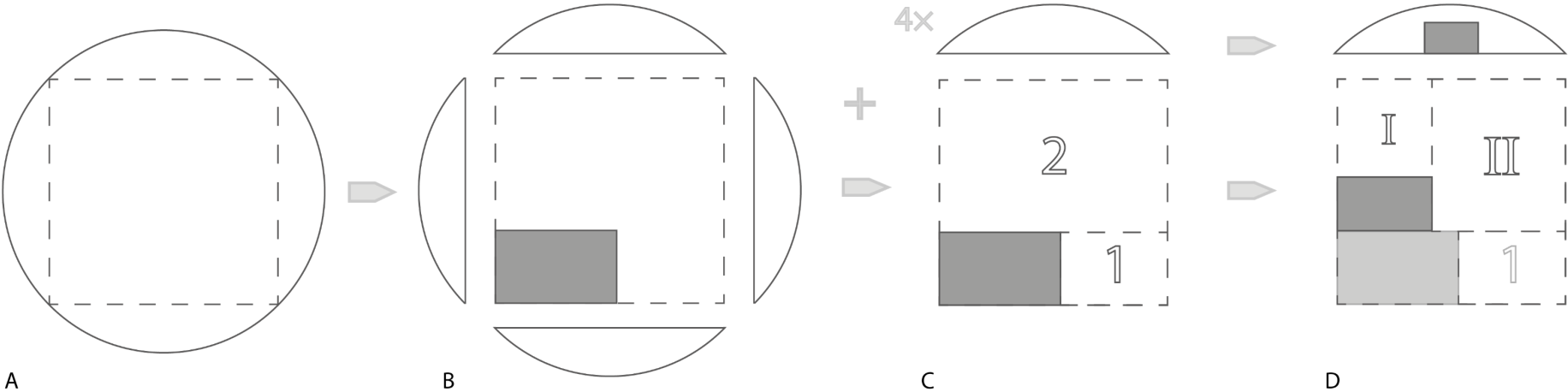


Figure 18:
Visual representation of packing heuristic in 2D
(Source: Author)

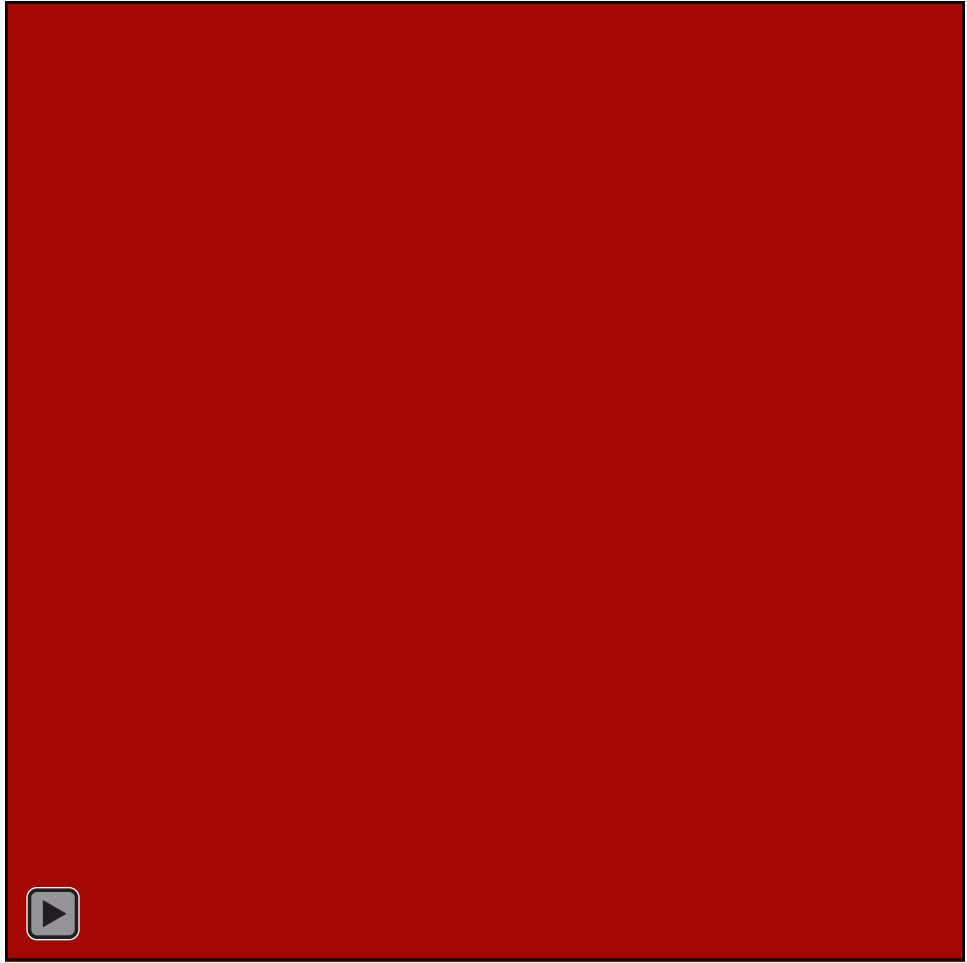
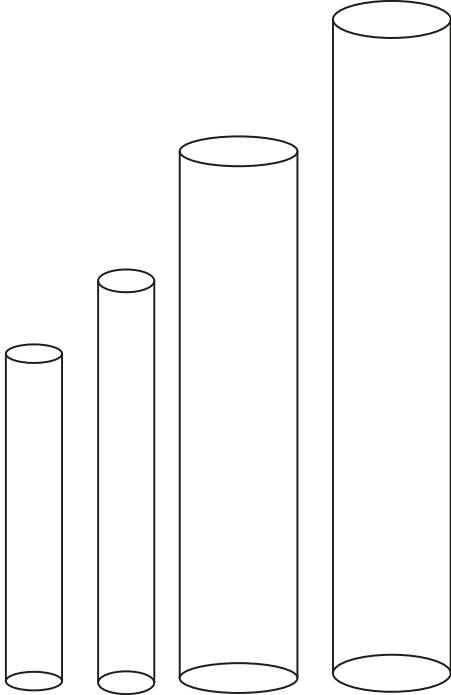


Figure 19:
GIF visualization of packing heuristic in 3D
(Source: Author)

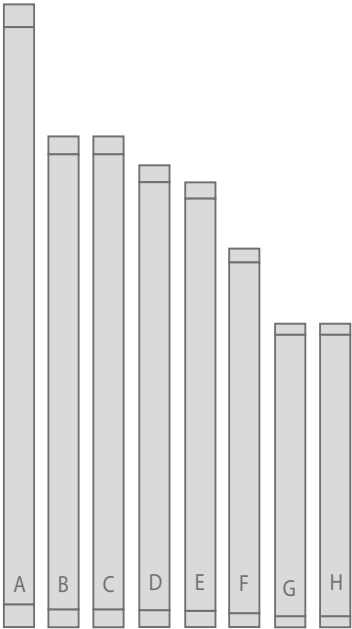
**Optimization
by genetic algorithm**

Optimization by genetic algorithm
Bin & Element order relevance

Stock:



Bins

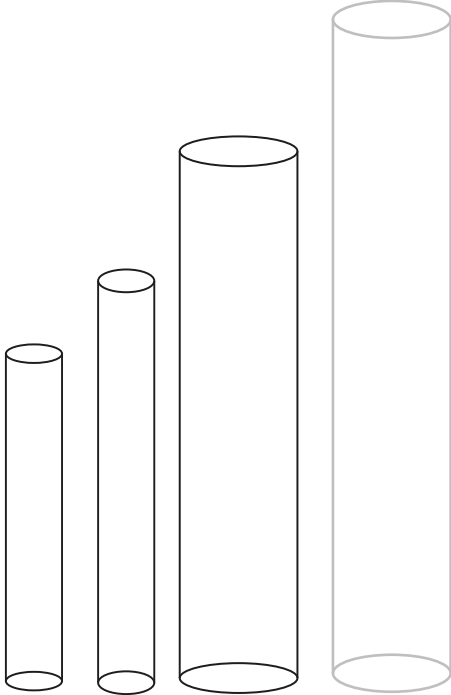


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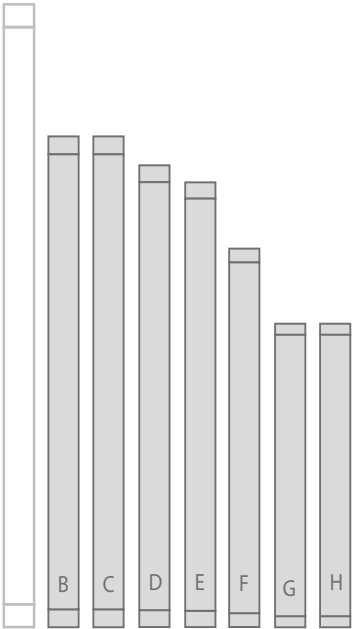
Figure 20:
Visual explanation of order relevance
(Source: Author)

Bin & Element order relevance

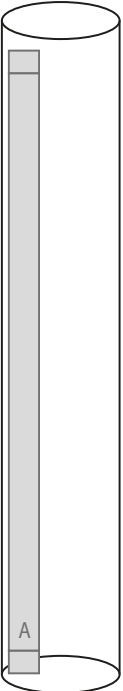
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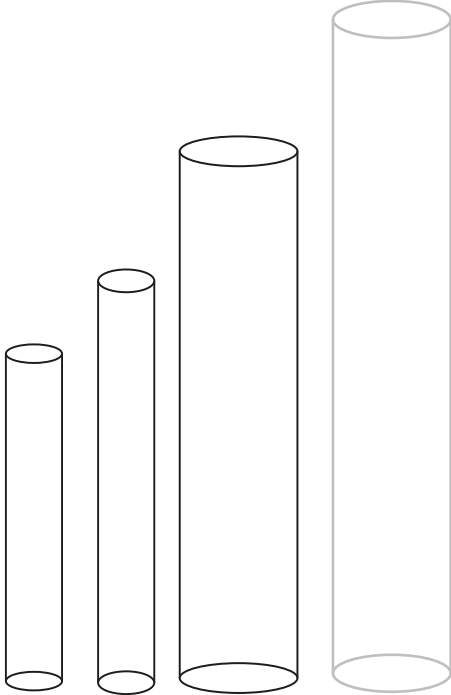
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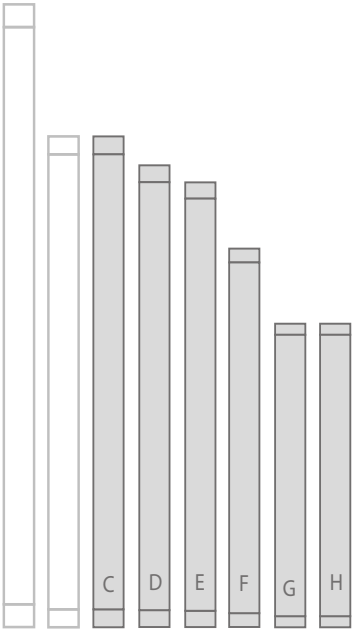
Graphic 20:
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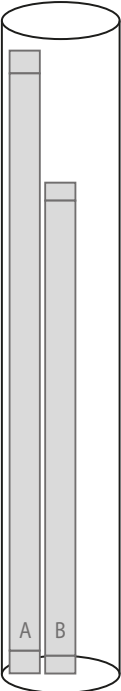
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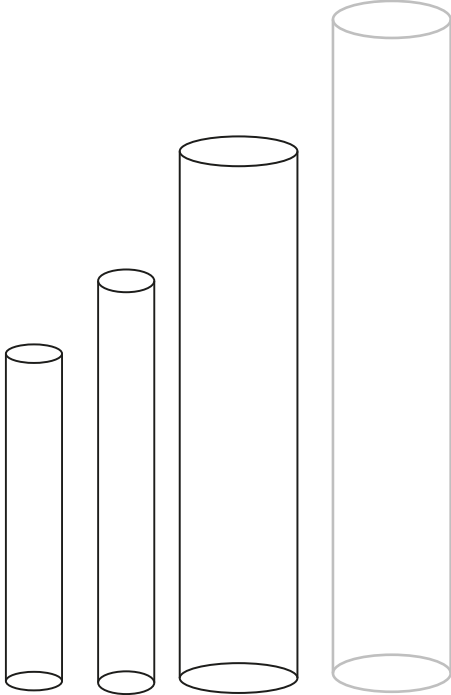
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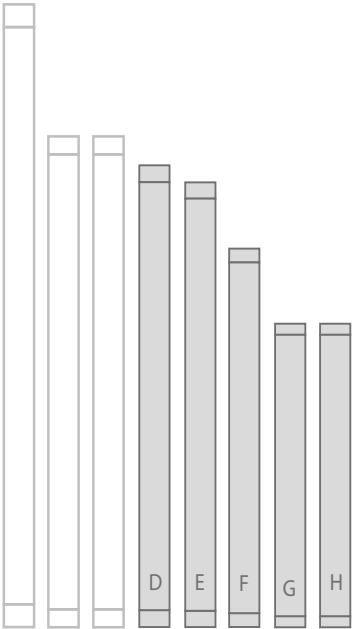
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Optimization by genetic algorithm
Bin & Element order relevance

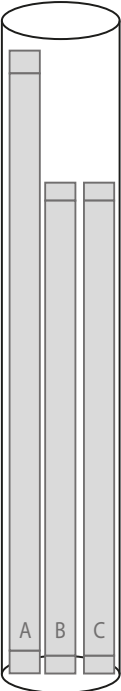
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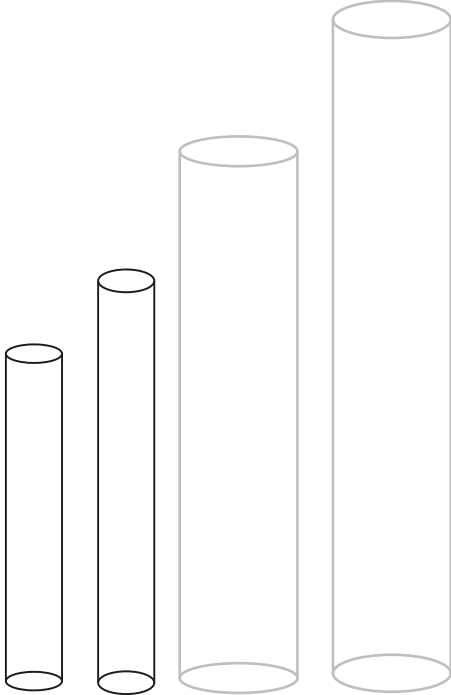
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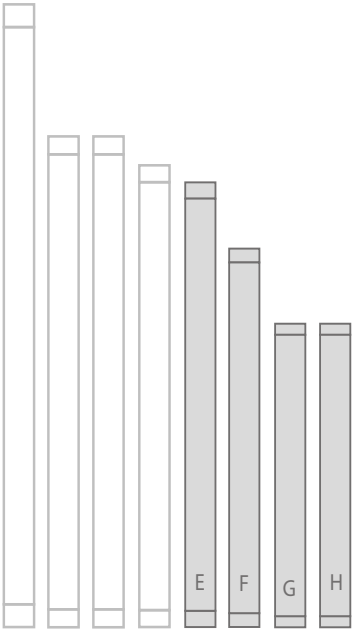
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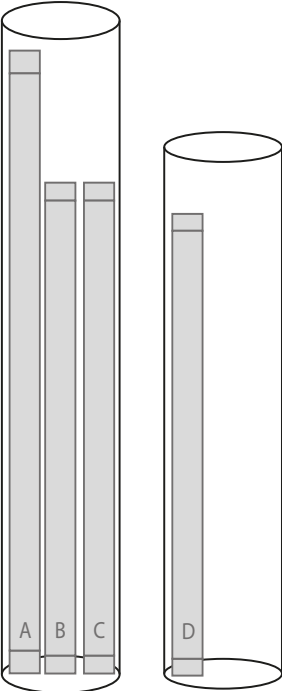
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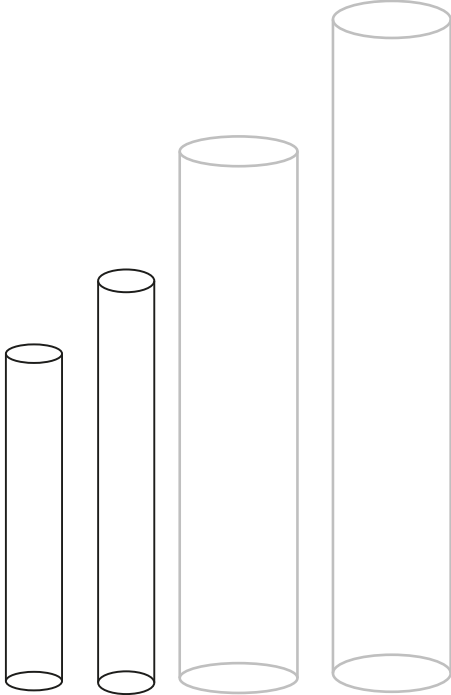
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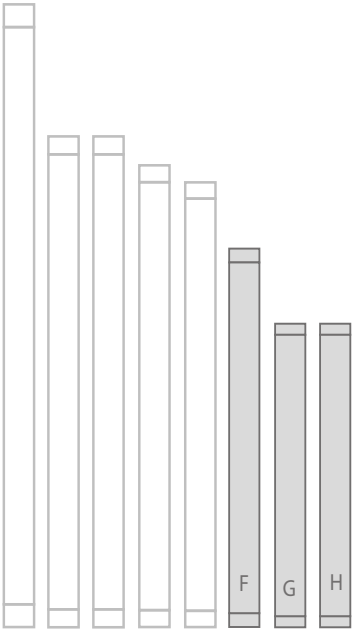
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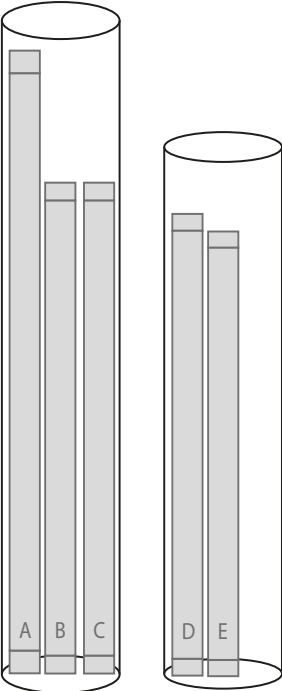
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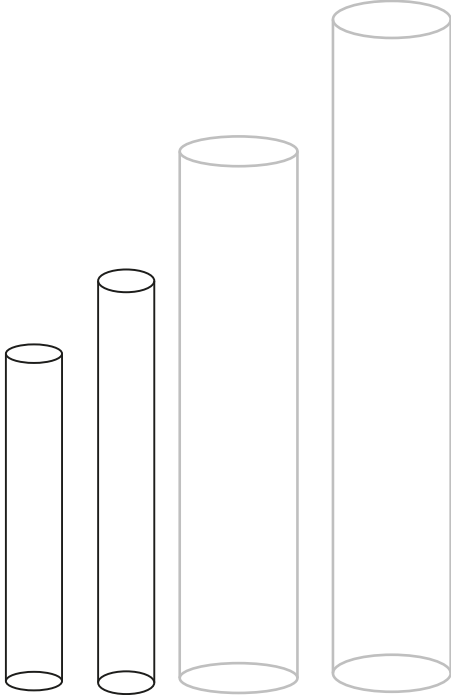
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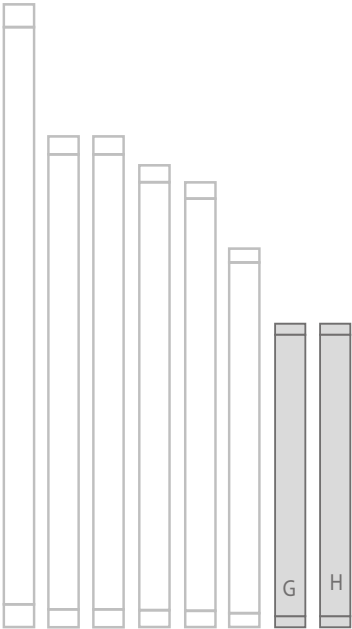
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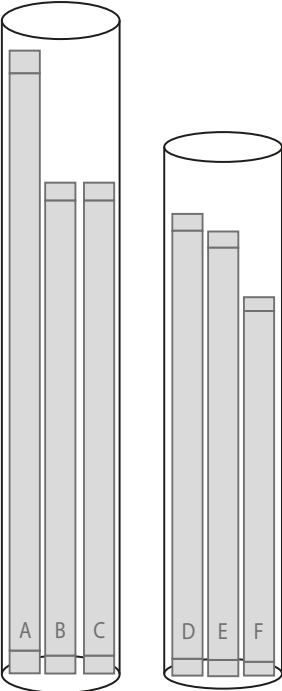
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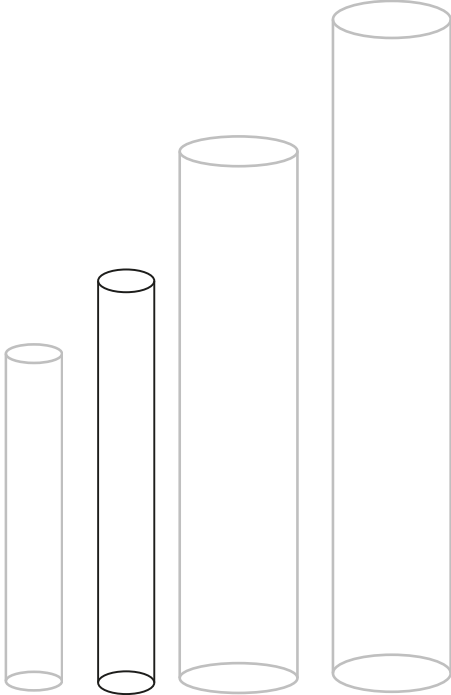
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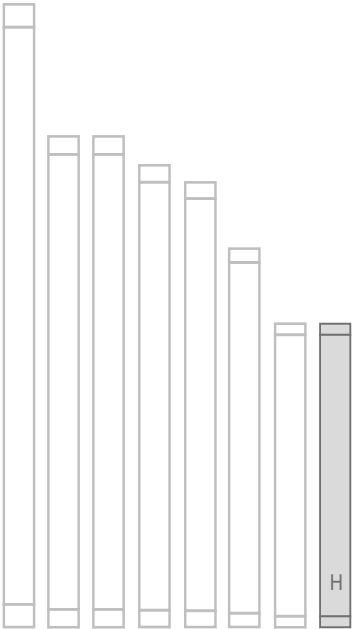
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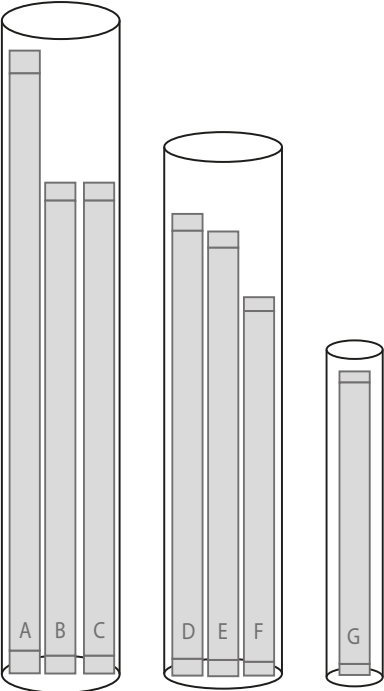
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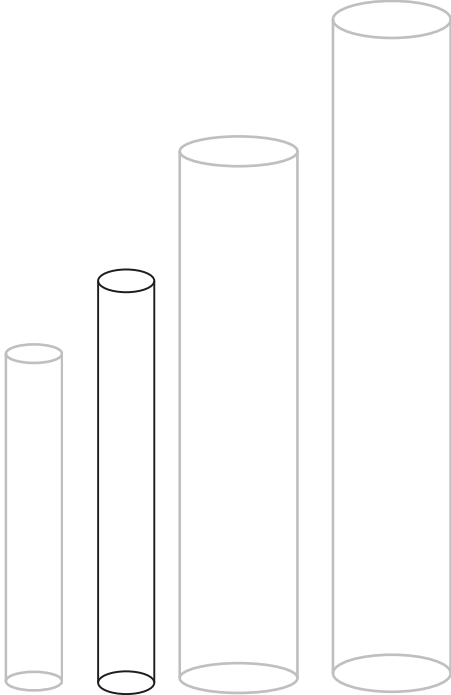
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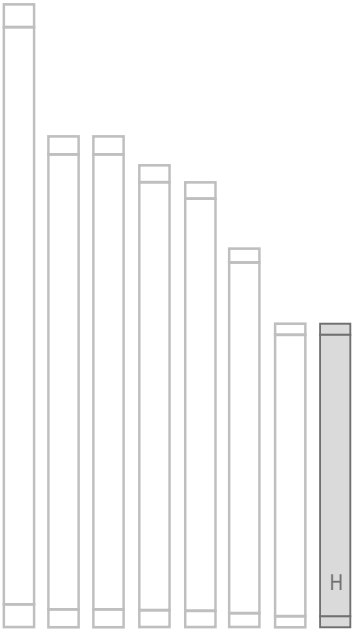
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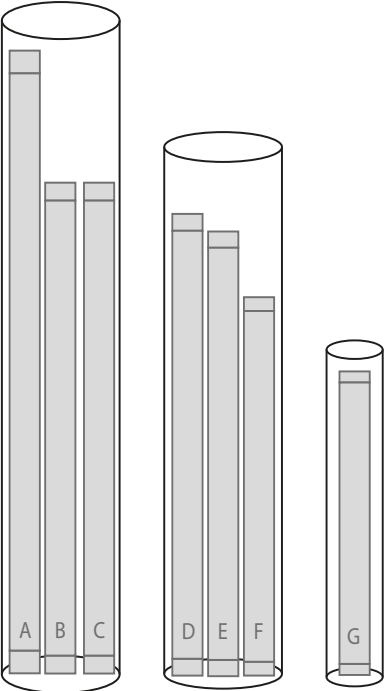
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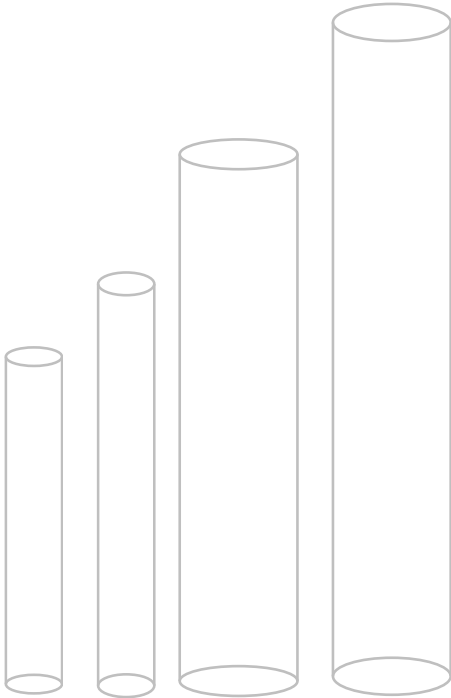
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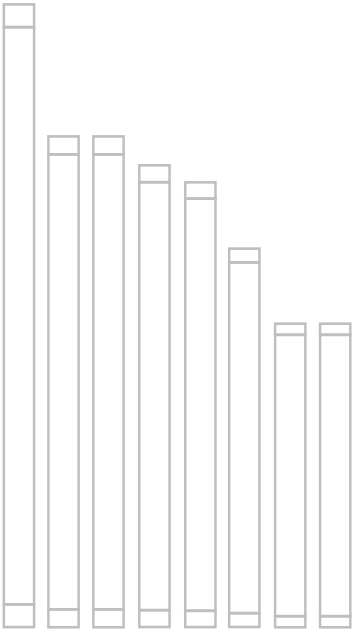
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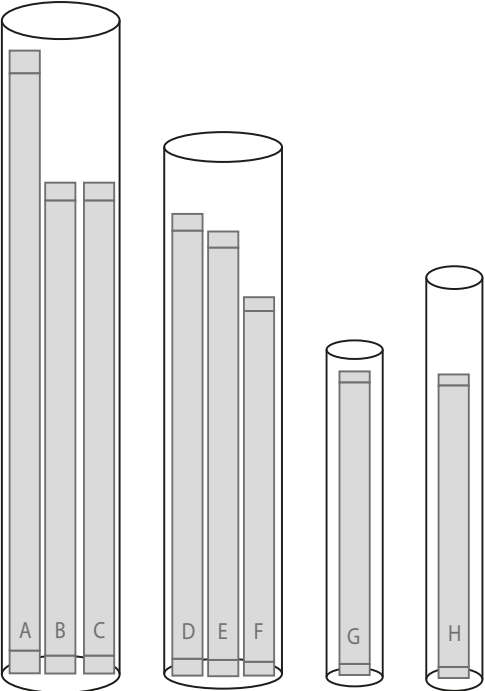
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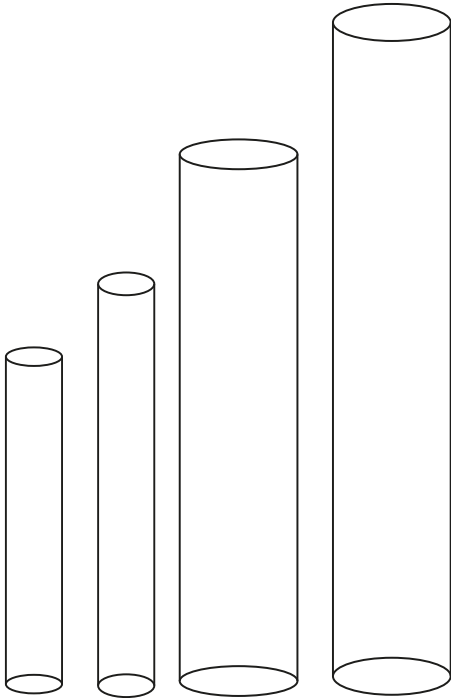
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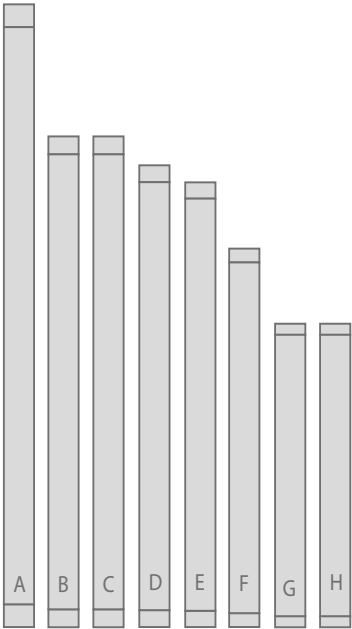
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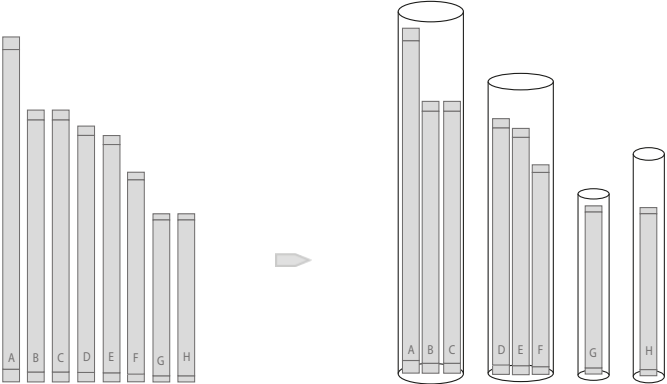
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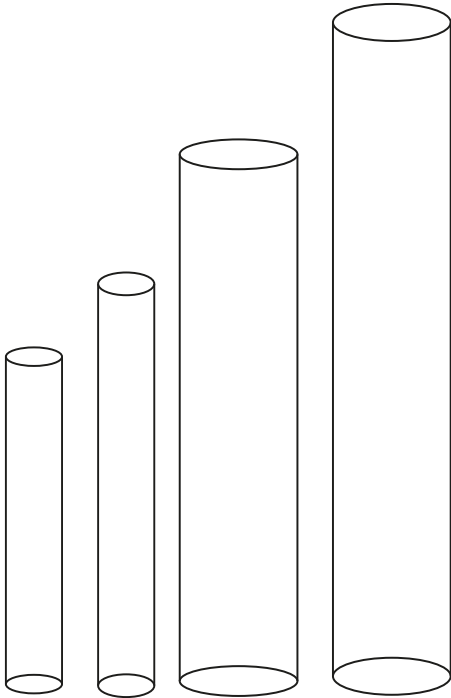
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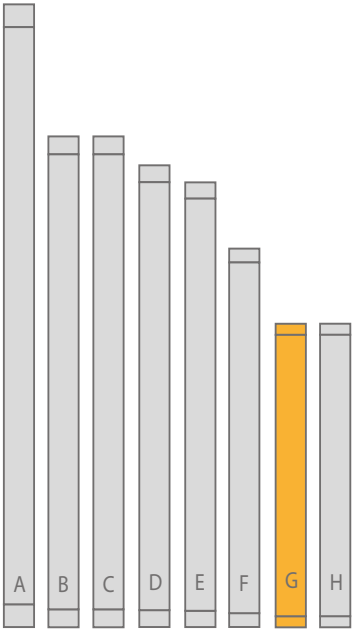
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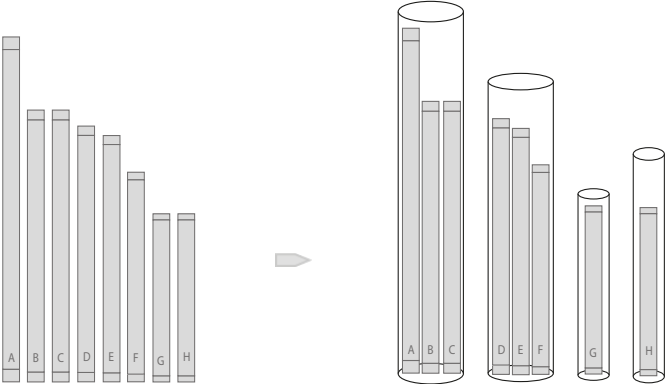
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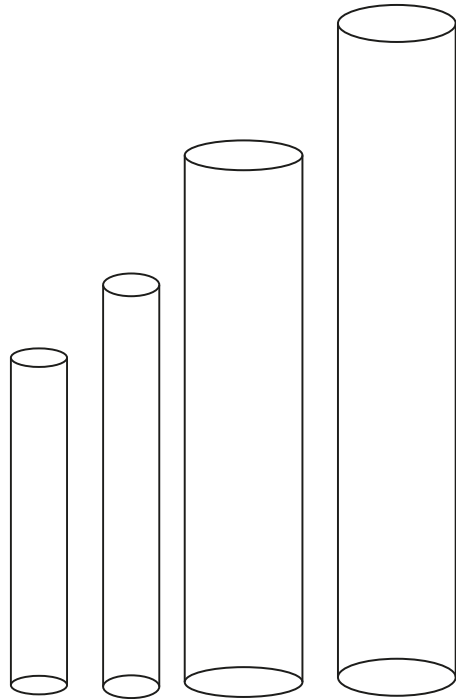
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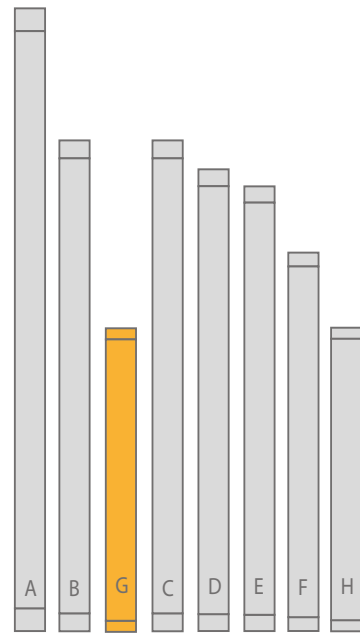
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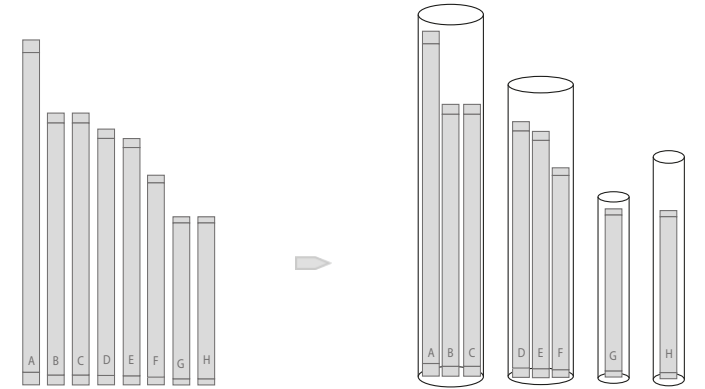
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Bins



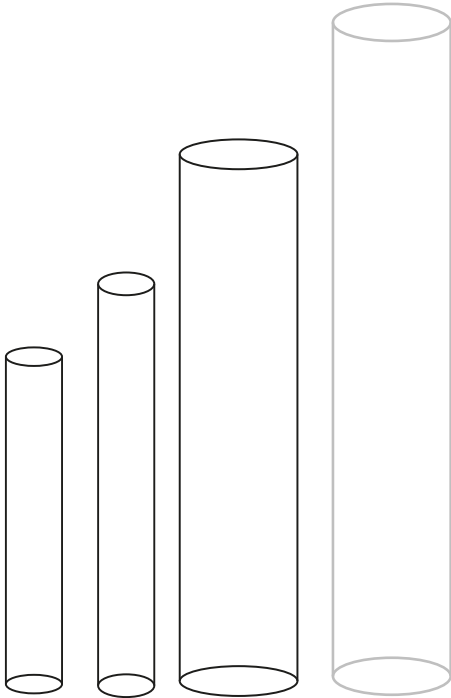
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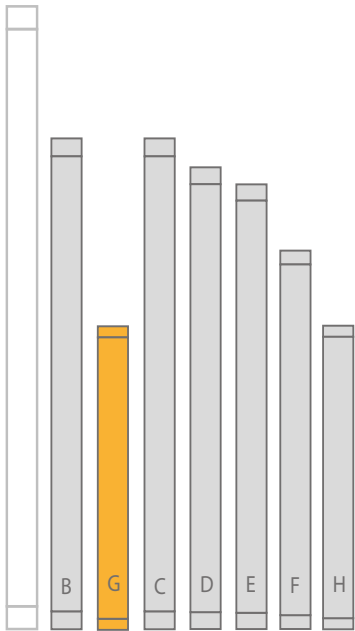
Graphic 20:
Visual explanation of order relevance
(Source: Author)

Optimization by genetic algorithm
Bin & Element order relevance

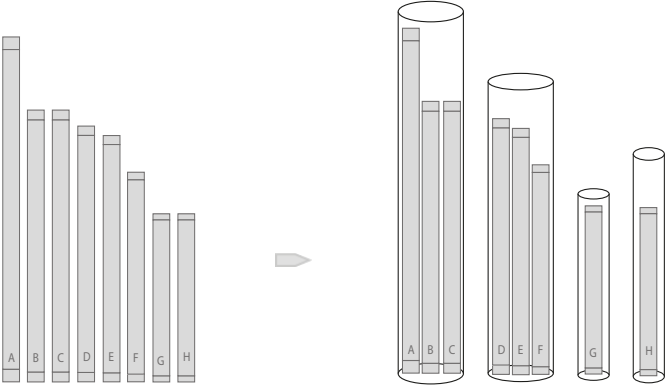
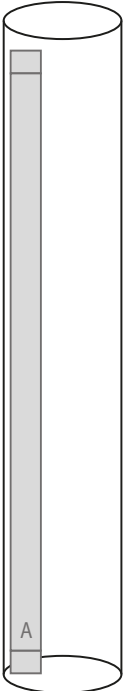
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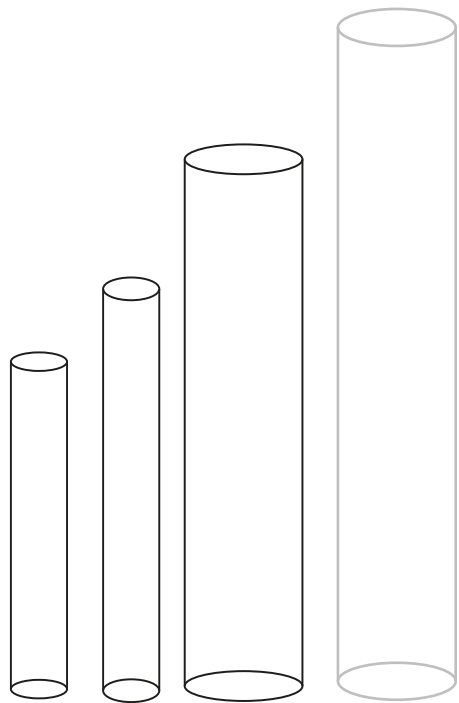
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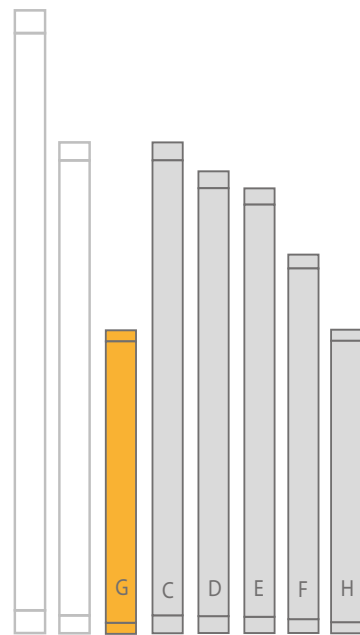
Graphic 20:
Visual explanation of order relevance
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Optimization by genetic algorithm
Bin & Element order relevance

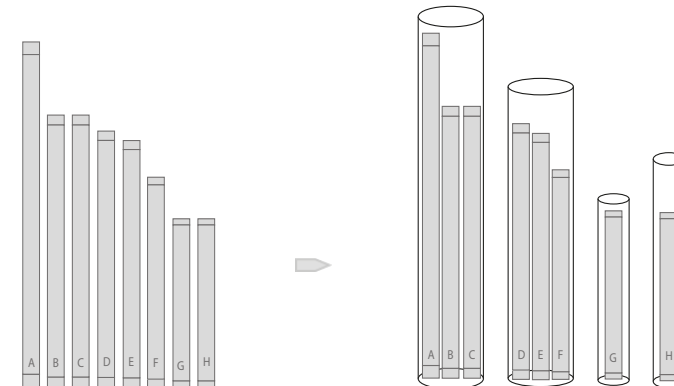
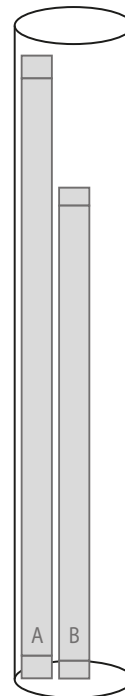
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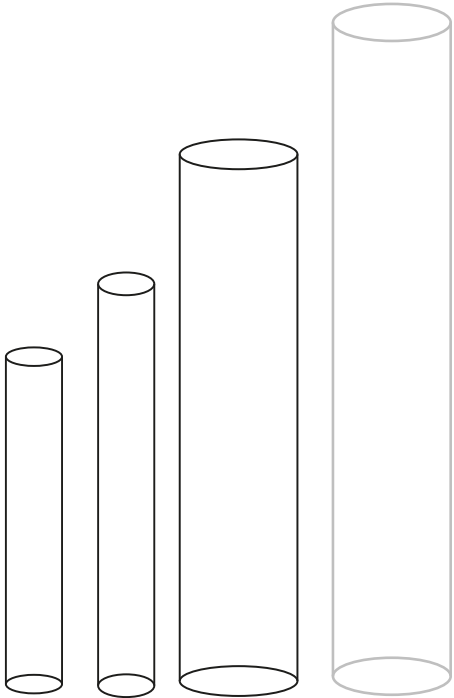
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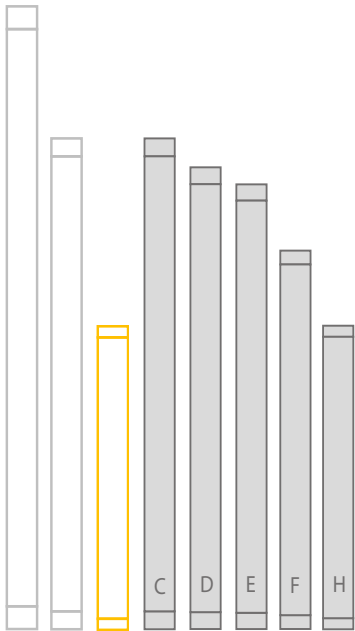
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Visual explanation of order relevance
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Bin & Element order relevance

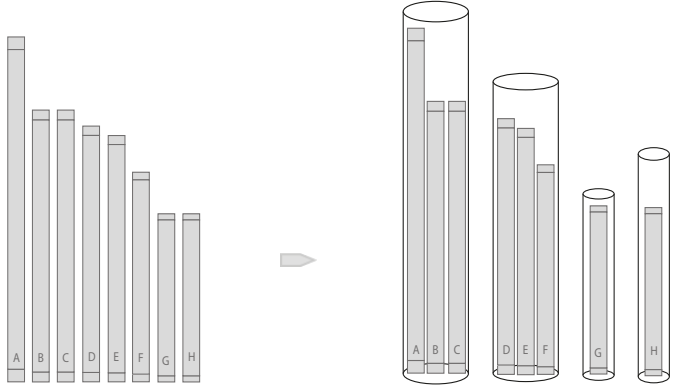
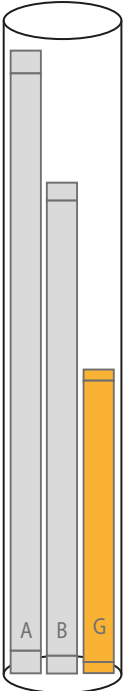
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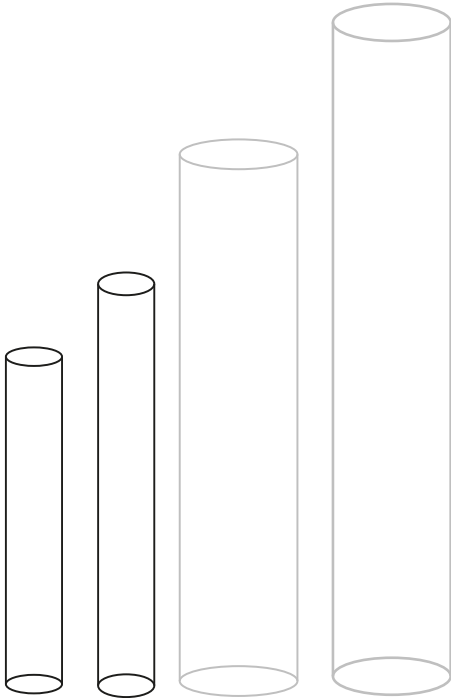
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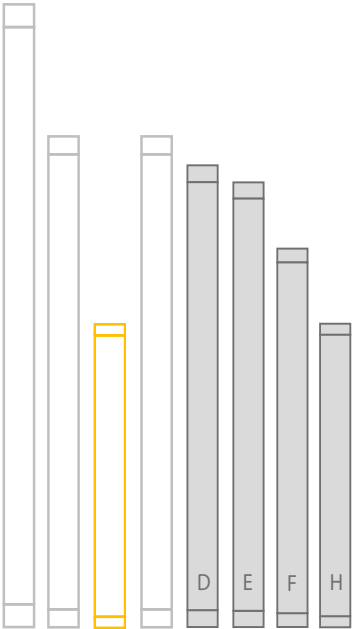
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Visual explanation of order relevance
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Optimization by genetic algorithm
Bin & Element order relevance

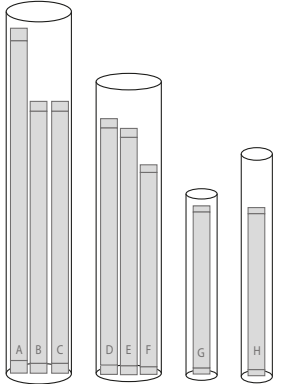
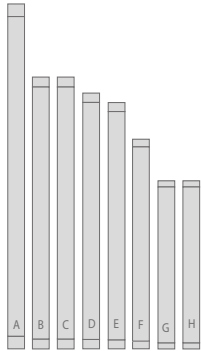
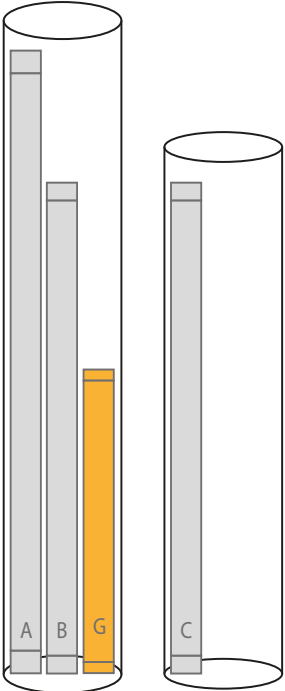
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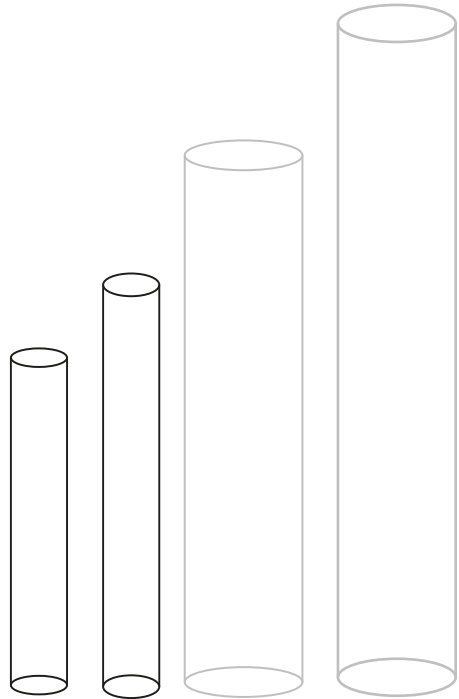
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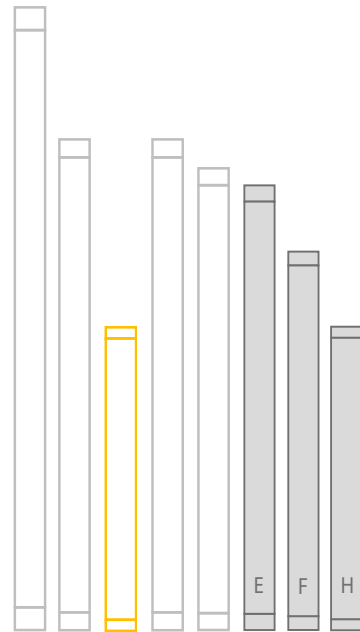
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Visual explanation of order relevance
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Optimization by genetic algorithm
Bin & Element order relevance

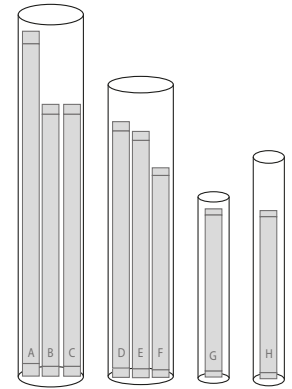
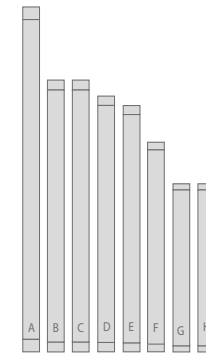
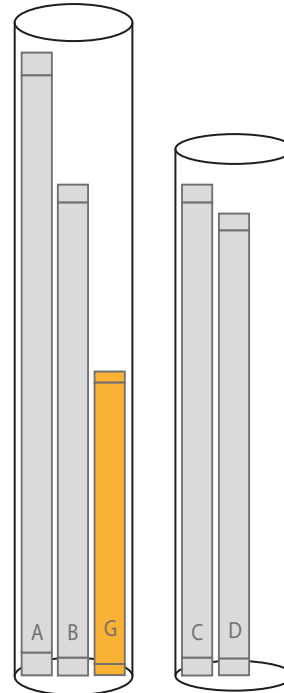
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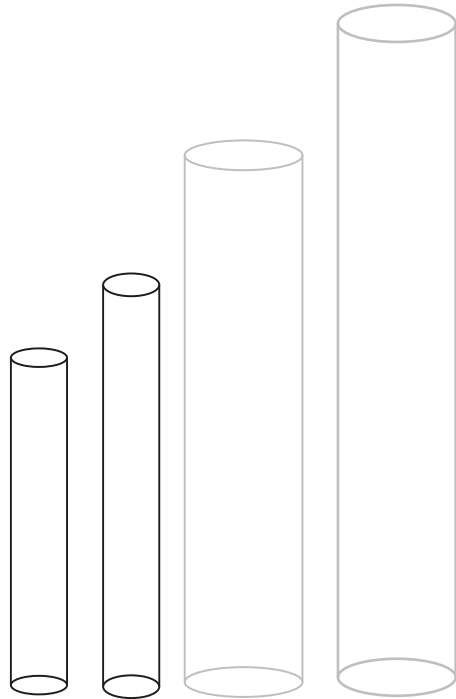
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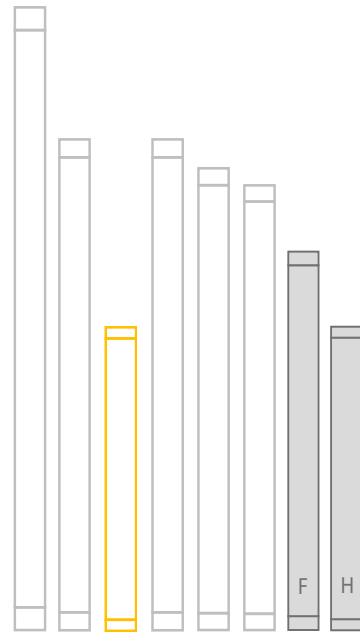
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Visual explanation of order relevance
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Optimization by genetic algorithm
Bin & Element order relevance

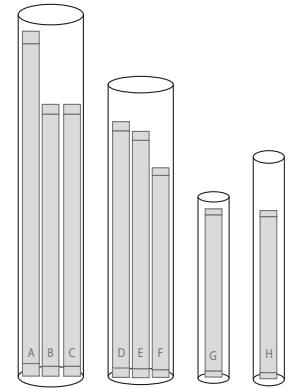
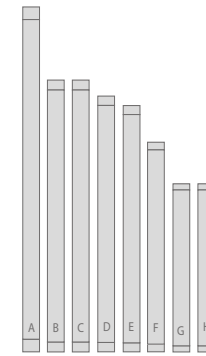
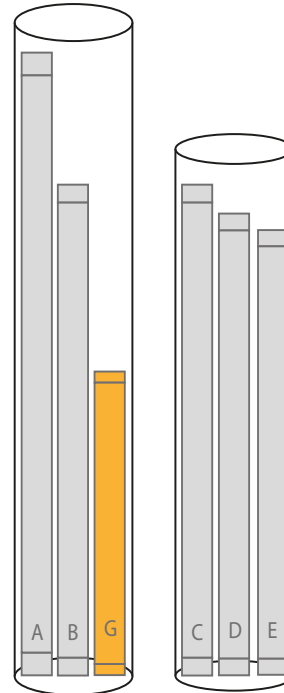
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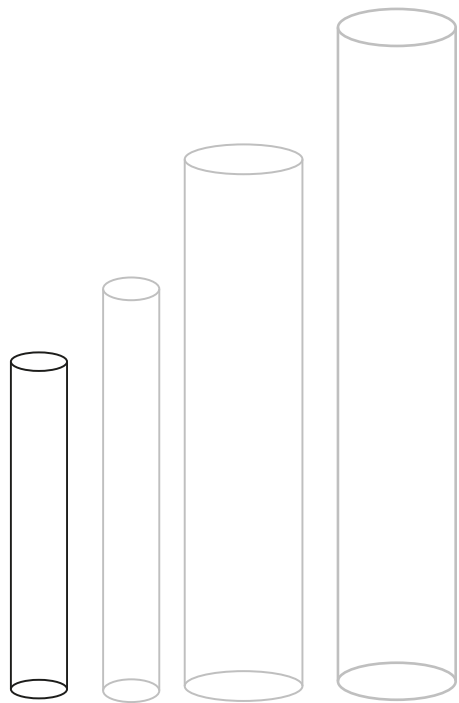


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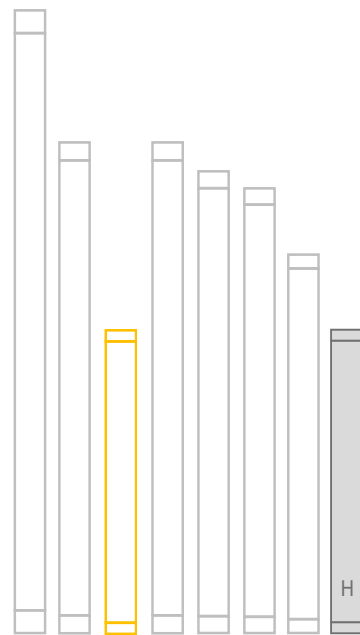


Optimization by genetic algorithm
Bin & Element order relevance

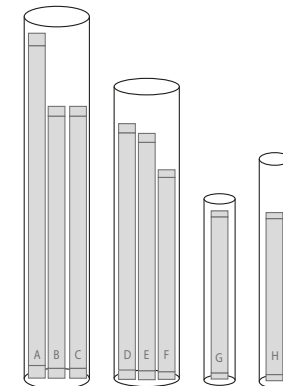
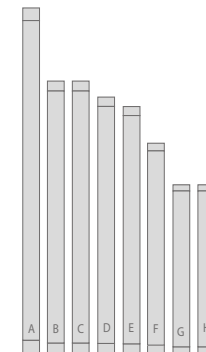
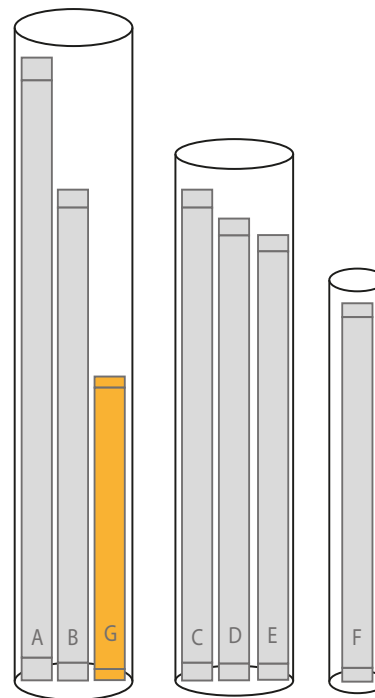
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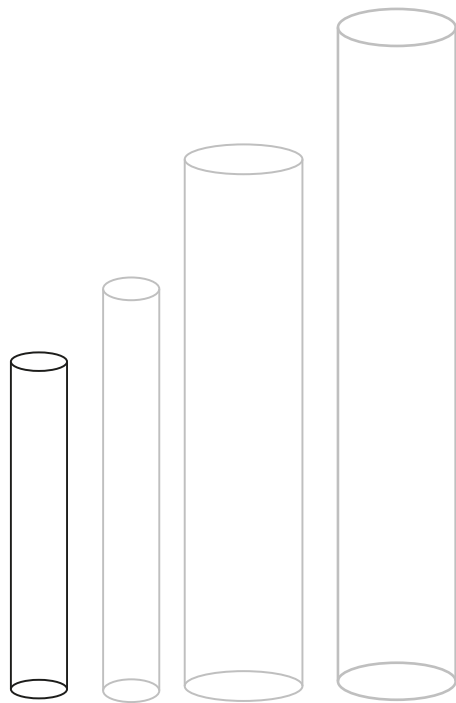
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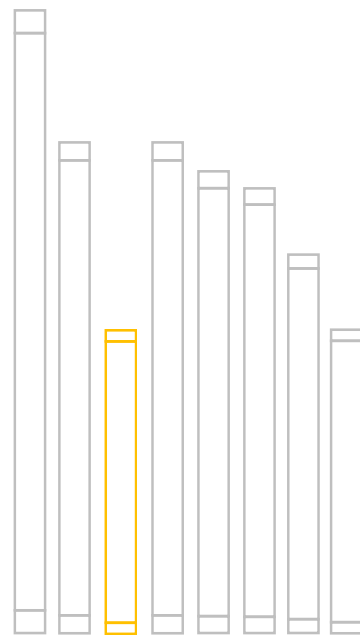
Graphic 20:
Visual explanation of order relevance
(Source: Author)

Optimization by genetic algorithm
Bin & Element order relevance

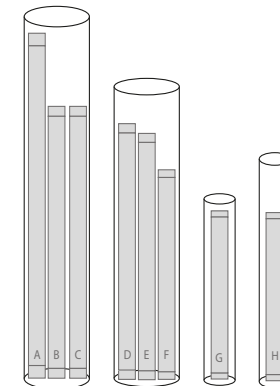
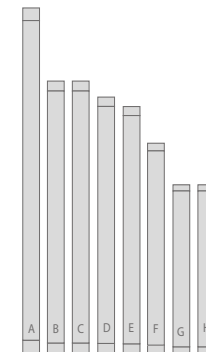
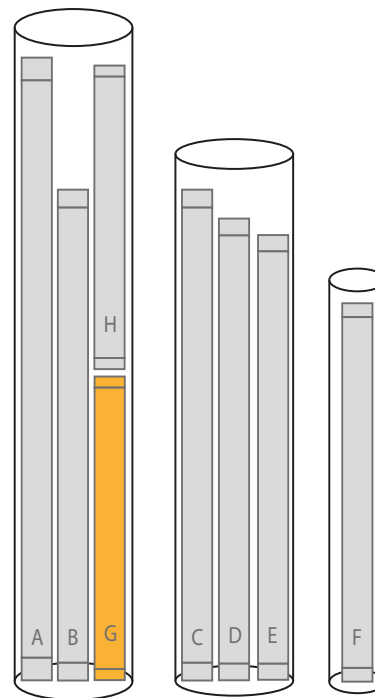
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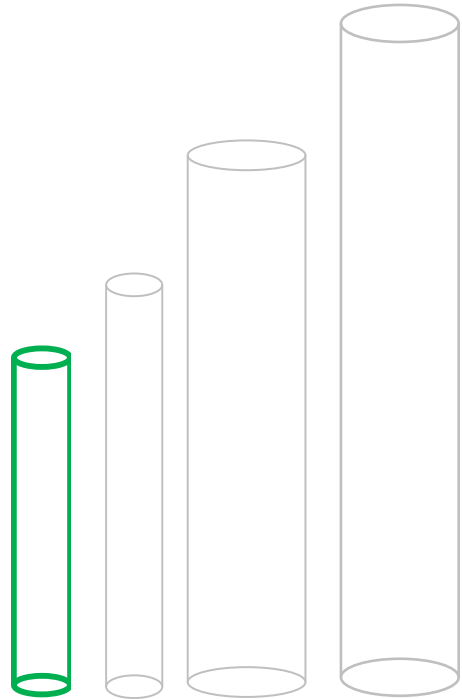
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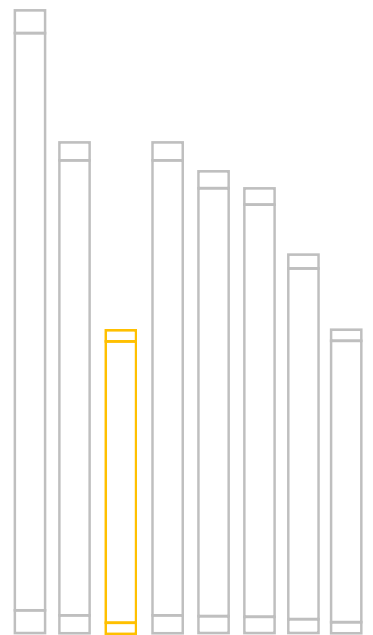
Graphic 20:
Visual explanation of order relevance
(Source: Author)

Optimization by genetic algorithm
Bin & Element order relevance

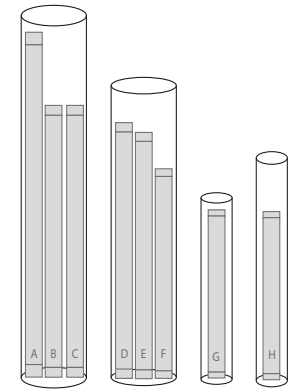
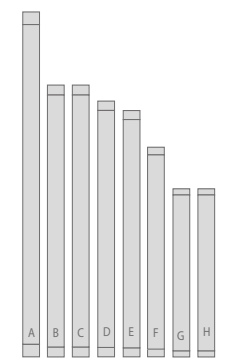
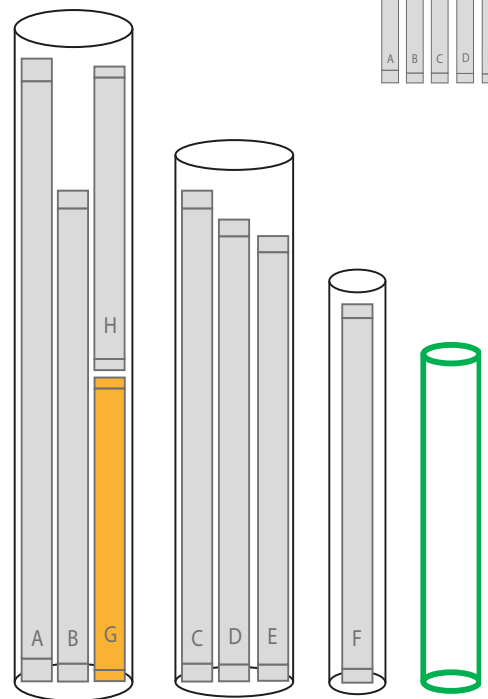
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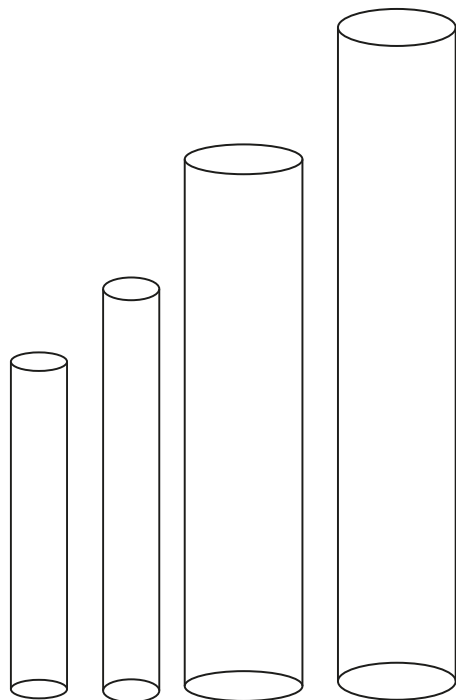
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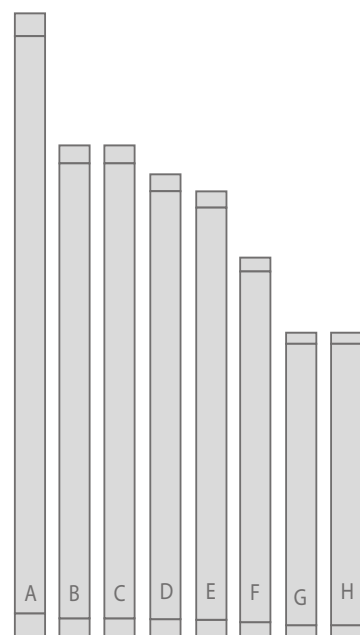
Graphic 20:
Visual explanation of order relevance
(Source: Author)

Optimization by genetic algorithm
Bin & Element order relevance

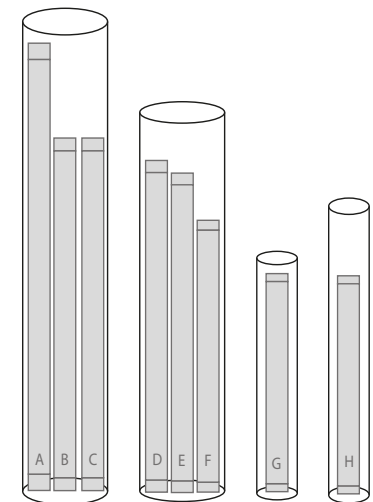
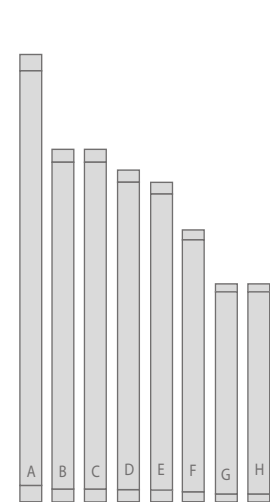
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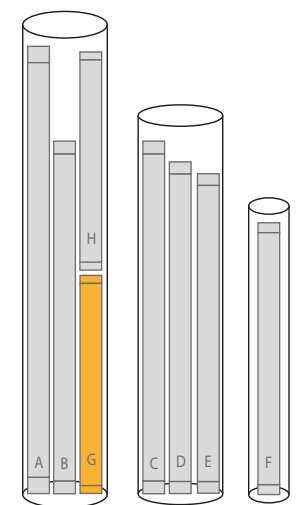
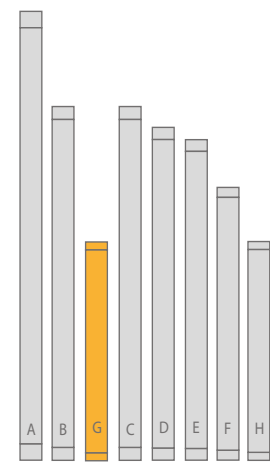
Bins



Elements



Order 1

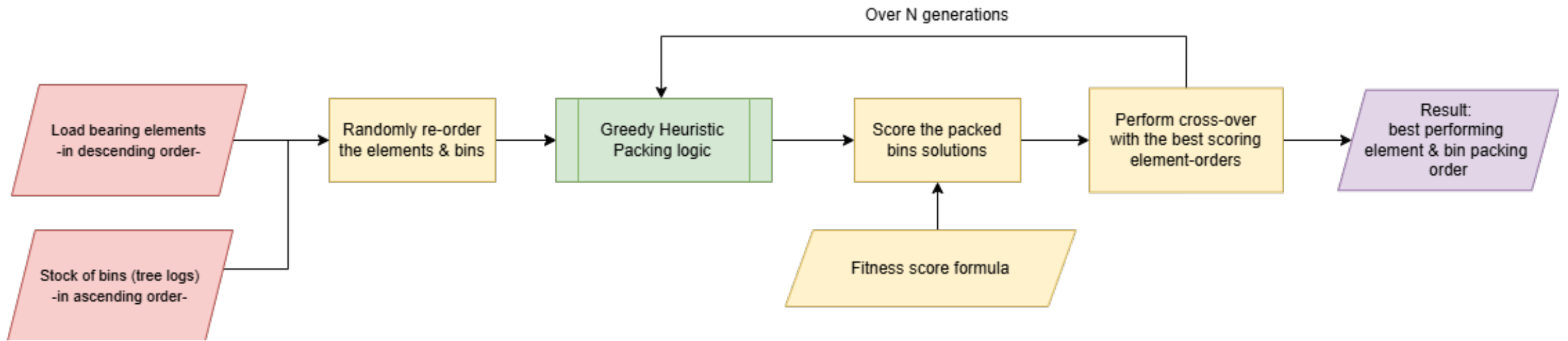


Order 2

Graphic 20:
Visual explanation of order relevance
(Source: Author)

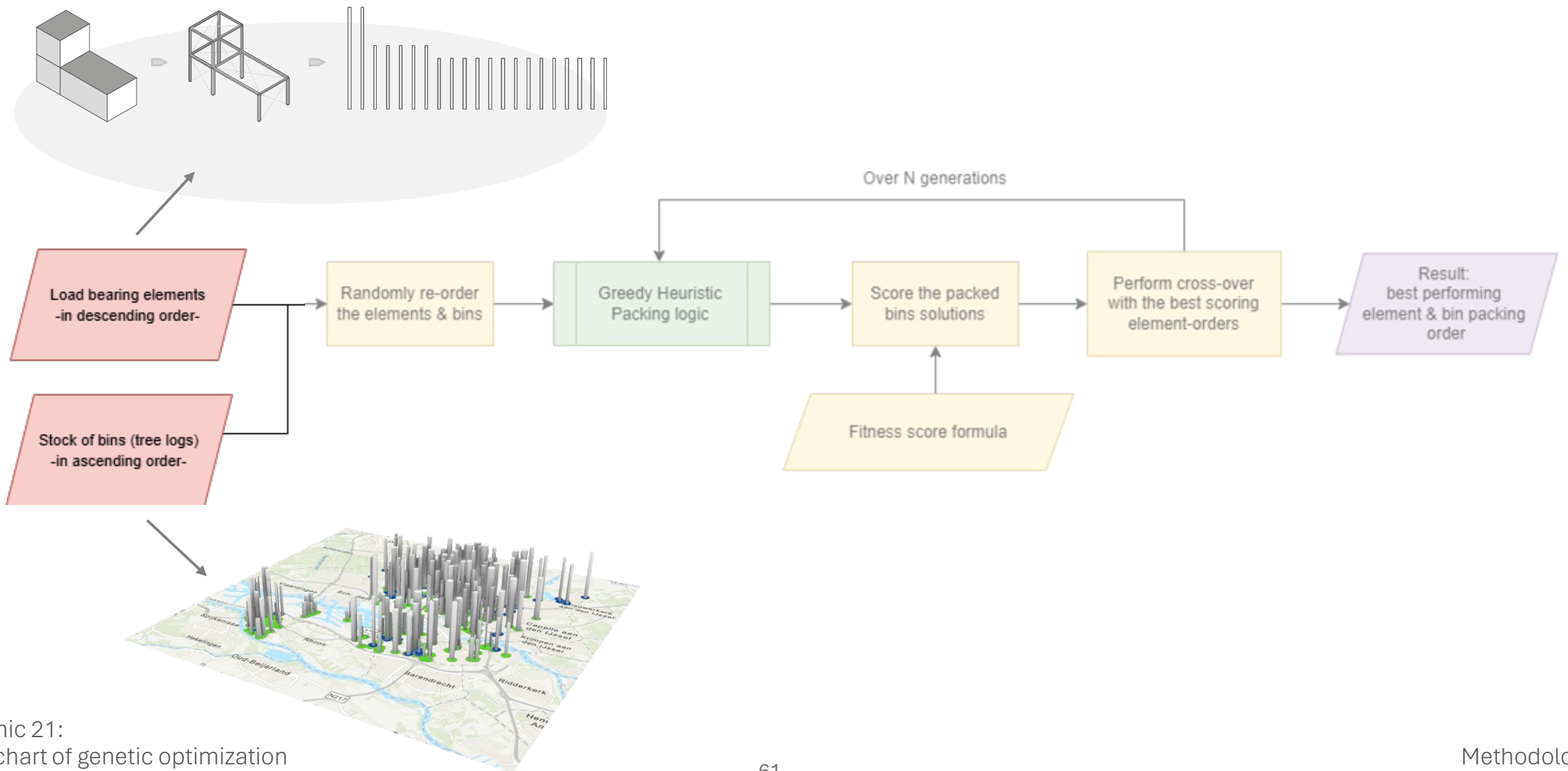
Genetic optimization

Genetic optimization



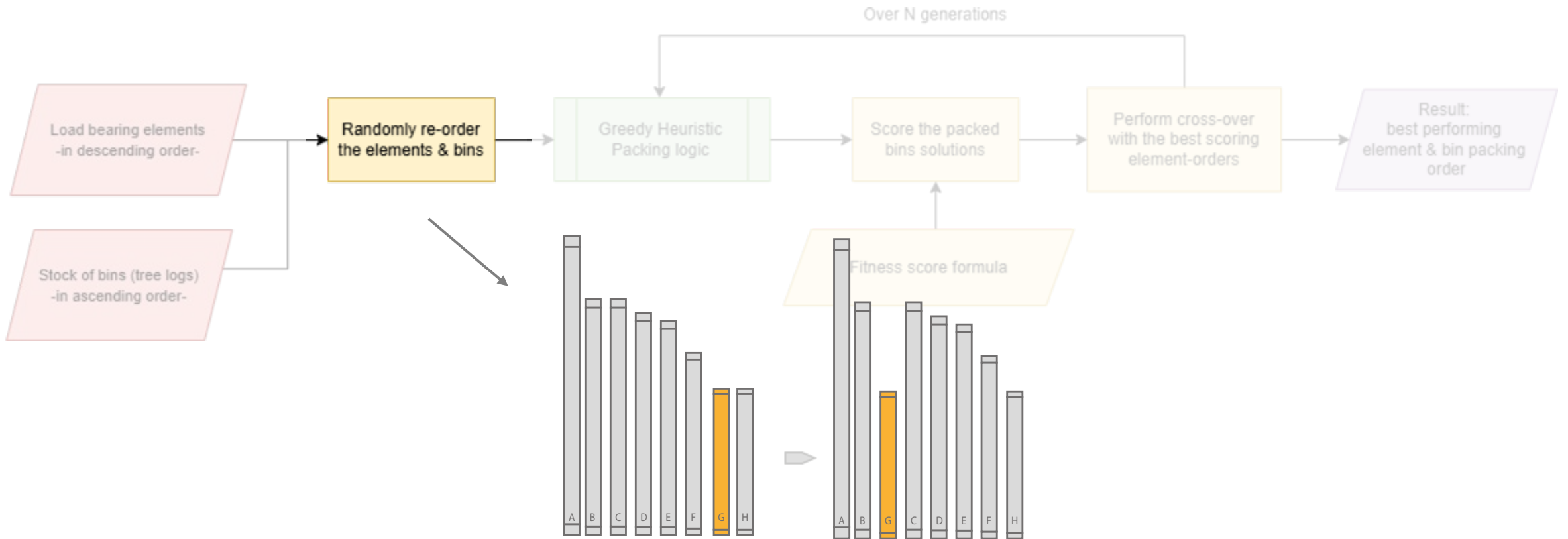
Graphic 21:
Flowchart of genetic optimization
(Source: Author)

Genetic optimization



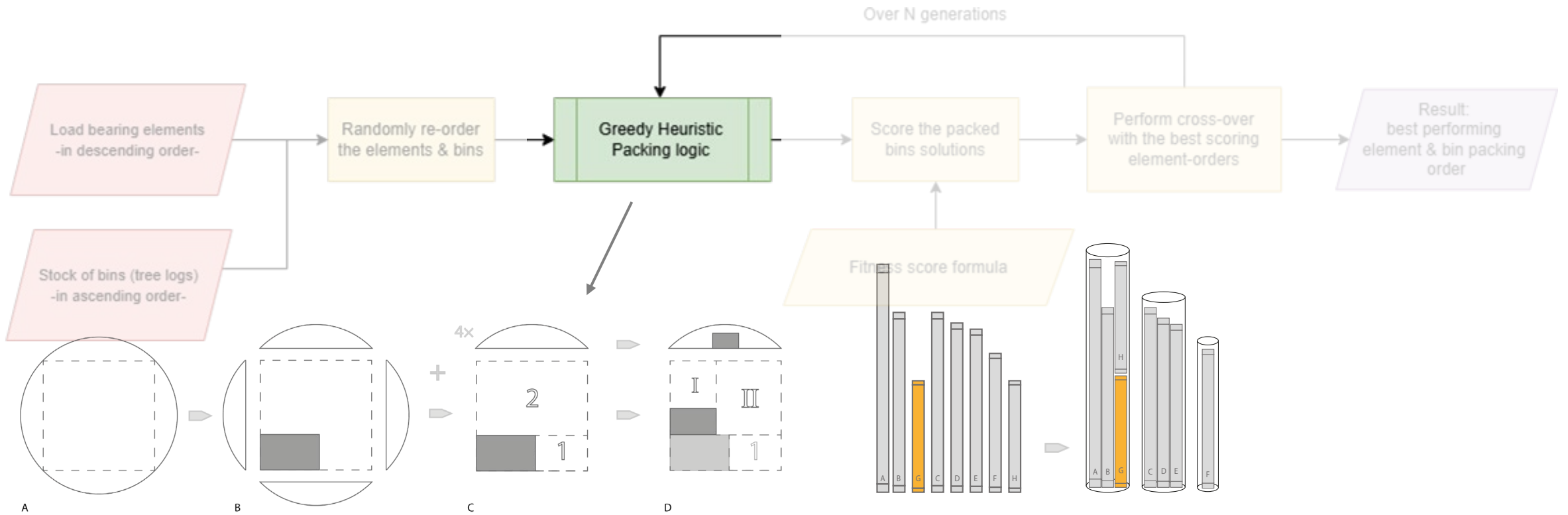
Graphic 21:
Flowchart of genetic optimization
(Source: Author)

Genetic optimization



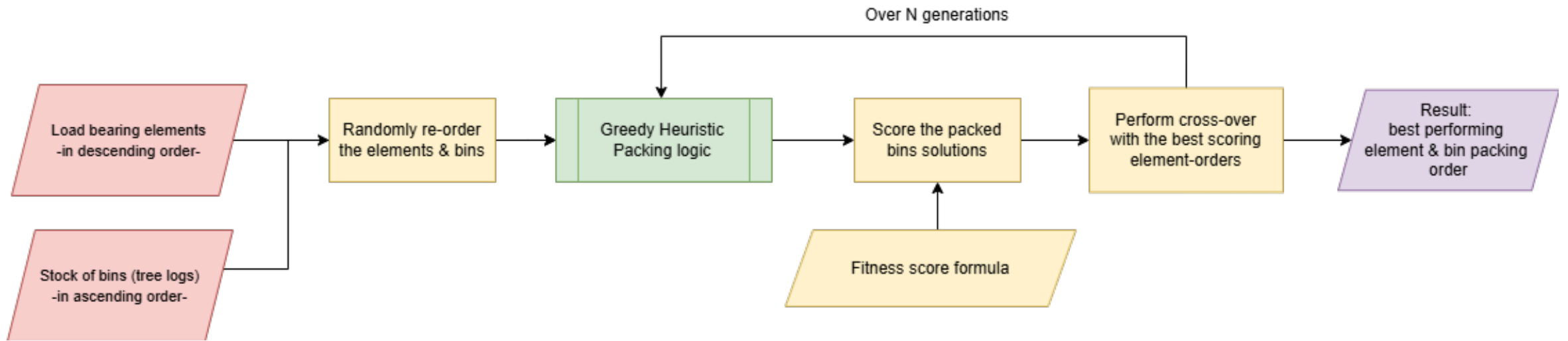
Graphic 21:
Flowchart of genetic optimization
(Source: Author)

Genetic optimization



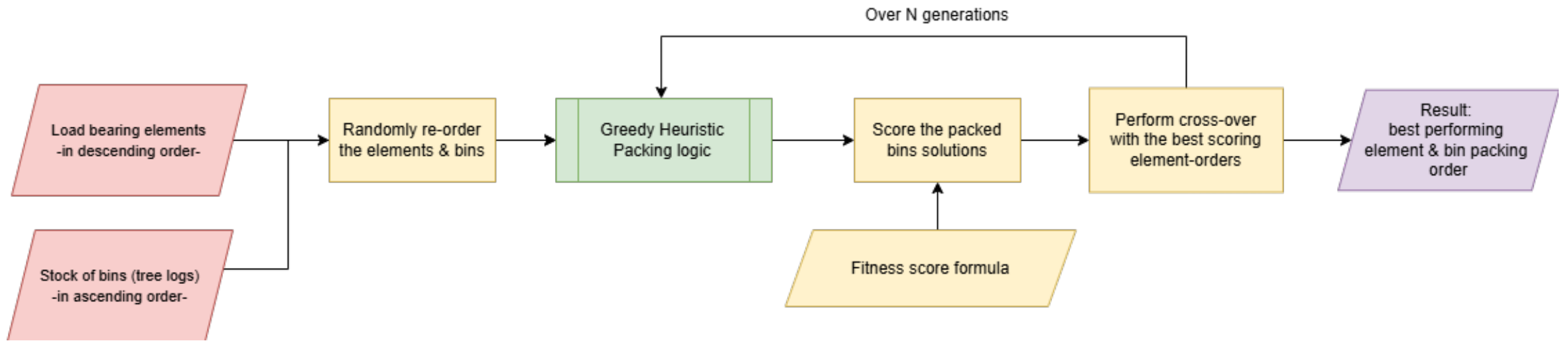
Graphic 21:
Flowchart of genetic optimization
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Genetic optimization



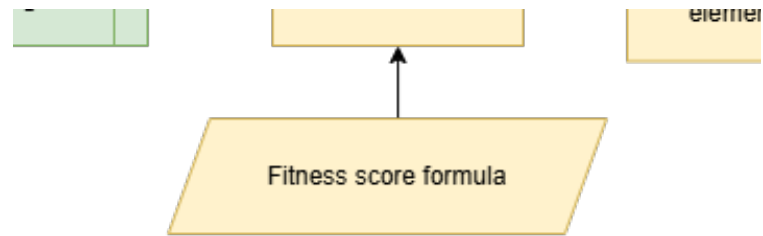
Graphic 21:
Flowchart of genetic optimization
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Genetic optimization



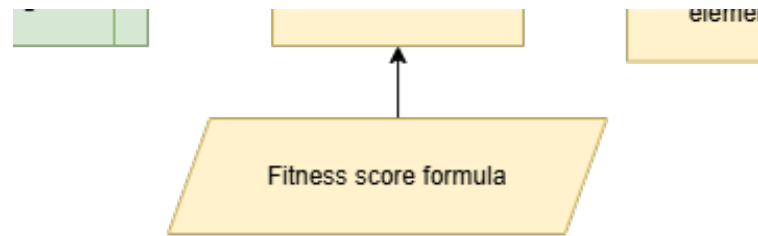
Graphic 21:
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(Source: Author)

Genetic optimization



Graphic 21:
Flowchart of genetic optimization
(Source: Author)

Genetic optimization

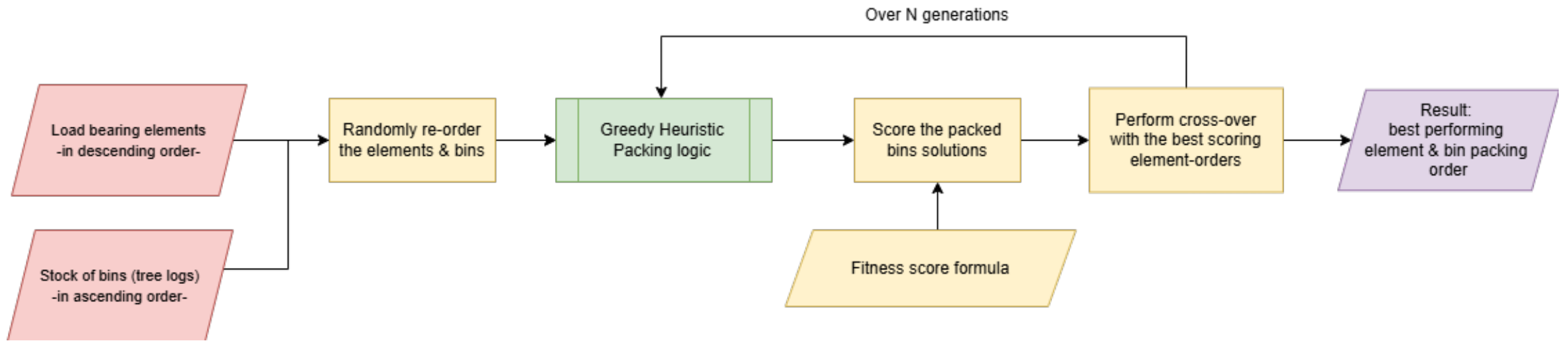


$$score = (100 \times util_sum) - (10 \times bins_used)$$

Util_sum = sum of the utilization over all opened bins

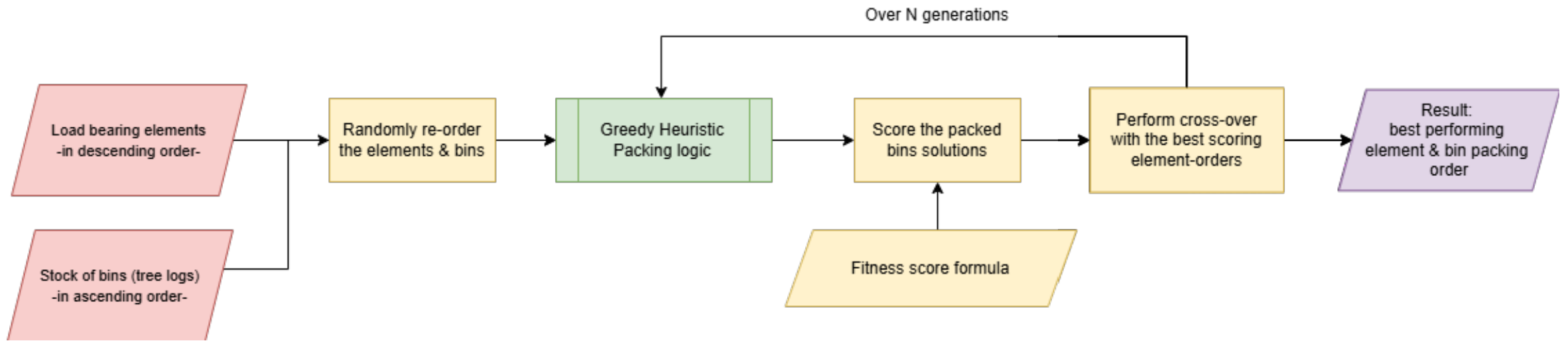
Bins_used = the total number of bins.

Genetic optimization



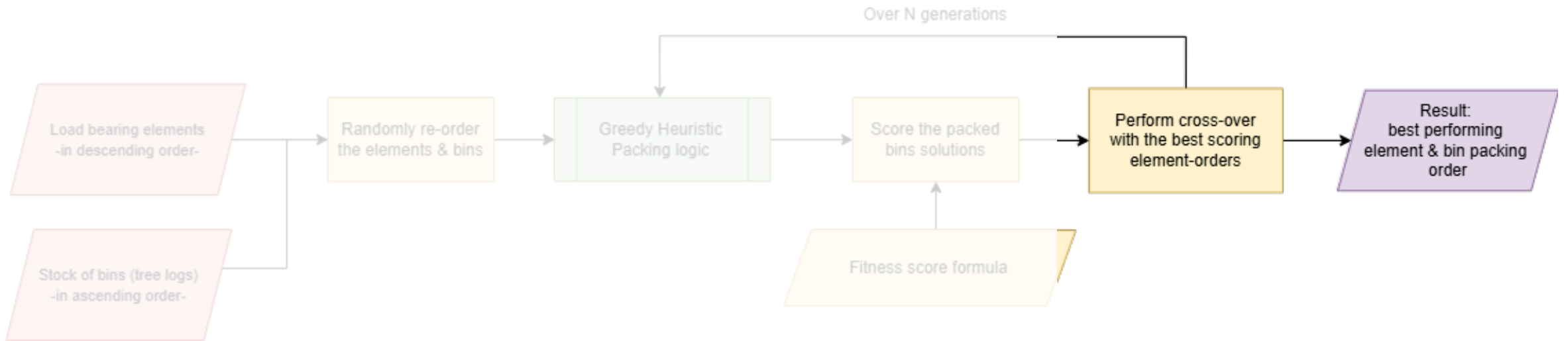
Graphic 21:
Flowchart of genetic optimization
(Source: Author)

Genetic optimization



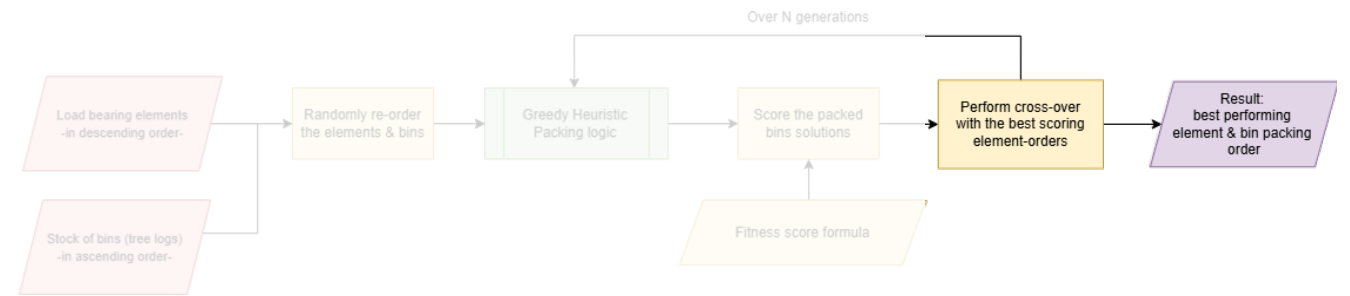
Graphic 21:
Flowchart of genetic optimization
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Genetic optimization



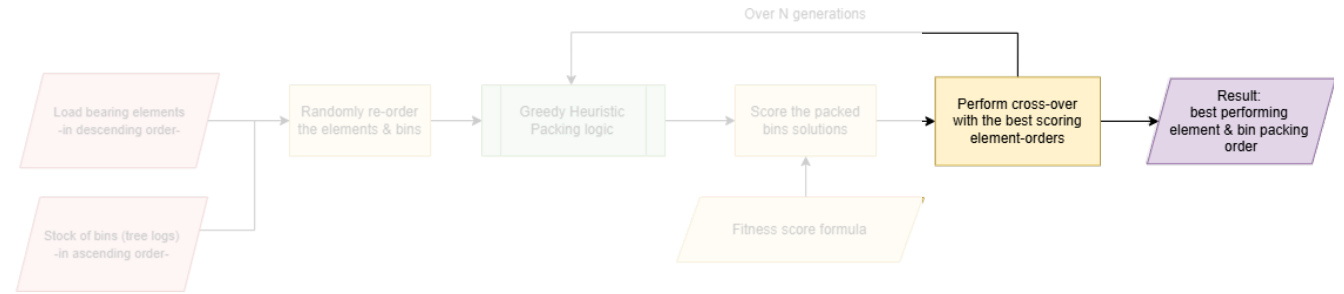
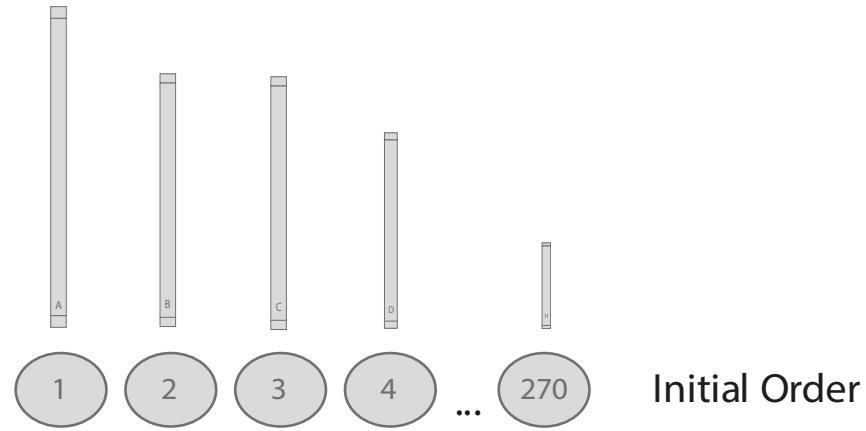
Graphic 21:
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Genetic optimization



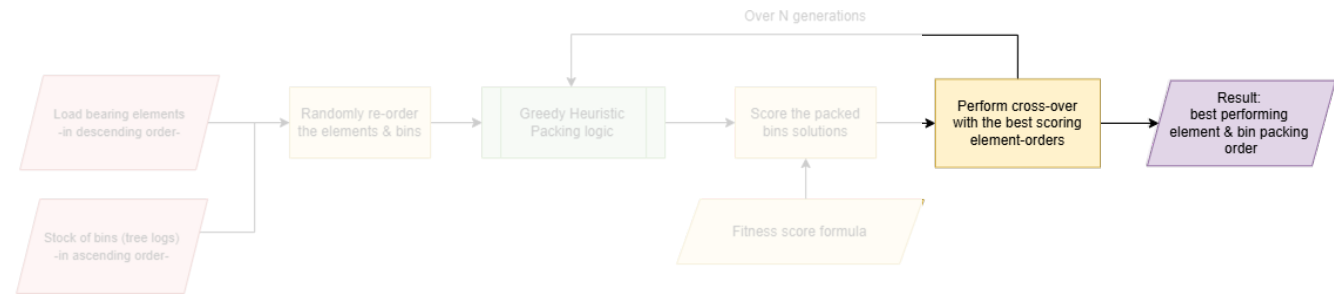
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Flowchart of genetic optimization
(Source: Author)

Genetic optimization



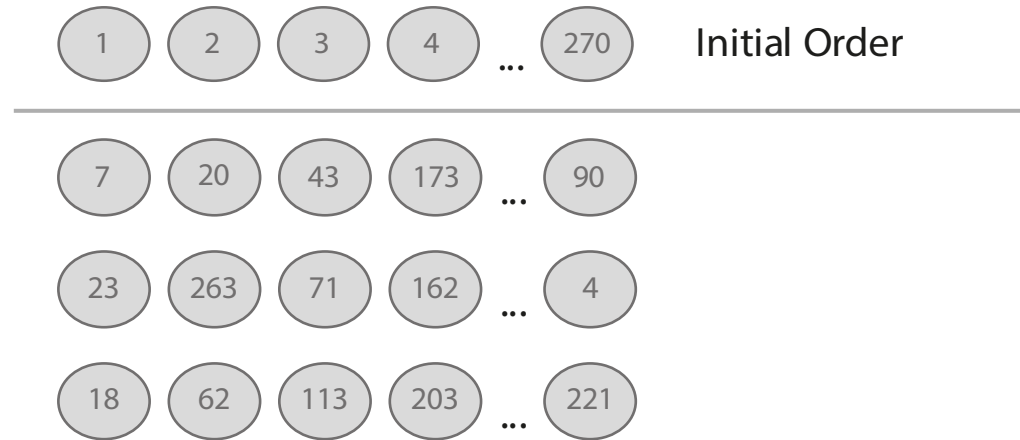
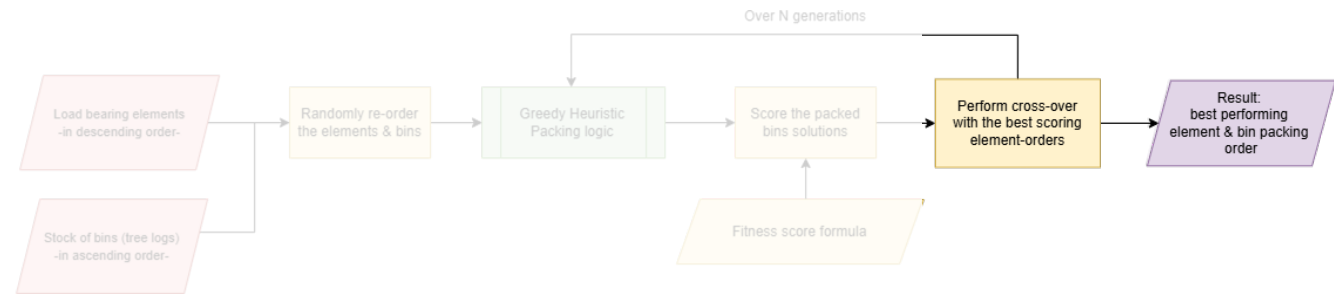
Graphic 22:
Visualisation cross-over & GA terminology
(Source: Author)

Genetic optimization



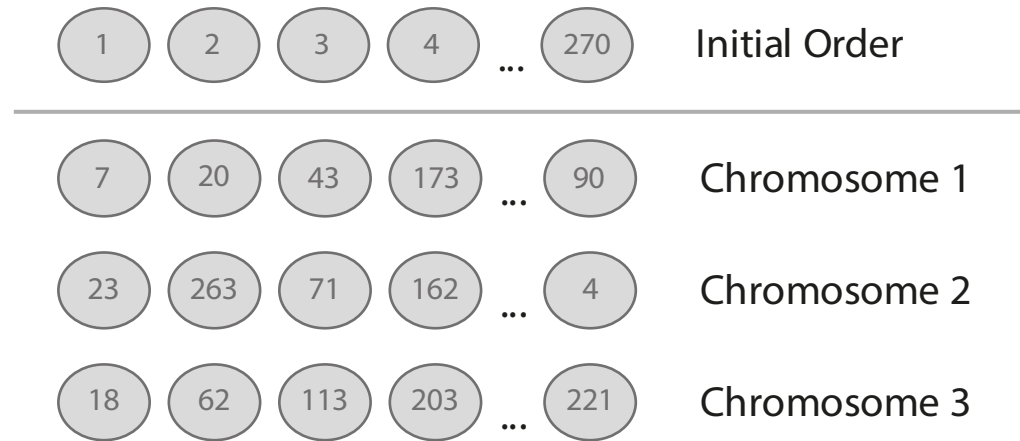
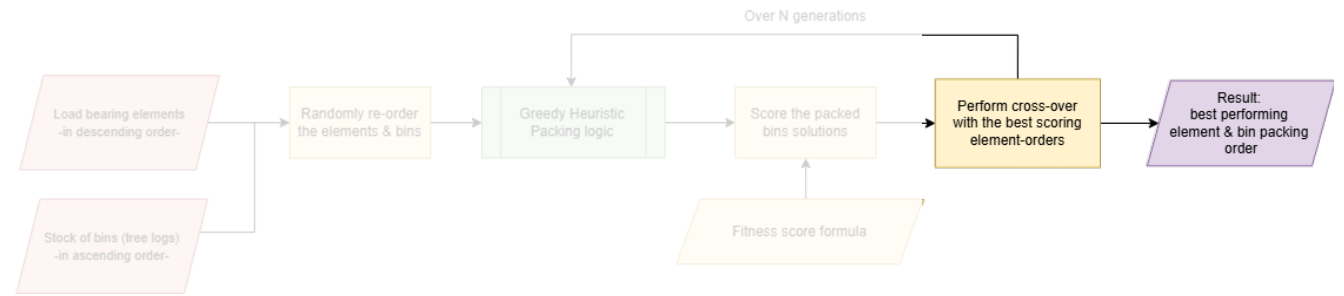
Graphic 22:
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Genetic optimization



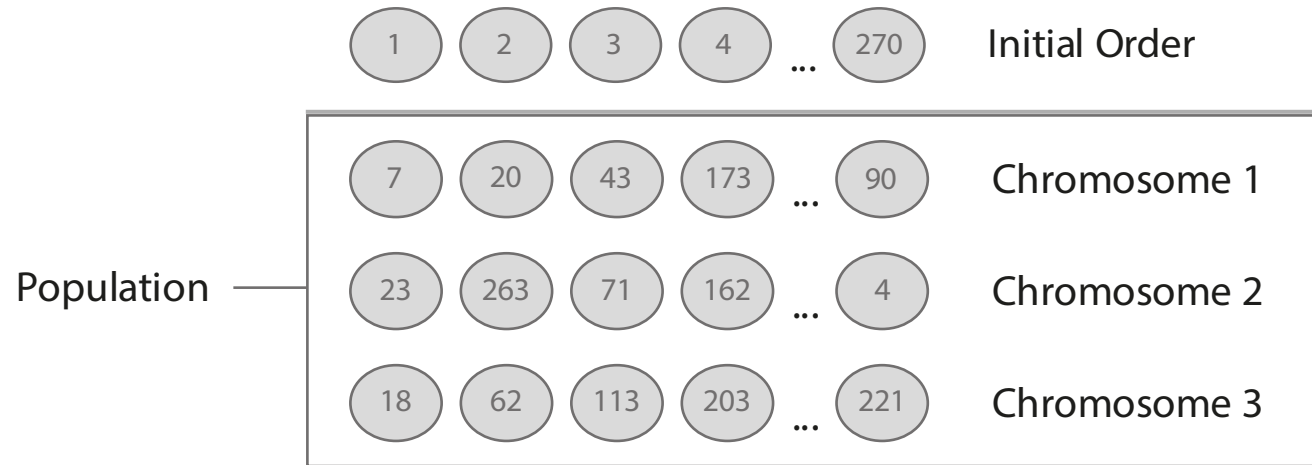
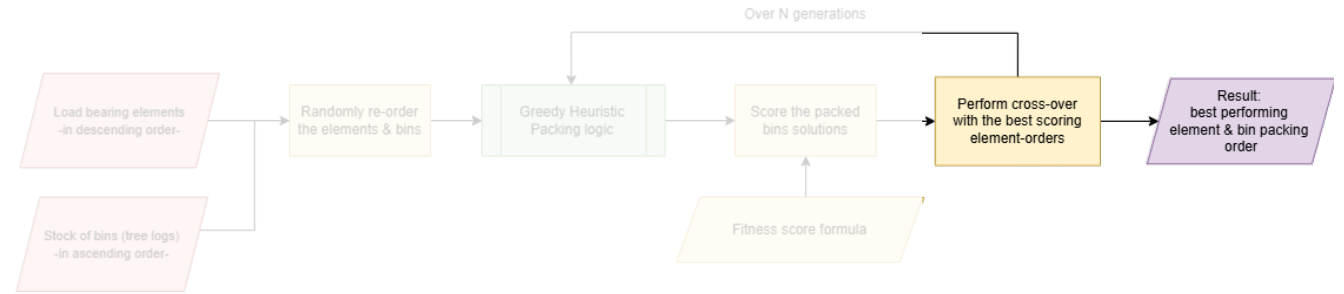
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Genetic optimization



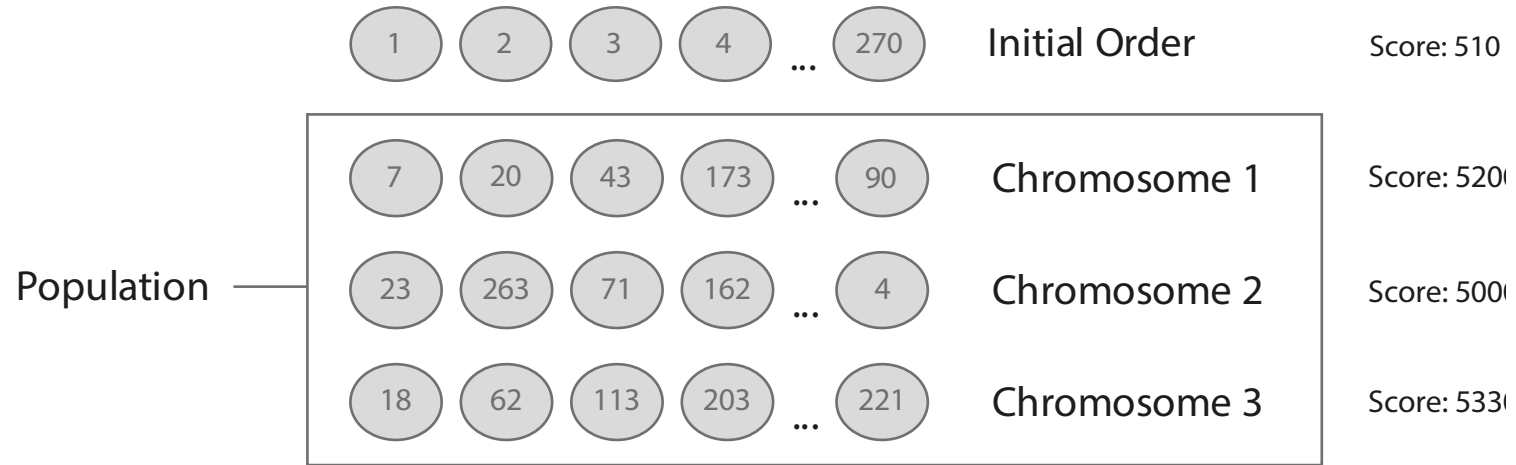
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Genetic optimization



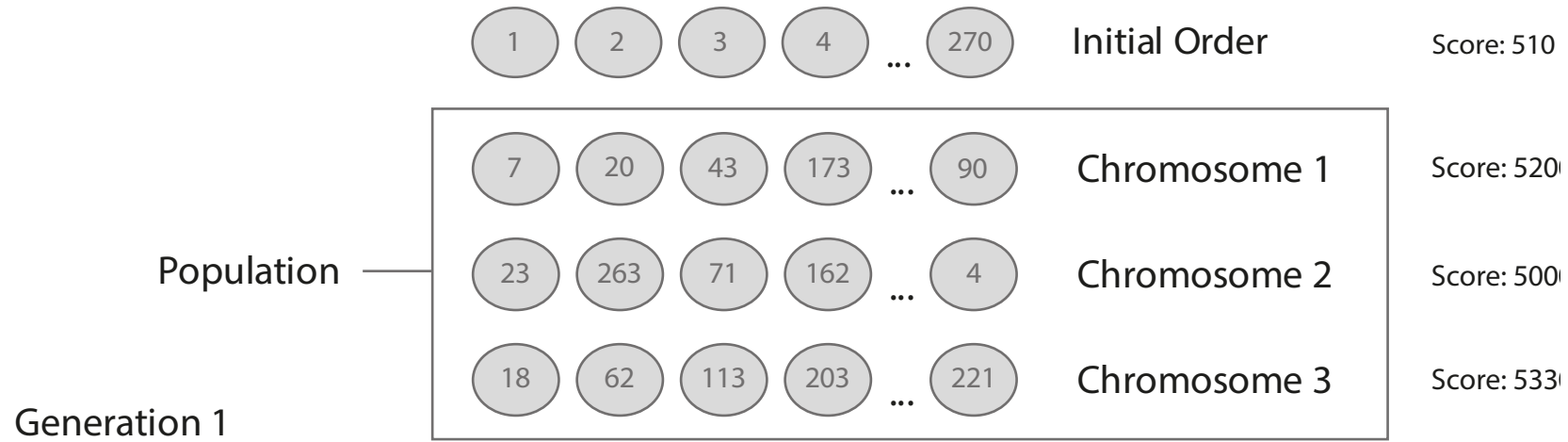
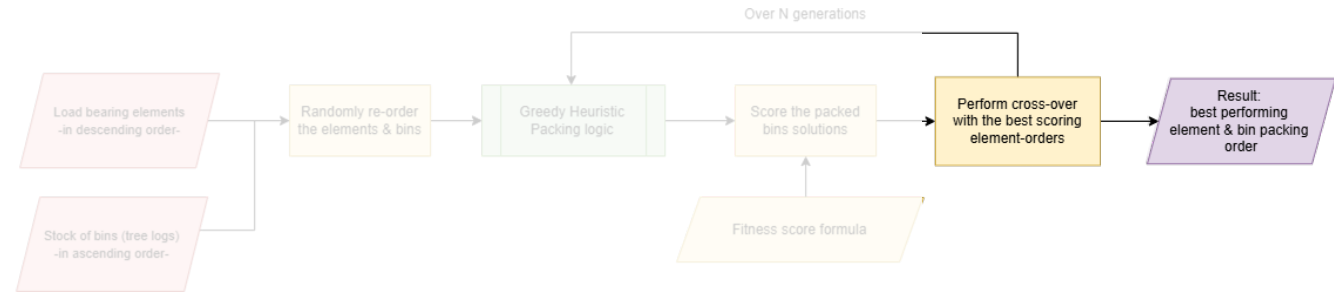
Graphic 22:
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Genetic optimization



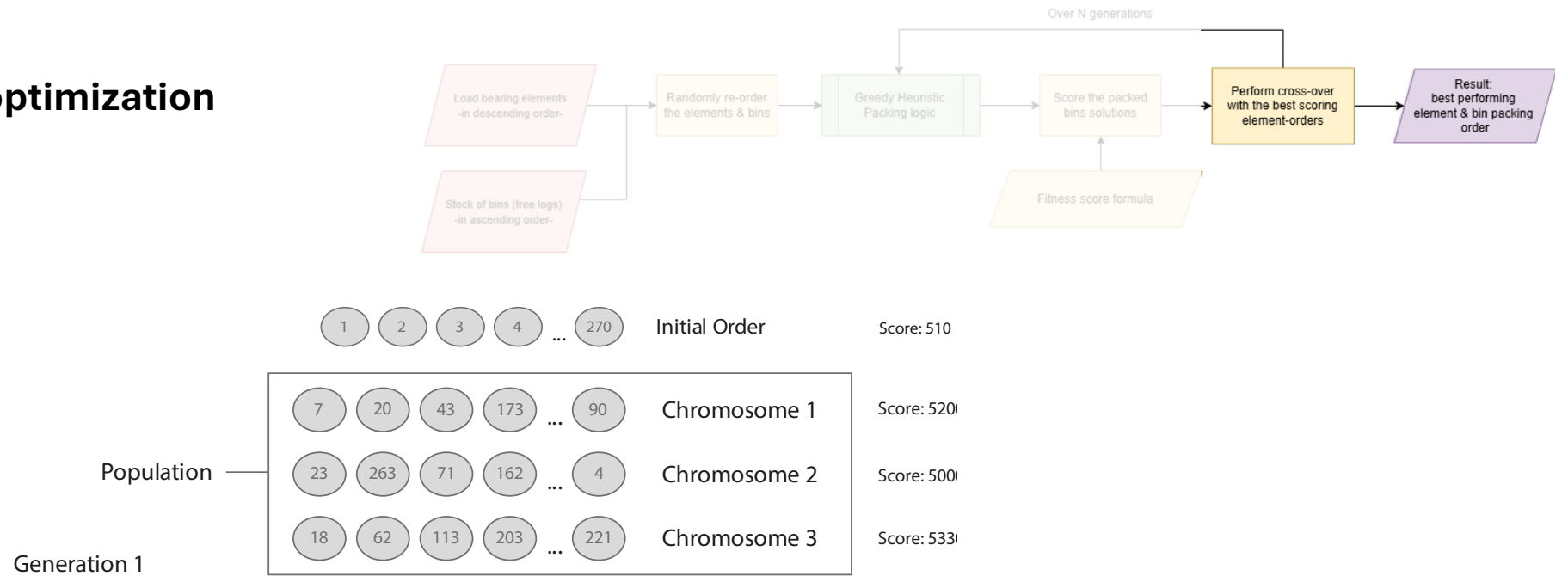
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Genetic optimization



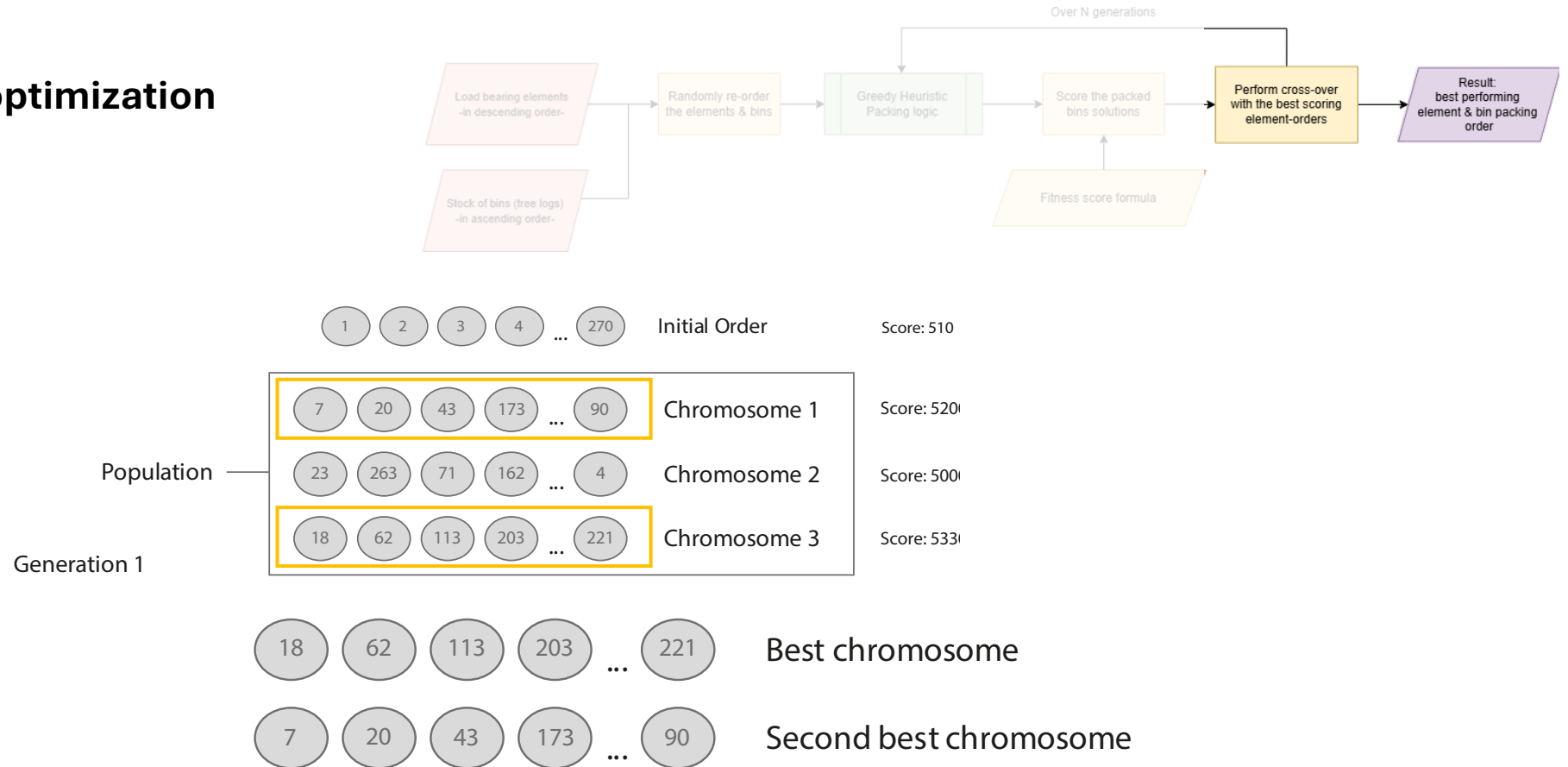
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 Visualisation cross-over & GA terminology
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Genetic optimization



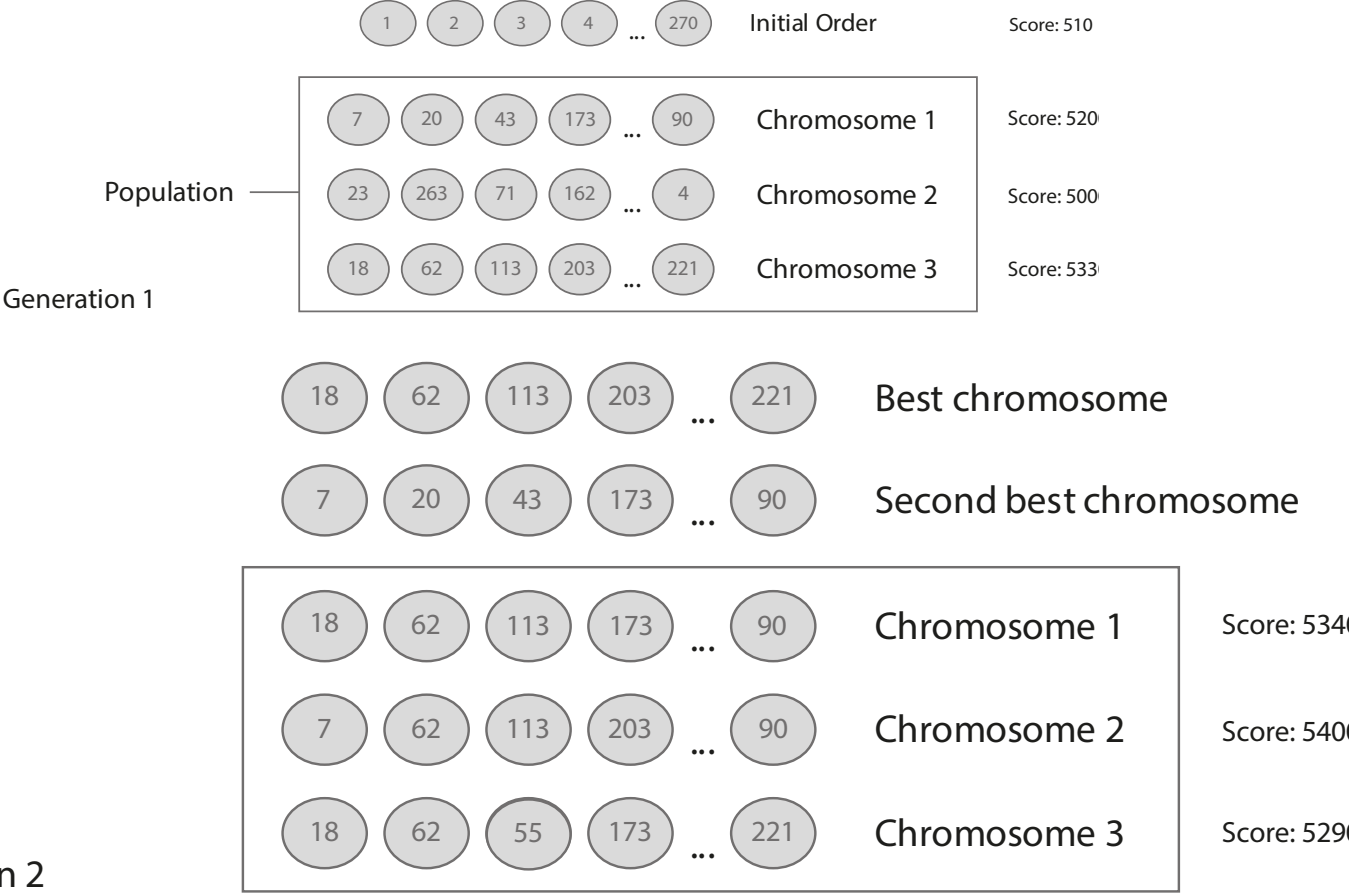
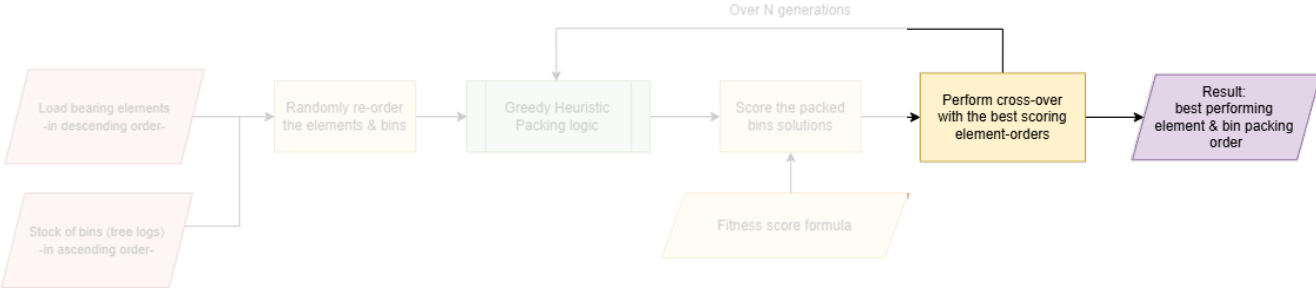
Graphic 22:
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Genetic optimization



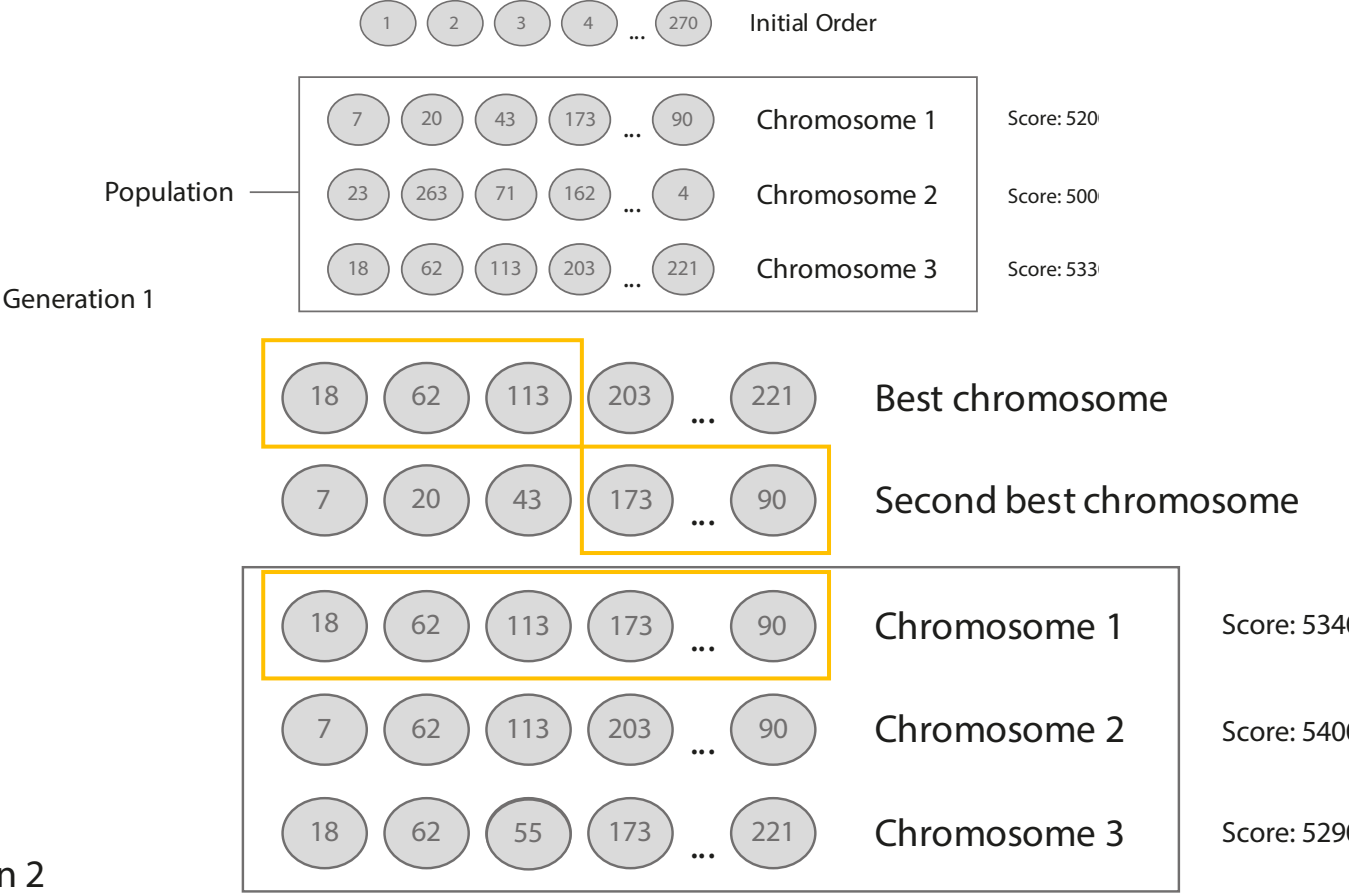
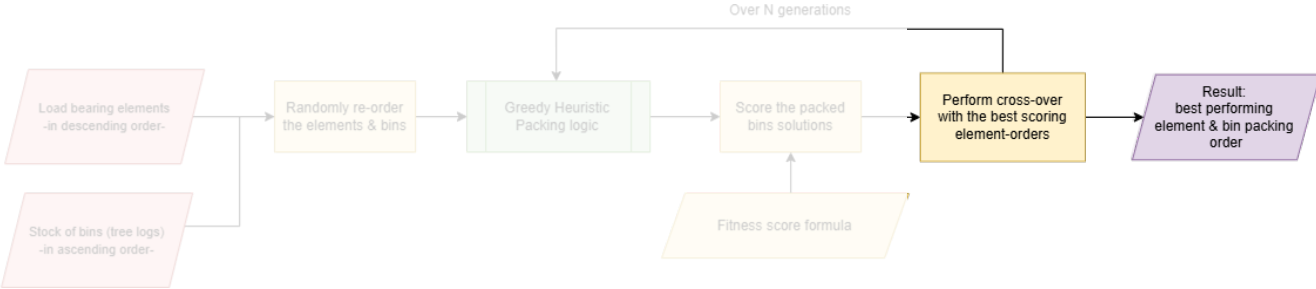
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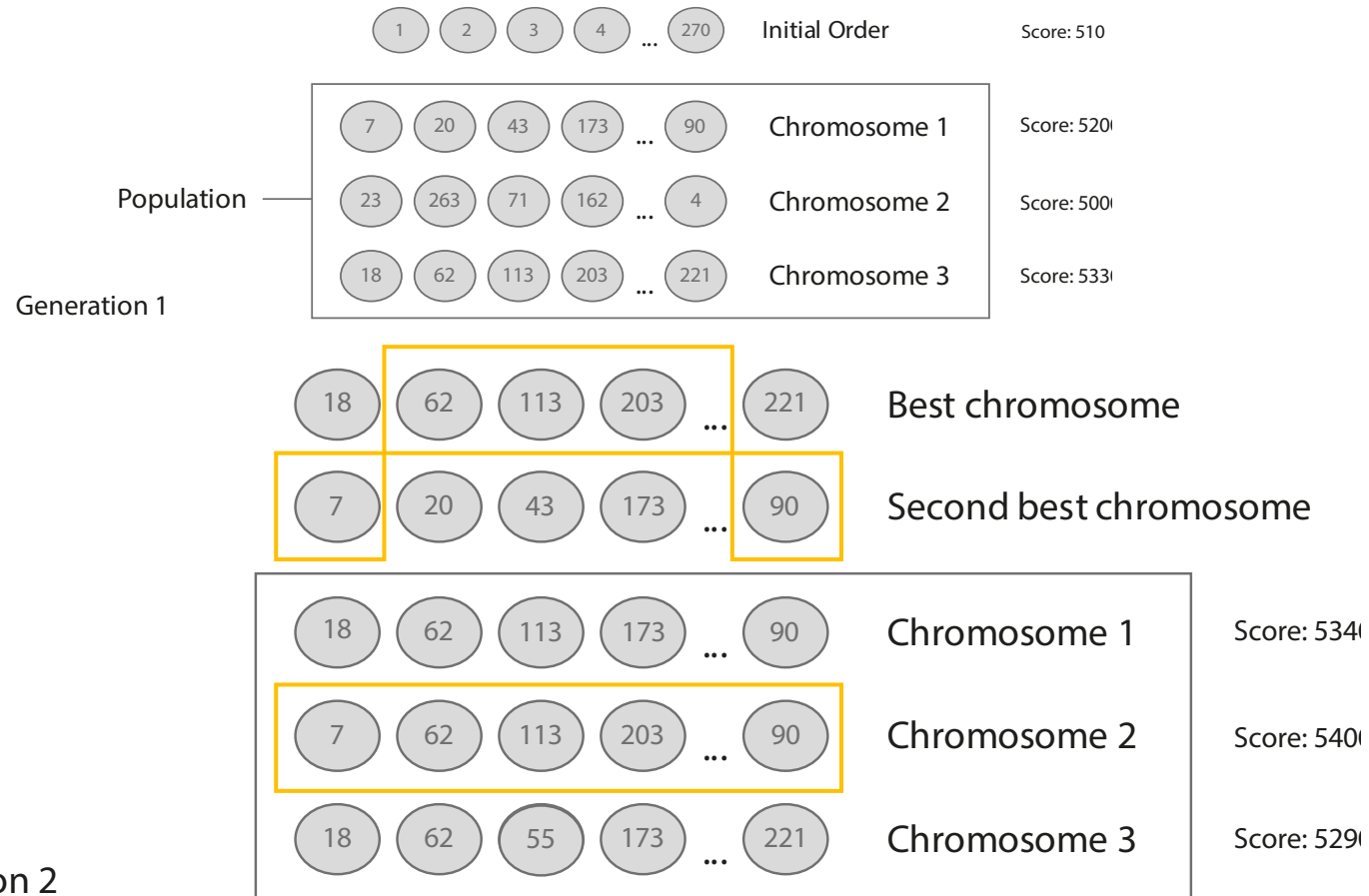
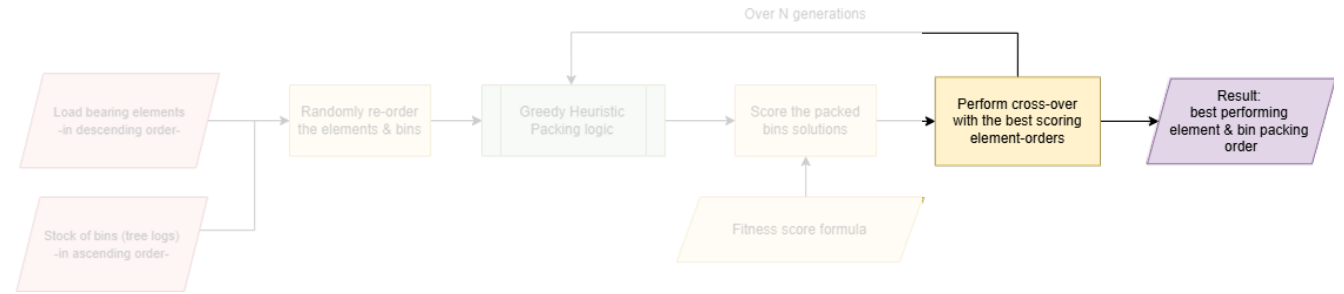
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Genetic optimization



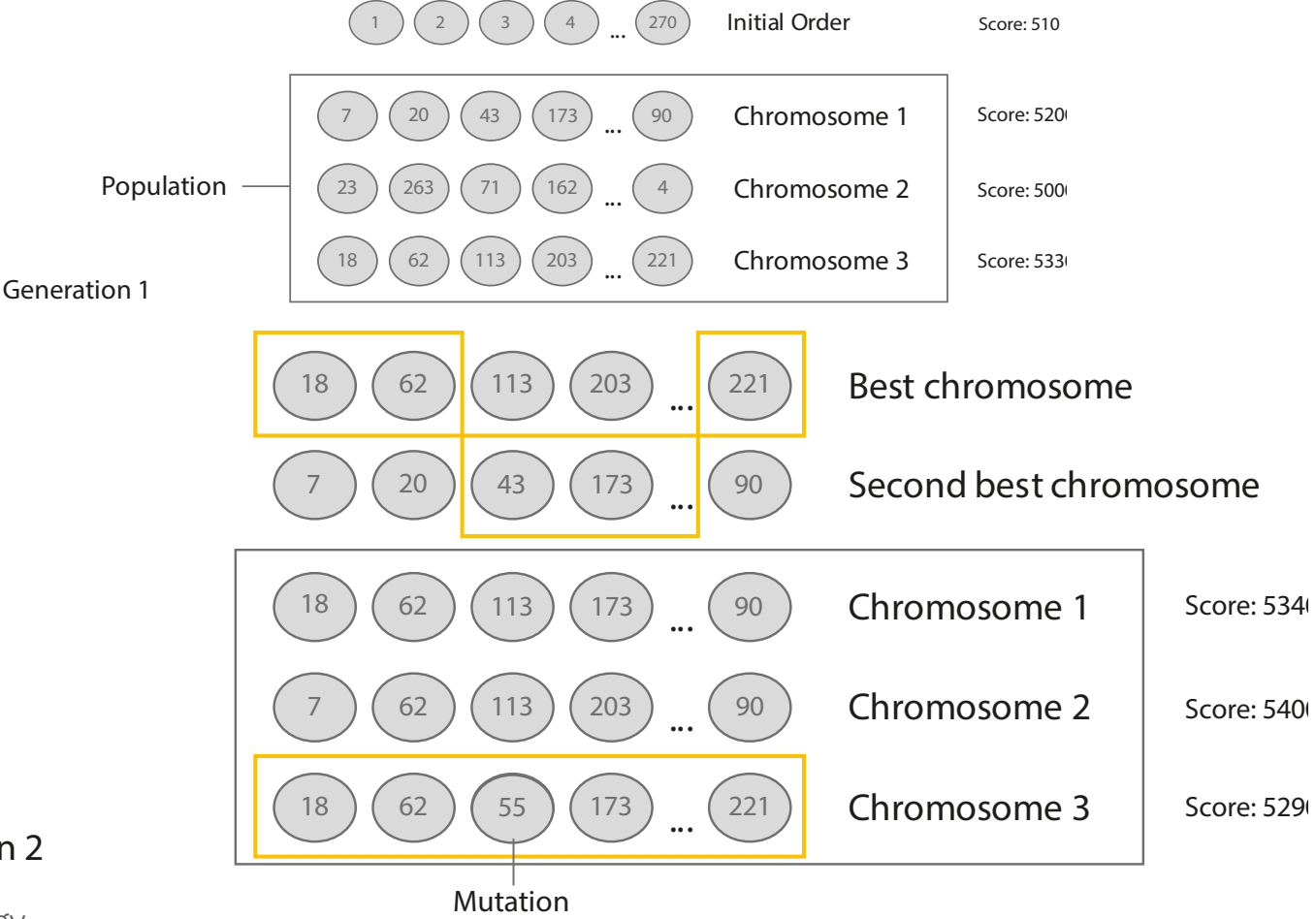
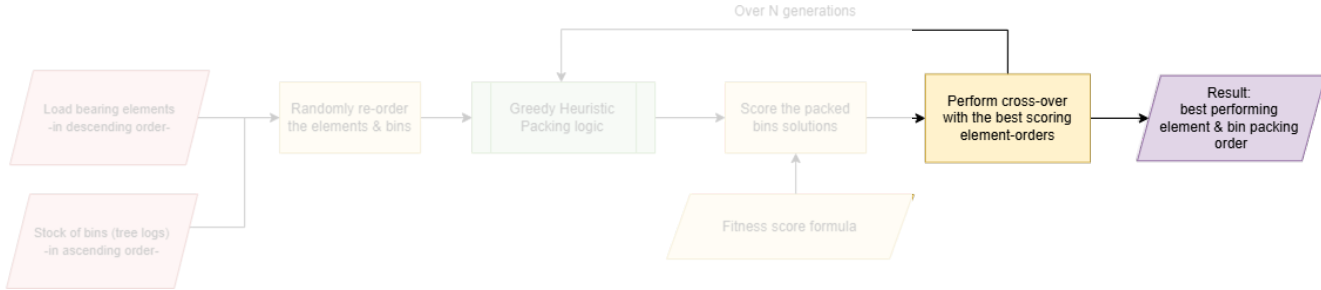
Graphic 22: Visualisation cross-over & GA terminology (Source: Author)

Genetic optimization



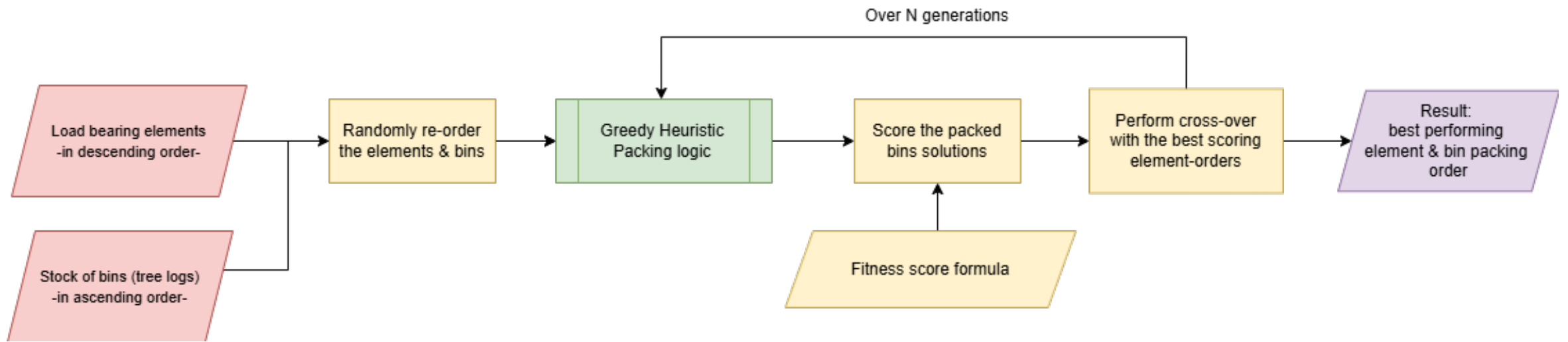
Graphic 22:
Visualisation cross-over & GA terminology
(Source: Author)

Genetic optimization



Graphic 22: Visualisation cross-over & GA terminology (Source: Author)

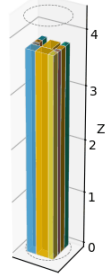
Genetic optimization



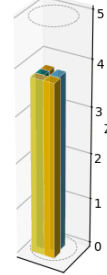
Graphic 21:
Flowchart of genetic optimization
(Source: Author)

Gen 1 Best Solution
Score: 5234.73 | Packed: 88

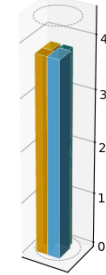
Robinia ($\varnothing=0.84\text{m}$)
Util: 0.38



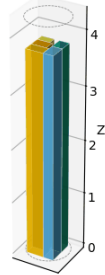
Robinia ($\varnothing=0.99\text{m}$)
Util: 0.26



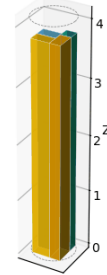
Robinia ($\varnothing=0.86\text{m}$)
Util: 0.37



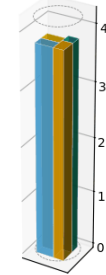
Robinia ($\varnothing=0.84\text{m}$)
Util: 0.45



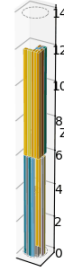
Robinia ($\varnothing=0.79\text{m}$)
Util: 0.47



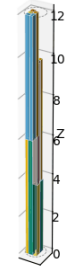
Robinia ($\varnothing=0.81\text{m}$)
Util: 0.42



Oak ($\varnothing=1.39\text{m}$)
Util: 0.35



Oak ($\varnothing=1.06\text{m}$)
Util: 0.36



Oak ($\varnothing=0.85\text{m}$)
Util: 0.18

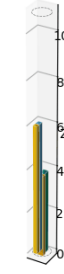


Figure 23:
GIF visualizing the working of the GA
(Source: Author)

Results

Result Element Dimensioning

Fire-safety the main determinant.
Average **30%** increase

Timber species effect
8.8% lower in size
Strongest vs Lowest

Result Bin-Packing

Interpretation of cutting patterns

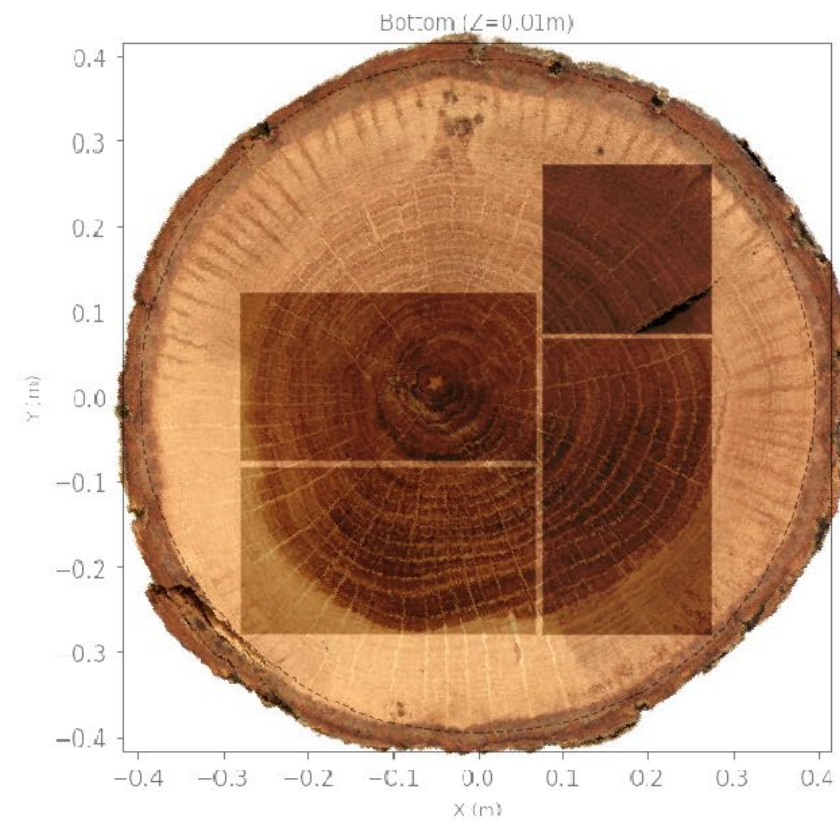
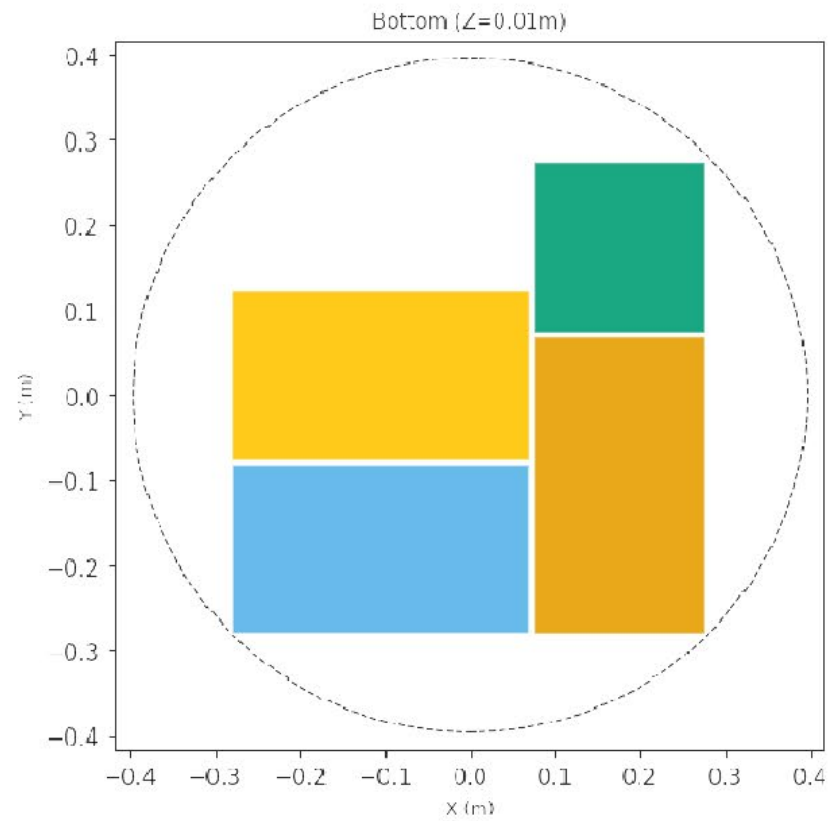
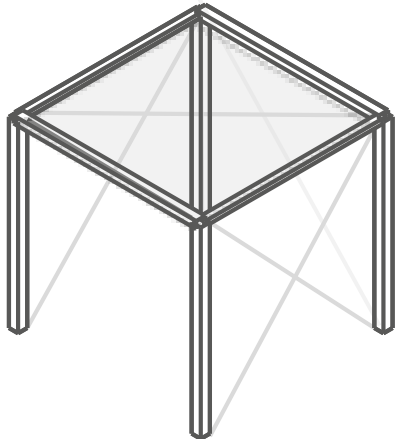
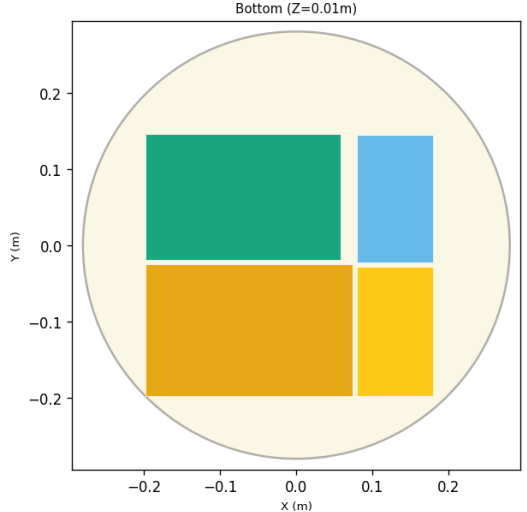
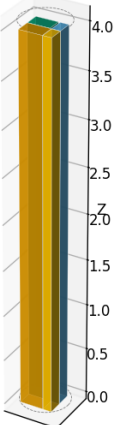


Figure 24:
Interpretation of cutting patterns
(Source: Author)

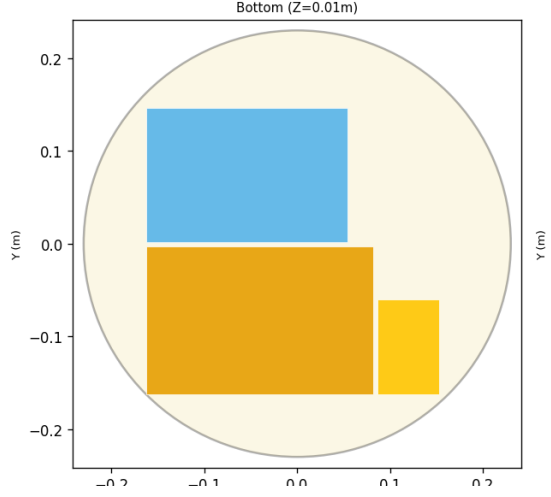
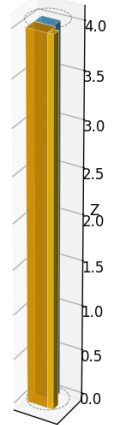
Results Heuristic bin-packing



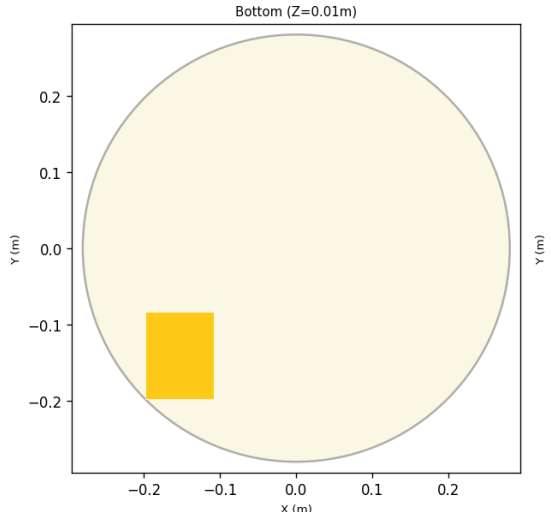
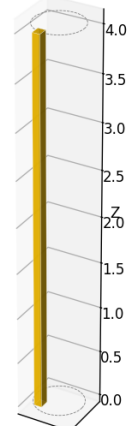
Robinia (Ø=0.56m)
Util: 0.49



Robinia (Ø=0.46m)
Util: 0.46



Poplar (Ø=0.56m)
Util: 0.04



3 trees: 2x Robinia, 1x Poplar
Average utilization: 33.05%

Figure 25:
Result of Heuristic bin-packing
(Source: Author)

Results MetaHeuristic bin-packing

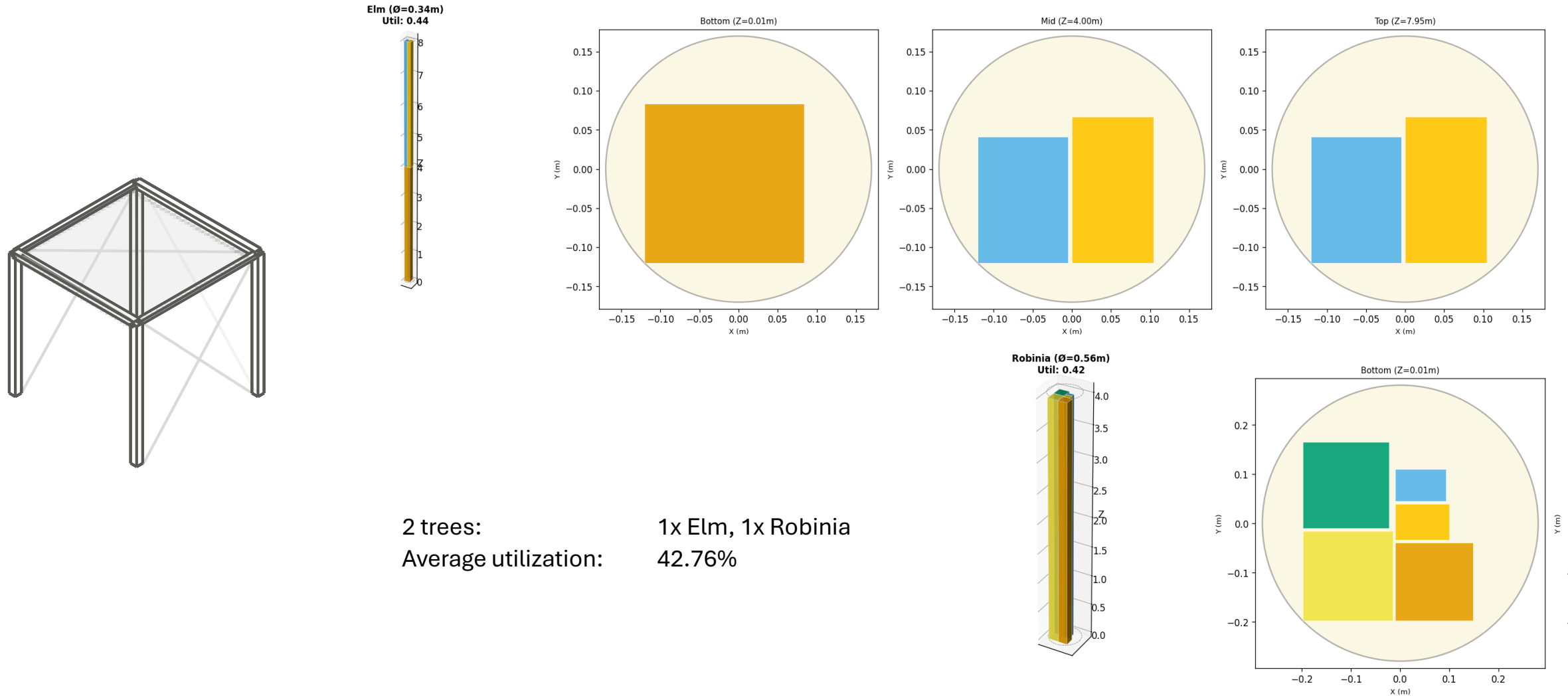
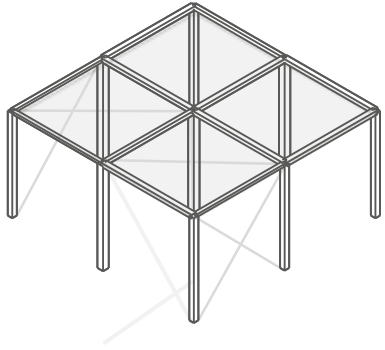


Figure 26:
Result of bin-packing with GA
(Source: Author)

Results bin-packing



Heuristic:

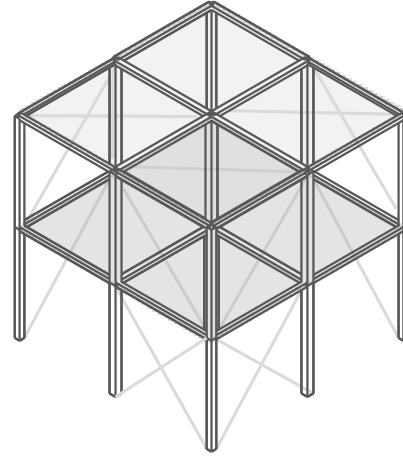
11 trees: 6x Robinia, 5x Poplar

Average utilization: 25.82%

MetaHeuristic:

5 trees: 2x Ash, 2x Poplar,
1x Robinia

Average utilization: 45.26%



Heuristic:

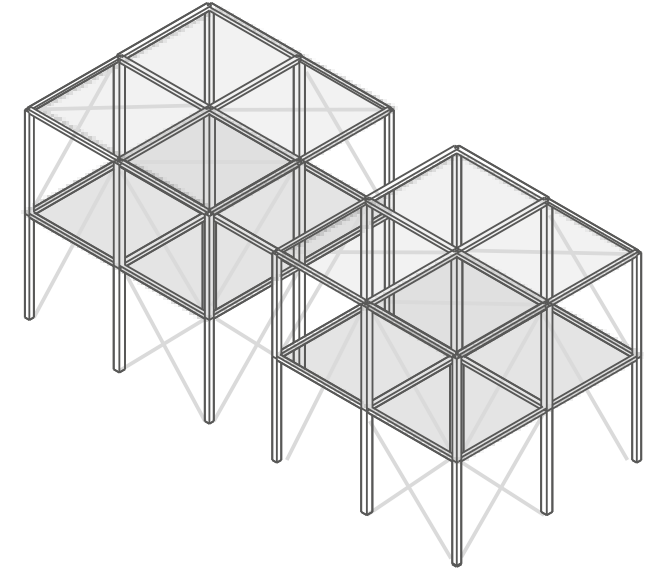
20 trees: 10x Robinia, 10x Poplar

Average utilization: 29.10%

MetaHeuristic:

14 trees: 7x Robinia, 7x Poplar

Average utilization: 44.48%



Heuristic:

41 trees: 19x Robinia, 18x Poplar, 1x
Chestnut, 2x Elm, 1x Maple

Average utilization: 26.77%

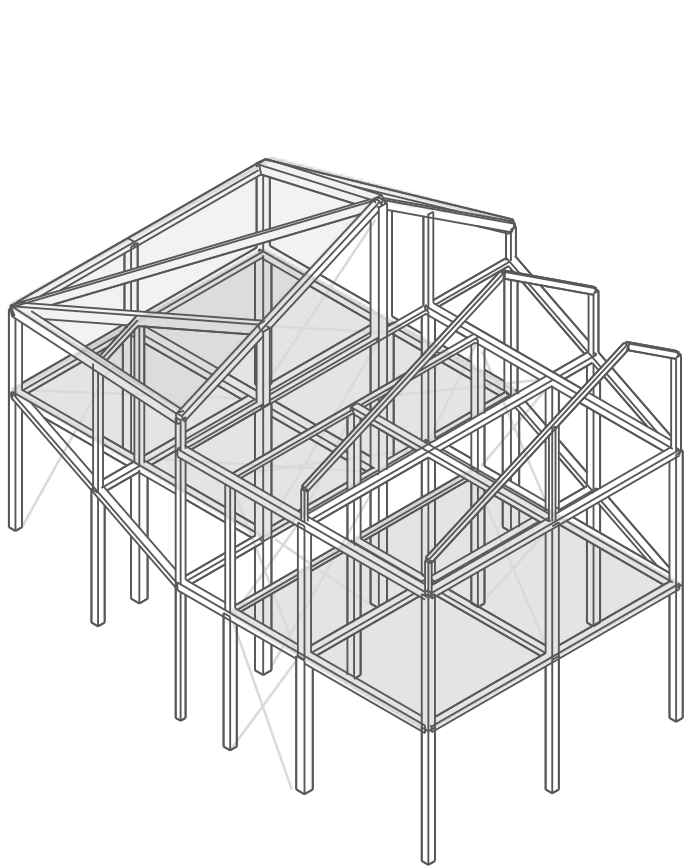
MetaHeuristic:

28 trees: 13x Robinia, 11x Poplar
4x Elm

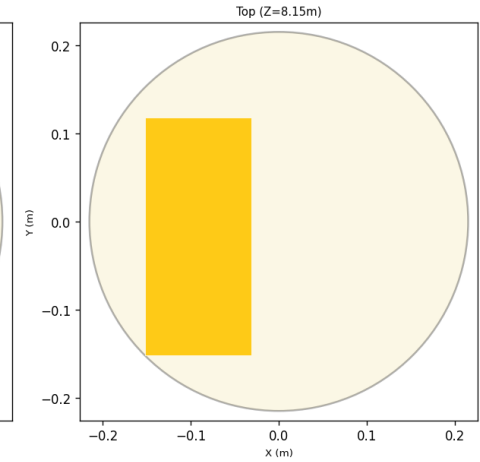
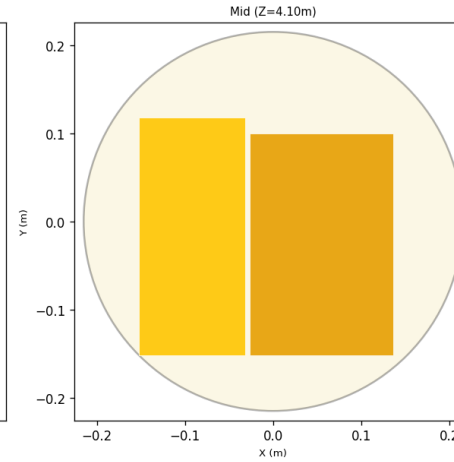
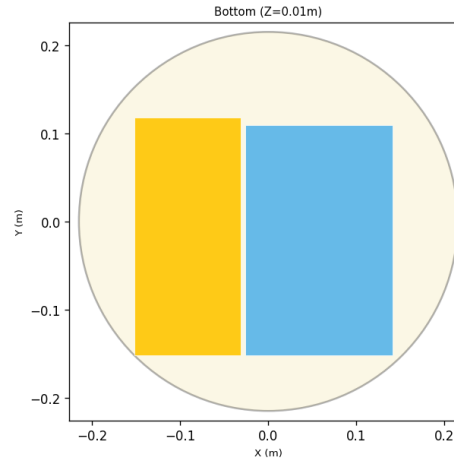
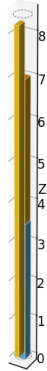
Average utilization: 43.49%

Figure 27:
Results of bin-packing reference structures
(Source: Author)

Results MetaHeuristic bin-packing



Ash ($\varnothing=0.43\text{m}$)
Util: 0.46



33 trees:

11x Robinia, 1x Oak,
6x Ash, 1x Elm, 6x
Maple, 8x Poplar

Average utilization:

39.60%

Poplar ($\varnothing=0.39\text{m}$)
Util: 0.45

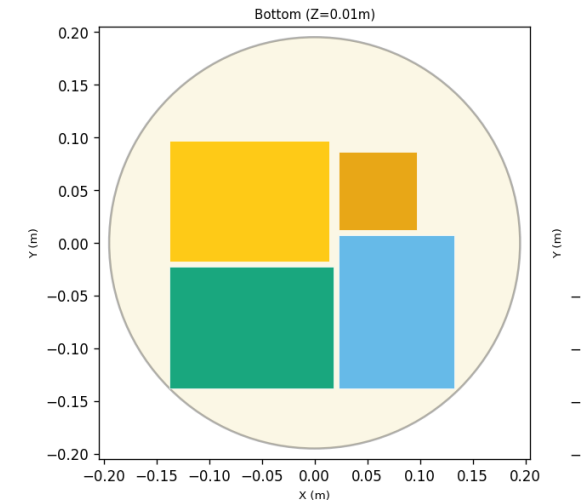
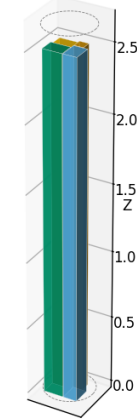


Figure 28:
Results of bin-packing *Muiden* Structure
(Source: Author)

Progress report Genetic Algorithm -*Muiden* structure

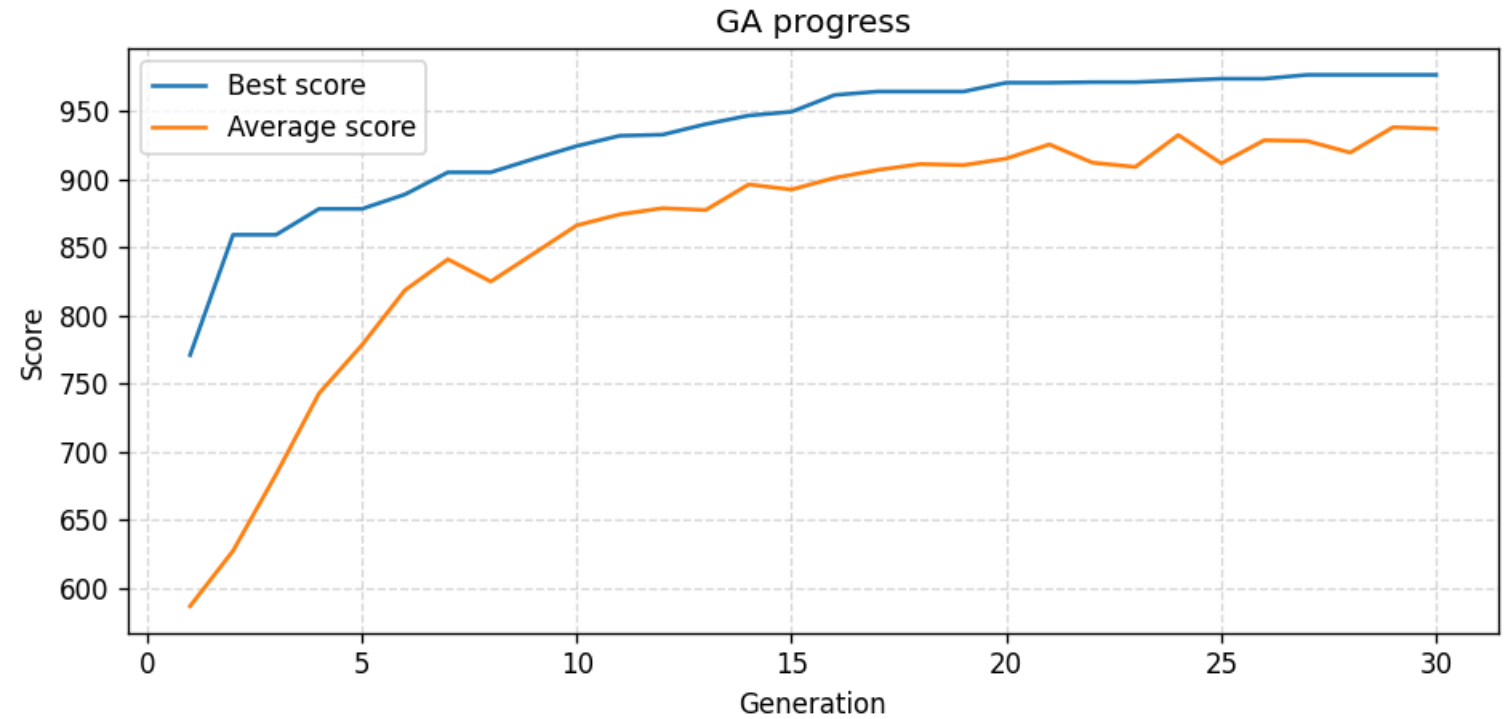
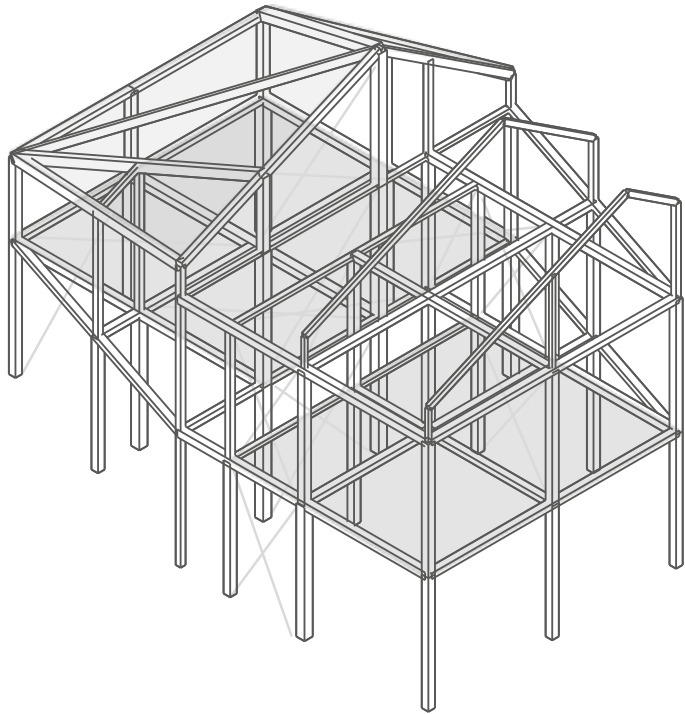


Figure 29:
Graph with progress report of GA on *Muiden* structure
(Source: Author)

Results bin-packing

Heuristic VS Metaheuristic						
Structure	Heuristic		MetaHeuristic		Difference	
	Trees #	Utilization [%]	Trees #	Utilization [%]	Trees #	+ Utilization
4x4	3	33.05	2	42.76	1	9,71
8x8	11	25.82	5	47.70	6	21,88
8x8x2	20	29.10	14	44.48	6	15,38
2x8x8x2	41	26.72	28	43.49	13	16,77
Muiden	39	29.77	33	39.60	5	9,83

Figure 30:
Table with overview results for all structures
(Source: Author)

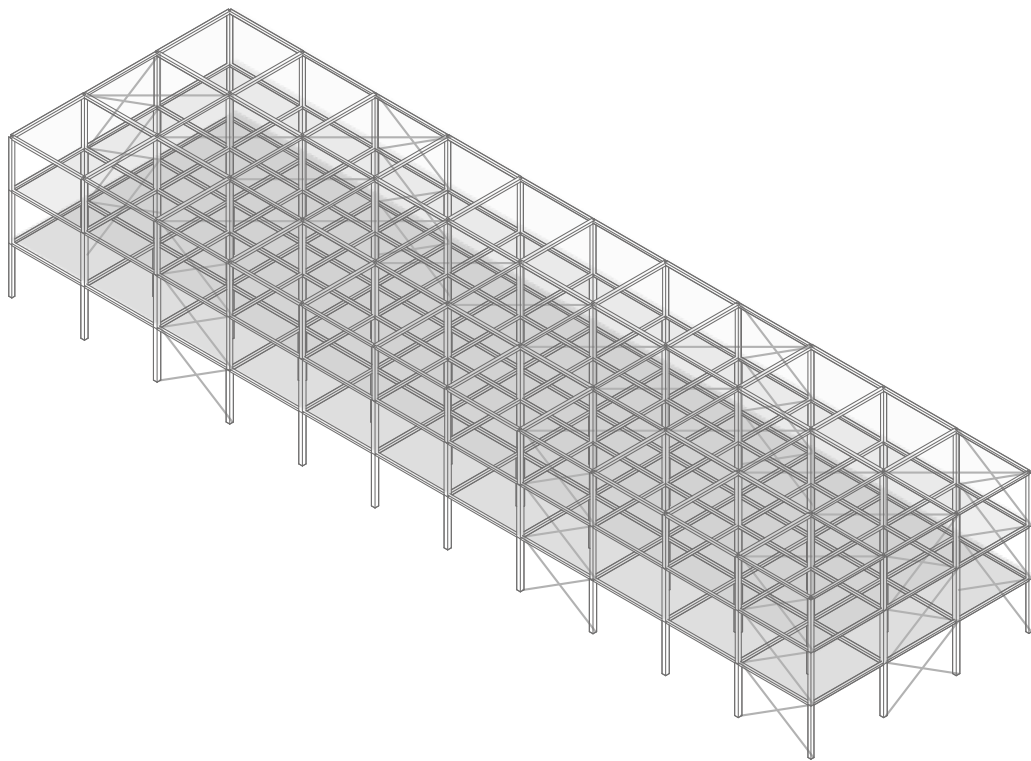
Parameter exploration

More extreme reference building



Photograph of the *Floating Office Rotterdam* by Powerhouse Company

More extreme reference building



Results binpackingFOR	
Required logs	Total: 167
	63x Maple
	41x Ash
	22x Robinia
	19x Poplar
	9x Elm
	8x Oak
	4x Chestnut
	1x Beech
Average utilisation	34.11%

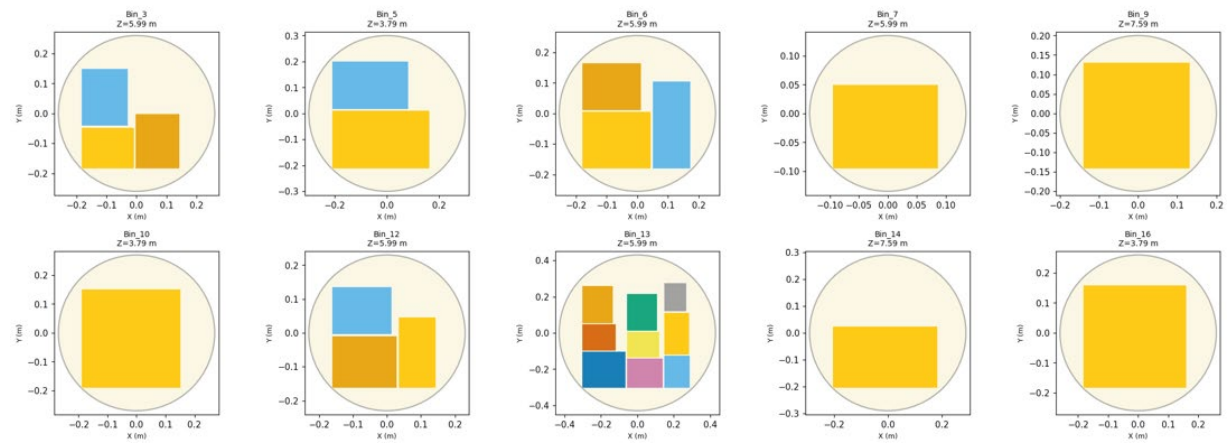
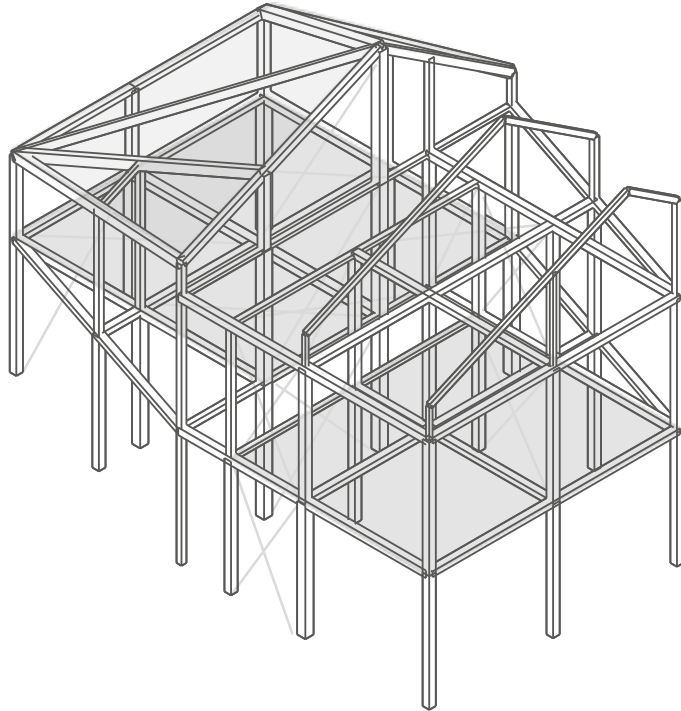


Figure 31:
Result packing Floating Office Rotterdam
(Source: Author)

Weighted Timber Use



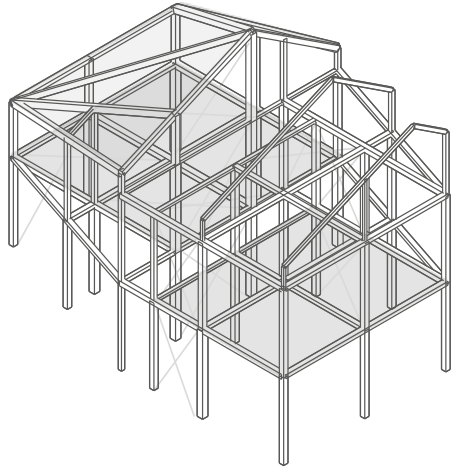
Results weighted timber species		value_species
Required logs	Total:33	-
	11xRobinia	-
	8xPolar	-
	6xMaple	-
	6xAsh	-
	1xOak	-
	1xElm	-
Average utilisation	39.60%	-



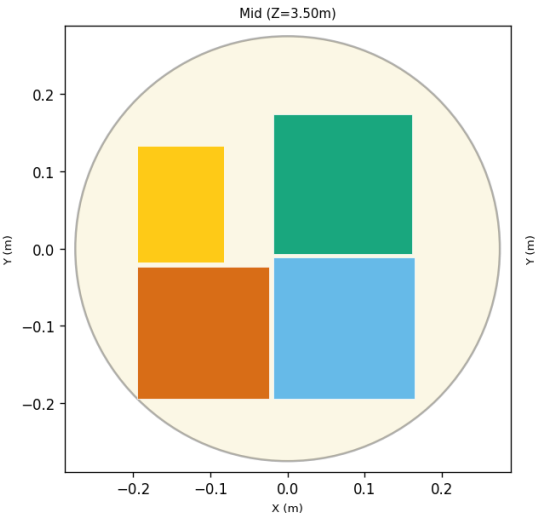
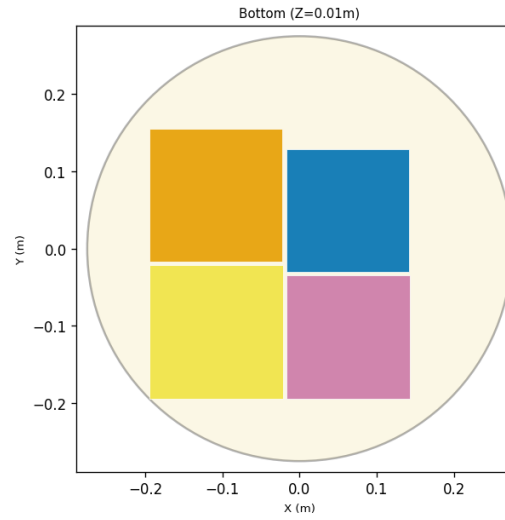
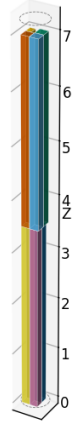
Results weighted timber species		value_species
Required logs	Total: 34	Robinia: 0.01
	18xPoplar	Oak: 0.10
	8xMaple	Ash: 0.20
	4xRobinia	Beech: 0.30
	3xChestnut	Elm: 0.50
	1xOak	Maple: 0.55
		Chestnut: 0.70
Average utilisation	38.83%	Poplar: 0.80

Figure 32:
Result weighted timber species
(Source: Author)

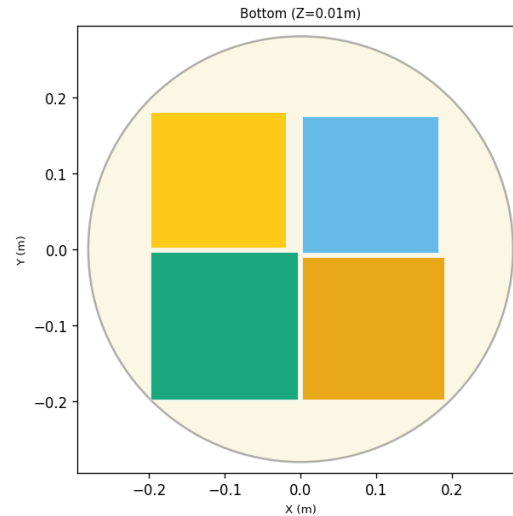
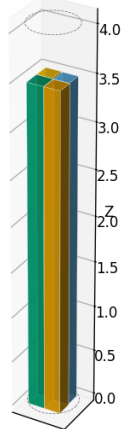
Preserve tall tree



Ash ($\theta=0.55m$)
Util: 0.45



Poplar ($\theta=0.56m$)
Util: 0.48



Poplar ($\theta=0.55m$)
Util: 0.45

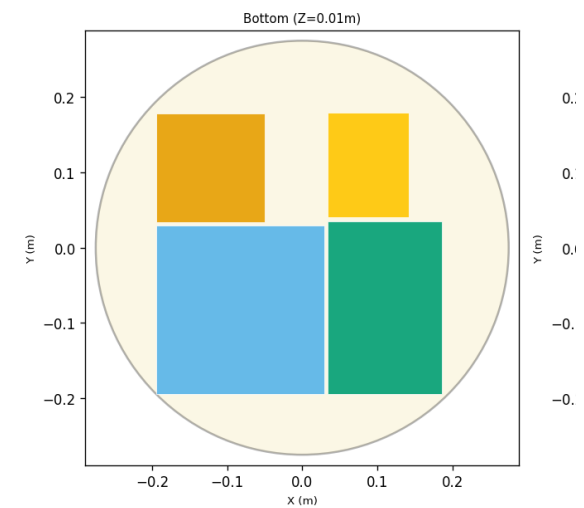
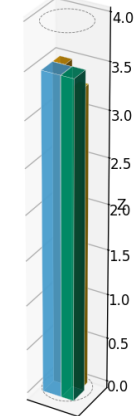


Figure 33:
Result of tall tree preservation
(Source: Author)

Inclusion non-Loadbearing elements

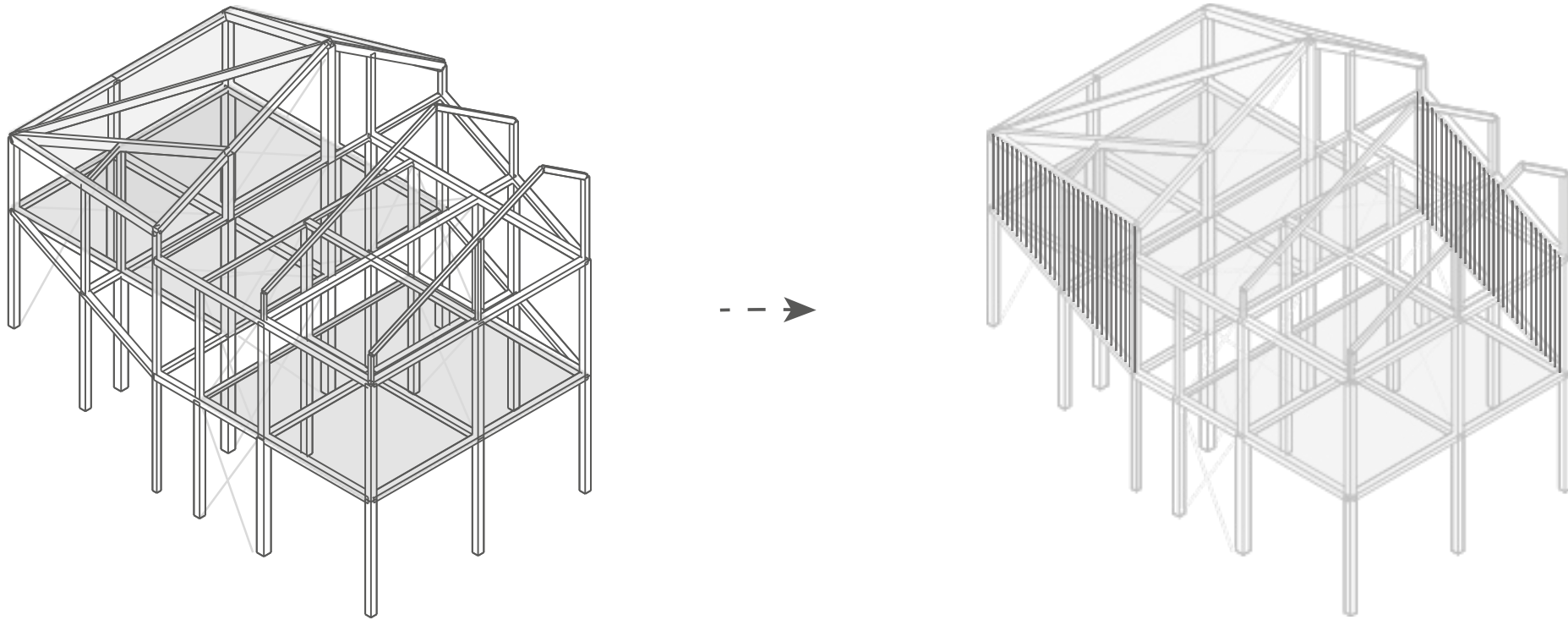
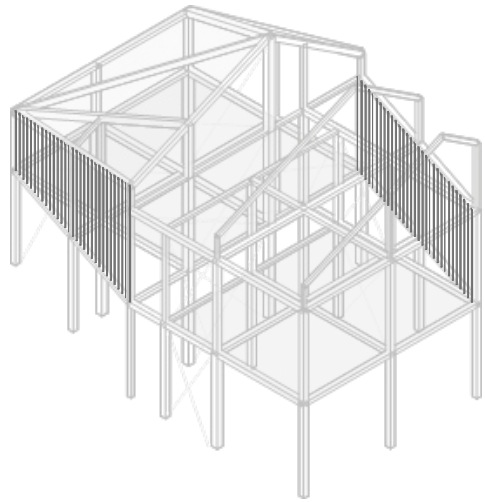
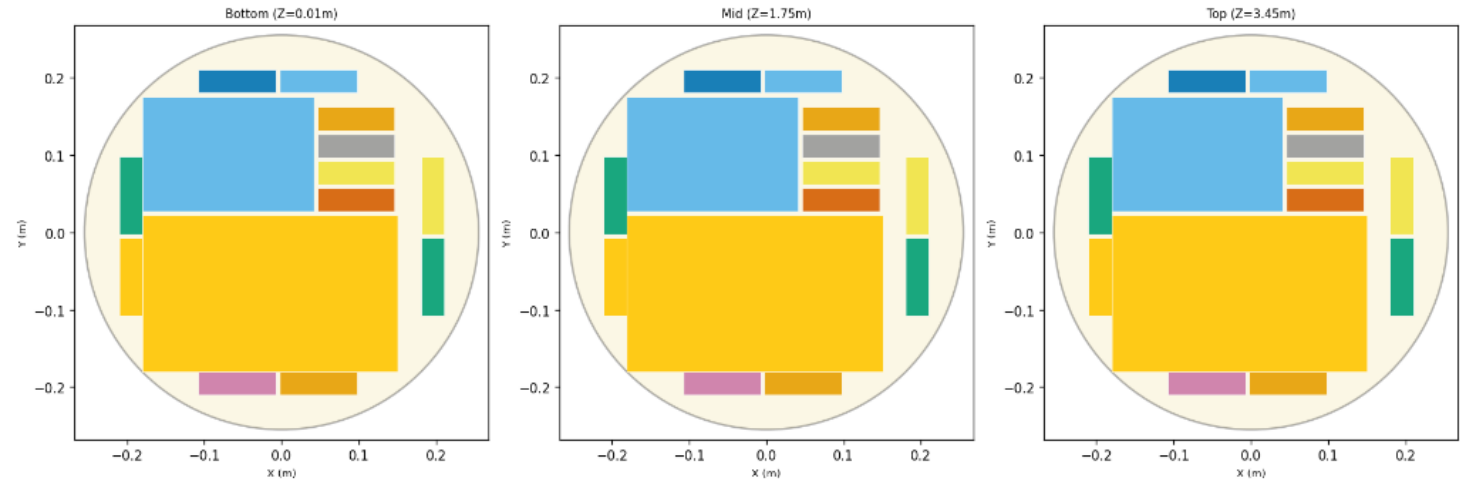
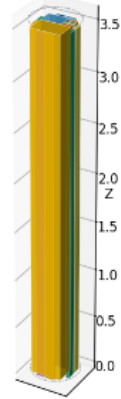


Figure 34:
Inclusion of shades in *Woonhuis Muiden* structure
(Source: Author)

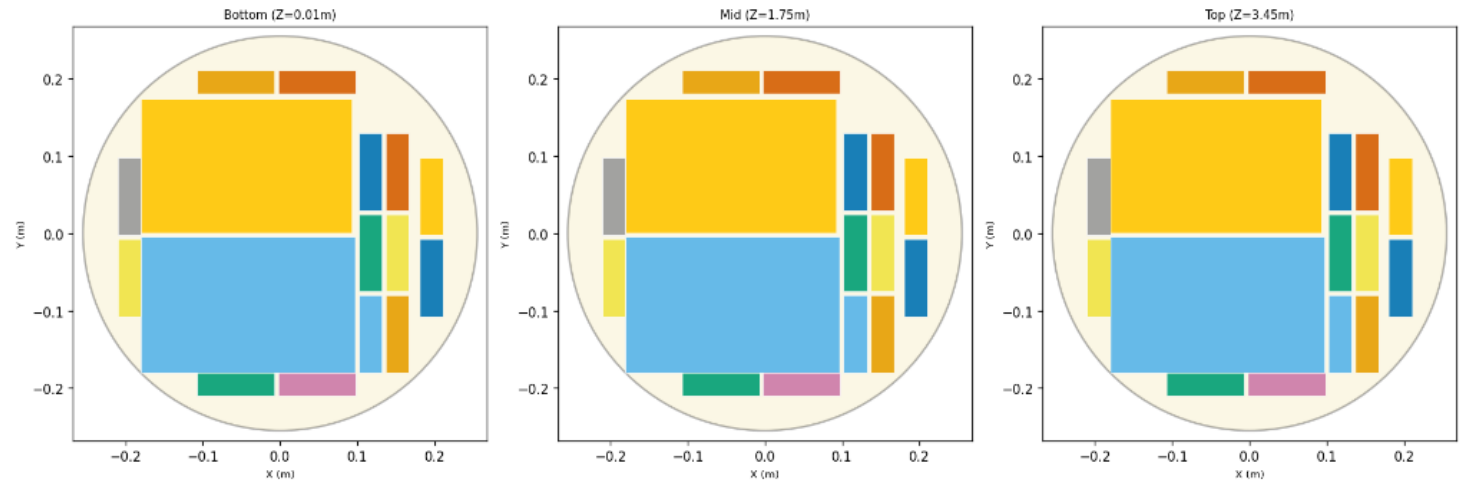
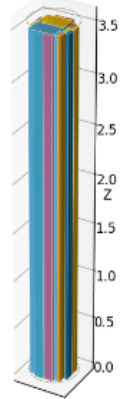
Inclusion non-Loadbearing elements



Robinia (Ø=0.51m)
Util: 0.65



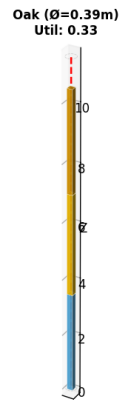
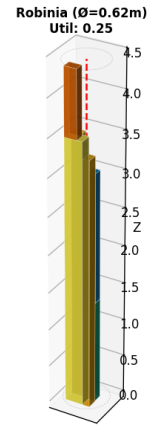
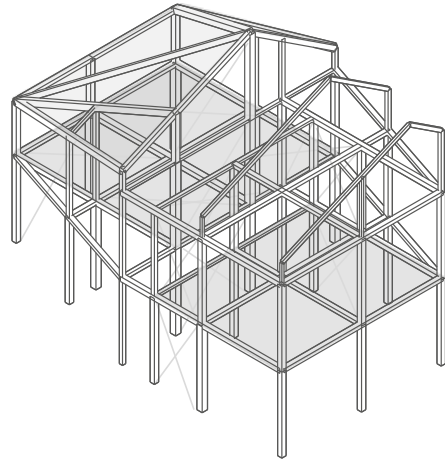
Poplar (Ø=0.51m)
Util: 0.67



Results binpacking with non loadbearing elements	
Required logs	Total: 49
	13x Robinia
	13x Poplar
	12x Maple
	5x Ash
	3x Oak
	2x Chestnut
	1x Elm
Average utilisation	39.62%

Figure 35: Results of inclusion shades *Muiden* (Source: Author)

Inclusion of pith & sapwood restrictions



Results binpacking with biological behavior	
Required logs	Total: 34
	11xRobinia
	7xOak
	6xAsh
	1xBeech
	7xMaple
	2xChestnut
Average utilisation	22.97%

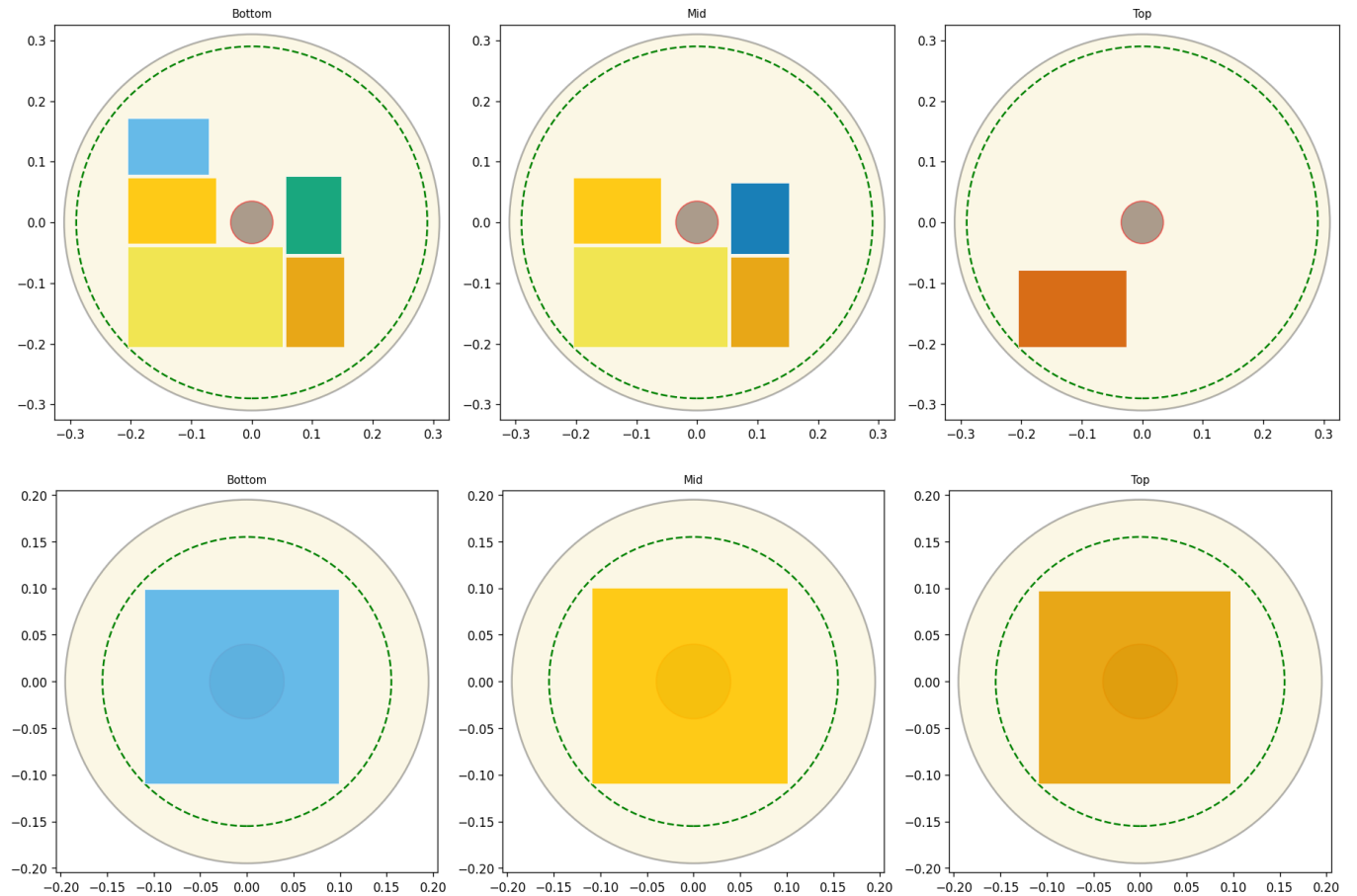
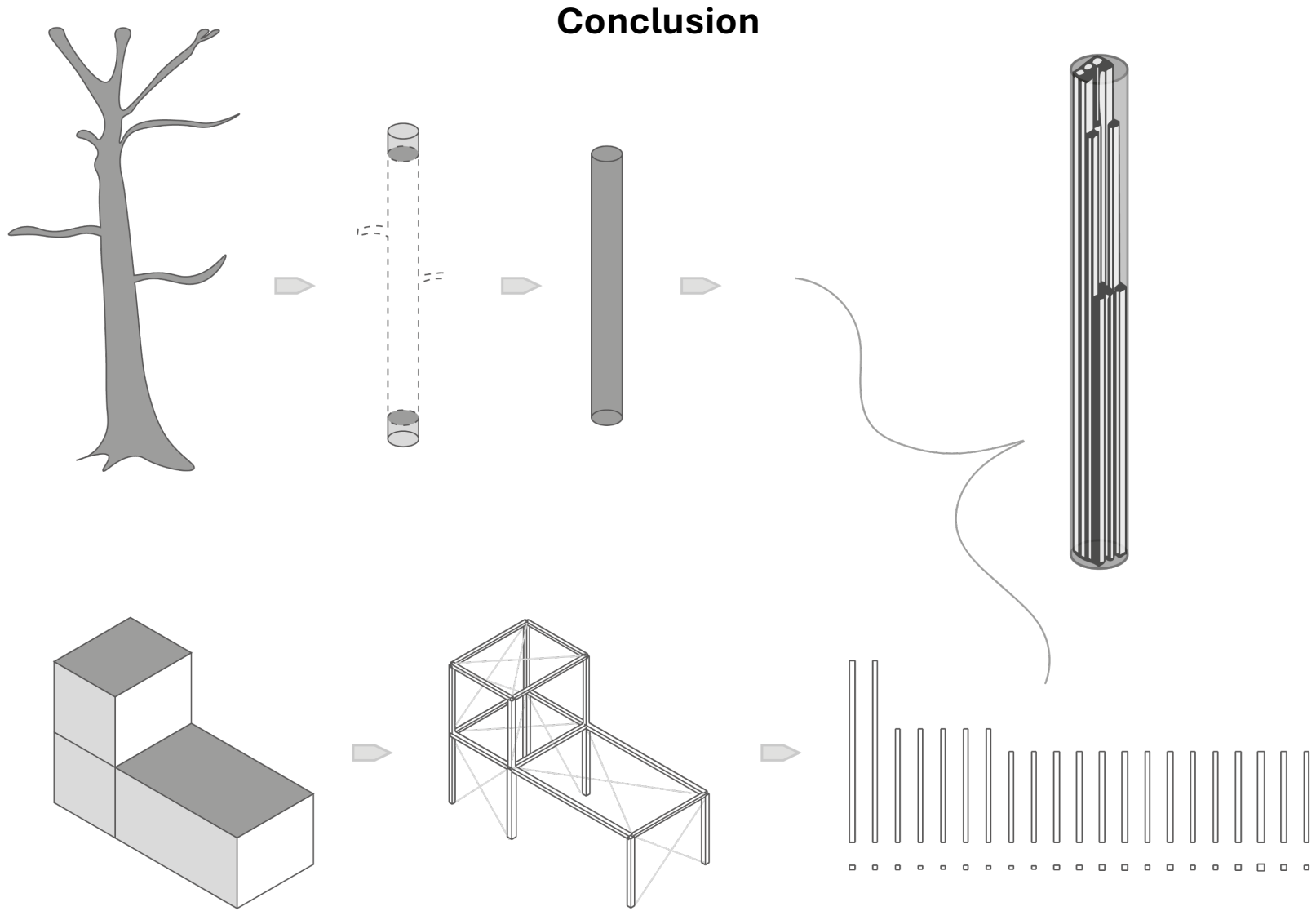


Figure 36:
Results of inclusion biological behavior
(Source: Author)

Conclusion



Conclusion

Figure 7:
Overview
(Source: Author)

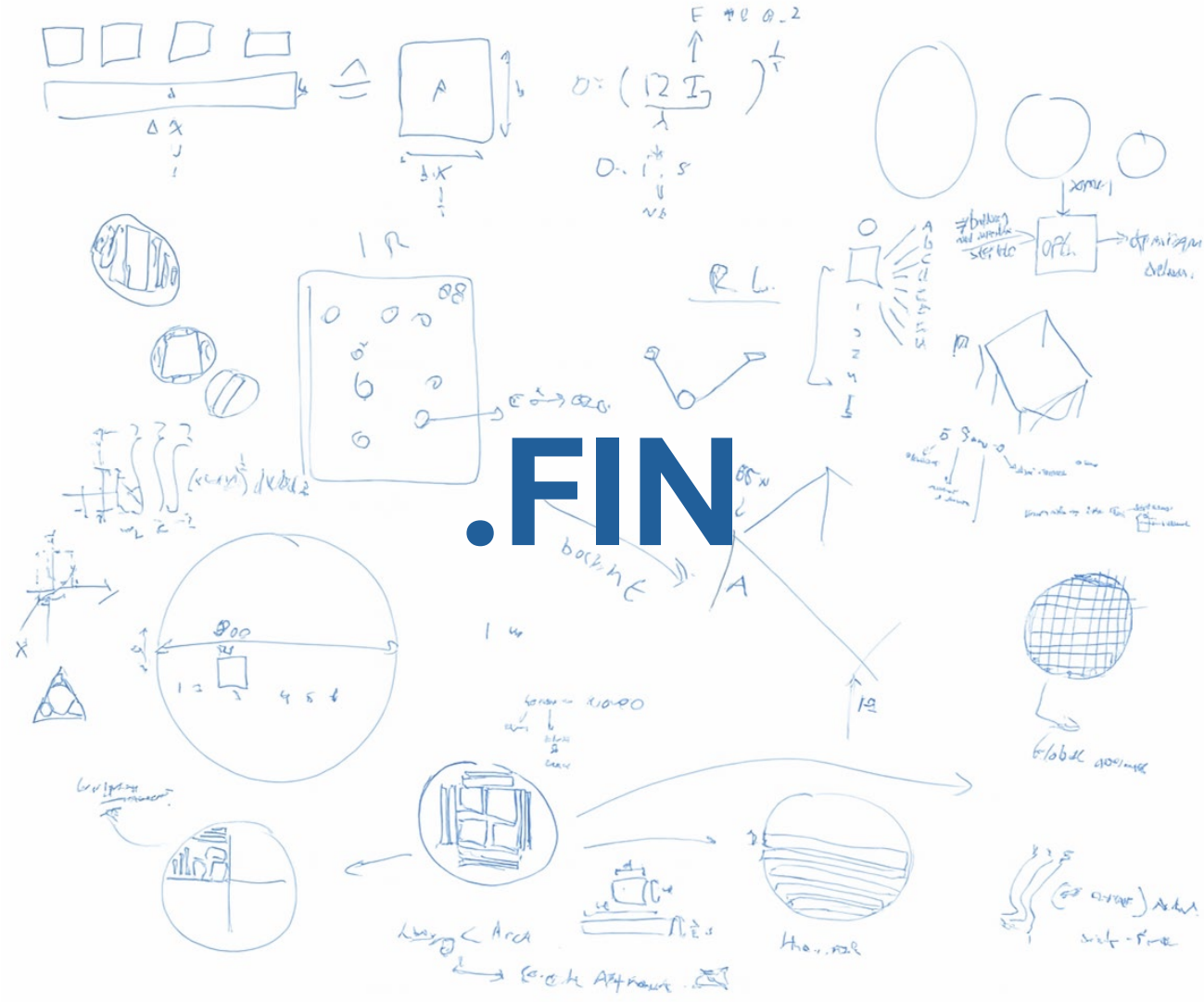
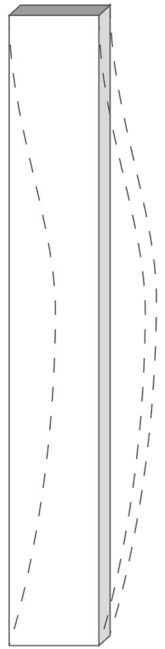


Figure 37:
Whiteboard brainstorm drawings
(Source: Author)

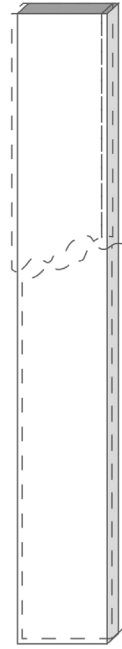
Source List

- ***1** Tom van der Put <https://shorturl.at/bE3QF> =
https://storage.pubble.nl/67c86d35/content/2023/4/4f2d9cdd-3c6f-423d-90a8-cfa1a80892ff_thumb1920.jpg
- ***2** Gemeente Rotterdam <https://shorturl.at/8l3DL> =
https://www.arcgis.com/apps/mapviewer/index.html?url=https://services.arcgis.com/zP1tGdLpGvt2qNJ6/ArcGIS/rest/services/Kapvergunningen_bomen_openbaar/FeatureServer&source=sd
- ***3** Model of *Woonhuis Muiden* by Moke Architects:
 - Retrieved from: <https://www.mokearchitecten.nl/portfolio/woonhuis-muiden>, December 2025
- ***4** Visual Render 3D packed Tree, <https://tinyurl.com/44rjcu fz> =
 - Retrieved from:
<https://preview.redd.it/z8xjvnrd bwhz.jpg?auto=webp&s=16530543647c951e5db99fb6857f17998a24b260> December 2025
- ***5** Photograph FOR building: <https://shorturl.at/bQZn2> =
 - Retrieved from: https://static.dezeen.com/uploads/2022/10/floating-office-rotterdam-powerhouse-company_dezeen_2364_col_23-852x568.jpg December 2025

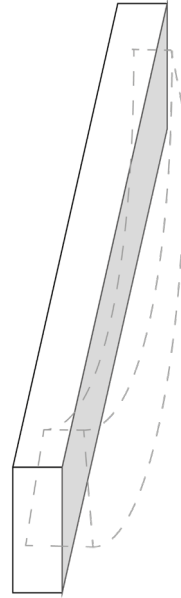
EXTRA SLIDES FOR REFERENCE, DEFENCE



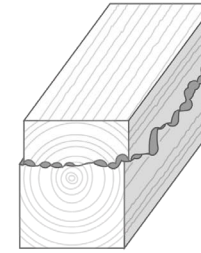
(A) Buckling



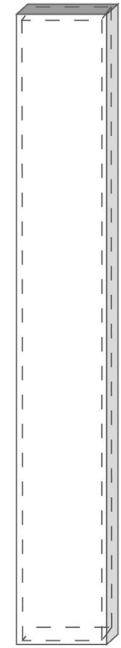
(B) Compression



(C) Bending Moment



(D) Longitudinal shear



(E) Charring layer

$$P_{crit} = \frac{(\pi^2 EI)}{(Le)^2}$$

$$b = \sqrt[4]{\frac{60P_{crit} (Le)^2}{xE\pi^2}}$$

$$\sigma_c = \frac{F}{A} \leq f_{c,0,d}$$

$$b = \sqrt[2]{\frac{FA}{xf_{c,0,d}}}$$

$$\sigma_m = \frac{M}{W} \leq f_{m,d}$$

$$h = \sqrt[3]{\frac{6xM}{\sigma_m}}$$

$$\tau = \frac{S A_c \bar{y}}{I b}$$

$$b \geq \sqrt[2]{\frac{3S}{2f_{v,k}x}}$$

$$h = h_{eff} + a_{eff}$$

$$b = b_{eff} + 2a_{eff}$$

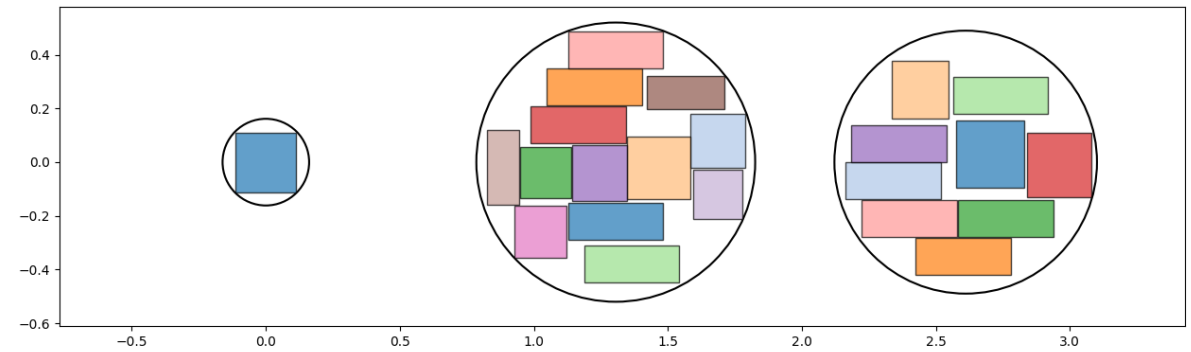
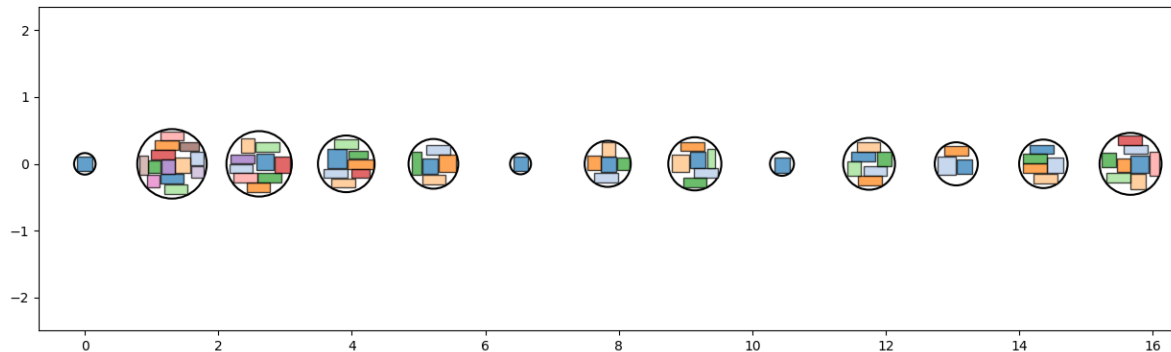
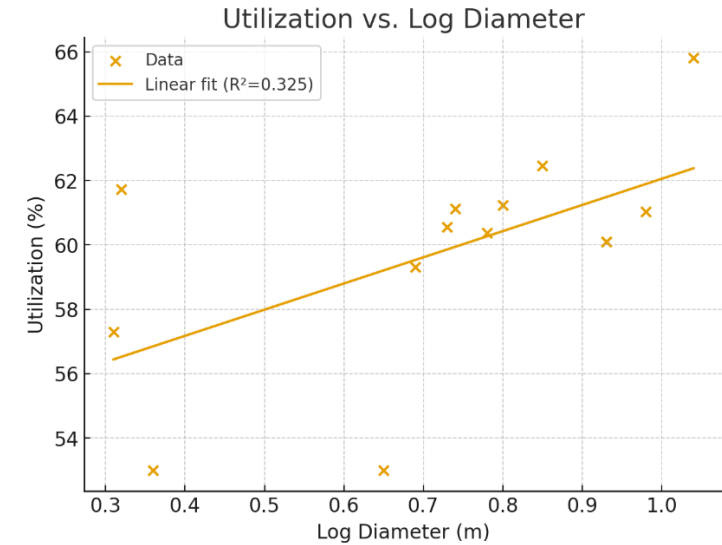
$$h = h_{eff} + 2a_{eff}$$

$$b = b_{eff} + 2a_{eff}$$

Results: Bin Packing

Freeform (2D)

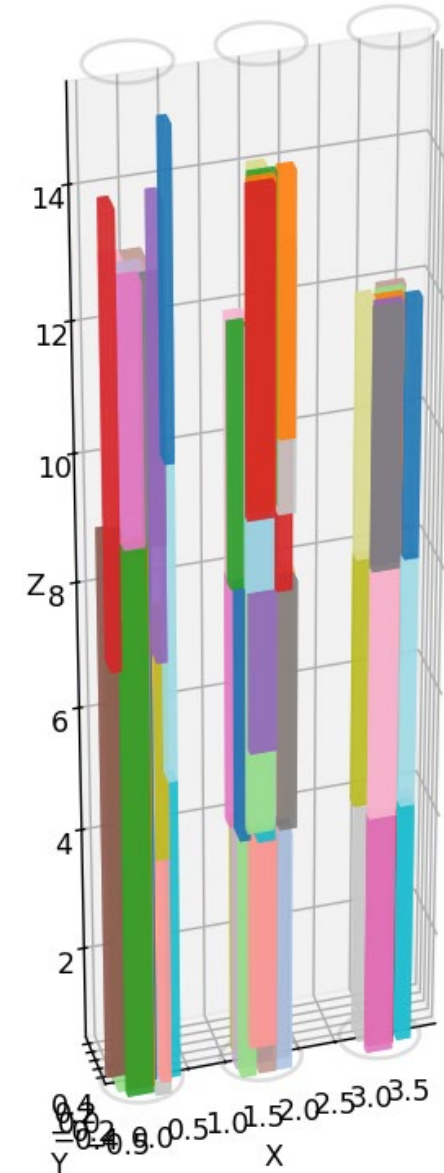
- Achieved average area utilization of **60.9%** across the dataset.
- Lowest area utilization value: 52.9%
- Highest area utilization value: 65.8%
- 13 logs were used to place all elements.
- These logs were of the Robinia, Oak and Ash family



Results: Bin Packing

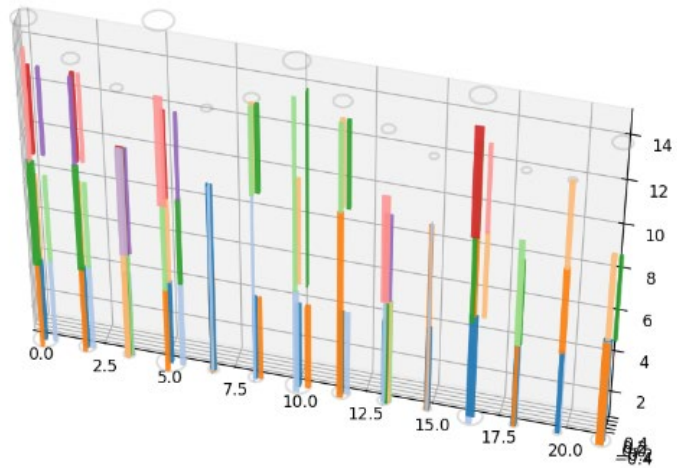
Freeform (3D)

- 3 logs were used to place all elements
All of which are Oak
- Achieved average area utilization of **37,0%** across the dataset.
- The utilization of the logs are:
 - . Log1: 43,46%
 - . Log2: 39,54%
 - . Log3: 28,00%



Results: Bin Packing

Restricted

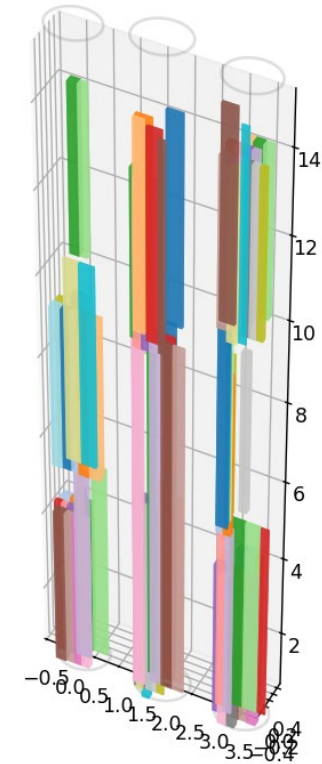
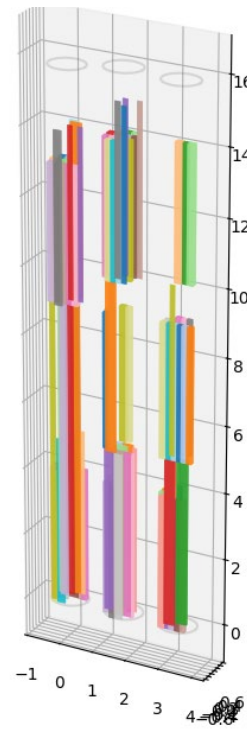
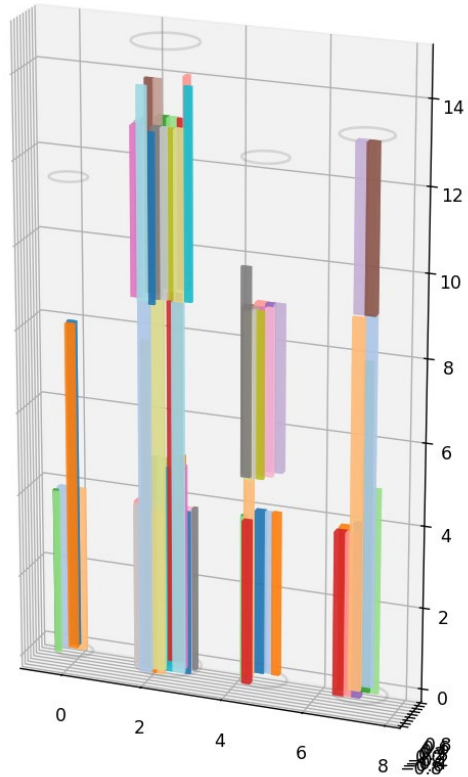


Algorithm	Logs Used	Utilization (%)	Notes
Greedy first-fit	~20	~9-15%	Very simple, quick but inefficient
Shelf packing	~14	~20%	Better, grouped by height, practical for guillotine
MaxRects	~14	~20%	Competitive to shelf packing

Results: Bin Packing

Restricted

Optimizer	Logs Used	Utilization (%)	Runtime
SA	~4	~40%	Long or solutions plateaued
GA	~3	~30%	Stable and <2 minutes
LNS	~3	~47%	Long and increases fast



Methodology: Bin Packing of Stock

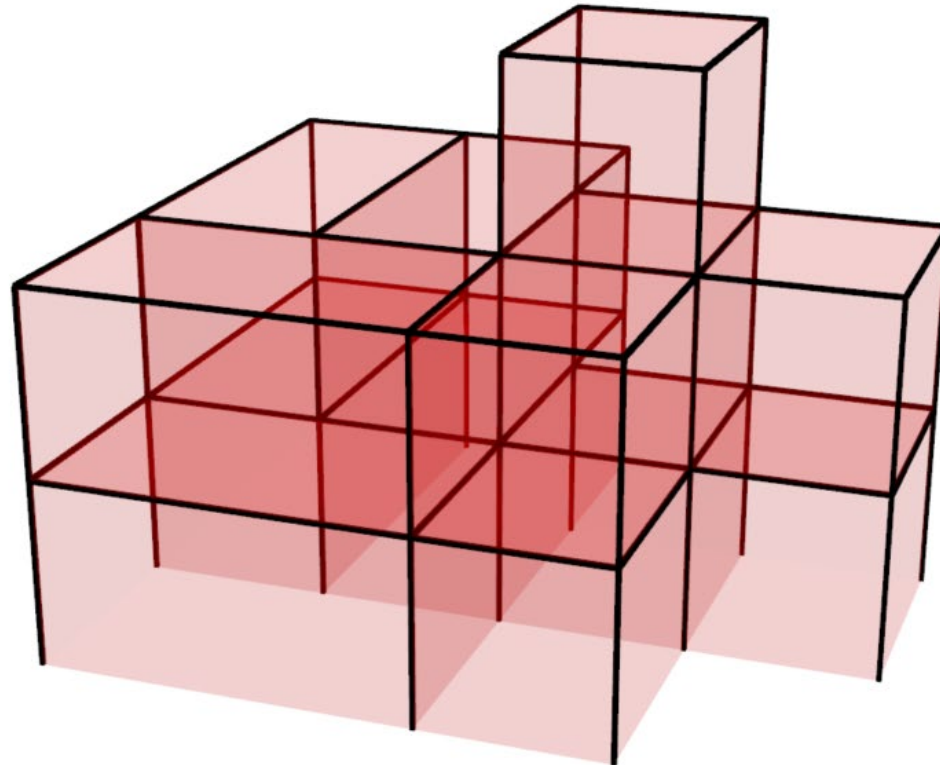
Algorithmic approaches:

/.Heuristics

- First fit
- Shelf Packing
- MaxRects

- Logs are treated as 3D cylindrical bins defined by diameter and length
- Beam & Columns are rectangular elements defined by width, height and length.
 - Restrictions:
 - Guillotine cutting
 - Enforce a kerf size

Results: Test model



Results: Element dimensioning

Fire-safety the main determinant.

Average **30%** increase

Timber species effect

8.8% lower in size

Strongest vs Lowest

Ratio's

1:1 & 1:2 for columns

1:1, 1:3 & 1:5 for beams

	Average Width x Height (cm)	Average Width x Height (cm)
Wood type	1:1 Column	1:3 Beam
Robinia	20.6x20.6	13.7x22.7
Oak	21.4x21.4	14.3x24.4
Ash	21.4x21.4	14.0x23.6
Beech	21.2x21.2	14.0x23.4
Elm	22.0x22.0	14.5x25.1
Maple	21.4x21.4	14.0x23.4
Chestnut	22.6x22.6	15.1x26.6
Poplar	22.6x22.6	15.3x27.4

Ratio w:h	min. Value (cm)	max. Value (cm)	Average (cm)	Average Area (cm ²)
Column 1:1	18.1x18.1	29.3x29.3	22.6x22.6	521
Column 1:2	16.4x25.5	25.8x44.3	20.2x33.0	680
Column 1:3	15.5x31.8	24.1x57.5	19.0x42.2	815
Column 1:4	15.0x37.8	22.9x69.5	18.2x50.5	935
Column 1:5	14.6x43.2	22.0x80.8	18.0x58.4	1045
Beam 1:1	17.7x21.4	21.4x23.9	20.1x23.8	561
Beam 1:2	16.2x21.4	20.1x29.2	17.7x24.4	502
Beam 1:3	14.2x24.0	17.1x32.9	15.3x27.4	484
Beam 1:4	13.0x26.0	15.4x35.8	13.9x29.8	477
Beam 1:5	12.2x27.7	14.3x38.3	13.0x31.7	475



Methodology: Element dimensioning

Buckling:

$$P_{crit} = \frac{(\pi^2 EI)}{5(Le)^2} \longrightarrow b = \sqrt[4]{\frac{12Iy}{x}}$$

Compression:

$$\sigma_c = \frac{F}{A} \leq f_{c,0,d} \longrightarrow b = \sqrt[2]{\frac{A}{x}}$$

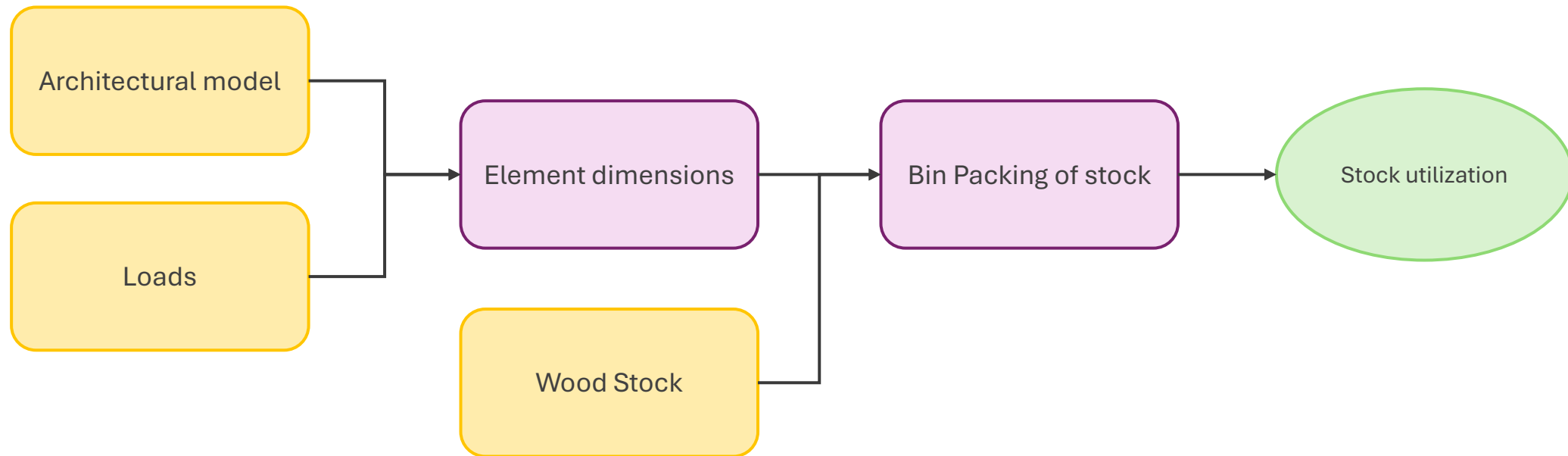
Bending Moment:

$$\sigma_m = \frac{M}{W} \longrightarrow h = \sqrt[3]{6Wx}$$

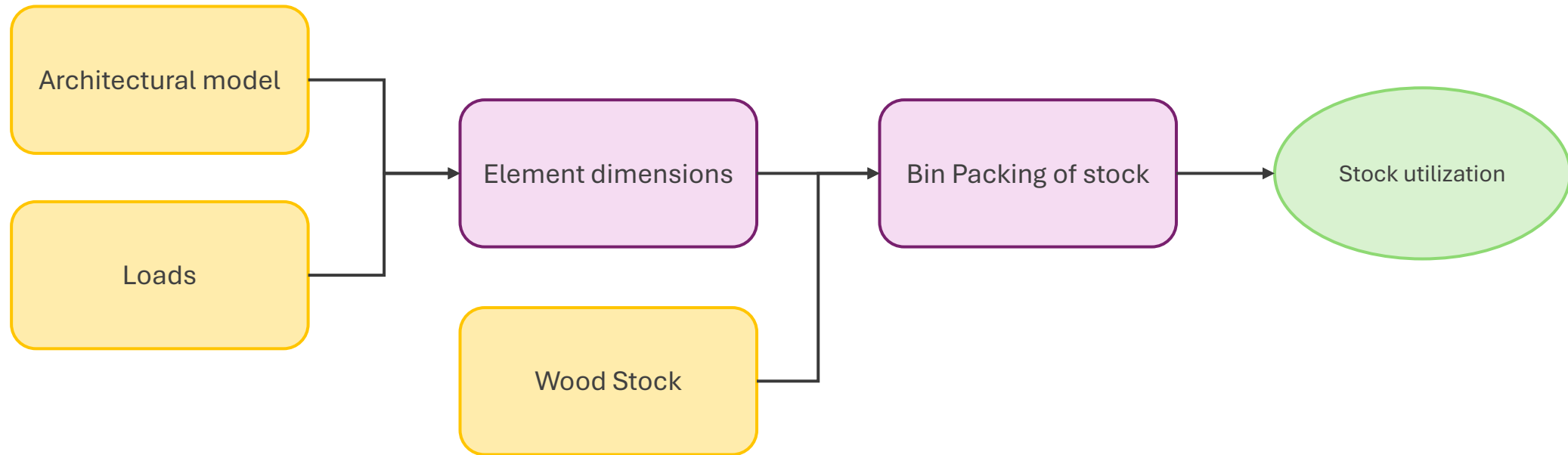
Longitudinal shear equation:

$$\tau = \frac{S A_c \bar{y}}{I b} \longrightarrow b \geq \sqrt[2]{\frac{3S}{2f_{v,k}x}}$$

Methodology: General



Methodology: General



Methodology: Element dimensioning

./Loads used in the research model

Permanent Actions

-Self-weight roof:	3.0	kN/m ²
-Self-weight floor:	2.0	kN/m ²
-Self-weight structure:	0.162	kN/m

Variable Loads

-Snow load:	1.5	kN/m ²
-Wind load:	0.38	kN/m ²

Ultimate limit state:

Factor 1.35

Fire Resistance:

Factor 1

Ultimate limit state:

Factor 1.5

Fire Resistance:

Factor 0.5

Factor 0

Charring Rate (Fire Resistance)

$$a_{eff} = \beta_n t + k_0$$

$$a_{eff} = 37 \text{ mm}$$