

Supplementary material 1 – OpenStreetMap Tags

OpenStreetMap (OSM) tags used for some criteria used in the Multi-criteria Decision Analysis were described here. The OSM tags define each criteria. Column names are keys and the body text were their values. For example, landuse = allotments is one of the attribute that used to compose green areas.

Table S1. OSM Tags for the definition of extent of green space

Landuse	Natural	Tourism
allotments	flowerbed	viewpoint
city_green	forest	resort
community_garden	garden	camp_site
conservation	grass	caravan_site
deforestation	grassland	picnic_site
flowerbed	greenfield	zoo
forest		
forestry	meadow	
garden	orchard	
garden	scrub	
grass	scrub#	
grassland	shrub	
green	shrubbery	
greenery	tree	
greenfield	tree_group	
greenhouse_horticulture	tree_row	
greenland	wetland	
greenschool	wood	
landscaping	moor	
meadow	mountain_range	
meadow_orchad	grasslan	
nature	plant	
nature_reserve	trees	
orchard		
park		
plant_nursery		
playground		
reactional_ground		
recreation_ground		
scrub		
street_grass		
street_green		
tree		
tree_group		
tree_pit		
trees		
village_green		
vineyard		
wood		

Table S2. OSM Tags for the definition of extent of residential areas

Landuse	Residential	Place
residential	apartment	neighbourhood
		quarter
		suburb

Table S3. OSM Tags for the definition of extent of commercial areas

Landuse	Building
commercial	commercial
industrial	

Table S4. OSM Tags for the definition of hospital locations

Amenity	Healthcare
hospital	hospital

Table S5. OSM Tags for the definition of kindergartens locations

Amenity	Building
kindergartens	kindergartens

Table S6. OSM Tags for the definition of markets

Amenity	Shop
marketplace	supermarket

Table S7. OSM Tags for the definition of power stations

Power
tower
substation
cable
terminal

Table S8. OSM Tags for the definition of school locations

Amenity	Building
schools	schools
university	university

Table S9. OSM Tags for the definition of transport stations

Amenity	Railway	Public Transport	Aeroway
bus station	station	station	aerodrome

Supplementary Material 2 – Detailed description of area calculation of the modules and their arrangement

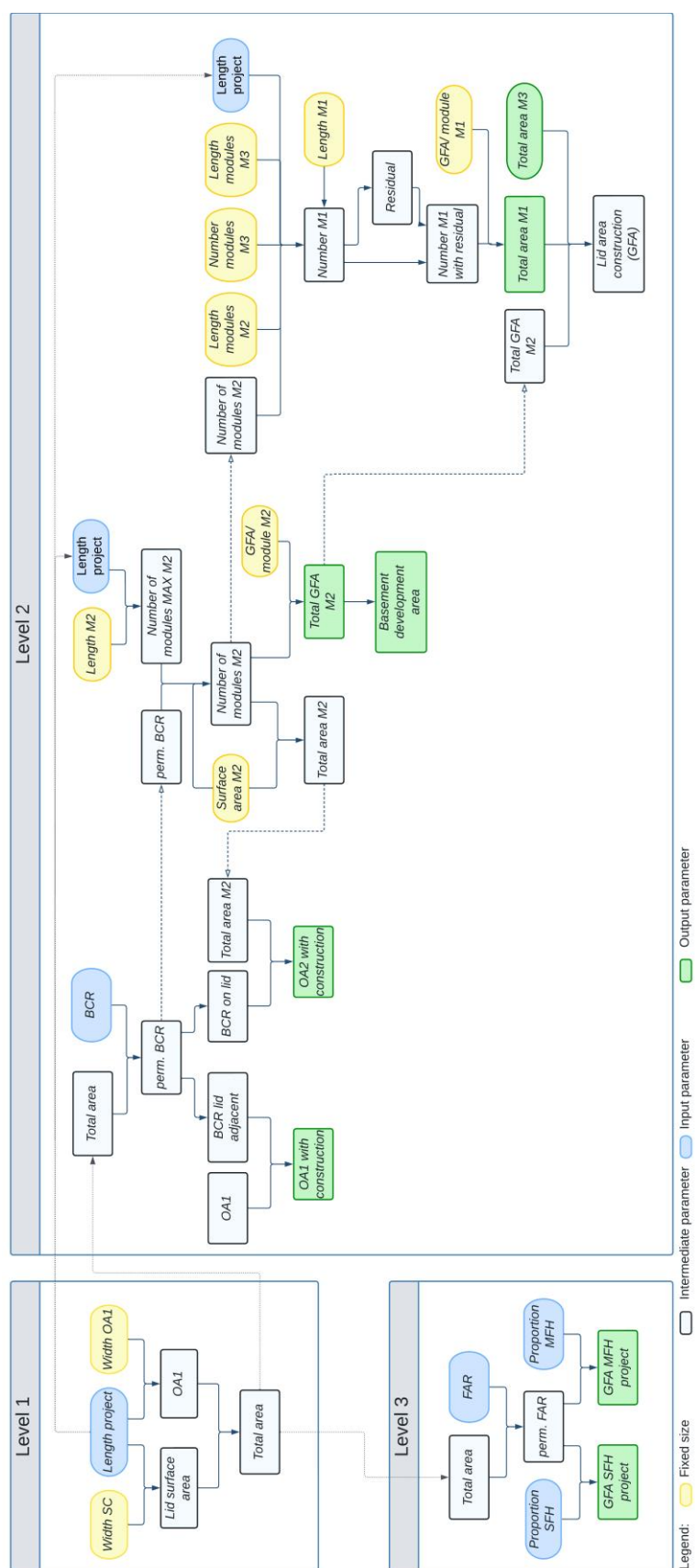


Figure S1. Cost Calculation Scheme at all levels

Table S10. Area calculation table

Parameter	Value
Length project	Parameter
Width (standard cross section)	43.5 m
Lid surface area (LSA)	Length project x width
Lid area construction	Incl. hollow lid M2
Width OA1	16.6 m x 2
OA1	Width OA1 x length project
OA1 with construction	OA1 – BCR on lid
Total area	LSA + OF1
Basement development area	GFA M2
Basement usable area	60.6% of Basement development area (BKI 2022)
Parking & traffic area	46.4 % of GFA M2
Cellar rooms	14.2% of GFA M2
Parking spaces	Assumption 35 m ² usable area/ parking space (of parking & traffic area), BKI 24.11 m ² GFA/ parking space
BCR I	Parameter (BCR I without garage)
FAR I	Parameter (FAR I without garage)
Perm. BCR	BCR I x total area
Perm. FAR	FAR I x total area
BCR on lid	If $BCR \leq 0.6$: $0.7 \times GRF M2$ If $BCR > 0.6$: $0.8 \times GRF M2$
BCR next to lid	Perm. BCR – BCR on lid
Project usable area	For SFH: 67.0% of perm. GFA (BKI 2022) For MFH: 66.7% of perm. GFA (BKI 2022)

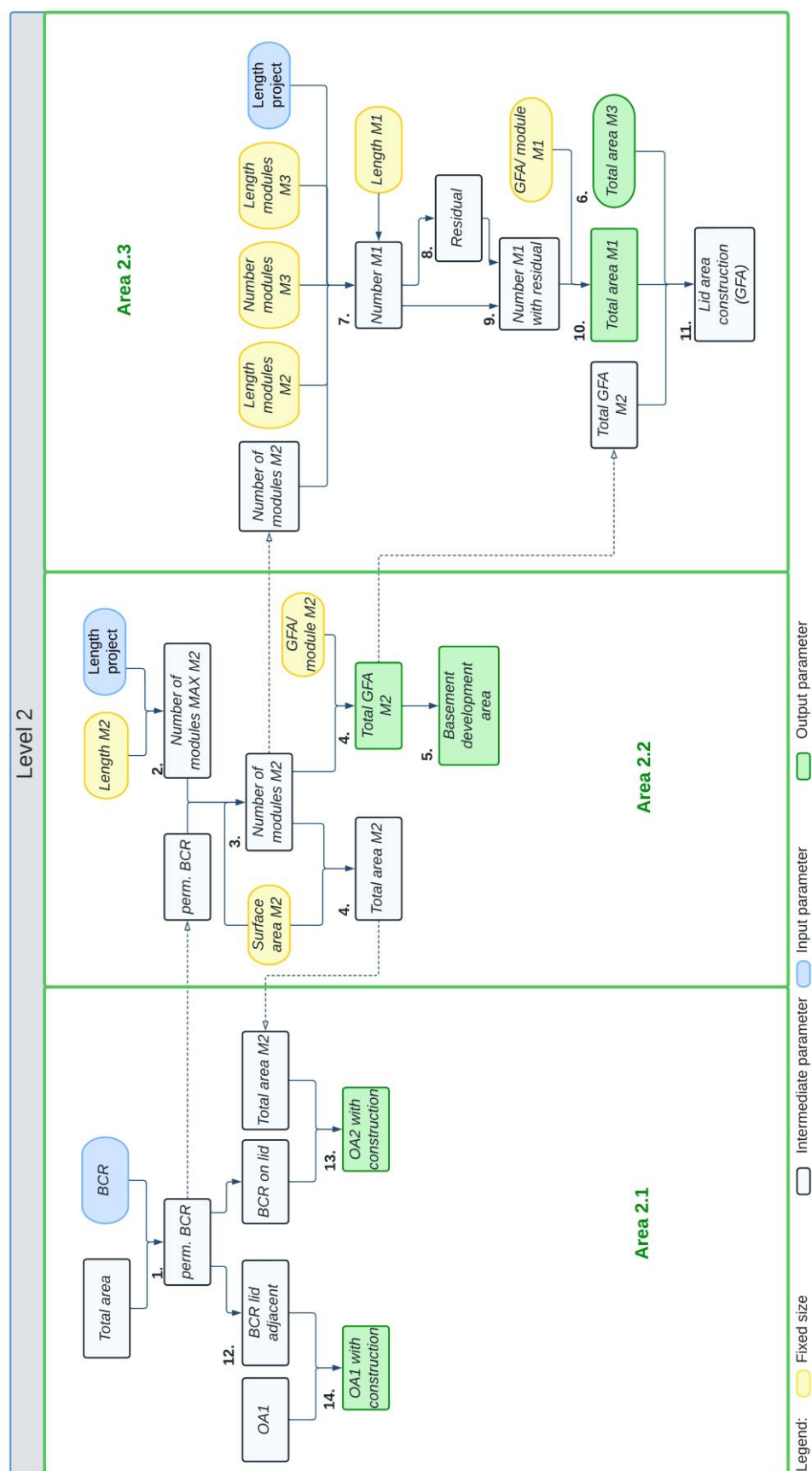


Figure S2. Calculation scheme at level 2 with steps

Calculation steps Level 2

Calculation steps at the level 2 were described here.

1. permissible BCR (area 2.1)

The total area was multiplied by the specified BCR of the development plan of the surrounding properties and results in the permissible BCR.

2. number of modules MAX M2 (area 2.2)

The length of the project was divided by the length of the module M2 (36 m) and results in the maximum number of modules M2 that can be used.

This maximum number limits the number of modules. This means that even if the permissible BCR would allow more modules with buildings, the length limits the project and in this case the outer area next to the cover must be used (more on this under "14. OA1 with buildings").

3. number of modules M2 (area 2.2)

The permissible BCR was divided by the area M2 (1,566 m²) to give the number of M2 modules.

This was adjusted by the number of modules MAX M2, if the calculated number is higher than the maximum number of modules M2.

It was then rounded up so that a minimum area is available.

4. total area M2, total GFA M2 (area 2.2)

The area M2 (1,566 m²) was multiplied by the number of modules M2 to give the total area M2.

The GFA of module M2 (1,990 m²) was multiplied by the number of calculated modules M2 and results in the total GFA of M2

5. basement development area (area 2.2)

The total GFA of M2 was equal to the basement development area.

6. total area M3 (area 2.3)

The number of access bridges has been set as 1 per project for simplicity. If several access bridges were required, this would only have a minor impact on the costs. The adjustment in the model would not be problematic and would be entered as a number.

7. number M1 (area 2.3)

First, the length of all M2 modules was subtracted from the length of the project (the number of M2 modules multiplied by the length of M2, 36m), as well as the length of all M3 modules (the number of M3 modules multiplied by the length of M3, 16m). This remaining length was then divided by the length of the M1 modules (10m) to find the number of possible M1 modules.

Then the number of M1 modules was rounded down so that the remainder can be calculated. 8.

8. remaining length M1 (range 2.3)

The length of the project was reduced by the lengths of the modules used so far (in each case the number of the module multiplied by the length of the respective module). This resulted in the remaining length M1.

9. number of M1 with remainder (range 2.3)

The number of rounded M1 modules plus one.

10. total area M1 (area 2.3)

The number of M1 modules rounded down multiplied by the area M1 (696 m²). Add to this the multiplication of the remaining length M1 with the width M1 (43.5m).

11. cover area construction (GFA) (area 2.3)

Addition of the total area M1 with the total GFA M2 and the total area M3 results in the cover area construction (GFA).

12. BCR on / next to cover (area 2.1)

In general, no specification was made as to where the base areas of the houses must be located. Nevertheless, it was necessary to determine approximately how much area will be built on module M2 and how much on the areas next to the lids, as the cost parameters of the outdoor facilities vary. The sizes of the outdoor areas are determined by the positioning of the buildings (area size minus the built-up area equals outdoor area).

It was determined for a BCR up to 0.6 that the areas of the M2 modules can be built on up to 70% and the remainder of the permissible BCR can be built on the areas next to the cover.

0.7 multiplied by the total area M2 results in the BCR on the lid.

The permissible BCR minus the BCR on the cover results in the BCR next to the cover.

From a BCR of 0.7 (0.7-0.8), it is determined that the areas of the M2 modules can be built on up to 80% and the remainder of the permissible BCR can be built on the areas next to the lid. (From a BCR of 0.6, the area of the M2 modules no longer changes due to the limitation of the length: this is why a densification of the development on the lid is brought about, otherwise the rest of the development no longer fits on the area next to the lid).

0.8 multiplied by the total area M2 results in the BCR on the lid.

The permissible BCR multiplied by the BCR on the lid results in the BCR next to the lid.

13. OA2 with development (area 2.1)

The total area M2 minus the BCR on the lid results in the OA2 with building development.

14. OA1 with development (area 2.1)

OA1 minus BCR next to the cover results in OA1 with development

Supplementary Material 3 - Cost calculations for cost parameters

Cost calculation for individual module with parameters were described in the following with respected to their cost group and the index of the third quarter of 2022.

1. The lid

Preparatory measures

The preparatory measures include the terrain modelling of the outer areas around the cover (OA1). The key cost figure was taken from the feasibility study in Freiburg am Neckar[1] and calculated to the current quarter (New: Q3 2022, incl. VAT).

Table S11. Preparatory measures cost parameters (Q3 2022, incl. VAT)

Cost Parameter	Cost
CP CG 200	393 €/m ²
CP CG 700 (30%)	118 €/m ²
CPP 200 total	511 €/m ²

Building - Cover Construction Modules

The building or the cover construction consists of three different modules that can be individually assembled. The cost parameters of the modules are based on the feasibility study and calculated for the current quarter (new: Q3 2022, incl. VAT).[1]

Module 1 - Light green bridge

"The costs for the light green bridge include, among others, the foundation, outer cover wall incl. sealing, middle wall as well as the membranes with cable net construction and extensive greening [...]" the feasibility study stated.[1]

Table S12. Module 1 - Light Green Bridges (1.0) cost parameters (Q3 2022, incl. VAT)

Cost Parameter	New
CP CG 300	1,652,288 €/module
CP CG 700 (30%)	495,686 €/module
CP 300 total	2,147,975 €/module

Due to the individual calculation of the scenarios and the modules, it is also necessary to consider the costs per m² GFA for the first module.

Table S13. Module 1 - Light Green Bridges (2.0) cost parameters (Q3 2022, incl. VAT)

Cost Parameter	New
CP CG 300	2,374 €/m ²
CP CG 700 (30%)	712 €/m ²
CP 300 total	3,086 €/m ²

Module 2 - Hollow lid

According to the feasibility study in Freiberg am Neckar, the costs for the hollow cover include, among other things, the foundation, cover outer wall incl. sealing, centre wall as well as the prestressed concrete ceiling incl. beams with bracing walls in the cover.. [1]

Table S14. Module 2 - Hollow lid cost parameters (Q3 2022, incl. VAT)

Cost Parameter	New
CP CG 300	5,473,838 €/module
CP CG 700 (30%)	1,642,151 €/module

CP 300 total	7,115,990 €/module
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Module 3 - Access bridge

"The costs for the access bridge include, among other things, the foundation, outer cover wall incl. sealing, centre wall as well as the steel structure with truss girders and prestressed concrete ceiling [...]", according to the feasibility study.

Table S15. Module 3 - Access bridge cost parameters (Q3 2022, incl. VAT)

Cost Parameter	New
CP CG 300	2,078,031 €/module
CP CG 700 (30%)	623,409 €/module
CP 300 total	2,701,441 €/module

Technical installations tunnel

The cost parameters for the technical facilities in the tunnel are taken from the feasibility study and calculated for the current quarter (new: Q3 2022, incl. VAT). It should be noted that with increasing length (>400), other requirements are placed on the tunnel and this can lead to an increase in costs, which according to the feasibility study n are: "the costs for the operational and safety equipment [...] include the lighting as well as the equipment required according to FGSV-RABT 2016 for tunnels with a tunnel length [only] < 400 m: an emergency call system, tunnel radio (BOS, operation), loudspeaker system, video surveillance, extinguishing water supply and escape route marking .".

Table S16. Technical installations tunnel cost parameters (Q3 2022, incl. VAT)

Cost Parameter	New
CP CG 400	28,691 €/rm
CP CG 700 (30%)	8,607 €/rm
CP 400 total	37,298 €/rm

Outdoor facilities next to cover (OA1)

The key cost figures for the technical facilities in the tunnel are taken from the feasibility study and calculated for the current quarter (new: Q3 2022, incl. VAT). "For the implementation of the outdoor facilities next to the cover, the construction of roads and paths with asphalt pavement, line drainage and lighting as well as the earthworks for planting and lawn areas and planting works for the planting and lawn areas were assumed [...]".

Table S17. Outdoor installations next to lid cost parameters (Q3 2022, incl. VAT)

Cost Parameter	New
CP CG 500	426 €/m ²
CP CG 700 (30%)	187 €/m ²
CP 500 total	554 €/m ²

Outdoor facilities on cover, without M1 (OA2)

The key cost figures for the technical facilities in the tunnel are taken from the feasibility study and calculated for the current quarter (new: Q3 2022, incl. VAT). "The outdoor facilities on the cover are comparable to the structures of a flat roof, whereby a substrate/vegetation depth of 50 cm is planned for the greening. The costs for the development and media of the lid development are also taken into account [...]", the feasibility study states.

Table S18. Outdoor installations on lid, without M1 cost parameters (Q3 2022, incl. VAT)

Cost Parameter	New
CP CG 500	622 €/m ²
CP CG 700 (30%)	187 €/m ²
CP 500 total	809 €/m ²

2. Development cover basement

Module 2 is constructed as a box girder. In this box girder there are areas for parking and traffic areas, including parking spaces and cellar rooms .

Table S19. Development lid basement, without M1 cost parameters (Q3 2022, incl. VAT)

Cost Parameter	New
CP CG 300-400	518 €/m ²
CP CG 700 (30%)	155 €/m ²
CP 300-400 total	673 €/m ²

3. Development

The development on the lid can be designed individually. The cost parameters for single-family houses and multi-family houses are given to provide orientation in terms of costs.

Only the production costs of the buildings are taken into account, as the costs for the excavation/earthworks (KG 310) and foundations, substructure (KG 320) are omitted. For this purpose, the percentage shares of cost groups 310 and 320 were deducted from cost group 300.

Single-family houses (SFH)

The cost ratios are taken from the BKI 2022 (detached and semi-detached houses, no basement, medium standard, medium value) and are calculated to the current quarter (New: Q3 2022, incl. VAT).

Table S20. Single-family home cost parameters (Q3 2022, incl. VAT)

Cost Group	Cost
CP CG 300-400	1,125 €/m ²
CP CG 700 (30%)	337 €/m ²
CP 300-400 total	1,462 €/m ²

Apartment buildings (MFH)

The cost ratios are taken from the BKI 2022 (residential buildings, with up to 15% mixed use, medium standard, medium value) and are calculated for the current quarter (New: Q3 2022, incl. VAT). For the development of the multi-family

houses, characteristic values are taken from the BKI for mixed uses, as the concept of the cover is oriented towards an inner-city, urban area. It is planned to use the lower floors of the apartment buildings as office space, if necessary.

Table S21. Multi-family home cost parameters (Q3 2022, incl. VAT)

Cost Group	Cost
CP CG 300-400	1,356 €/m ²
CP CG 700 (30%)	407 €/m ²
CP 300-400 total	1,763 €/m ²

1. Herrmann, M.; Arnold, M.; Fentzloff, A.; Otterbach, S.; Hawlik, J.; Kunz-Wedler, L. Abschlussbericht FREIRAUM für FREIBERG: Eine Landschaftsbrücke in hybrider Leichtbauweise mit Wohn- und Bürobebauung über die A81 für mehr Grün in Freibergs Mitte. **2020**, 85.