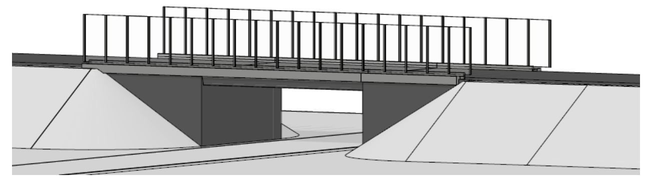
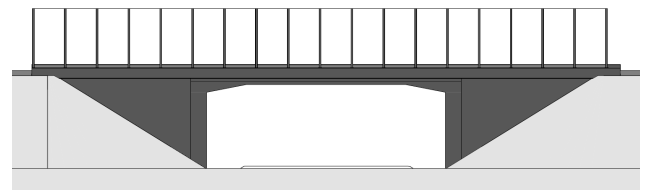
Multi Criteria Analysis - Value Engineering   Case 1   Underpass Comparison

Criteria Group	Weight	Number	Description	Comments	Scoring			Weight
					C1.A	C1.B	C1.C	
Economical	40	C1	Structure construction cost (CAPEX)	Rough estimated costs, factors which are depending on location such as transport costs or costs for safety measure for other buildings are not included.	20,0	16,0	0,0	20
		C2	Structure maintenance and operation cost during its life time (OPEX)	Average cost during design life of structure	15,0	12,0	0,0	15
		C3	End of life cost	Dismantle and recycling (eventually for replacement) of the structure	5,0	5,0	5,0	5
Technical (design and structural aspects)	25	C4	Accessibility and complexity for maintenance	Easiness for access of planned maintenance operations	6,0	6,0	6,0	6
		C5	Reliability of solution	Well proven solutions, with good structural behaviour and durability	7,0	7,0	7,0	7
		C6	Possibility of upgrade	Upgrade of: rolling stock speed, widening of deck, increase loads, etc.	6,0	6,0	0,0	6
		C7	Interaction with other infrastructures	Limitations for other infrastructure operation, maintenance and future development	0,0	0,0	6,0	6
Environmental	15	C8	Temporary environmental impacts	Consider positive and negative impacts. More detailing is necessary depending on the specific situation and in aspects that can differentiate the different solutions	0,0	4,0	4,0	4
		C9	Permanent environmental impacts	Consider positive and negative impacts. More detailing is necessary depending on the specific situation and in aspects that can differentiate the different solutions	0,0	0,0	6,0	6
		C10	Visual and aesthetic integration	slenderness, wide opening, integration in surrounding	0,0	2,5	5,0	5
Construction	20,0	C11	Time schedule and works duration	Time necessary for construction; Time duration is given in a range of month, depending on landscape, logistics, bridge size, the construction time is either in the beginning or in the end of the range.	8,0	8,0	0,0	8
		C12	Construction complexity	Equipment, phases, operations, logistics, risks regarding budget and schedule.	6,0	3,0	0,0	6
		C13	Labor resources	Quantity and/or qualification, construction and supervision	6,0	3,0	0,0	6
Total	100				**79**	**73**	**39**	100

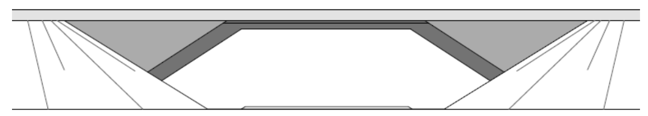
Case 1.A - Straight



Case 1.B - Haunched



Case 1.C - V-form



Notes

The goal of this analysis is to compare different structural solutions for a certain crossing.
Multi Criteria Analysis could be skipped in very simple situations where the preferred solution is know and this analysis was already performed in the project, so the solutions and their characteristics are well known.
Criteria are presented in a general way, but different criteria can be added or disregarded in specific situation. The weight of the criteria can also be adjusted to the specific situation.
According to the scoring rules the solutions with the highest/best value will get the maximum score in a criteria, the solutions with the lowest/worst score will get zero

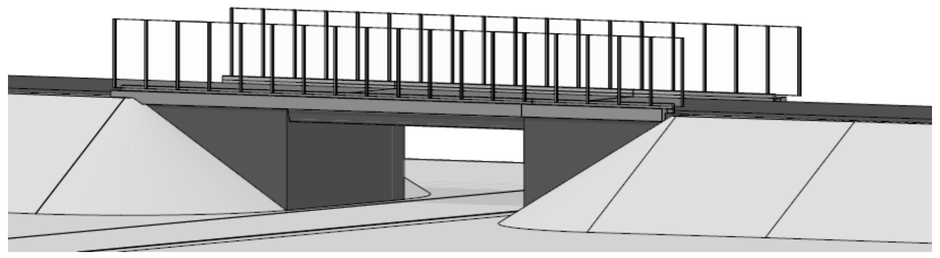
Qualitative assessment:
Type 1 - from bad = 1 to very good = 5
Type 2 - from low = 1 to very high = 5

$$Score\ 1\ (maximum\ value\ is\ best) = \frac{Weight}{(Max\ value\ - Min\ value)} \times (Value\ - Min\ Value)$$

$$Score\ 2\ (minimum\ value\ is\ best) = \frac{Weight}{(Min\ value\ - Max\ value)} \times (Value\ - Max\ Value)$$

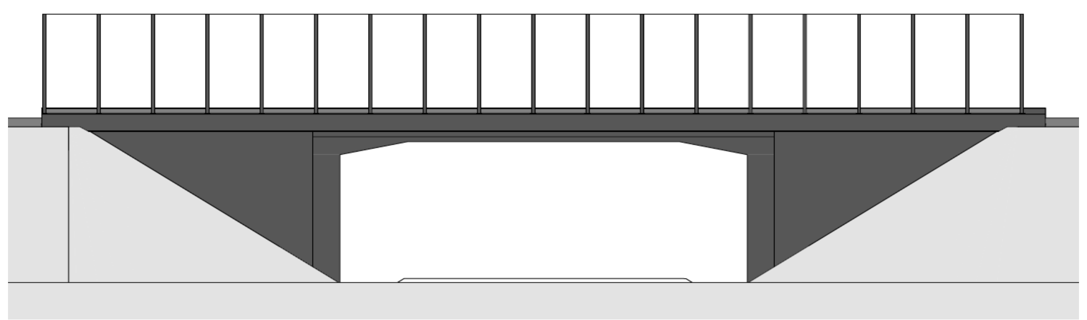
Multi Criteria Analysis - Value Engineering   Case 1.A   Underpass - Straight

Criteria Group	Weight	Number	Description	Comments	Value min.	Value max.	Value Average	Metrics	Scoring	Weight
Economical	40	C1	Structure construction cost (CAPEX)	Due to low complexity of construction C1.A is the most economical solution for case 1 underpasses. Rough estimated costs, factors which are depending on location such as transport costs or costs for safety measure for other buildings are not included.	2.000	2.300	2.150	EURO/m²	20,0	20
		C2	Structure maintenance and operation cost during it's life time (OPEX)	OPEX is around 1 - 1.5 % of CAPEX	20	34,5	27,25	EURO/m²/a	15,0	15
		C3	End of life cost	All Materials for Case 1.A, B and C are concrete. Either prefabricated or in-situ concrete. Thus, the End of life cost per square meter is about the same.	200			EURO/m²	5,0	5
Technical (design and structural aspects)	25	C4	Accessibility and complexity for maintenance	accessibility would be better if span is wider than crossing street	4			Qualitative-T1	6,0	6
		C5	Reliability of solution	well proven solutions, with good structural behaviour and durability	5			Qualitative-T1	7,0	7
		C6	Possibility of upgrade	rolling stock speed and increase of loads is very good; widening of deck is easier possible than for other solutions	5			Qualitative-T1	6,0	6
		C7	Interaction with other infrastructures	due to prefabricated elements other infrastructure operation is not disturbed so much in construction phase, for maintenance other infrastructure is partly interrupted	4			Qualitative-T1	0,0	6
Environmental	15	C8	Temporary environmental impacts	temporary environmental impacts while construction phase is low because of prefabricated elements but monolithic construction needs more time, so more impact while construction	3			Qualitative-T2	0,0	4
		C9	Permanent environmental impacts	Permanent environmental impact is higher in comparison to cases 1.C because opening is smaller and does impact crossing partner more. But still it is low.	2			Qualitative-T2	0,0	6
		C10	Visual and aesthetic integration	monotonous, standard, small opening	2			Qualitative-T1	0,0	5
Construction	20,0	C11	Time schedule and works duration	Works duration for construction for cases 1.A and 1.B is about the same. Evan if case 1.A uses prefabricated elements for superstructure, more complex connection details and same effort for substructure leads to closely same construction time.	6	8	7	Months	8,0	8
		C12	Construction complexity	Complexity is low, but not very low because of connection details.	2			Qualitative-T2	6,0	6
		C13	Labor resources	Needed labor resources are low, but not very low because of connection details.	2			Qualitative-T2	6,0	6
Additional Comments			For railway lines with ballast bed a Frame is a very good solution. If a solid track system is used, a frame has less opportunity for regularisation.							
Total	100								79	100



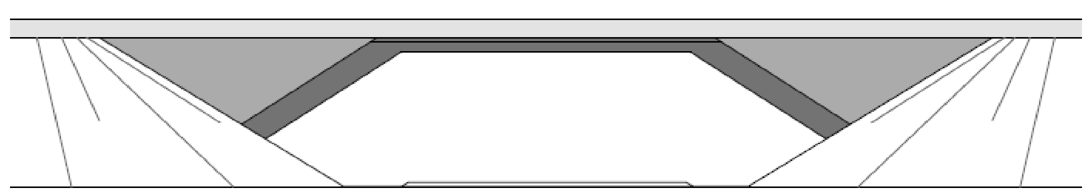
Multi Criteria Analysis - Value Engineering **Case 1.B** **Underpass - Haunched**

Criteria Group	Weight	Number	Description	Comments	Value min.	Value max.	Value Average	Metrics	Scoring	Weight
Economical	40	C1	Structure construction cost (CAPEX)	Due to a bit higher complexity of construction C1.B is not as economical as solution C1.A. Rough estimated costs, factors which are depending on location such as transport costs or costs for safety measure for other buildings are not included.	2.100	2.400	2.250	EURO/m²	16,0	20
		C2	Structure maintenance and operation cost during it's life time (OPEX)	OPEX is around 1 - 1.5 % of CAPEX	21	36	29	EURO/m²/a	12,0	15
		C3	End of life cost	All Materials for Case 1.A, B and C are concrete. Either prefabricated or in-situ concrete. Thus, the End of life cost per square meter is about the same.	200			EURO/m²	5,0	5
Technical (design and structural aspects)	25	C4	Accessibility and complexity for maintenance	accessibility very good, but inclined surfaces have to be inspected	4			Qualitative-T1	6,0	6
		C5	Reliability of solution	well proven solutions, with good structural behaviour and durability	5			Qualitative-T1	7,0	7
		C6	Possibility of upgrade	rolling stock speed and increase of loads is very good; widening of deck is easier possible than for other solutions	5			Qualitative-T1	6,0	6
		C7	Interaction with other infrastructures	no prefabrication -> other infrastructure operation is disturbed in construction phase (if prefabricated elements would be used, what is possible, the value would be better), vertical clearance is very good in comparison -> less interaction with other infrastructures	4			Qualitative-T1	0,0	6
Environmental	15	C8	Temporary environmental impacts	in-situ concrete, so more impact while construction	2			Qualitative-T2	4,0	4
		C9	Permanent environmental impacts	Permanent environmental impact is higher in comparison to cases 1.C because opening is smaller and does impact crossing partner more. But still it is low.	2			Qualitative-T2	0,0	6
		C10	Visual and aesthetic integration	Because of haunches opening seems wider than in comparison to case 1.A. In Comparison to case 1.C opening is still not as wide.	3			Qualitative-T1	2,5	5
Construction	20,0	C11	Time schedule and works duration	Works duration for construction for cases 1.A and 1.B is about the same. Evan if case 1.A uses prefabricated elements for superstructure, more complex connection details and same effort for substructure leads to closely same construction time.	6	8	7	Months	8,0	8
		C12	Construction complexity	Complexity is higher in comparison to case 1.A because more formwork and inclined surfaces (haunches) have to be built.	3			Qualitative-T2	3,0	6
		C13	Labor resources	More Labor resources in comparison to case 1.A, because formwork is needed. Less Labor resources in comparison to case 1.C, because lower complexity.	3			Qualitative-T2	3,0	6
Additional Comments			Main advantage is high vertical clearance and high slenderness in field due to haunches.							
Total	100								73	100



Multi Criteria Analysis - Value Engineering **Case 1.C** **Underpass - V-form**

Criteria Group	Weight	Number	Description	Comments	Value min.	Value max.	Value Average	Metrics	Scoring	Weight
Economical	40	C1	Structure construction cost (CAPEX)	Due to a higher complexity of construction in comparison to cases 1.A and 1.B, this solution is uneconomical. Rough estimated costs, factors which are depending on location such as transport costs or costs for safety measure for other buildings are not included.	2.500	2.800	2.650	EURO/m²	0,0	20
		C2	Structure maintenance and operation cost during it's life time (OPEX)	OPEX is around 1 - 1.5 % of CAPEX	25	42	34	EURO/m²/a	0,0	15
		C3	End of life cost	All Materials for Case 1.A, B and C are concrete. Either prefabricated or in-situ concrete. Thus, the End of life cost per square meter is about the same.	200			EURO/m²	5,0	5
Technical (design and structural aspects)	25	C4	Accessibility and complexity for maintenance	accessibility very good, but inclined surfaces have to be inspected	4			Qualitative-T1	6,0	6
		C5	Reliability of solution	well proven solutions, with good structural behaviour and durability	5			Qualitative-T1	7,0	7
		C6	Possibility of upgrade	rolling stock speed and increase of loads is good; widening of deck is possible but more difficult than for other solutions, upgrading is possible but more difficult for this solution	4			Qualitative-T1	0,0	6
		C7	Interaction with other infrastructures	due to prefabricated elements other infrastructure operation is not disturbed so much in construction phase, for maintenance other infrastructure is partly interrupted	5			Qualitative-T1	6,0	6
Environmental	15	C8	Temporary environmental impacts	temporary environmental impacts while construction phase is higher, because construction needs more time, so more impact while construction	2			Qualitative-T2	4,0	4
		C9	Permanent environmental impacts	Permanent environmental impact is lower in comparison to cases 1.A and 1.B because opening is wider and does not impact crossing partner so much.	1			Qualitative-T2	6,0	6
		C10	Visual and aesthetic integration	High recognition value, high clearance, wide opening	4			Qualitative-T1	5,0	5
Construction	20,0	C11	Time schedule and works duration	Works duration for construction 1.C is a bit more than for cases 1.A and 1.B due to higher complexity.	7	9	8	Months	0,0	8
		C12	Construction complexity	Especially connection between angular substructure and partly prefabricated superstructure is complex.	4			Qualitative-T2	0,0	6
		C13	Labor resources	Due to high complexity a high labor resource is necessary even if prefabricated elements are used.	4			Qualitative-T2	0,0	6
Additional Comments			Main advantage is the high recognition value of this solution and the wide opening, so risk of collision is very low.							
Total	100								39	100

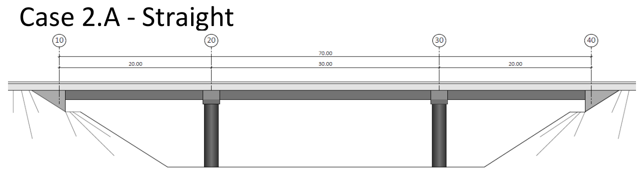


Rail Baltica
Coordinated by RB Rail

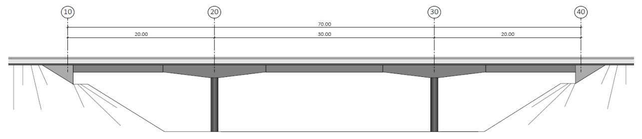
Multi Criteria Analysis - Value Engineering   Case 2   Railway Viaduct Comparison

Criteria Group	Weight	Number	Description	Comments	Scoring			Weight
					C2.A	C2.B	C2.C	
Economical	40	C1	Structure construction cost (CAPEX)	Rough estimated costs, factors which are depending on location such as transport costs or costs for safety measure for other buildings are not included.	20,0	16,0	0,0	20
		C2	Structure maintenance and operation cost during its life time (OPEX)	Average cost during design life of structure	15,0	12,0	0,0	15
		C3	End of life cost	Dismantle and recycling (eventually for replacement) of the structure	5,0	5,0	5,0	5
Technical (design and structural aspects)	25	C4	Accessibility and complexity for maintenance	Easiness for access of planned maintenance operations	6,0	6,0	0,0	6
		C5	Reliability of solution	Well proven solutions, with good structural behaviour and durability	7,0	7,0	0,0	7
		C6	Possibility of upgrade	Upgrade of: rolling stock speed, widening of deck, increase loads, etc.	6,0	6,0	0,0	6
		C7	Interaction with other infrastructures	Limitations for other infrastructure operation, maintenance and future development	6,0	6,0	0,0	6
Environmental	15	C8	Temporary environmental impacts	Consider positive and negative impacts. More detailing is necessary depending on the specific situation and in aspects that can differentiate the different solutions	4,0	0,0	0,0	4
		C9	Permanent environmental impacts	Consider positive and negative impacts. More detailing is necessary depending on the specific situation and in aspects that can differentiate the different solutions	6,0	6,0	6,0	6
		C10	Visual and aesthetic integration	slenderness, wide opening, integration in surrounding	5,0	5,0	5,0	5
Construction	20,0	C11	Time schedule and works duration	Time necessary for construction; Time duration is given in a range of month, depending on landscape, logistics, bridge size, the construction time is either in the beginning or in the end of the range.	8,0	8,0	0,0	8
		C12	Construction complexity	Equipment, phases, operations, logistics, risks regarding budget and schedule.	6,0	3,0	0,0	6
		C13	Labor resources	Quantity and/or qualification, construction and supervision	6,0	0,0	0,0	6
Total	100				**100**	**80**	**16**	100

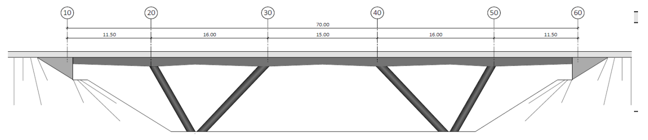
Case 2.A - Straight



Case 2.B - Haunched



Case 2.C - V-form



Notes

The goal of this analysis is to compare different structural solutions for a certain crossing.
Multi Criteria Analysis could be skipped in very simple situations where the preferred solution is know and this analysis was already performed in the project, so the solutions and their characteristics are well known.
Criteria are presented in a general way, but different criteria can be added or disregarded in specific situation. The weight of the criteria can also be adjusted to the specific situation.
According to the scoring rules the solutions with the highest/best value will get the maximum score in a criteria, the solutions with the lowest/worst score will get zero

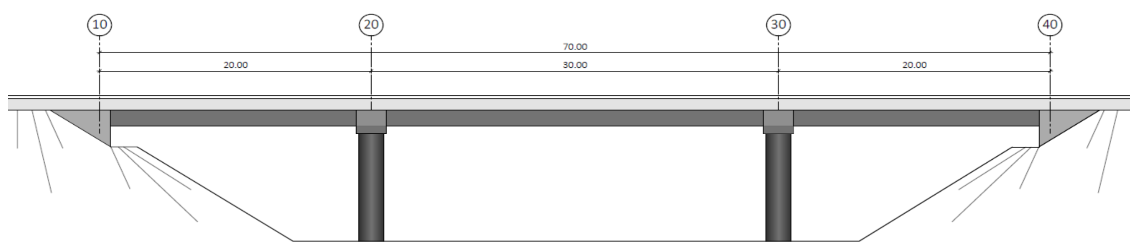
Qualitative assessment:
Type 1 - from bad = 1 to very good = 5
Type 2 - from low = 1 to very high = 5

$$Score\ 1\ (maximum\ value\ is\ best) = \frac{Weight}{(Max\ value\ - Min\ value)} \times (Value\ - Min\ Value)$$

$$Score\ 2\ (minimum\ value\ is\ best) = \frac{Weight}{(Min\ value\ - Max\ value)} \times (Value\ - Max\ Value)$$

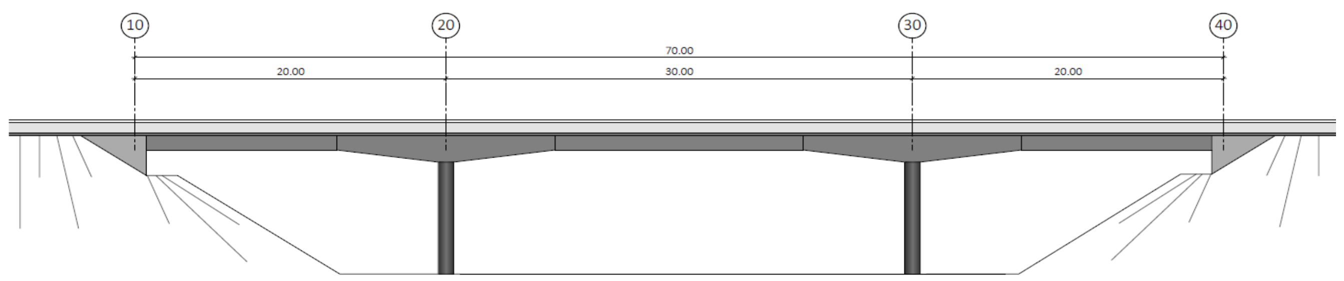
Multi Criteria Analysis - Value Engineering **Case 2.A** **Railway Viaduct - Straight**

Criteria Group	Weight	Number	Description	Comments	Value			Metrics	Scoring	Weight
					min.	max.	Average			
Economical	40	C1	Structure construction cost (CAPEX)	Due to low complexity of construction C2.A is the most economical solution for case 2 railway viaduct. Rough estimated costs, factors which are depending on location such as transport costs or costs for safety measure for other buildings are not included.	1.900	2.200	2.050	EURO/m²	20,0	20
		C2	Structure maintenance and operation cost during it's life time (OPEX)	OPEX is around 1 - 1.5 % of CAPEX	19	33	26	EURO/m²/a	15,0	15
		C3	End of life cost	All Materials for Case 2.A, B and C are concrete. Either prefabricated or in-situ concrete. Thus, the End of life cost per square meter is about the same.	200			EURO/m²	5,0	5
Technical (design and structural aspects)	25	C4	Accessibility and complexity for maintenance	accessibility is as good as for case 2.B, because this are nearly the same geometries	4			Qualitative-T1	6,0	6
		C5	Reliability of solution	Well proven solutions, with good structural behaviour and durability	5			Qualitative-T1	7,0	7
		C6	Possibility of upgrade	rolling stock speed and increase of loads is very good; widening of deck is easier possible than for other solutions	5			Qualitative-T1	6,0	6
		C7	Interaction with other infrastructures	due to prefabricated elements other infrastructure operation is not disturbed so much in construction phase, wide opening for undercrossing of other infrastructures	5			Qualitative-T1	6,0	6
Environmental	15	C8	Temporary environmental impacts	Average temporary environmental impacts, prefabricated elements are fast, but building substructure also impacts environment.	3			Qualitative-T2	4,0	4
		C9	Permanent environmental impacts	Permanent environmental impact is very low because openings are wide and does not impact animals and nature so much.	1			Qualitative-T2	6,0	6
		C10	Visual and aesthetic integration	higher transparency than for Case 1.A	3			Qualitative-T1	5,0	5
Construction	20,0	C11	Time schedule and works duration	In comparison to Case 1.A construction time is longer, due to additional substructure and larger bridge. Works duration for construction for cases 2.A and 2.B is about the same. Evan if case 2.A uses prefabricated elements for superstructure, more complex connection details and same effort for substructure leads to closely same construction time. Also for Case 2.A supporting structure is needed to make sure that connection can be build integral and still substructure does not get to big.	8	12	10	Months	8,0	8
		C12	Construction complexity	Complexity is low, but not very low because of connection details.	2			Qualitative-T2	6,0	6
		C13	Labor resources	Needed labor resources are low, but not very low because of connection details.	3			Qualitative-T2	6,0	6
Additional comments			Straight and clear concept.							
Total	100								100	100



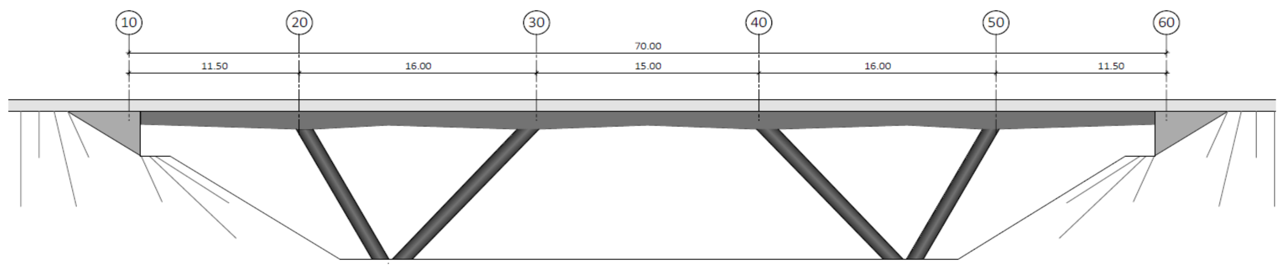
Multi Criteria Analysis - Value Engineering — Case 2.B — Railway Viaduct - Haunched

Criteria Group	Weight	Number	Description	Comments	Value			Metrics	Scoring	Weight
					min.	max.	Average			
Economical	40	C1	Structure construction cost (CAPEX)	Due to a bit higher complexity of construction C2.B is not as economical as solution C2.A. Rough estimated costs, factors which are depending on location such as transport costs or costs for safety measure for other buildings are not included.	2.000	2.300	2.150	EURO/m²	16,0	20
		C2	Structure maintenance and operation cost during it's life time (OPEX)	OPEX is around 1 - 1.5 % of CAPEX	20	34,5	27	EURO/m²/a	12,0	15
		C3	End of life cost	All Materials for Case 2.A, B and C are concrete. Either prefabricated or in-situ concrete. Thus, the End of life cost per square meter is about the same.		200		EURO/m²	5,0	5
Technical (design and structural aspects)	25	C4	Accessibility and complexity for maintenance	accessibility is as good as for case 2.A, because this are nearly the same geometries		4		Qualitative-T1	6,0	6
		C5	Reliability of solution	well proven solutions, with good structural behaviour and durability		5		Qualitative-T1	7,0	7
		C6	Possibility of upgrade	rolling stock speed and increase of loads is very good; widening of deck is easier possible than for other solutions		5		Qualitative-T1	6,0	6
		C7	Interaction with other infrastructures	very good, because of high slenderness in middle field		5		Qualitative-T1	6,0	6
Environmental	15	C8	Temporary environmental impacts	in-situ concrete, so more impact while construction		4		Qualitative-T2	0,0	4
		C9	Permanent environmental impacts	Permanent environmental impact is very low because openings are wide and does not impact animals and nature so much.		1		Qualitative-T2	6,0	6
		C10	Visual and aesthetic integration	transparency as case 2.A, high slenderness		3		Qualitative-T1	5,0	5
Construction	20,0	C11	Time schedule and works duration	Works duration for construction for cases 2.A and 2.B is about the same. Evan if case 2.A uses prefabricated elements for superstructure, more complex connection details and same effort for substructure leads to closely same construction time.	8	12	10	Months	8,0	8
		C12	Construction complexity	Complexity is higher in comparison to case 2.A because more formwork and inclined surfaces (haunches) have to be built.		3		Qualitative-T2	3,0	6
		C13	Labor resources	More Labor resources in comparison to case 2.A, because formwork is needed. In comparison to case 2.C is about the same Labor resources. The complexity is less, but formwork is needed for construction.		4		Qualitative-T2	0,0	6
Additional Comments			Main advantage is high vertical clearance and high slenderness in field due to haunches.							
Total	100								80	100



Multi Criteria Analysis - Value Engineering **Case 2.C** **Railway Viaduct - V-form**

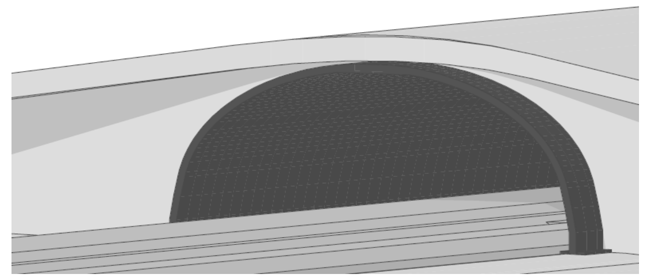
Criteria Group	Weight	Number	Description	Comments	Value			Metrics	Scoring	Weight
					min.	max.	Average			
Economical	40	C1	Structure construction cost (CAPEX)	Due to a higher complexity of construction in comparison to cases 2.A and 2.B, this solution is uneconomical. Rough estimated costs, factors which are depending on location such as transport costs or costs for safety measure for other buildings are not included.	2.400	2.700	2.550	EURO/m²	0,0	20
		C2	Structure maintenance and operation cost during it's life time (OPEX)	OPEX is around 1 - 1.5 % of CAPEX	24	40,5	32	EURO/m²/a	0,0	15
		C3	End of life cost	All Materials for Case 2.A, B and C are concrete. Either prefabricated or in-situ concrete. Thus, the End of life cost per square meter is about the same.	200			EURO/m²	5,0	5
Technical (design and structural aspects)	25	C4	Accessibility and complexity for maintenance	accessibility good, but inclined surfaces have to be inspected	3			Qualitative-T1	0,0	6
		C5	Reliability of solution	solution with good structural behaviour and durability, but not used as common as case 2.A and 2.B	4			Qualitative-T1	0,0	7
		C6	Possibility of upgrade	rolling stock speed and increase of loads is good; widening of deck is possible but more difficult than for other solutions, upgrading is possible but more difficult for this solution	4			Qualitative-T1	0,0	6
		C7	Interaction with other infrastructures	horizontal clearance is limited because of angulated substructure, vertical clearance better, because of smaller spans	4			Qualitative-T1	0,0	6
Environmental	15	C8	Temporary environmental impacts	longer construction time, longer impact to environment	4			Qualitative-T2	0,0	4
		C9	Permanent environmental impacts	Permanent environmental impact is very low because openings are wide and does not impact animals and nature so much.	1			Qualitative-T2	6,0	6
		C10	Visual and aesthetic integration	very high recognition value, due to four angulated substructure clearance is not as good as in case 2.B and 2.C	3			Qualitative-T1	5,0	5
Construction	20,0	C11	Time schedule and works duration	Works duration for construction 2.C is a bit more than for cases 2.A and 2.B due to higher complexity.	10	14	12	Months	0,0	8
		C12	Construction complexity	Especially connection between angular substructure and partly prefabricated superstructure is complex.	4			Qualitative-T2	0,0	6
		C13	Labor resources	Due to high complexity a high labor resource is necessary even if prefabricated elements are used.	4			Qualitative-T2	0,0	6
Additional Comments			Main advantage is the high recognition value of this solution.							
Total	100								16	100



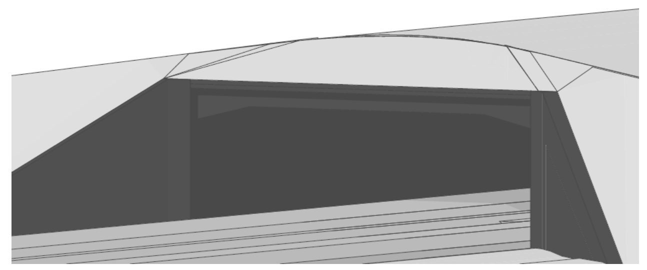
Multi Criteria Analysis - Value Engineering | Case 3 | Animal Overpass Comparison

Criteria Group	Weight	Number	Description	Comments	Scoring C3.A	Scoring C3.B	Scoring C3.C	Weight
Economical	40	C1	Structure construction cost (CAPEX)	Rough estimated costs, factors which are depending on location such as transport costs or costs for safety measure for other buildings are not included.	20,0	0,0	20,0	20
		C2	Structure maintenance and operation cost during its life time (OPEX)	Average cost during design life of structure	15,0	0,0	15,0	15
		C3	End of life cost	Dismantle and recycling (eventually for replacement) of the structure	5,0	5,0	5,0	5
Technical (design and structural aspects)	25	C4	Accessibility and complexity for maintenance	Easiness for access of planned maintenance operations	6,0	6,0	0,0	6
		C5	Reliability of solution	Well proven solutions, with good structural behaviour and durability	0,0	0,0	7,0	7
		C6	Possibility of upgrade	Upgrade of: rolling stock speed, widening of deck, increase loads, etc.	6,0	6,0	6,0	6
		C7	Interaction with other infrastructures	Limitations for other infrastructure operation, maintenance and future development	6,0	6,0	6,0	6
Environmental	15	C8	Temporary environmental impacts	Consider positive and negative impacts. More detailing is necessary depending on the specific situation and in aspects that can differentiate the different solutions	4,0	0,0	4,0	4
		C9	Permanent environmental impacts	Consider positive and negative impacts. More detailing is necessary depending on the specific situation and in aspects that can differentiate the different solutions	6,0	0,0	6,0	6
		C10	Visual and aesthetic integration	slenderness, wide opening, integration in surrounding	5,0	0,0	5,0	5
Construction	20,0	C11	Time schedule and works duration	Time necessary for construction; Time duration is given in a range of month, depending on landscape, logistics, bridge size, the construction time is either in the beginning or in the end of the range.	8,0	0,0	8,0	8
		C12	Construction complexity	Equipment, phases, operations, logistics, risks regarding budget and schedule.	6,0	0,0	0,0	6
		C13	Labor resources	Quantity and/or qualification, construction and supervision	6,0	0,0	0,0	6
Total	100				**93**	**23**	**82**	100

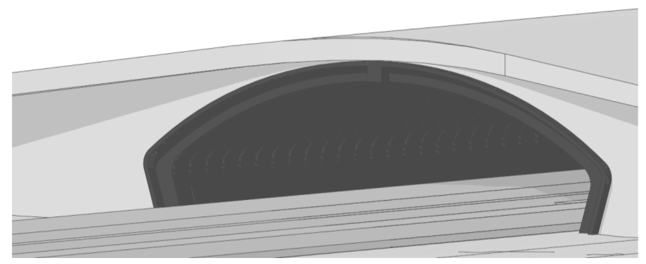
Case 3.A - Arch



Case 3.B - Frame



Case 3.C - three hinged Arch



Notes

The goal of this analysis is to compare different structural solutions for a certain crossing.
Multi Criteria Analysis could be skipped in very simple situations where the preferred solution is know and this analysis was already performed in the project, so the solutions and their characteristics are well known.
Criteria are presented in a general way, but different criteria can be added or disregarded in specific situation. The weight of the criteria can also be adjusted to the specific situation.
According to the scoring rules the solutions with the highest/best value will get the maximum score in a criteria, the solutions with the lowest/worst score will get zero

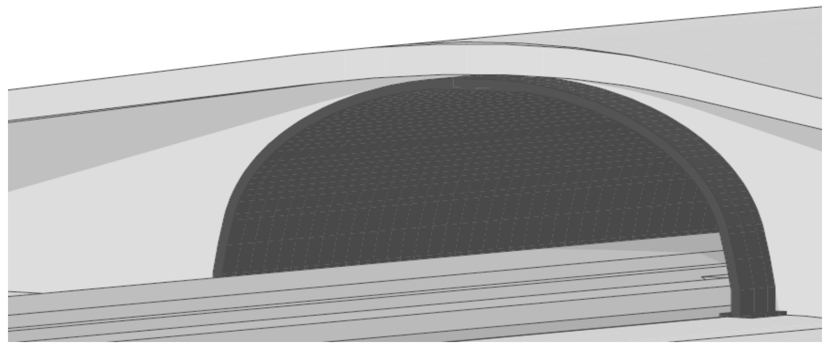
Qualitative assessment:
Type 1 - from bad = 1 to very good = 5
Type 2 - from low = 1 to very high = 5

$$Score\ 1\ (maximum\ value\ is\ best) = \frac{Weight}{(Max\ value\ - Min\ value)} \times (Value\ - Min\ Value)$$

$$Score\ 2\ (minimum\ value\ is\ best) = \frac{Weight}{(Min\ value\ - Max\ value)} \times (Value\ - Max\ Value)$$

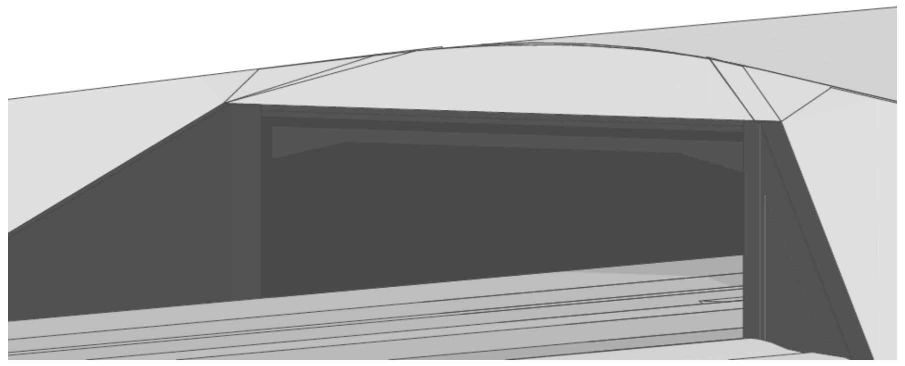
Multi Criteria Analysis - Value Engineering **Case 3.A** **Animal Overpass - Arch**

Criteria Group	Weight	Number	Description	Comments	Value			Metrics	Scoring	Weight
					min.	max.	Average			
Economical	40	C1	Structure construction cost (CAPEX)	Due to small demand of material, solution 3.A is the most economic solutions in comparison to solution 3.B and 3.C. Rough estimated costs, factors which are depending on location such as transport costs or costs for safety measure for other buildings are not included.	1.700	2.000	1.850	EURO/m²	20,0	20
		C2	Structure maintenance and operation cost during it's life time (OPEX)	OPEX is around 1 - 1.5 % of CAPEX	17	30	23,5	EURO/m²/a	15,0	15
		C3	End of life cost	All Materials for Case 3.A, B and C are concrete. Either prefabricated or in-situ concrete. Thus, the End of life cost per square meter is about the same.	200			EURO/m²	5,0	5
Technical (design and structural aspects)	25	C4	Accessibility and complexity for maintenance	In comparison to case 3.C complexity for maintenance is better.	4			Qualitative-T1	6,0	6
		C5	Reliability of solution	Higher requirements for back filling.	4			Qualitative-T1	0,0	7
		C6	Possibility of upgrade	rolling stock speed and increase of loads is very good; widening of railway line is not possible, same in all three cases 3.A, 3.B and 3.C	4			Qualitative-T1	6,0	6
		C7	Interaction with other infrastructures	average interaction for all three cases 3.A, 3.B and 3.C	3			Qualitative-T1	6,0	6
Environmental	15	C8	Temporary environmental impacts	Average temporary environmental impacts while construction phase, prefabricated elements save time, but great amounts of earth have to be moved and fit into place.	3			Qualitative-T2	4,0	4
		C9	Permanent environmental impacts	Animal overpasses are a solution to reduce environmental impacts of infrastructure in nature. Thus, the permanent environmental impacts are very low in comparison to cases 1,2 and 4.	1			Qualitative-T2	6,0	6
		C10	Visual and aesthetic integration	construction form follows landscape form	4			Qualitative-T1	5,0	5
Construction	20,0	C11	Time schedule and works duration	Using of prefabricated elements reduces works duration, connection points are not as complicated as for cases 1,2 and 4 but a bigger amount of earth has to be moved. And Backfill has to reach an high quality.	6	8	7	Months	8,0	8
		C12	Construction complexity	low complexity, prefabricated elements with simple connections	2			Qualitative-T2	6,0	6
		C13	Labor resources	low labor resource, prefabricated elements with simple connections	2			Qualitative-T2	6,0	6
Additional Comments			Very slender solution, but backfill has to reach high quality.							
Total	100								93	100



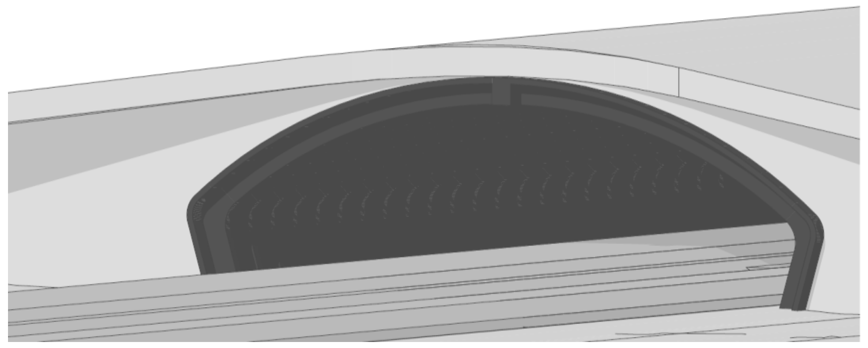
Multi Criteria Analysis - Value Engineering **Case 3.B** **Animal Overpass - Frame**

Criteria Group	Weight	Number	Description	Comments	Value min.	Value max.	Value Average	Metrics	Scoring	Weight
Economical	40	C1	Structure construction cost (CAPEX)	Due to highest demand of material, solution 3.B is the least economic solutions in comparison to solution 3.A and 3.C. Rough estimated costs, factors which are depending on location such as transport costs or costs for safety measure for other buildings are not included.	1.900	2.200	2.050	EURO/m²	0,0	20
		C2	Structure maintenance and operation cost during it's life time (OPEX)	OPEX is around 1 - 1.5 % of CAPEX	19	33	26	EURO/m²/a	0,0	15
		C3	End of life cost	All Materials for Case 3.A, B and C are concrete. Either prefabricated or in-situ concrete. Thus, the End of life cost per square meter is about the same.	200			EURO/m²	5,0	5
Technical (design and structural aspects)	25	C4	Accessibility and complexity for maintenance	In comparison to case 3.C complexity for maintenance is better.	4			Qualitative-T1	6,0	6
		C5	Reliability of solution	bending for load transfer, not as good as compressive force load transfer for frames	4			Qualitative-T1	0,0	7
		C6	Possibility of upgrade	rolling stock speed and increase of loads is very good; widening of railway line is not possible, same in all three cases 3.A, 3.B and 3.C	4			Qualitative-T1	6,0	6
		C7	Interaction with other infrastructures	average interaction for all three cases 3.A, 3.B and 3.C	3			Qualitative-T1	6,0	6
Environmental	15	C8	Temporary environmental impacts	Very great amounts of earth increase the temporary environmental impacts while construction phase in comparison to case 3.A and 3.C.	4			Qualitative-T2	0,0	4
		C9	Permanent environmental impacts	Same as in Case 3.A and 3.B, but because of different geometry of bridge structure and landscape. The landscape has to be adjusted more than for the solutions in case 3.A and 3.B.	2			Qualitative-T2	0,0	6
		C10	Visual and aesthetic integration	construction form and landscape have a totally different geometry and do not fit together	2			Qualitative-T1	0,0	5
Construction	20,0	C11	Time schedule and works duration	longer construction time due to high amounts of earth and additional in-situ concrete on top of prefabricated elements	8	10	9	Months	0,0	8
		C12	Construction complexity	average complexity, standard solution	3			Qualitative-T2	0,0	6
		C13	Labor resources	average labor resources, standard solution but additional in-situ concrete is needed	3			Qualitative-T2	0,0	6
Additional Comments			Standard solution but construction form does not follow landscape form.							
Total	100								23	100



Multi Criteria Analysis - Value Engineering **Case 3.C** **Animal Overpass - three hinged arch**

Criteria Group	Weight	Number	Description	Comments	Value min.	Value max.	Value Average	Metrics	Scoring	Weight
Economical	40	C1	Structure construction cost (CAPEX)	Due to demand of material, solution 3.C is not as economical as solution 3.A but more economical than solution 3.B. Rough estimated costs, factors which are depending on location such as transport costs or costs for safety measure for other buildings are not included.	1.800	2.100	1.950	EURO/m²	20,0	20
		C2	Structure maintenance and operation cost during it's life time (OPEX)	OPEX is around 1 - 1.5 % of CAPEX	18	31,5	25	EURO/m²/a	15,0	15
		C3	End of life cost	All Materials for Case 3.A, B and C are concrete. Either prefabricated or in-situ concrete. Thus, the End of life cost per square meter is about the same.	200			EURO/m²	5,0	5
Technical (design and structural aspects)	25	C4	Accessibility and complexity for maintenance	Complexity for maintenance is higher in comparison to case 3.A and 3.B, because of ribs also in abutment area.	3			Qualitative-T1	0,0	6
		C5	Reliability of solution	solutions, with good structural behaviour and durability	5			Qualitative-T1	7,0	7
		C6	Possibility of upgrade	rolling stock speed and increase of loads is very good; widening of railway line is not possible, same in all three cases 3.A, 3.B and 3.C	4			Qualitative-T1	6,0	6
		C7	Interaction with other infrastructures	average interaction for all three cases 3.A, 3.B and 3.C	3			Qualitative-T1	6,0	6
Environmental	15	C8	Temporary environmental impacts	Average temporary environmental impacts while construction phase, prefabricated elements save time, but great amounts of earth have to be moved and fit into place.	3			Qualitative-T2	4,0	4
		C9	Permanent environmental impacts	Animal overpasses are a solution to reduce environmental impacts of infrastructure in nature. Thus, the permanent environmental impacts are very low in comparison to cases 1,2 and 4.	1			Qualitative-T2	6,0	6
		C10	Visual and aesthetic integration	construction form follows landscape form	4			Qualitative-T1	5,0	5
Construction	20,0	C11	Time schedule and works duration	Using of prefabricated elements reduces works duration, connection points are not as complicated as for cases 1,2 and 4 but a bigger amount of earth has to be moved. And Backfill has to reach an high quality.	6	8	7	Months	8,0	8
		C12	Construction complexity	Average complexity, prefabricated elements but more complexity in comparison to case 3.A because of ribs and needed support structure in construction time.	3			Qualitative-T2	0,0	6
		C13	Labor resources	Average Labor resources, prefabricated elements but more complexity in comparison to case 3.A because of ribs.	3			Qualitative-T2	0,0	6
Additional Comments			Construction follows landscape, very good structural behaviour.							
Total	100								82	100

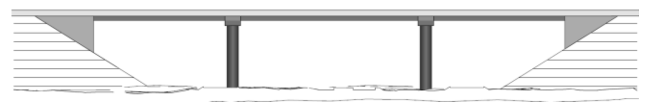


Rail Baltica
Coordinated by RB Rail

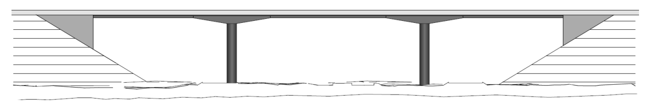
Multi Criteria Analysis - Value Engineering Case 4 Road Overpass Comparison

Criteria Group	Weight	Number	Description	Comments	Scoring			Weight
					C4.A	**C4.B**	**C4.C**	
Economical	40	C1	Structure construction cost (CAPEX)	Rough estimated costs, factors which are depending on location such as transport costs or costs for safety measure for other buildings are not included.	20,0	16,0	0,0	20
		C2	Structure maintenance and operation cost during its life time (OPEX)	Average cost during design life of structure	15,0	12,0	0,0	15
		C3	End of life cost	Dismantle and recycling (eventually for replacement) of the structure	5,0	5,0	5,0	5
Technical (design and structural aspects)	25	C4	Accessibility and complexity for maintenance	Easiness for access of planned maintenance operations	0,0	0,0	6,0	6
		C5	Reliability of solution	Well proven solutions, with good structural behaviour and durability	7,0	7,0	0,0	7
		C6	Possibility of upgrade	Upgrade of: rolling stock speed, widening of deck, increase loads, etc.	6,0	6,0	0,0	6
		C7	Interaction with other infrastructures	Limitations for other infrastructure operation, maintenance and future development	0,0	6,0	0,0	6
Environmental	15	C8	Temporary environmental impacts	Consider positive and negative impacts. More detailing is necessary depending on the specific situation and in aspects that can differentiate the different solutions	4,0	0,0	4,0	4
		C9	Permanent environmental impacts	Consider positive and negative impacts. More detailing is necessary depending on the specific situation and in aspects that can differentiate the different solutions	6,0	6,0	6,0	6
		C10	Visual and aesthetic integration	slenderness, wide opening, integration in surrounding	5,0	5,0	5,0	5
Construction	20,0	C11	Time schedule and works duration	Time necessary for construction; Time duration is given in a range of month, depending on landscape, logistics, bridge size, the construction time is either in the beginning or in the end of the range.	8,0	0,0	0,0	8
		C12	Construction complexity	Equipment, phases, operations, logistics, risks regarding budget and schedule.	6,0	3,0	0,0	6
		C13	Labor resources	Quantity and/or qualification, construction and supervision	6,0	0,0	0,0	6
Total	100				**88**	**66**	**26**	100

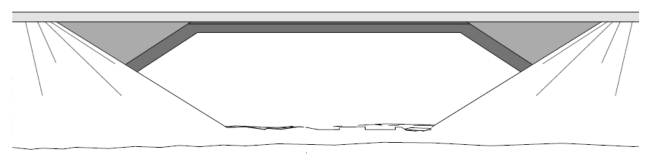
Case 1.A - Straight



Case 1.B - Haunched



Case 4.C - V-form



Notes

The goal of this analysis is to compare different structural solutions for a certain crossing.
Multi Criteria Analysis could be skipped in very simple situations where the preferred solution is know and this analysis was already performed in the project, so the solutions and their characteristics are well known.
Criteria are presented in a general way, but different criteria can be added or disregarded in specific situation. The weight of the criteria can also be adjusted to the specific situation.
According to the scoring rules the solutions with the highest/best value will get the maximum score in a criteria, the solutions with the lowest/worst score will get zero

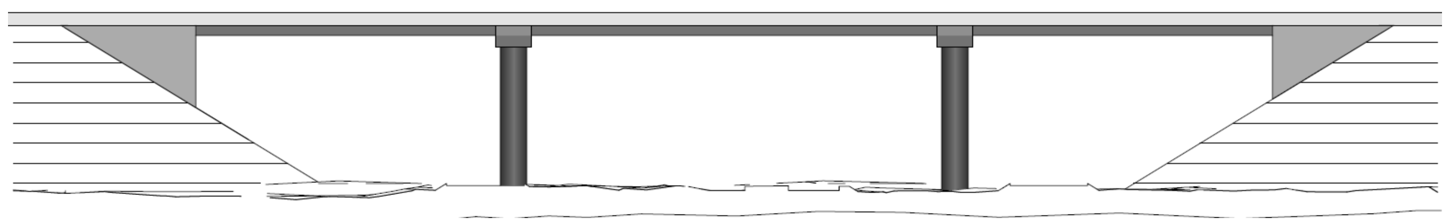
Qualitative assessment:
Type 1 - from bad = 1 to very good = 5
Type 2 - from low = 1 to very high = 5

$$Score\ 1\ (maximum\ value\ is\ best) = \frac{Weight}{(Max\ value\ - Min\ value)} \times (Value\ - Min\ Value)$$

$$Score\ 2\ (minimum\ value\ is\ best) = \frac{Weight}{(Min\ value\ - Max\ value)} \times (Value\ - Max\ Value)$$

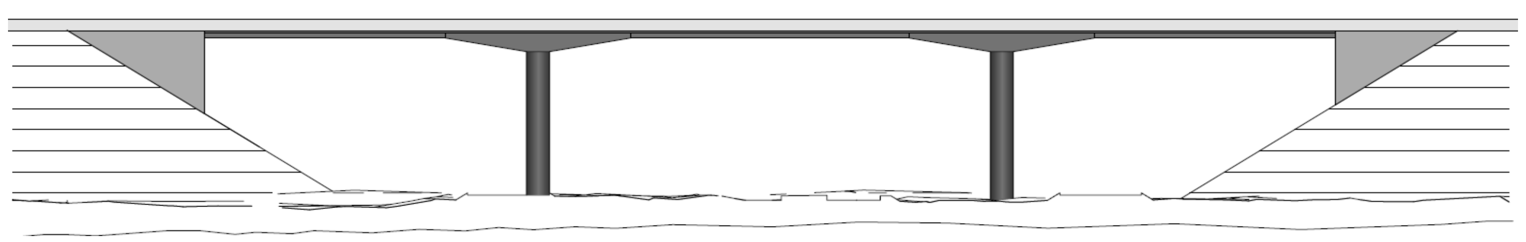
Multi Criteria Analysis - Value Engineering **Case 4.A** **Road Overpass - Straight**

Criteria Group	Weight	Number	Description	Comments	Value			Metrics	Scoring	Weight
					min.	max.	Average			
Economical	40	C1	Structure construction cost (CAPEX)	Due to low complexity of construction C4.A is the most economical solution for case 4 road overpasses. Rough estimated costs, factors which are depending on location such as transport costs or costs for safety measure for other buildings are not included.	1.700	2.000	1.850	EURO/m²	20,0	20
		C2	Structure maintenance and operation cost during it's life time (OPEX)	OPEX is around 1 - 1.5 % of CAPEX	17	30	23,5	EURO/m²/a	15,0	15
		C3	End of life cost	All Materials for Case 4.A, B and C are concrete. Either prefabricated or in-situ concrete. Thus, the End of life cost per square meter is about the same.	200			EURO/m²	5,0	5
Technical (design and structural aspects)	25	C4	Accessibility and complexity for maintenance	For maintenance other infrastructure is partly interrupted, but accessibility for maintenance is very good.	4			Qualitative-T1	0,0	6
		C5	Reliability of solution	well proven solutions, with good structural behaviour and durability	5			Qualitative-T1	7,0	7
		C6	Possibility of upgrade	rolling stock speed and increase of loads is very good; widening of deck is easier possible than for other solutions	5			Qualitative-T1	6,0	6
		C7	Interaction with other infrastructures	in use phase interaction with other infrastructures is good, due to prefabricated elements other infrastructure operation is not disturbed so much in construction phase, for maintenance other infrastructure is partly interrupted	4			Qualitative-T1	0,0	6
Environmental	15	C8	Temporary environmental impacts	Average temporary environmental impacts, prefabricated elements are fast, but building substructure also impacts environment.	3			Qualitative-T2	4,0	4
		C9	Permanent environmental impacts	Permanent environmental impact is very low because openings are wide and does not impact animals and nature so much.	1			Qualitative-T2	6,0	6
		C10	Visual and aesthetic integration	higher transparency than for Case 1.A	4			Qualitative-T1	5,0	5
Construction	20,0	C11	Time schedule and works duration	In comparison to Case 1.A construction time is longer, due to additional substructure and larger bridge. But construction time is less than case 2.A because it is a road bridge with a much smaller superstructure.	7	9	8	Months	8,0	8
		C12	Construction complexity	Complexity is low, but not very low because of connection details.	2			Qualitative-T2	6,0	6
		C13	Labor resources	Needed labor resources are low, but not very low because of connection details.	3			Qualitative-T2	6,0	6
Additional Comments			Straight and clear concept.							
Total	100								88	100



Multi Criteria Analysis - Value Engineering **Case 4.B** **Road Overpass - Haunched**

Criteria Group	Weight	Number	Description	Comments	Value			Metrics	Scoring	Weight
					min.	max.	Average			
Economical	40	C1	Structure construction cost (CAPEX)	Due to a bit higher complexity of construction C4.B is not as economical as solution C4.A. Rough estimated costs, factors which are depending on location such as transport costs or costs for safety measure for other buildings are not included.	1.800	2.100	1.950	EURO/m²	16,0	20
		C2	Structure maintenance and operation cost during it's life time (OPEX)	OPEX is around 1 - 1.5 % of CAPEX	18	31,5	25	EURO/m²/a	12,0	15
		C3	End of life cost	All Materials for Case 4.A, B and C are concrete. Either prefabricated or in-situ concrete. Thus, the End of life cost per square meter is about the same.	200			EURO/m²	5,0	5
Technical (design and structural aspects)	25	C4	Accessibility and complexity for maintenance	For maintenance other infrastructure is partly interrupted, but accessibility for maintenance is very good, even if inclined surfaces have to be inspected.	4			Qualitative-T1	0,0	6
		C5	Reliability of solution	well proven solutions, with good structural behaviour and durability	5			Qualitative-T1	7,0	7
		C6	Possibility of upgrade	rolling stock speed and increase of loads is very good; widening of deck is easier possible than for other solutions	5			Qualitative-T1	6,0	6
		C7	Interaction with other infrastructures	very good, because of high slenderness in middle field	5			Qualitative-T1	6,0	6
Environmental	15	C8	Temporary environmental impacts	in-situ concrete, so more impact while construction	4			Qualitative-T2	0,0	4
		C9	Permanent environmental impacts	Permanent environmental impact is very low because openings are wide and does not impact animals and nature so much.	1			Qualitative-T2	6,0	6
		C10	Visual and aesthetic integration	high transparency, high slenderness	4			Qualitative-T1	5,0	5
Construction	20,0	C11	Time schedule and works duration	The construction time for case 4.B is a bit longer than for case 4.A. because of a bit higher construction complexity.	8	10	9	Months	0,0	8
		C12	Construction complexity	Complexity is higher in comparison to case 4.A because more formwork and inclined surfaces (haunches) have to be built.	3			Qualitative-T2	3,0	6
		C13	Labor resources	More Labor resources in comparison to case 4.A, because formwork is needed. In comparison to case 4.C is about the same Labor resources. The complexity is less, but formwork is needed for construction and in case 4.C less substructures have to be built.	4			Qualitative-T2	0,0	6
Additional Comments			Main advantage is high vertical clearance and high slenderness in field due to haunches.							
Total	100								66	100



Multi Criteria Analysis - Value Engineering **Case 4.C** **Road Overpass - V-form**

Criteria Group	Weight	Number	Description	Comments	Value min.	Value max.	Value Average	Metrics	Scoring	Weight
Economical	40	C1	Structure construction cost (CAPEX)	Due to a higher complexity of construction in comparison to cases 4.A and 4.B, this solution is uneconomical. Rough estimated costs, factors which are depending on location such as transport costs or costs for safety measure for other buildings are not included.	2.200	2.500	2.350	EURO/m²	0,0	20
		C2	Structure maintenance and operation cost during it's life time (OPEX)	OPEX is around 1 - 1.5 % of CAPEX	22	37,5	30	EURO/m²/a	0,0	15
		C3	End of life cost	All Materials for Case 4.A, B and C are concrete. Either prefabricated or in-situ concrete. Thus, the End of life cost per square meter is about the same.	200			EURO/m²	5,0	5
Technical (design and structural aspects)	25	C4	Accessibility and complexity for maintenance	maintenance is possible without interruption of railway operation	5			Qualitative-T1	6,0	6
		C5	Reliability of solution	solution with good structural behaviour and durability, but not used as common as case 4.A and 4.B	4			Qualitative-T1	0,0	7
		C6	Possibility of upgrade	rolling stock speed and increase of loads is good; widening of deck is possible but more difficult than for other solutions, upgrading is possible but more difficult for this solution	4			Qualitative-T1	0,0	6
		C7	Interaction with other infrastructures	in use phase interaction with other infrastructures is good, due to prefabricated elements other infrastructure operation is not disturbed so much in construction phase, for maintenance other infrastructure is partly interrupted like in case 4.A	4			Qualitative-T1	0,0	6
Environmental	15	C8	Temporary environmental impacts	Average temporary environmental impacts, prefabricated elements are fast, but building substructure also impacts environment. Complexity is higher, so longer construction time and longer temporary environmental impact while construction phase in comparison to case 1 . But, less substructures so less temporary environmental impacts in comparison to case 4.B.	3			Qualitative-T2	4,0	4
		C9	Permanent environmental impacts	Permanent environmental impact is very low because openings are wide and does not impact animals and nature so much.	1			Qualitative-T2	6,0	6
		C10	Visual and aesthetic integration	high transparency, high slenderness, "open gate"	4			Qualitative-T1	5,0	5
Construction	20,0	C11	Time schedule and works duration	The construction time for case 4.C is nearly same in comparison to case 4.B. Complexity for case 4.C is higher, but no pier walls have to be build, so time for substructure is less in comparison to case 4.B.	8	10	9	Months	0,0	8
		C12	Construction complexity	Especially connection between angular substructure and partly prefabricated superstructure is complex.	4			Qualitative-T2	0,0	6
		C13	Labor resources	More Labor resources in comparison to case 4.A, because of higher complexity. In comparison to case 4.B is about the same Labor resources. The complexity is higher, but less formwork is needed for construction and less substructures have to be built.	4			Qualitative-T2	0,0	6
Additional Comments			Main advantage is the high recognition value of this solution.							
Total	100								26	100