

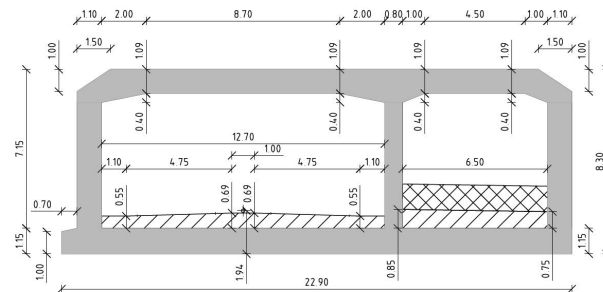
# MEMO

Job Sjøtunnel Tønsberg  
Client Statens Vegvesen  
Memo no. 01 – Estimation of economic consequence of removal pedestrian/cyclist tube.  
Date 31/03/2017  
To Steiner Aspen  
From Kai Midtskogen, Søren Gamst, Ton Hemel  
Copy to Lars Lundberg, Jan Ole Kaupang

## 1. Background

This memo has been prepared as addition to the sketch design of the “Undersjøisk tunnel Nøtterøy-Tønsberg” prepared by Rambøll, end of March 2017. In the sketch design two different alignments have been considered (alignment 12200 situated east-west and alignment 16730 situated south-north). For each alignment two different tunnel lay-outs have been considered.

One lay-out consisting of one traffic tube containing one traffic lane in each direction (H5, 12.50 meter internal width) combined with one tube for pedestrians and cyclists (6.5 meter internal width).



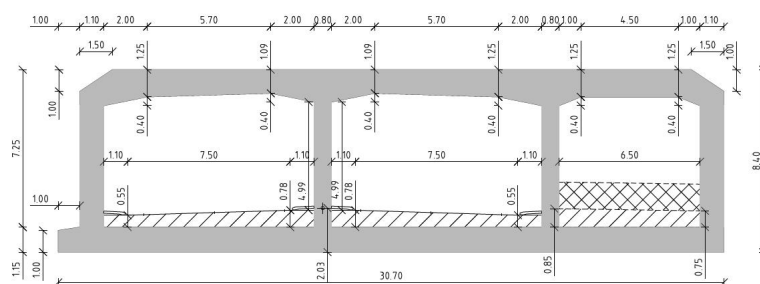
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The other lay-out consisting of two traffic tubes containing each 2 traffic lanes in one direction (H6, each tube 9.5 meter wide) combined with one tube for pedestrians and cyclists (6.5 meter internal width).

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Types and length of structures along alignment 12200 (east-west):

Item	Length [m]
Ramp east	295
C&C east	45
Immersed tunnel	490
C&C west	45
Ramp west	120

Total tunnel length: 580 meter.

Total length connection: 995 meter.

Types and length of structures along alignment 16730 (south-north):

Item	Length [m]
Ramp south	210
C&C south	45
Immersed tunnel	580
C&C north	45
Ramp north	120

Total tunnel length: 670 meter.

Total length connection: 1,000 meter.

For the complete sketch design reference is made to the sketch design report and the drawings prepared for "Undersjøisk Tunnel Nøtterøy-Tønsberg, Skisseprosjekt" (dated March 2017).

## 2. Purpose of the memo

The question has been raised what approximate saving (in percent) can be expected if the tunnel cross section is prepared without a tube for pedestrians/cyclists. A separate estimate is requested for the H5 alternative and the H6 alternative.

## 3. Consequences of removing pedestrian/cyclist tube.

Removing the pedestrian/cyclist tube from the cross section results, beside the economic consequences, in safety consequences for the H5 alternative. This is briefly described below in section 3.1. The economic consequences are described in section 3.2.

### 3.1 Safety consequences

The amount of traffic (ÅDT>8.000) and the length of the tunnel (>500 meter) result in the requirement of emergency exits to be present (Håndbok N500 section 3.6 "Nødutganger").

The emergency exit requirement can for the H6 alternative be fulfilled by emergency exits between the traffic tubes, allowing the complete pedestrian/cyclist tube to be removed without conflicting with safety requirements.

For the H5 alternative the emergency exits need to be provided between the traffic tube and the pedestrian/cyclist tube. Removal of the complete pedestrian/cyclist tube would result in not fulfilling the requirements.

Håndbok N500 states in section 3.6 "For ettløps tunneler kan nødutganger etableres med utganger til rømningstunnel." "Rømningstunnel skal ha tunnelprofil T5.5".

The required width of the escape tube (5.5 m) is only marginally smaller compared to the width of the pedestrian/cyclist tube (6.5 m), and for that reason it is not further considered in this memo.

### 3.2 Economic consequences

The economic consequences are determined on the basis of the following assumption:

- H6 alternative: removal of pedestrian/cyclist tube (6.5 m) and removal of internal wall (0.8 m). This reduces the tunnel width from 30.7 meter to 23.4 meter, a reduction of approximately 25%.
- H5 alternative: removal of pedestrian/cyclist tube (6.5 m) and removal of internal wall (0.8 m). This reduces the tunnel width from 22.9 meter to 15.6 meter, a reduction of approximately 30%.

The reduction factor for the tunnel permanent works part would be approximately the same as the indicated reduction for the width as the width of the tunnel has an almost direct relation to the amount of structural concrete.

The reduction factor for the temporary works would be smaller compared to the indicated reduction for the width as for example the required length of retaining structure along the ramp is hardly changed when reducing the width of the construction pit.

For the different parts of the project different reduction factors have been estimated by multiplying the width reduction with an estimated effectiveness factor. The effectiveness factors have been determined by means of expert estimation. The considered reduction factors for the different parts are shown in the tables below for the two different alternatives.

Each cost item has a different percentage in the overall cost estimate. The weight (or percentage) of each item is indicated in the table below and is determined on the basis of the cost estimate which is part of the prepared sketch design. For each alignment the weight is indicated.

By combining the estimated reduction factors of the different parts with the weight of that part the overall reduction for removal of the pedestrian/cyclist tube is found.

Table: Estimation reduction H6

Cost item	Weight		Estimated reduction factor	Reduction	
	12200	16730		12200	16730
Structures					
• Ramp					
• Temporary work	28%	13%	0.25 x 0.25	1.8%	0.8%
• Permanent work	5%	5%	0.25 x 0.7	0.9%	0.9%
• C&C					
• Temporary work	17%	14%	0.25 x 0.4	1.7%	1.4%
• Permanent work	3%	4%	0.25 x 0.7	0.5%	0.7%
• Tunnel					
• Temporary work	24%	35%	0.25 x 0.5	3.0%	4.4%
• Permanent work	18%	23%	0.25 x 0.7	3.2%	4.0%
Installations	3%	4%	0.25 x 0.5	0.5%	0.6%
Finishing					
• P&C tunnel	1%	1%	1.0	1%	1%
• Rest	1%	1%	0.0	0%	0%
Total	100%	100%		12.4%	13.7%

Table: Estimation reduction H5

Cost item	Weight		Estimated reduction factor	Reduction	
	12200	16730		12200	16730
Structures					
• Ramp					
• Temporary work	29%	15%	0.30 x 0.25	2.2%	1.1%
• Permanent work	5%	5%	0.30 x 0.7	1.1%	1.1%
• C&C					
• Temporary work	17%	13%	0.30 x 0.4	2.0%	1.6%
• Permanent work	3%	4%	0.30 x 0.7	0.6%	0.8%
• Tunnel					
• Temporary work	25%	34%	0.30 x 0.5	3.8%	5.1%
• Permanent work	16%	23%	0.30 x 0.7	3.4%	4.8%
Installations	3%	4%	0.30 x 0.5	0.5%	0.6%
Finishing					
• P&C tunnel	1%	1%	1.0	1%	1%
• Rest	1%	1%	0.0	0%	0%
Total	100%	100%		14.5%	16.1%

Even if the indicated reductions are indicated with one decimal it shall be kept in mind that it is based on estimates and only intend to indicate the order of magnitude.

#### 4. Conclusion

The estimated cost saving when removing the 6.5 meter wide tube for the pedestrian/cyclists is:

- On alignment 12200 (east-west):
  - For the H6 alternative: 10% to 15%.
  - For the H5 alternative: 12% to 17%; provided that no emergency exits are required from the traffic tube (this is a deviation from the requirements, which states that tunnels longer than 500m must have emergency exits). If emergency exits are required, no cost saving can be achieved for this alternative.
- On alignment 16730 (south-north):
  - For the H6 alternative: 10% to 15%.
  - For the H5 alternative: 12% to 17%; provided that no emergency exits are required from the traffic tube (this is a deviation from the requirements, which states that tunnels longer than 500m must have emergency exits). If emergency exits are required, no cost saving can be achieved for this alternative.