## Measurement and visual evaluation of the lighting of the Borups Allé tunnel

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## 1. Introduction and conclusions

The Borups Allé tunnel leads from the Hillerød motorway to other roads towards the centre of Copenhagen. It is only about 600 m long but illuminated like a long tunnel because of a bend. It is a double tunnel with two wide driving lanes and a reserve in each direction.

The tunnel in the south-east direction has a signal-controlled junction between the main road and a local road with little traffic about 300 m in front of the tunnel.

Therefore, the traffic towards the tunnel comes in pulses with virtually no traffic in between the pulses. This allows for stays on the road for periods of almost 1 minute. Additionally, the reserves in the tunnel and at the road in front of the tunnel offer safe places in periods with traffic.

This was used to do measurements by means digital images taken with a LMK luminance calibrated camera. The camera was used with a setting that leads to 3 exposures with different exposure times so that the combined picture spans a range of luminance from 0,1 to 10.000 cd $\cdot$ m<sup>-2</sup>.

Additionally, when starting from the local road, one can drive undisturbed towards and through the tunnel to evaluate the tunnel lighting visually. This can even be done conveniently with different driving speeds as there is an easy way to return to the local road and make repeated drives. The driving speeds were, 50, 60, 70 and 80 km/h The maximum driving speed is normally 60 km/h but can be controlled by variable message signs.

The authors of this note carried out the measurements and the evaluations described below on Friday 9 September 2022. It was a nice weather with sunlight on thin clouds above the tunnel.

The conclusions are that the Borups Allé tunnel has a very good tunnel lighting and that both drivers could approach and drive through the tunnel in comfort at any of the driving speeds. The lows speeds gave the most comfort as could be expected.

The excel file "Analysis of tunnel lighting based on visual performance and visual comfort" shows that even old drivers are offered a visibility level of at least 12 in the lighting conditions of the Borups Allé tunnel.

## 2. Measurements

Figure 1 shows a digital picture taken at a position of approximately 300 m in front of the tunnel entrance. The total of 9 pictures are shown are shown in annex A.

NOTE: Additional pictures, for instance a full set with the camera placed in the second driving lane, are not shown.



Figure 1: Digital picture.

The distance of the camera from the tunnel entrance in the individual pictures are shown in table 1. These are obtained by triangulation based on the width of the tunnel entrance, and by counting the lines in the broken lane line. A negative value means that the location of the camera in inside the tunnel.

Picture:	1	2	3	4	5	6	7	8	9
Distance (m):	299	255	210	165	120	76	32	-12	-58

Table 1: The distances of the camera from the tunnel entrance in the individual pictures.

For each location outside the tunnel, the  $L_{20}$  value has been determined as the average luminance within the circle shown in figure 2. The  $L_{20}$  values are shown in table 2.

NOTE: It is possible to also determine the L<sub>seq</sub> value, but this is assumed not to bring valuable additional information.



Figure 2: Determination of L<sub>20</sub>.

Table	2: Val	ues	of	L <sub>20</sub> .
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Picture:	1	2	3	4	5	6	7	8	9
L <sub>20</sub> (cd·m <sup>-2</sup> )	5265	4653	5224	5347	5245	4633	1571	-	-

However, the  $L_{20}$  values must be calculated and applied at the relevant stopping distances. These are derived by interpolation and shown in table 3.

Further, the threshold luminance  $L_{th}$  is measured in picture 7 as the luminance of the road surface just inside of the tunnel entrance. The value is 388 cd·m<sup>-2</sup>. Using this value, the k factors are calculated and added to table 3.

Table 3: Driving speeds	s, stopping	distance, L <sub>20</sub>	values and	k factors.
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Driving speed (km/h)	50	60	70	80
Stopping distance (m)	51	66	84	103
L <sub>20</sub> value (cd·m <sup>-2</sup> )	2885	3974	4745	5007
k factor (Lth/L20)	0,134	0,098	0,082	0,077

Table 4 in CIE 88:1990 "Guide for the lighting of road tunnel and underpasses" recommends k factor values of 0,05 or 0,06 for the stopping distances of table 3. This shows that the Borups Allé tunnel has a

generously high value of L<sub>th</sub>. Actually, the lighting is good all through the threshold zone, the transition zone and the interior zone.

By means of the excel file "Analysis of tunnel lighting based on visual performance and visual comfort" it is shown that even older drivers get a visibility level of at least 12 throughout the Borups Allé tunnel.

## 3. Visual appraisal of the lighting

The authors drove towards and through the tunnel repeatedly at driving speeds og 50, 60, 70 and 80 km/h. At all these drives, there was a feeling that one can look into the tunnel during the approach. There was no discomfort at the low driving speeds, but some at the higher driving speeds.

Annex A: Digital pictures simulating a drive towards and into the Borup Allé tunnel

Figure A.1







Figure A.2

Figure A.3



Figure A.4

Figure A.4

Figure A.6



Figure A.7

Figure A.8

Figure A.9