Relationship between lighting levels and vehicle speed in the urban area of Ljubljana

Lanlan Wei, Matej Bernard Kobav, Grega Bizjak

University of Ljubljana

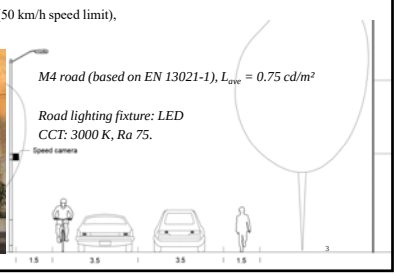
October 2021

Two hypotheses:

a. Vehicle speed decreases as the illuminance/luminance decreases.
b. Vehicle speed at night is lower than during the day time.

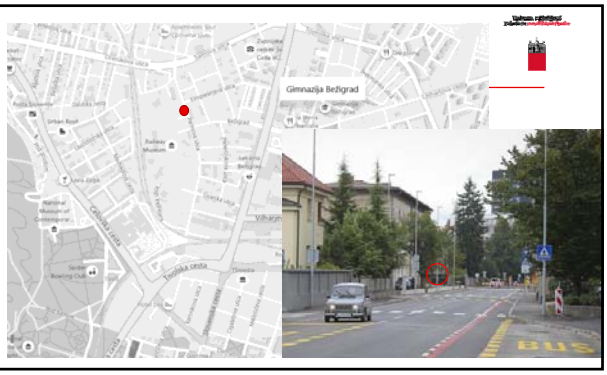
Camera location

Parmova street, Ljubljana Bežigrad (50 km/h speed limit),
Installation height: 2.5 m



M4 road (based on EN 13021-1), L_{ave} = 0.75 cd/m²

Road lighting fixture: LED
CCT: 3000 K, Ra 75.



1 Database

Define the important relevant variables and the structure of the database

Group 1: Traffic volume
1. Time 1 (Record data time based on vehicle time)
2. Speed
3. Type of vehicle
4. etc.

Group 2: Precipitation
1. Time 2 (Record data time based half hour)
2. Precipitation amount
3. etc.

Group 3: Sunset
1. Time 3 (by day)
2. Sunrise
3. Sundown

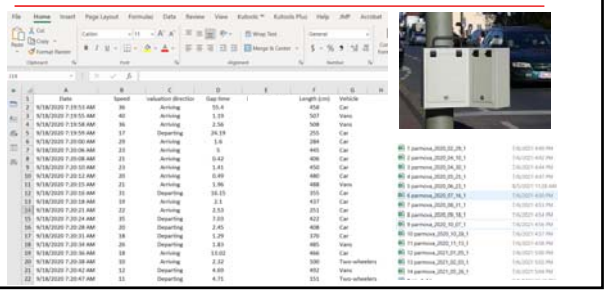
Group 4: Artificial lighting level
1. Time 4 (by day)
2. Level 1
3. Level 0.8
4. Level 0.6

Database

	Group 1	Group 2	Group 3	Group 4
1				
2				
3				
.				
.				

5

1.1 Traffic volume data, Group 1



1.2 Precipitation data, Group 2

Lighting level – Speed analysis will exclude times with wet road

7

1.3 Sunset / sunrise data, Group 3

	A	B
1	Calculation of local times of sunrise, solar noon, and sunset based on the calculation procedure by NOAA (http://www.srrb.noaa.gov/highlights/sunrise/sunrise.html)	
2		
3	**Input**	
4	latitude in decimal degrees (positive in northern hemisphere)	46.600
5	longitude in decimal degrees (negative for western hemisphere)	14.683
6	year	2021
7	month	5
8	day	13
9	time zone in hours relative to GMT/UTC (PST= -8, MST= -7, CST= -6, EST= -5)	2
10	daylight savings time (no= 0, yes= 1)	0
11		
12	**Output (local time in days)**	
13	sunrise	5:29 AM
14	sunset	8:26 PM

8

1.4 Artificial lighting level, Group 4

	A	B	C	D
1	Date	Month	Year	Lighting level
2	29	2	2020	1
3	1	3	2020	1
4	2	3	2020	1
5	3	3	2020	1
6	4	3	2020	1
7	5	3	2020	1
8	6	3	2020	1
9	7	3	2020	1
10	8	3	2020	1

1.0, 100% output, from February 29, 2020, to August 3, 2020;
0.8, 80% output, from August 4, 2020, to December 21, 2020;
0.6, 60% output, from December 22, 2020, to February 4, 2021.

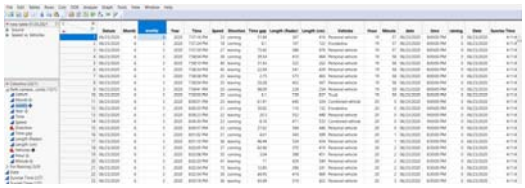
... 0.8

... 0.6

9

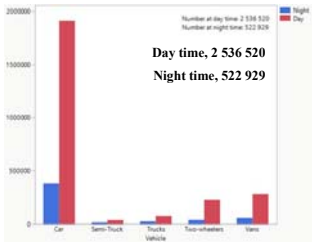
1.5 Data integration, edit

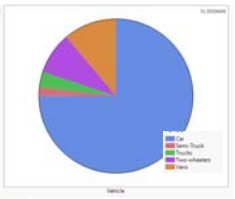
Data integration, edit, and analysis based on Excel and JMP® 15.2.1.
Totally **3 059 449 vehicles** was measured during this experiment, **from Feb. 2020 to Feb. 2021**



10

2 Results and explanation

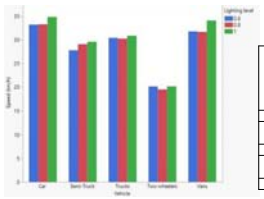




75 % cars, 11 % vans, 9 % two-wheelers such as motorcycles or bicycles, 3 % trucks, and 2 % semi-trucks.

11

a. Lighting level-speed relationship

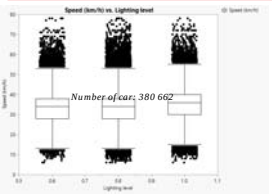


Type of vehicle	Lighting level 100 % (n=100 542)		Lighting level 80 % (n=257 242)		Lighting level 60 % (n=135 398)	
	Average	*SD*	*Average*	*SD*	*Average*	*SD*
Car	34.80	8.60	33.27	8.12	32.22	8.19
Semi-Truck	29.56	4.68	29.07	4.87	28.73	4.86
Trucks	30.82	7.93	30.25	6.91	30.45	7.17
Two-wheelers	20.12	9.14	19.47	7.77	19.73	8.16
Vans	34.06	8.24	31.65	7.69	32.33	7.89

Distribution of speed of vehicles with different lighting levels

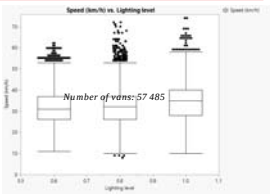
(1 represents the lighting output of 100 %, 0.8 represents dimming to 80 % output, and 0.6 represents dimming to 60 % output)

a. Lighting level-speed relationship



Vehicle type: Car

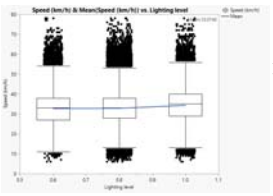
Lighting level 1,0-0.8-0.6, speed is 34.8 km/h-33.3 km/h-33.2 km/h.
7.6 % speed decrease when lighting level from 100% to 80%.



Vehicle type: Vans

Lighting level 1-0.8-0.6, speed is 34.1 km/h-31.7 km/h-32.3 km/h.
7.0 % speed decrease when lighting level from 100% to 80%.

a. Lighting level-speed relationship



Vehicles without two-wheeler

Minus Minus Minus

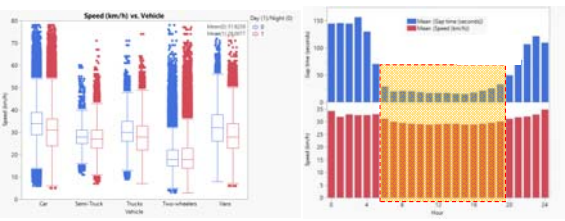
All vehicle data – wet road situation – daytime – two wheeler

from 100 % to 80 %, then to 60 %, the speed with the following function:

Speed = 29.65 + 3.10 * Lighting level.

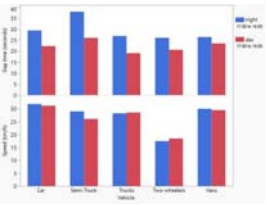
14

b. Distribution of vehicle speed (day/night)



15

b. Distribution of vehicle speed (day/night)



Vehicle	Nighttime speed		Daytime speed		Difference
	Average	*SD*	*Average*	*SD*	
Car	**33.56**	8.22	**30.27**	8.18	3.29
Semi-Truck	**28.09**	5.66	**24.08**	6.23	4.01
Trucks	**28.10**	7.37	**28.52**	7.72	-0.42
Two-wheelers	**19.65**	8.21	**19.74**	8.18	-0.09
Vans	**32.10**	7.96	**28.83**	7.41	3.27

Day-night difference of the speed of different types of vehicles

17:00 to 18:00, September 1, 2020 to September 7, 2020, day time
17:00 to 18:00, December 1, 2020 to December 7, 2020, night time

16

Summary

a. Decrease of the illuminance/luminance will affect the vehicle speed. The effect is more noticeable when the lighting level is reduced from 100 % to 80 % (from L_{ave} = 0.75 cd/m² to L_{ave} = 0.60 cd/m²) as when the lighting level is reduced from 80 % to 60 % (from L_{ave} = 0.60 cd/m² to L_{ave} = 0.45 cd/m²).

b. The speed during the day is lower than the speed during the night, because the volume of traffic is lower and the distance between vehicles is larger at night.

17

Thank you

Laboratory of Lighting and Photometry
Faculty of Electrical Engineering
University of Ljubljana

Lanlan Wei, *lanlan.wei@fe.uni-lj.si*
Matej Bernard Kobav, *matej.kobav@fe.uni-lj.si*
Grega Bizjak, *grega.bizjak@fe.uni-lj.si*

October 2021