THE ROLE OF TRAFFIC SPEED RANGE IN ROAD SAFETY

THE CASE OF TWO-LANE RURAL HIGHWAYS

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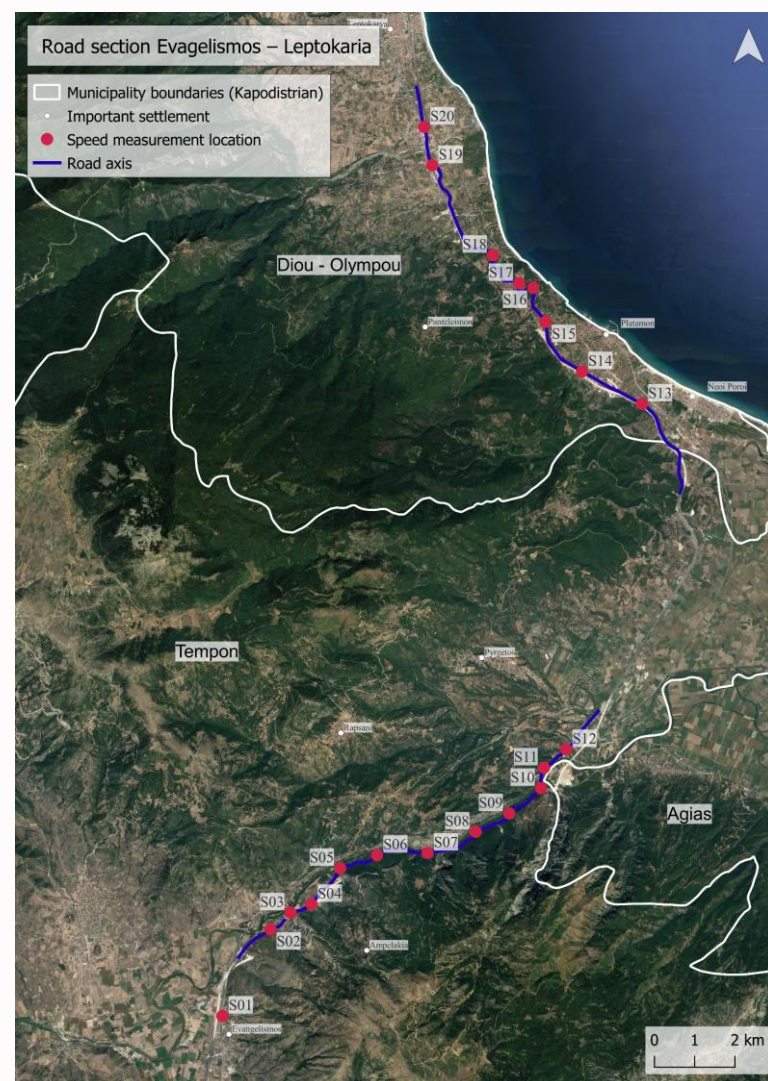
Objective of the Study

- Demonstrate the hazard correlation of a horizontal curve in relation to the variation of spot speed of travelling passenger cars and heavy vehicles
- Highlight differences and similarities between passenger cars and heavy vehicles, as well as between daytime and nighttime speeds.
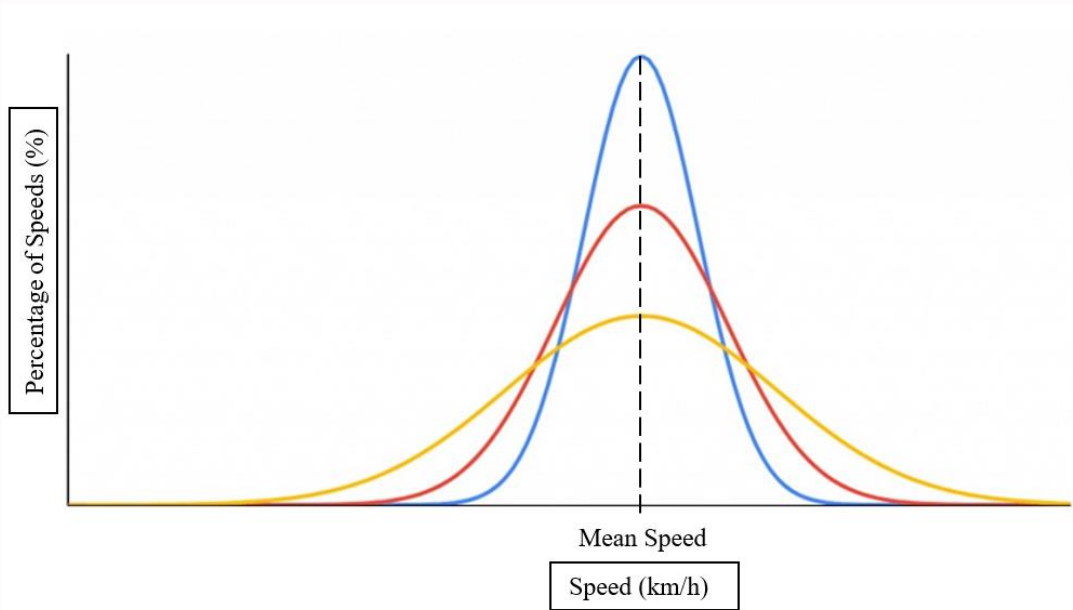
Theoretical Framework

- Free flow speeds follow the normal distribution.
- As dispersion increases the road safety level decreases.
- Parameters such as range, gradient, width and height of the diagram determine the dispersion.

Data Collection

Road section Evagelismos – Leptokaria

Legend:
- Municipality boundaries (Kapodistrian)
- Important settlement
- Speed measurement location
- Road axis

Road section:

- Two-lane rural highway

- Approximately 35km length

- Daily traffic volume approaches 10,000 vehicles

Traffic speed measurements:

- 20 locations

- 24-hour measurements 17 - 20 May 2016
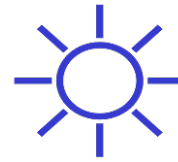
- 13 vehicle categories
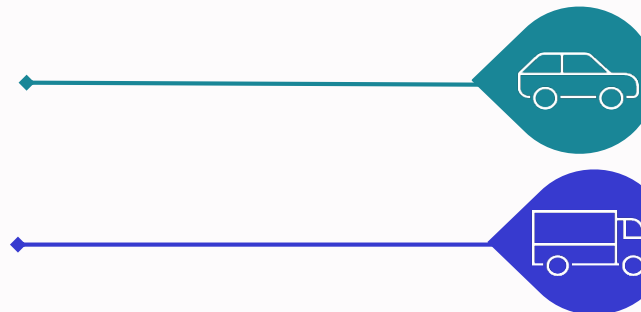
PC - Passenger Cars

HV - Heavy Vehicles (> 4 axles)

Data Analysis - Speed data processing

Free flow conditions

Only the cases with a headway greater than 6 seconds were utilized

Day-time

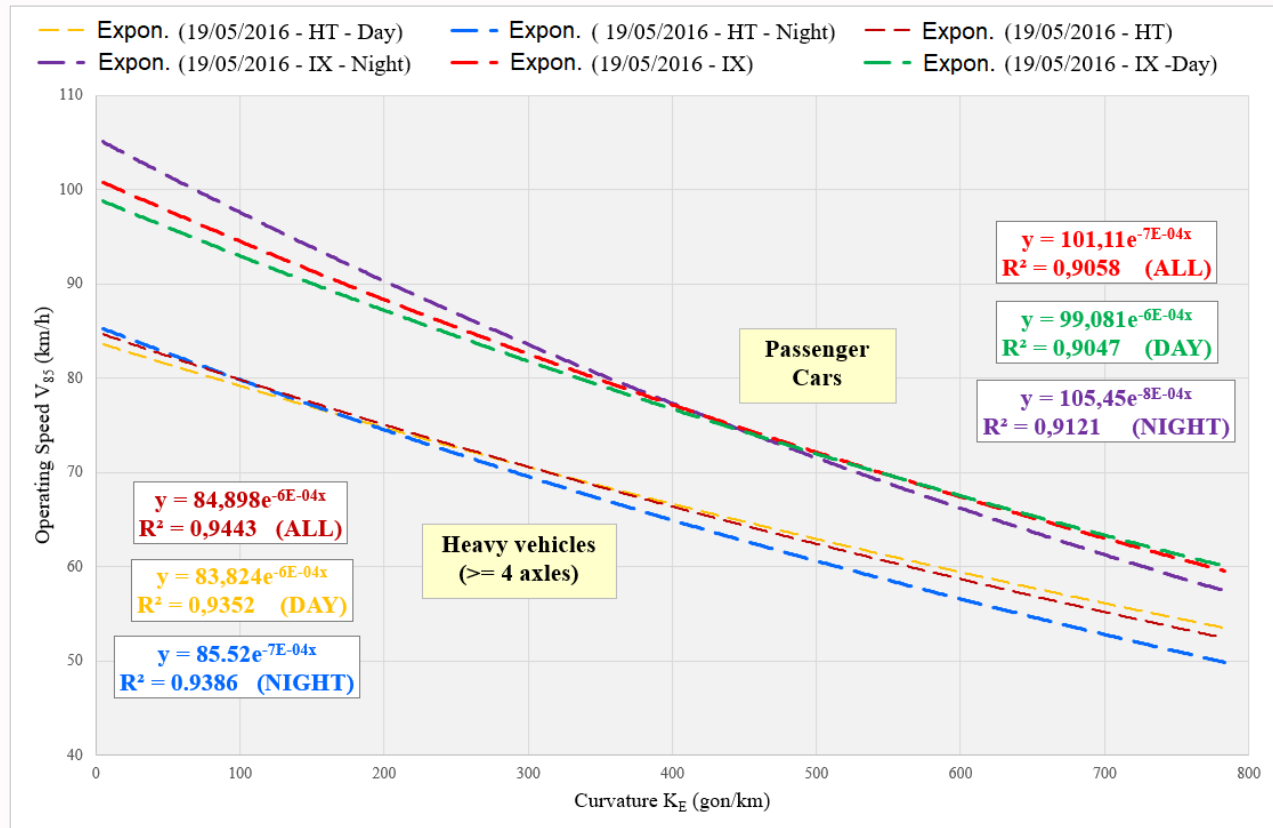Only passing vehicle data from 08:00 to 19:00 were utilized

Night-time

Only passing vehicle data from 22:00 to 06:00 were utilized

Data Analysis - Speed data processing

Legend:
- Expon. (19/05/2016 - HT - Day)
- Expon. (19/05/2016 - HT - Night)
- Expon. (19/05/2016 - HT)
- Expon. (19/05/2016 - IX - Night)
- Expon. (19/05/2016 - IX)
- Expon. (19/05/2016 - IX -Day)

Passenger Cars:
$$y = 101{,}11e^{-7E-04x}$$
$$R^2 = 0{,}9058 \quad (ALL)$$

$$y = 99{,}081e^{-6E-04x}$$
$$R^2 = 0{,}9047 \quad (DAY)$$

$$y = 105{,}45e^{-8E-04x}$$
$$R^2 = 0{,}9121 \quad (NIGHT)$$

Heavy vehicles (>= 4 axles):
$$y = 84{,}898e^{-6E-04x}$$
$$R^2 = 0{,}9443 \quad (ALL)$$

$$y = 83{,}824e^{-6E-04x}$$
$$R^2 = 0{,}9352 \quad (DAY)$$

$$y = 85{,}52e^{-7E-04x}$$
$$R^2 = 0.9386 \quad (NIGHT)$$

Operating Speed V_{85} (km/h) vs Curvature K_E (gon/km)

Relation between V_{85} and KE

- PC present higher speeds than HV regarding to all curvature values

- Speed of PC during nighttime is significantly higher at higher horizontal radius values and about 5-6 km/h higher than those of daytime in tangents

- At smaller horizontal curves, speeds during nighttime are lower than those of daytime for both PC and HV

Data Analysis - Speed data processing

- Coefficient of Variation

$$CV = \frac{\sigma}{\mu}$$

Higher values, regarding to common or identical operating speeds (V_{85}), leads to a reduced provided road safety level.
(J. Mason et al. TRB 2011)

- Normal Distribution Gradient

$$NDG = \pm \frac{\alpha}{\sigma^2 \cdot \sqrt{2 \cdot \pi}} \cdot e^{-0.5}$$

α = the step of speed selected

Defined in the context of this research as the gradient of the diagram «*Speed (km/h) – Percentage of passing vehicles*».

Theoretically, while NDG obtains higher values (i.e. for smaller variation of spot speed range) the provided level of road safety is increased.
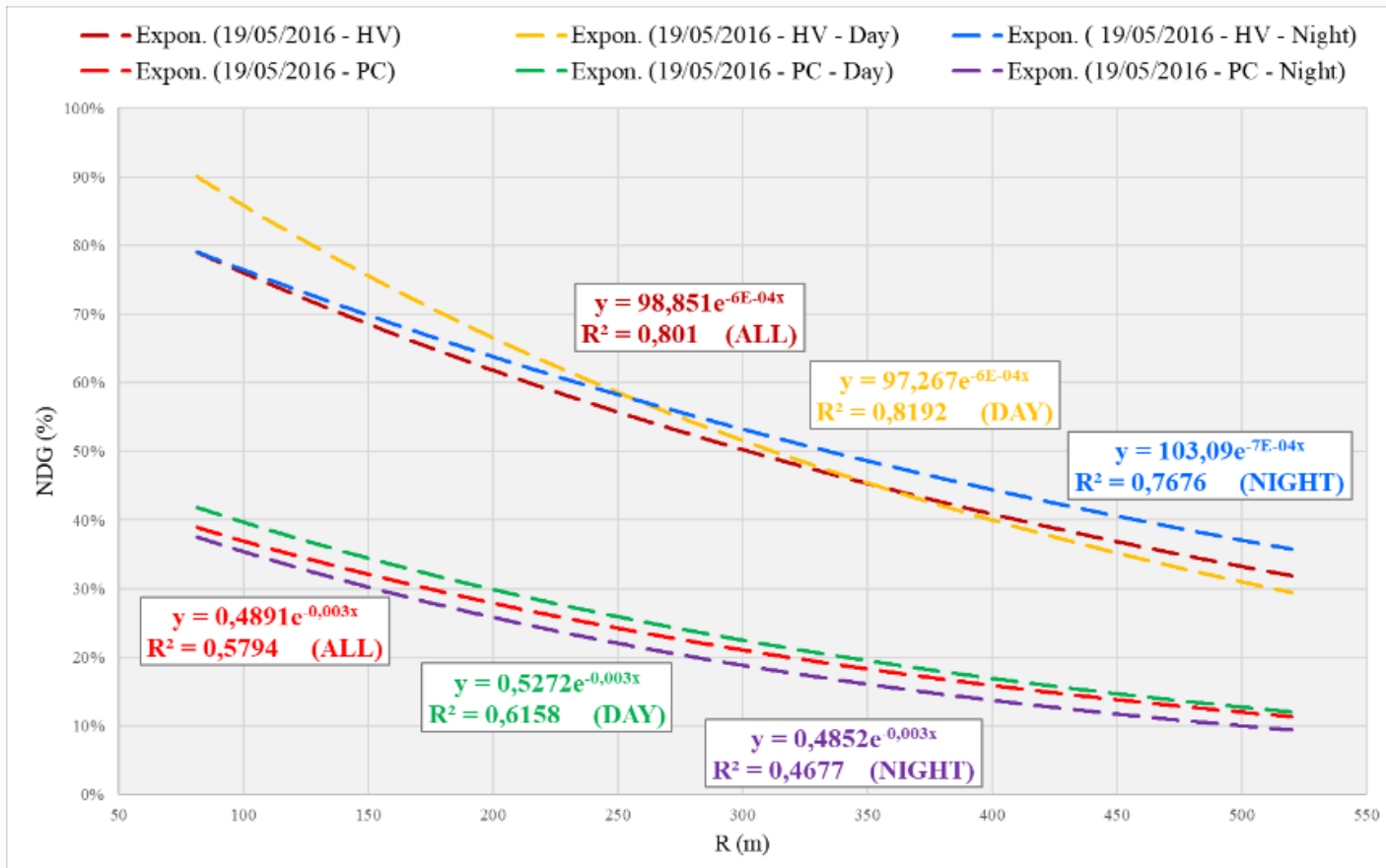
Normal Distribution Gradient (NDG)
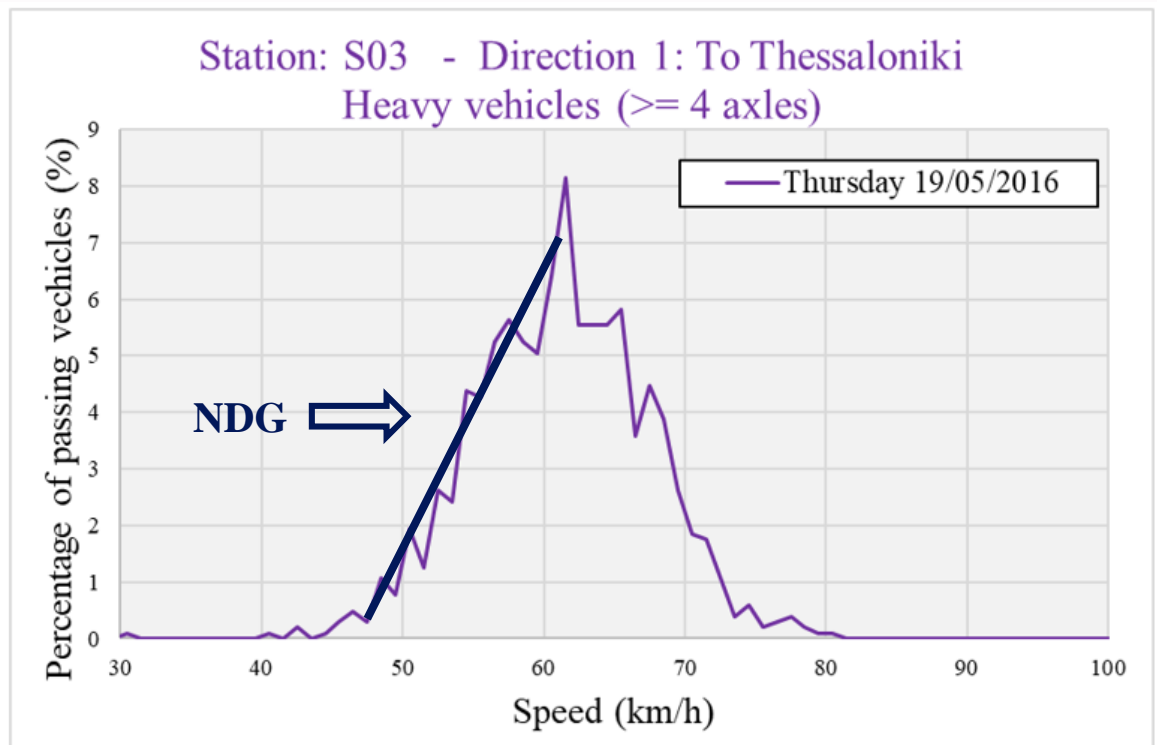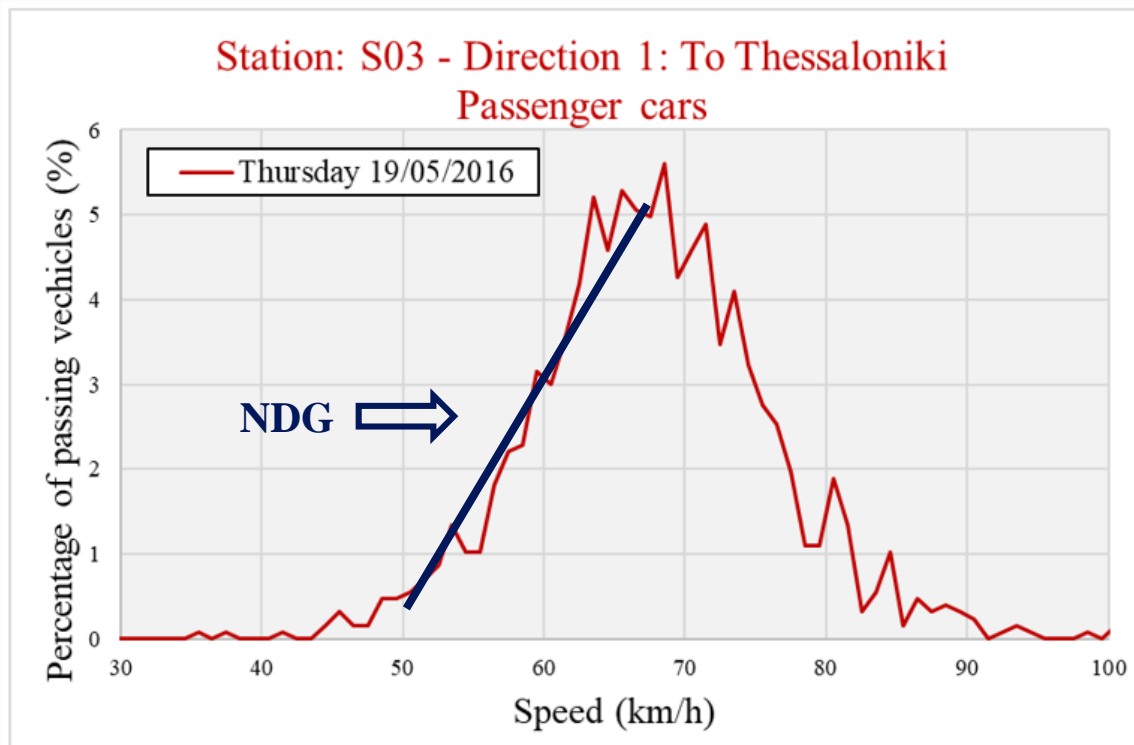
Indicative spot speed variation diagrams

Correlation between R and NDG

- NDG values are particularly high in the case of HV (almost doubled) compared to PC.

- NDG values during daytime are higher than those of nighttime regarding to PC. This observation is confirmed for HV only at larger horizontal radii.

- Dispersion of HV speeds is remarkably lower than dispersion of PC speeds, which is also confirmed by standard deviation's values.

Data Analysis - Methodologies and software

- Criterion II

It evaluates road safety level of a horizontal curve based on the deviation between operating speeds of two consecutive and independent geometric elements of the road .

For higher difference between the successive operating speeds (V_{85}), the provided road safety level is reduced.

- Predicted accidents according to CPM model of IHSDM software

"Crash prediction model" CPM, determines, based on a mathematical model, the accidents that are expected to occur per geometrical element of the road in the next 5 years.

For higher number of predicted accidents, the provided road safety level is reduced.

- FM 19 Software

The software is based on the same philosophy with Criterion II but is taking into account more parameters for the evaluation of the road safety level.

For higher software's value, the provided road safety level is reduced.

Results analysis and hierarchy

Direction	Location	R (m)	KE (gon/km)	Criterion II	FM19 Rank	Predicted accidents IHSDM	Passenger cars					Heavy Vehicles (>= 4 axles)				
							V85 (km/h)	Vμ (km/h)	S (km/h)	CV	NDG	V85 (km/h)	Vμ (km/h)	S (km/h)	CV	NDG
1	S4	250	254,8	-17,37	41,78	1,33	90,01	77,62	12,19	15,70%	16,29%	74,15	68,20	6,13	8,99%	64,33%
1	S5	160	398,125	-17,19	65,17	1,44	72,76	66,13	7,10	10,74%	47,94%	66,28	60,96	5,07	8,31%	94,28%
1	S6	180	353,88889	-14,51	53,56	1,74	76,14	67,68	8,82	13,03%	31,13%	67,59	61,58	5,78	9,39%	72,36%
1	S7	600	106,16667	-0,57	14,47	0,84	86,71	76,69	11,06	14,42%	19,78%	74,44	67,79	6,52	9,62%	56,87%
1	S8	120	530,83333	-26,48	76,89	2,07	63,54	56,26	7,96	14,14%	38,23%	60,10	52,86	7,98	15,09%	38,01%
1	S9	120	530,83333	-15,72	63,19	3,42	68,64	60,57	8,29	13,69%	35,18%	59,55	53,98	5,44	10,08%	81,69%
1	S10a	135	471,85185	-15,95	62,85	1,47	74,87	65,65	9,24	14,08%	28,32%	63,84	58,35	5,37	9,20%	83,93%
1	S10b	135	471,85185	-15,95	62,85	1,47	78,70	68,86	10,37	15,05%	22,51%	67,50	61,83	5,67	9,17%	75,26%
1	S11	230	276,95652	-13,59	54,45	0,93	77,90	69,75	8,58	12,30%	32,90%	69,61	63,86	5,72	8,95%	74,02%
1	S12a	280	227,5	0,00	42,94	1,07	79,79	69,40	11,11	16,01%	19,59%	72,51	65,77	6,79	10,32%	52,51%
1	S12b	170	374,70588	-7,78	40,30	2,59	76,34	66,25	11,65	17,59%	17,82%	70,82	64,25	6,58	10,23%	55,97%
1	S13a	520	122,5	-6,48	34,97	0,69	96,23	83,00	12,10	14,58%	16,52%	80,57	73,45	7,24	9,86%	46,11%
1	S13b	13000	4,9	0,92	0,67	0,53	97,21	83,00	13,64	16,44%	13,00%	81,90	75,03	7,00	9,33%	49,42%
1	S15	370	172,16216	-10,51	17,91	0,80	91,65	78,07	13,60	17,42%	13,08%	75,10	65,09	10,39	15,96%	22,41%
1	S16	81,3	783,51784	-21,35	64,33	1,67	64,17	57,12	7,04	12,33%	48,79%	51,73	46,90	4,86	10,36%	102,48%
2	S4	250	254,8	-17,37	41,78	1,33	86,56	75,40	11,20	14,85%	19,29%	71,66	65,18	6,70	10,27%	53,98%
2	S5	160	398,125	-17,19	65,17	1,44	74,01	66,27	8,08	12,19%	37,06%	66,15	61,02	5,25	8,60%	87,88%
2	S6	180	353,88889	-14,51	53,56	1,74	76,43	68,69	8,60	12,53%	32,69%	67,82	61,82	5,74	9,29%	73,40%
2	S7	600	106,16667	-0,57	14,47	0,84	83,30	74,18	10,97	14,79%	20,11%	73,13	66,72	6,27	9,40%	61,54%
2	S8	120	530,83333	-26,48	76,89	2,07	68,78	60,40	8,51	14,09%	33,40%	59,14	53,67	5,27	9,81%	87,22%
2	S9	120	530,83333	-15,72	63,19	3,42	69,35	61,82	7,75	12,54%	40,29%	59,50	54,36	5,42	9,96%	82,52%
2	S10a	135	471,85185	-15,95	62,85	1,47	74,66	65,01	10,12	15,57%	23,63%	62,60	56,51	6,26	11,08%	61,69%
2	S10b	135	471,85185	-15,95	62,85	1,47	80,42	70,76	10,35	14,63%	22,59%	68,28	61,97	6,34	10,23%	60,18%
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2	S12a	280	227,5	0,00	42,94	1,07	82,23	71,97	10,45	14,51%	22,17%	71,43	64,35	6,98	10,84%	49,73%
2	S12b	170	374,70588	-7,78	40,30	2,59	88,30	76,52	11,80	15,42%	17,37%	75,73	68,28	7,39	10,83%	44,27%
2	S13a	520	122,5	-6,48	34,97	0,69	101,42	86,41	14,52	16,80%	11,48%	85,28	77,28	7,41	9,58%	44,11%
2	S13b	13000	4,9	0,92	0,67	0,53	106,62	91,40	15,42	16,87%	10,17%	88,49	81,36	7,58	9,31%	42,15%
2	S15	370	172,16216	-10,51	17,91	0,80	90,03	76,10	14,11	18,54%	12,16%	71,46	62,34	10,30	16,52%	22,83%
2	S16	81,3	783,51784	-21,35	64,33	1,67	59,86	53,57	6,47	12,09%	57,72%	53,29	47,30	5,87	12,42%	70,17%

Low risk

Moderate risk

High risk

Very high risk

- Connection between CV, NDG and all software results for both types of vehicle

Connection between software results

Connection between CV and NDG for both types of vehicle

	Criterion II	FM19 rank	Predicted accidents IHSDM	CV	NDG - Passenger vehicles	NDG - Heavy vehicles
Low risk - green	> 0	< 25	< 1	< 0,13	> 0,3	> 0,75
Moderate risk -yellow	Between 0 and -10	Between 25 and 50	Between 1 and 2	Between 0,13 and 0,16	Between 0,3 and 0,2	Between 0,75 and 0,5
High risk - orange	Between -10 and -20	Between 50 and 75	Between 2 and 3	Between 0,16 and 0,19	Between 0,2 and 0,1	Between 0,5 and 0,25
Very high risk - red	< -20	> 75	> 3	> 0,19	< 0,1	< 0,25

Correlation of NDG with the provided road safety level - Passenger Cars

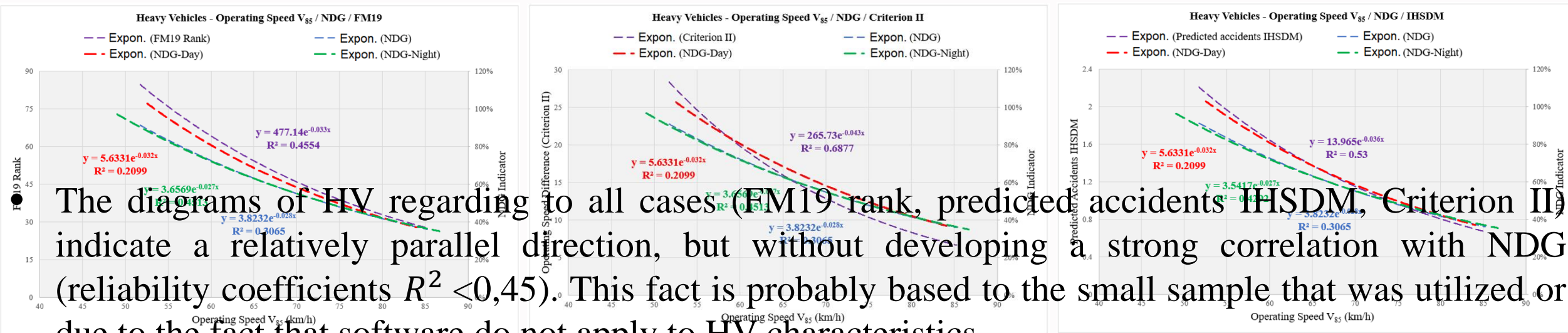Correlation between NDG and FM19 rank, Criterion II and predicted accidents IHSDM according to V85 variation
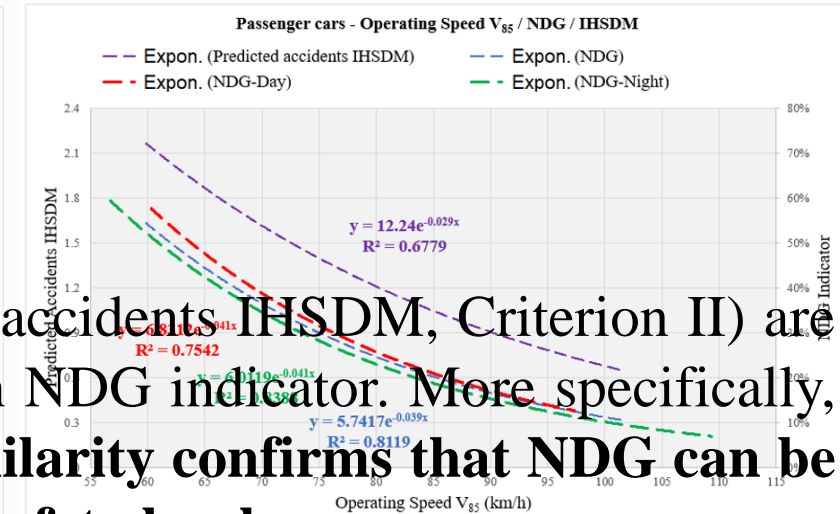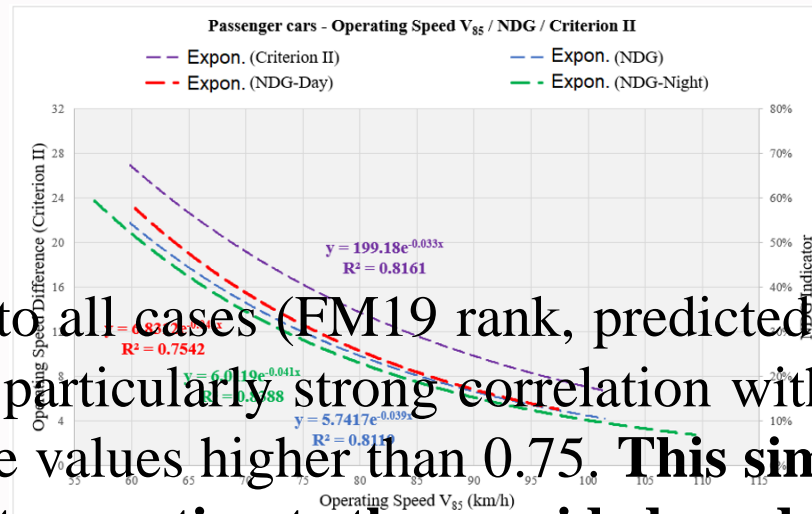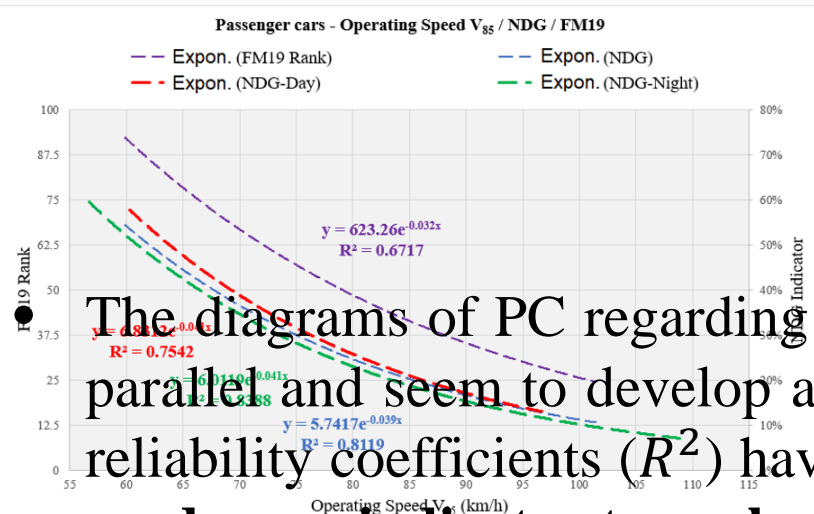
- The diagrams of PC regarding to all cases (FM19 rank, predicted accidents IHSDM, Criterion II) are parallel and seem to develop a particularly strong correlation with NDG indicator. More specifically, reliability coefficients (R^2) have values higher than 0.75. **This similarity confirms that NDG can be used as an indicator to evaluate or estimate the provided road safety level.**

- Indicator's values (NDG) concerning to PC appear to be higher during daytime and lower during nighttime, which shows that the speeds dispersion is more intense during day than night.

Correlation of NDG with the provided road safety level - Heavy vehicles

Correlation between NDG and FM19 rank, Criterion II and predicted accidents IHSDM according to V85 variation

- The diagrams of HV regarding to all cases (FM19 rank, predicted accidents IHSDM, Criterion II) indicate a relatively parallel direction, but without developing a strong correlation with NDG (reliability coefficients R^2 <0,45). This fact is probably based to the small sample that was utilized or due to the fact that software do not apply to HV characteristics.

- However, a similarity between NDG and the software results also occurs.

- Indicator's values concerning to HV appear to be significantly higher during daytime and lower during nighttime, which indicates that speeds dispersion is particularly stronger during day than night.

Conclusions

1. The correlation NDG achieved with all software evaluating the provided road safety level seems particularly strong in the case of passenger cars and important in the case of heavy vehicles, which indicates that it can be used as an indicator for estimating/evaluating the provided level of road safety for a single curve or an individual location of a road section. This is very important as it becomes possible to evaluate an individual point/location exclusively by speed measurements and their statistical processing and analysis.

2. The difference in operating speed between heavy and passenger vehicles is about 20km/h in large horizontal curves and tangents and 10km/h in small value radii.

Conclusions

3. Speed during nighttime hours seems to be significantly higher for passenger cars in larger radii and tangents, while at small radii values regarding both types of vehicles speed is slightly lower during nighttime hours.

4. The form and trend in the diagrams of NDG indicator are similar to the corresponding forms and trends of all software evaluating the provided road safety level (FM19, IHSDM, Criterion II), which demonstrates its correlation with the provided safety level of a road section.

Subject for further research

- Confirmation of the present research results by using a larger sample of measurements and more two-lane road categories (national, provincial roads, etc.).

- Evaluation of corresponding speed measurements for highway sections in order to demonstrate correlation similarities and differences between operational speed and critical risk indicators, as well as with the expected and reported accidents.

- Evaluation of differences of research results for other types of vehicles e.g. motorcycles.

- Correlation of research results with available data in order to establish mathematical relationships/equations to define severity of accidents (fatalities, serious/light injuries, PDO) and not only their expected number.

Thank You!