NEW INDICATORS OF RIDING COMFORT BASED ON VEHICLE DYNAMICS

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BACKGROUND & PROBLEM

- Longitudinal unevenness of a road is one of key condition variables included in the Finnish RAMS since late 1980's
- IRI (International Roughness Index) calculated into 100 m intervals has been the index representing the longitudinal unevenness
- Many studies propose that IRI is not the best index concerning riding comfort (Loizos 2007, Kim et a. 2011, Nair et al 2011, Múčka et al 2016)
- The practical experiences in the Finnish Transport Agency support those statements.
    1. Rutting (60%)
    2. Cracks (30%)
    3. IRI (10%)

BACKGROUND & PROBLEM

- Typical statements have been that
  - it does not represent the riding comfort of pavements well enough and
  - it cannot show where the bad sections locate or
  - what the type of roughness is.
- A need/wish to a better index exists.

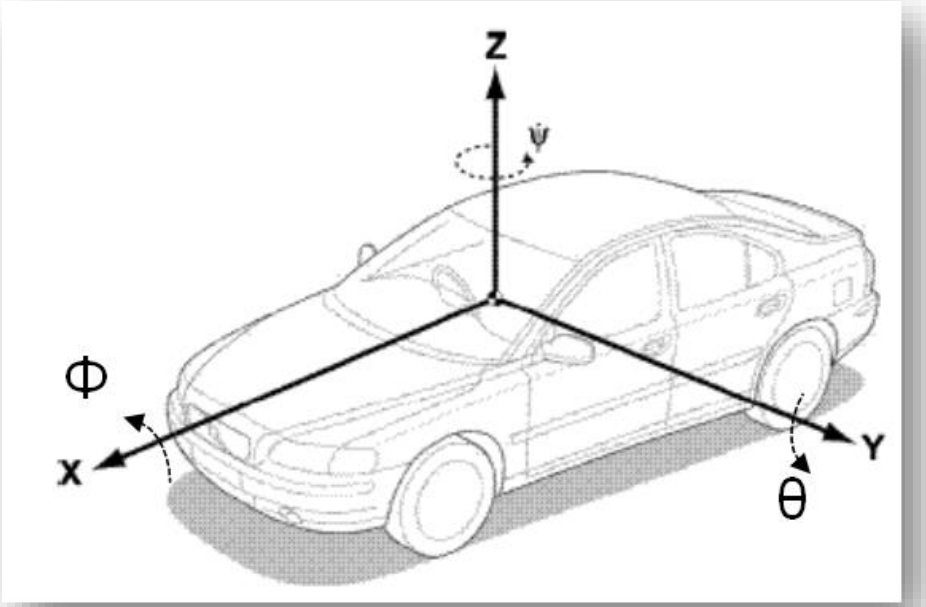
METHODS

- Root Cause Analysis
  - What could be the problem?
- Improving indexes (Simulations)
  - Improving the simulation model by increasing the DOF of the model and calculating new indexes
- Validation of results (MPR & ROC)
  - Analysing the goodness of an index by comparing the simulated outcomes to information from Mean Panel Rating
- Recommending better indicators if any to represent the riding comfort on a road

ROOT CAUSE ANALYSIS

A. Road:
   1. Road is represented by one longitudinal profile only.
   2. The wavelength of longitudinal profile data is filtered to cover wavelengths between 0.5 and 50 m.
   3. Simulated using a constant speed 80 km/h.

B. Model:
   1. Quarter car model can handle only one dimension of movement.
   2. Different suspension parameters than a typical European or Japanese car or a truck.
   3. The suspension system of the driver's seat is not included in the quarter car simulation model.



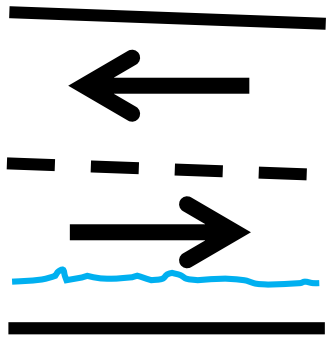
ROOT CAUSE ANALYSIS

C. Outcome:

1. IRI represents the vertical movement of a car chassis which is not the best source for searching factors causing discomfort. ISO 2631 uses vertical accelerations
2. The reporting interval of 100 m is too long to locate poor road sections accurately.
3. It also averages the outcome too much and important transients in roughness cannot be recognized.

IMPROVEMENTS

Source data | Model | Outcome



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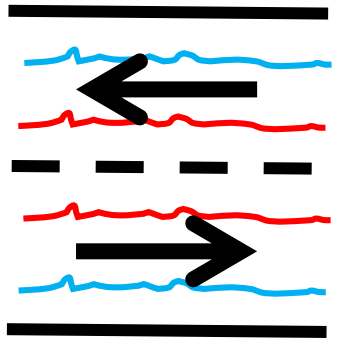
IRI



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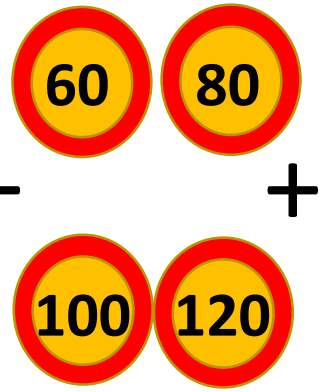

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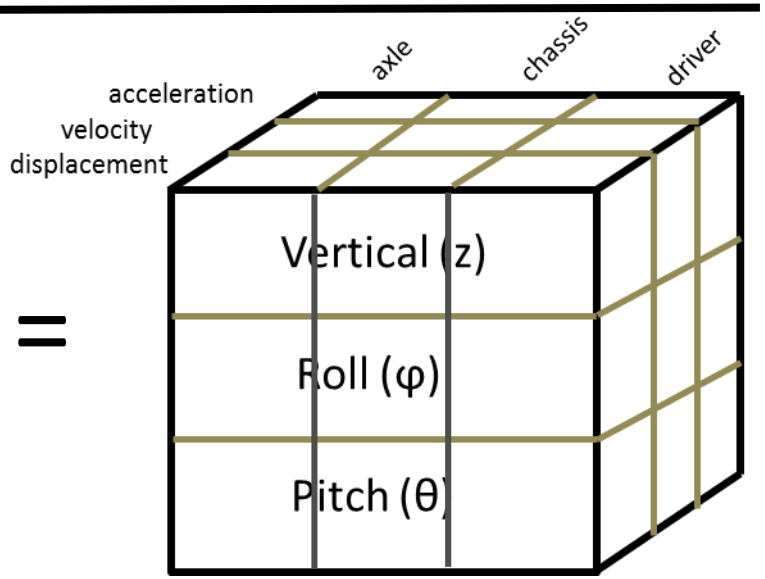


A1, A2 | A3 | B1 | C1, C2

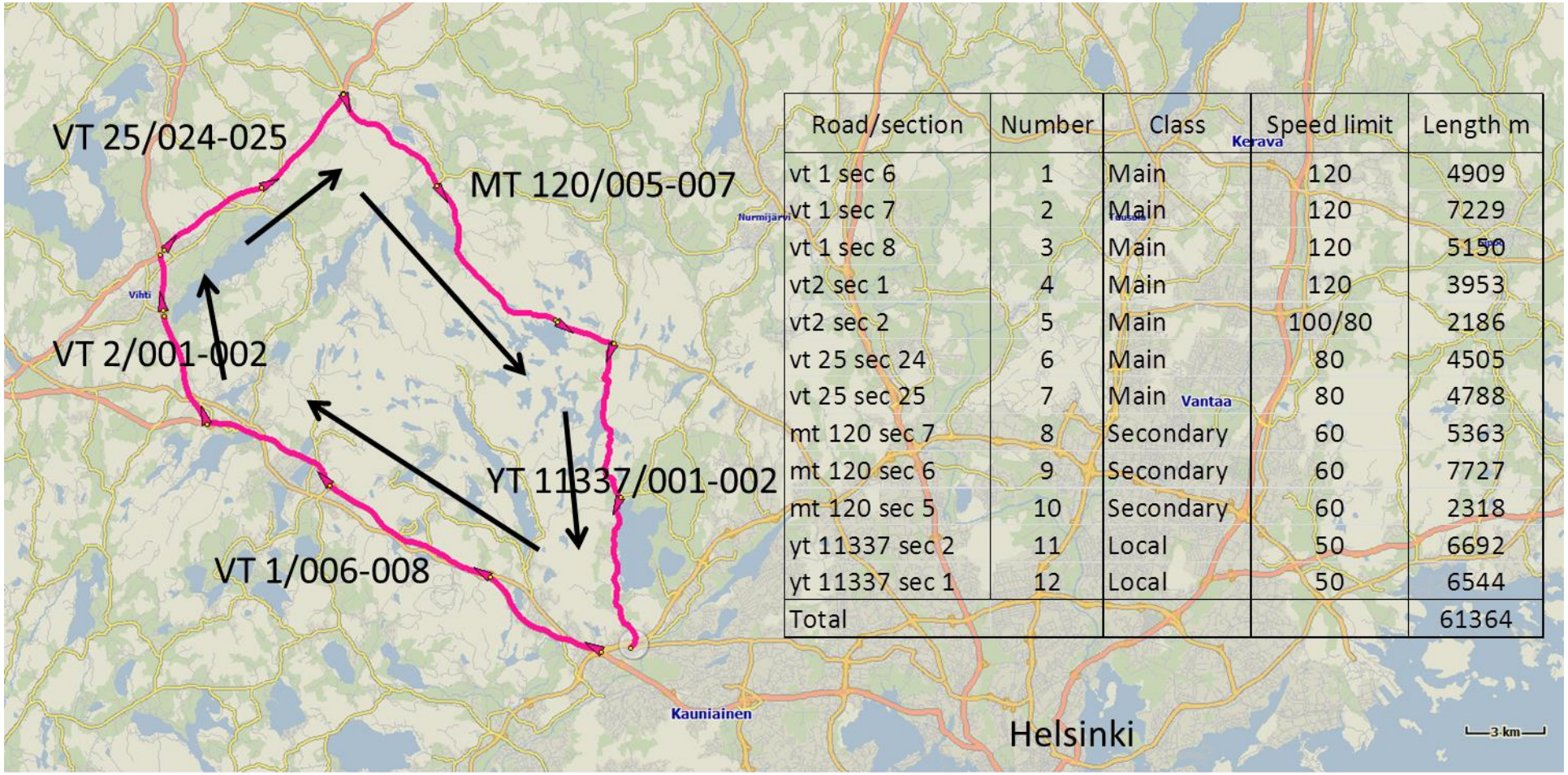
LOTS OF OUTCOMES

Table 2. Indexes

Type of displacement	Displacement	Velocity	Acceleration
Bounce of body	mean, std, max	mean, std, max	mean, std, max
Roll of body	mean, std, max	mean, std, max	mean, std, max
Pitch of body	mean, std, max	mean, std, max	mean, std, max
Combined acceleration of seat including bounce, roll and pitch			rms, std, max
ESAL (Equivalent Standard Axle Load) mean, std, max LTR (Load Transfer Ratio) mean, std, max Energy used in shocks (J/10m)			

37 OUTCOMES

METHODS – SIMULATIONS – MPR - VALIDATION



Road/section	Number	Class	Speed limit	Length m
vt 1 sec 6	1	Main	120	4909
vt 1 sec 7	2	Main	120	7229
vt 1 sec 8	3	Main	120	5150
vt2 sec 1	4	Main	120	3953
vt2 sec 2	5	Main	100/80	2186
vt 25 sec 24	6	Main	80	4505
vt 25 sec 25	7	Main	80	4788
mt 120 sec 7	8	Secondary	60	5363
mt 120 sec 6	9	Secondary	60	7727
mt 120 sec 5	10	Secondary	60	2318
yt 11337 sec 2	11	Local	50	6692
yt 11337 sec 1	12	Local	50	6544
Total				61364

METHODS – VALIDATION

Mean Panel Rating

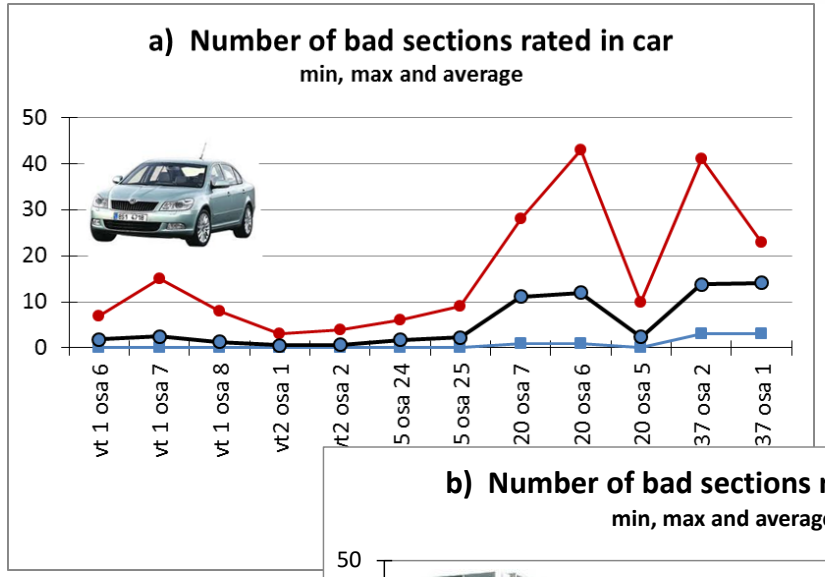
- 11 passengers in a car one by one
- 9 passengers in a truck one by one

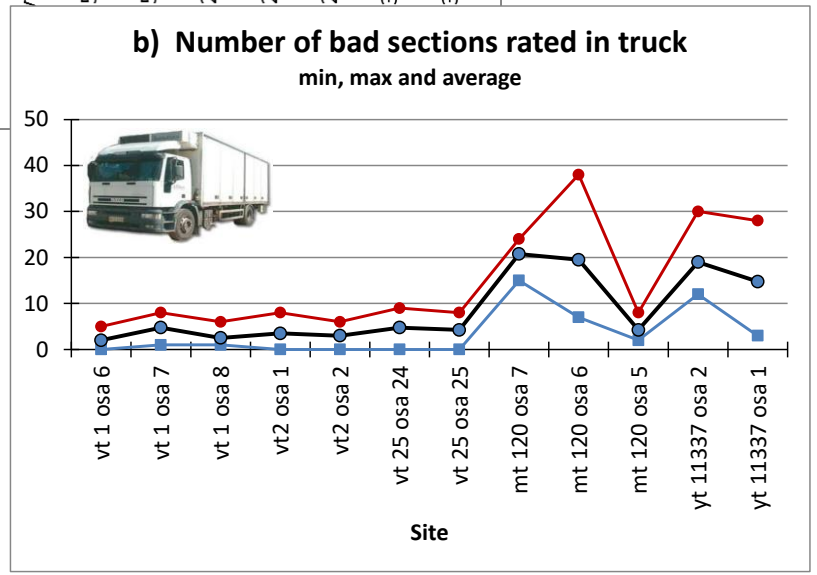
Car

- The average number of bad sections varied according to the site from 1 to 14.

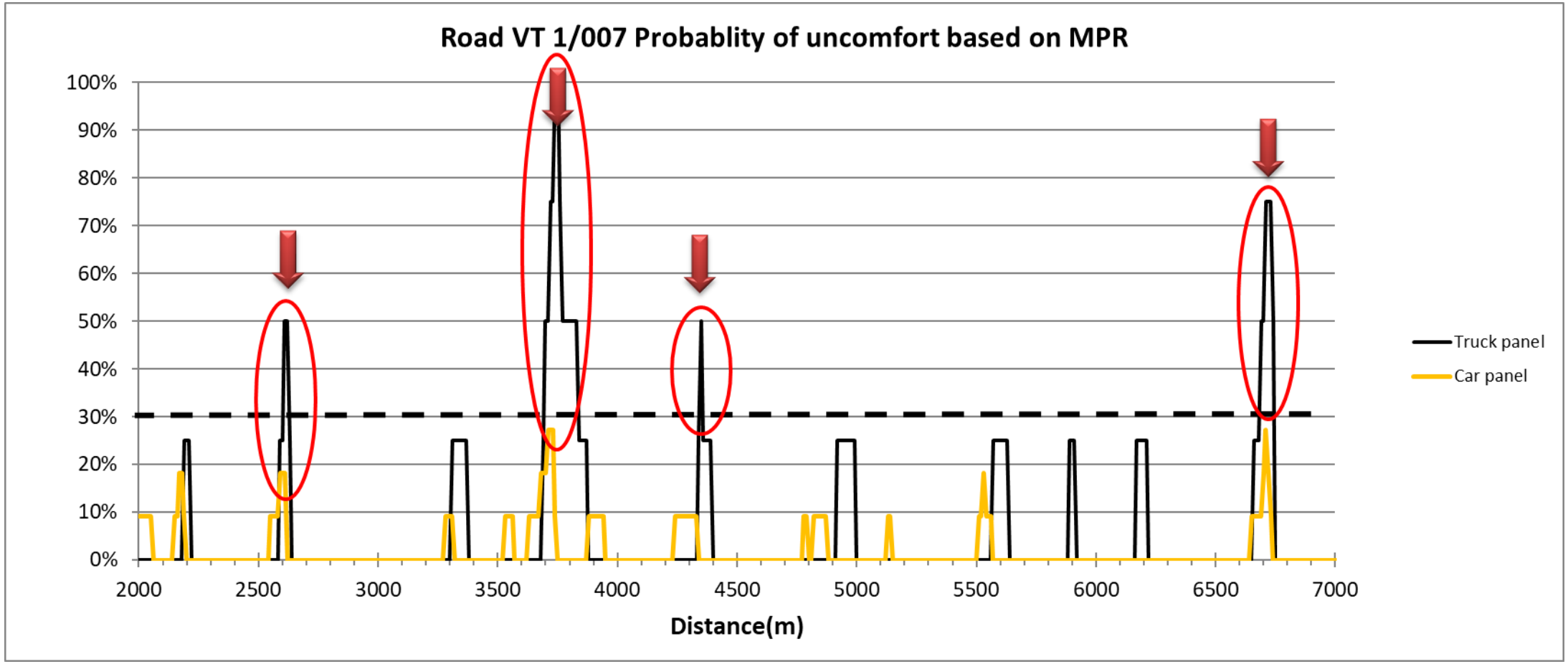
Truck

- The average number of bad sections varied according to the site from 2 to 21.
- Raters in truck gave 60 % more bad (uncomfortable) sections than raters in car.





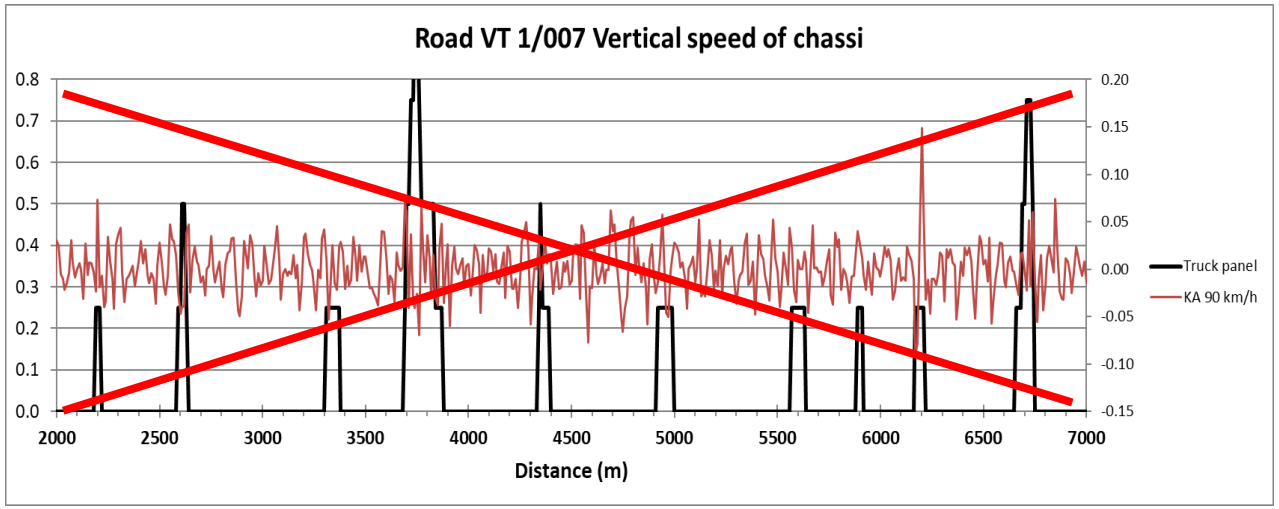
VALIDATION – GRAPHICAL SELECTION

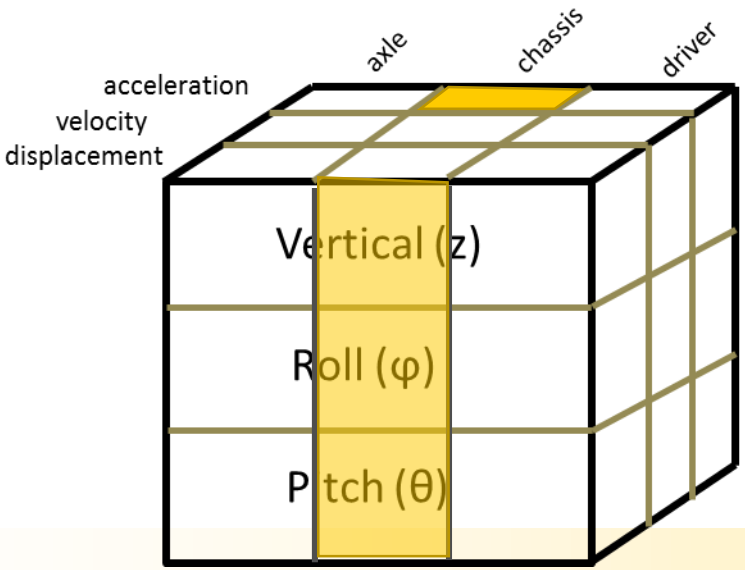


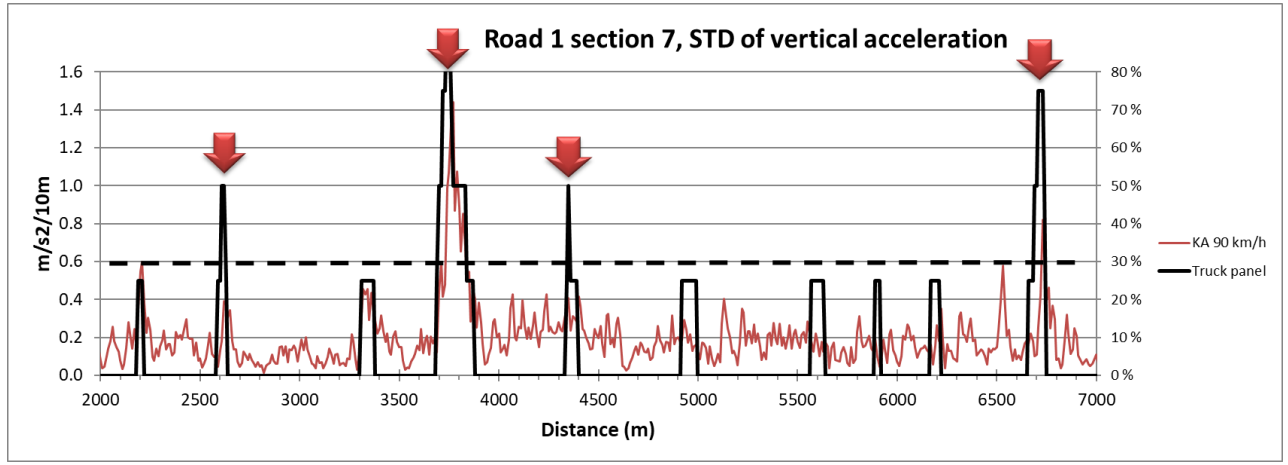
COMPARISON OF MPR-DATA & SIMULATED DATA

Preliminary selection of indicators <u>according to graphs</u>

- Best indicators were selected as bounce, roll and pitch, comb acc
- Best statistical indicators were selected as std of accelerations







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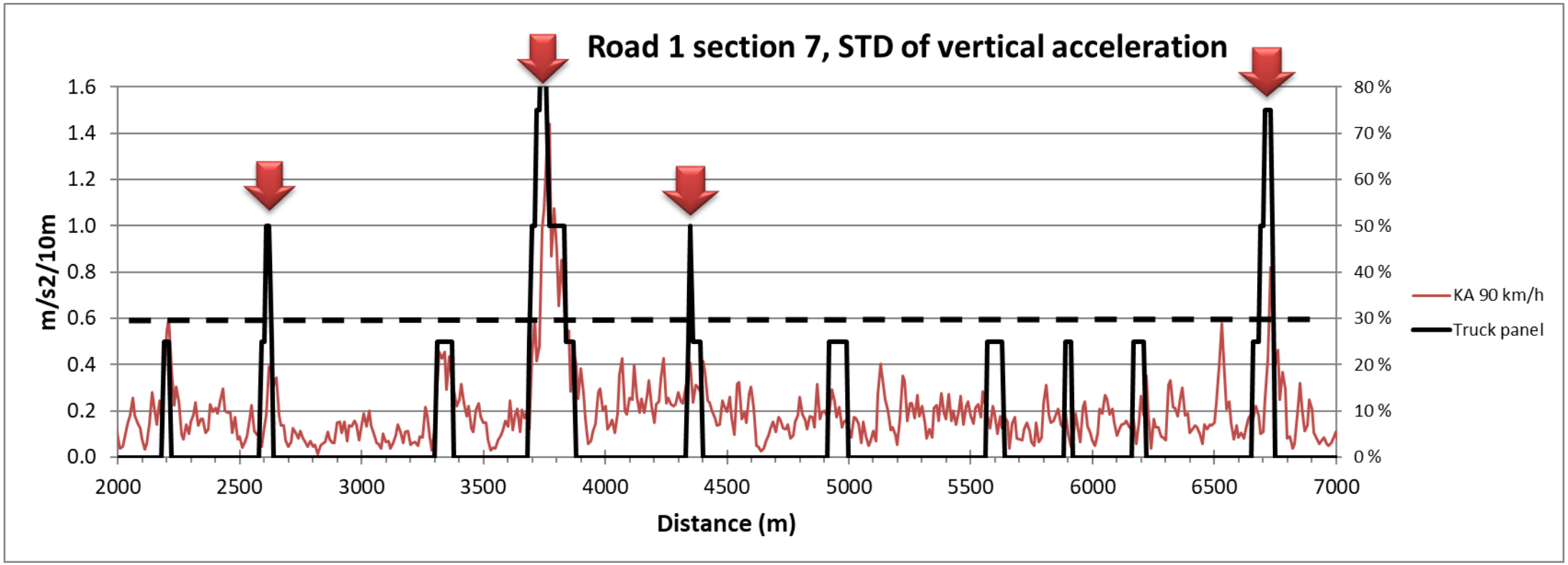
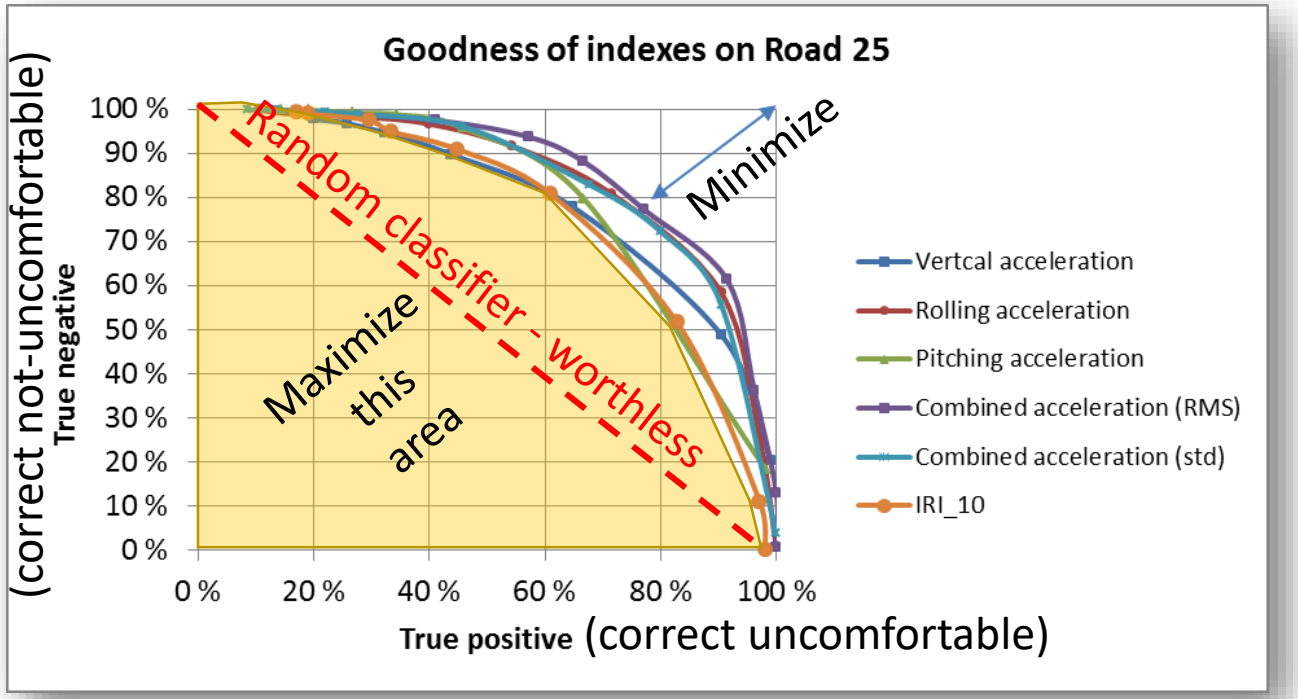


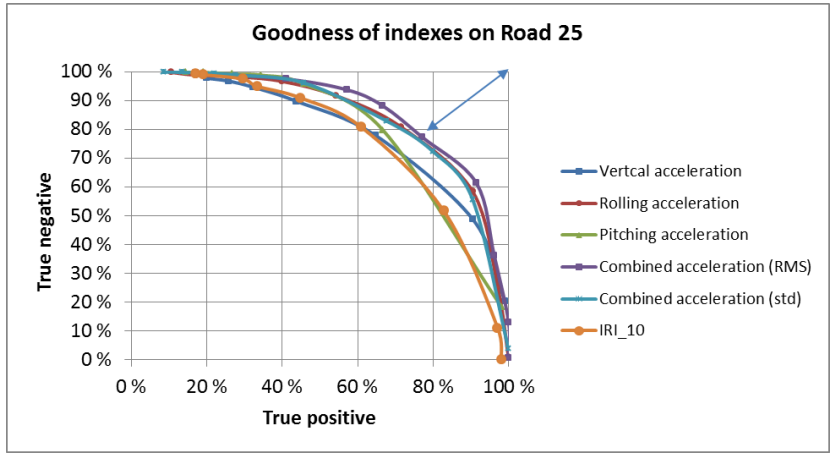
RECEIVER OPERATION CHARASTERISTIC – CURVE (ROC)

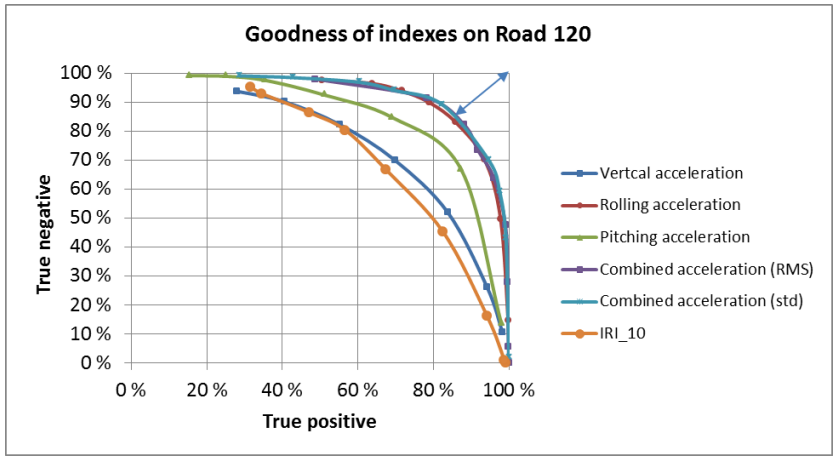
Receiver operating characteristic curve, i.e. ROC-curve,

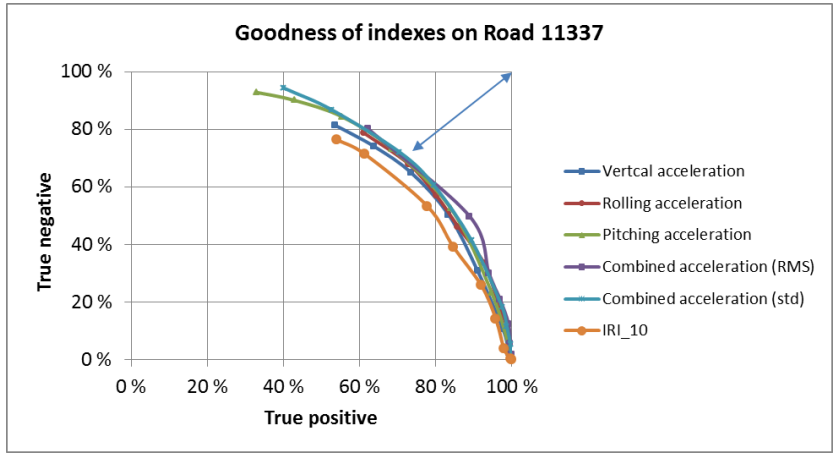
- Is a graphical plot that <u>illustrates the diagnostic ability of a binary classifier system as its discrimination threshold is varied</u>
- Horizontal axis = true positive
- Vertical axis = true negative
- Curves produced by varying threshold values from min to max
- Area under curve => goodness of indicator
  - Minimize distance from upper right corner



ROC-CURVES – BEST INDEXES







Road	Index					
	VERT_A_STD	ROLL_A_STD	PITCH_A_STD	COMB_A_RMS	COM_A_STD	IRI_10
1	3	5	4	1	2	6
2	5	6	3	1	2	4
25	4	2	5	1	3	6
120	5	3	4	2	1	6
11337	5	4	3	1	2	6
Average	4.4	4	3.8	1.2	2	5.6

RESULTS

- The riding comfort was rated more critically in a truck (than in a car).
- The best indexes able to distinguish “poor” sections from “not poor” sections were RMS and STD of combined acceleration.
- The STD of vertical acceleration, roll acceleration, and pitch acceleration (for a 10 m section) were also good indexes and additionally they gave information about what type of roughness caused the discomfort.
- The indexes worked best for high standard roads.
  - For a low standard poor condition road it didn’t matter so much what index was used.
- The IRI-index was the worst among selected 6 indexes to distinguish “poor” sections from “not poor” sections.

CONCLUSIONS

- High speed monitoring produces 3D data of the road pavement which is not very effectively used in IRI-model.
- Full car model uses 3D data and gives more information of the driving comfort on a road than IRI.
- Riding comfort is lower in a truck than in a car.
- Simulated accelerations correlate better with the riding comfort than simulated displacements do.
- Simulated variation of acceleration or RMS (on a 10 m section) locate the mileposts in poor condition better than simulated averages do.
- Simulation speeds should be taken from actual speed limits.

FURTHER ACTIONS

- New indexes are calculated and added to the data delivered from high speed monitoring.
  - IRI + RIDE-sim. (RIDE definition available)
  - Truck:
    - STD's of vertical accelerations, roll accelerations, pitch accelerations
    - STD & RMS of combined accelerations (ISO 2631)
    - STD of ESALS & LTR,
    - Energy used in shock absorbers
  - Car:
    - Energy used in shock absorbers
- Several field surveys give promising results
  - Classification of indexes ongoing