SOTA report on road condition monitoring and road/vehicle interaction

Proposals (from form)

HD video (4k - and 3-D)
- transverse evenness, surface texture, cracking, potholes, surface defects, other than cracking or potholes
- dynamic (high speed/traffic speed)
- barry nothard

HD video (3-D) with appropriate algorithms (these are the key) to identify surface characteristics (and other asset data) - this technique 'will' replace LiDAR as it requires less processing, less data and yet offers same benefits and allows geospatial location

More info from Prague working group meeting:
- combined with drones ?
- 4k = resolution, next generation: 5k ?
- measure inside the video/image
- can measure retroreflectivity of road markings, road studs and road signs
- two lanes in one go

Defect detection from videos
- cracking, potholes, surface defects, other than cracking or potholes
- dynamic (slow speed)
- Mehis Leigri

Eyevi - web application for pavement defects detection and defects viewing. This program is developed in 2016 and is ordered by Estonian Road Administartion for detecting pavement defects at network level. At first roads are filmed with 360 degree high definition camera which also has GPS. Filming is done at 50 km/h speed. Then those videos are processed so that in web application you can watch pavements in panorama view (like Google street view) or in ortho view. Videos are fitted to the roads addressing system. Biggest problem during filming is the sun because sometimes it makes videos to bright. In Eyevi is a fuction that allows you to adjust brightness of the viewing screen so you can make those bright videos better. Defects detection is done in ortho view by a person and during this defects get digital shapes and addresses (line, point or area shapes, address in roads address sytsem and X&Y coordinates). So you can make a map layer with this data in .shp file format and use it in different mapping programs. You can watch digitized defects also in panorama view. In Eyevi is good to assess the quality of the defect detection work because defects are drawn not
estimated. I hope I don’t lie if I say that this ortho view solution from 360 degree videos should be unique in defect detection programs :)

More info from Prague working group meeting:

- manual processing of defects
- Google streetview style, camera mounted on cars or drones (for structures)

**Ground Penetrating Radar – GPR**

- structural condition, other (specify in the description)
- dynamic (slow speed)
- Helena Lima (Portugal)

It is a non-destructive method to evaluate roads for pavement preservation, planning and rehabilitation. Most relevant aspects accessible with GPR are layer thickness, moisture in granular bases, HMA air voids and defects detection. I think it is very important a contribution to normalize GPR survey proceedings and equipment, and gives information about data acquisition and interpretation, mostly to the final users.

- other (specify in the description)
- dynamic (high speed/traffic speed)
- Michael Moffatt

Detection of boundaries between pavement layers using vehicle mounted radar systems. Also used to detect location of reinforcement in rigid pavements. Emerging work demonstrating utility for assessing moisture condition of pavement materials.

More info from Prague working group meeting:

- voids under concrete pavements
- drainage pipes
- RoadScanners @ ERPUG - combination with LIDAR
- bridge deck thickness
- tunnel profiles, radar directed upwards
- BRRC report
- debonding - asphalt layers

**Profile Scanner PPS**

- transverse evenness, longitudinal evenness
- dynamic (high speed/traffic speed)
- Roland Spielhofer
Laserscanner + Positioning system collects transv. profile data + attitude + position. Allows to transv. + long. profiles in arbitrary resolution and position.

More info from Prague working group meeting:


**ViaPPS 360 laser scanner**

- transverse evenness, surface texture, cracking, potholes, surface defects, other than cracking or potholes
- dynamic (high speed/traffic speed)
- Torleif Haugødegård (torleh@vegvesen.no)

The Norwegian Public Roads Administration have 16 vehicles with the ViaTech Pavement Profile Scanner (ViaPPS). We measure the transversal (360 degrees) profile and longitudinal profile from which we calculate rut depths, crossfall, IRI, MPD etc for every 20m. We also save two photos every 20m. All details can be found on the given web-sites:

For tunnels we use the 360 scanner data to calculate profiles and free vertical distances.

Laser types for transversal 360 scanning is "Z+F profiler 2015":
- [http://www.zf-laser.com/Z-F-PROFILER-R-9012.2d_laserscanner.0.html?&L=1](http://www.zf-laser.com/Z-F-PROFILER-R-9012.2d_laserscanner.0.html?&L=1)

Camera types from Basler:

Data and photos have GNSS references from Applanix:

**3D Laser**

- transverse evenness, longitudinal evenness, surface texture, cracking, potholes, surface defects, other than cracking or potholes, other (specify in the description)
- dynamic (high speed/traffic speed)
- Benoit Petitclerc

I think that Terrain Mapping should be part of the report. These data are now frequently used to control equipments on the construction site. The slope and cross slope are interesting too. All the geometry in fact is interesting.

More info from Prague working group meeting:

- similar to PPS
- [http://www.pavemetrics.com](http://www.pavemetrics.com)
LiDAR

- transverse evenness, longitudinal evenness, cracking, potholes, surface defects, other than cracking or potholes, structural condition
- dynamic (high speed/traffic speed)
- Dirk Ebersbach (ebersbach@lehmann-partner.de)

LiDAR gives a 3D Model of the Road. Based on that the Ride quality and distresses can be analyzed in 3D. There is an report available.

More info from Prague working group meeting:

- looking outside the road lanes
- environment wide
- cfr. paper SURF 2012 (Alex Wright) https://vtechworks.lib.vt.edu/handle/10919/50466
- TRIMM project report, http://trimm.fehrl.org/

CM-3000

- other (specify in the description)
- dynamic (high speed/traffic speed)
- Pedro Aliseda <paliseda@acciona.es>

Clearance Master 3000 is a vertical clearance system based on a couple of vertical distance sensors to measure vertical clearance of Structures, gantries, tunnels, etc

More info from Prague working group meeting:

- to included in the discussion of the other laser systems (pps, lidar)

OBSI method for tire-pavement noise

- other (specify in the description)
- dynamic (high speed/traffic speed)
- Erwin Kohler

The OBSI method (On-Board Sound Intensity), is being used in USA, Southamerica, Turkey and probably other places. It uses pairs of microphones and measures intensity, not sound pressure level

More info from Prague working group meeting:

- addition to the former report
FastFWD for Accelerated Pavement Testing

- structural condition, other (specify in the description)
- static
- Erwin Kohler

The FastFWD is more than just a faster FWD because it’s being used experimentally as an accelerated pavement testing tool. It simulates passage of a loaded tire at a rate of more than 2500 reps per hour.

More info from Prague working group meeting:

- update of FWD in old report 5.1.1
- Dynatest device
- http://www.dynatest.com/fastfwd

Traffic speed deflectometer

- structural condition, other (specify in the description)
- dynamic (high speed/traffic speed)
- Dirk Ebersbach (ebersbach@lehmann-partner.de)

high speed deflection

- structural condition
- dynamic (high speed/traffic speed)
- Florica Padure ROMANIA

TSD uses doppler laser sensors to measure the vertical velocity of the pavement surface as it moves down under deflection, rather than displacement directly. The displacement, or deflection, is estimated by analysis of the deflection velocity and some accurate timing. The doppler laser based technology has been applied to overcome the particular challenge of registering deflection values which can typically be at least an order of magnitude smaller than the pavement surface texture in which are being measured. The results from extensive field trials by the Laboratoire Centrale des Ponts et Chaussees (LCPC) using an earlier single sensor prototype, and more recent and ongoing work on two advanced prototypes (each with three doppler sensors), by the Danish Road Institute (DRI) and the UK Transport Research Laboratory (TRL) have demonstrated impressive repeatability. The work is continuing and commercial devices are anticipated.

- structural condition
- dynamic (high speed/traffic speed)
- Michael Moffatt
Whilst the technique was discussed briefly in the report of the former cycle, it might be beneficial to speak about the technique in more detail in the new report. The system uses Doppler lasers to measure the speed of the pavement surface movement resulting from rolling wheel loads. The system typically collects data at 80 km/h.

More info from Prague working group meeting:

- Guide to Asset Management part 5D
- https://www.greenwood.dk/tsd.php
- DaRTS group @ ERPUG 2016

**Traffic Speed Drain Meter**

- other (specify in the description)
- dynamic (high speed/traffic speed)
- Fernando Sánchez-Domínguez

The Polytechnic University of Catalonia (UPC) and Euroconsult have developed a Dynamic Drainometer, a system that uses image analysis technology to continuously calculate and integrate the number of splashed raindrops resulting from road traffic. The equipment consists of a tank, a standard pneumatic system controlling the force on the pavement, a water flow regulator, and a high-speed image and laser device. Water projection is an indirect measurement of the surface course’s permeability, the texture and the noise absorption by the pavement. This system allows for assessing how the drainability of open mixtures deteriorates over time, with the clogging the pores of the aggregates.

More info from Prague working group meeting:

- porous/open graded asphalt
- splash & spray
- cfr. SURF2012 papers
- https://vtechworks.lib.vt.edu/handle/10919/50474
- https://vtechworks.lib.vt.edu/handle/10919/50471

**ROAR Mk5, Friction measurement, fixed and variable slip**

- friction
- dynamic (high speed/traffic speed)
- Bård Nonstad, Norwegian Public Roads Administration, E-mail: bard.nonstad@vegvesen.no. mob: +47 97654306

ROAR Mark 5: Water tank 1250 liter, waterfilm 0,5 mm as a standard (0 and 1 mm is also possible). Ground pressure 120 kg. Measurement wheel ASTM 1551. Measurement mode:
Fixed slip (0-90 %) and also variable slip. Standard 18 % fix slip. Dynamic at high speed (normally 60km/h). Longitudinal measurement.

More info from Prague working group meeting:

- expand old report with an overview of existing equipment:
- three groups: transversal, longitudinal (low/high slip)
- CEN/TS 15901-xy
- overview with main properties (wheel type, slip ratio, load, …)

**OSCAR, Friction measurement, fixed and variable slip**

- friction
- dynamic (high speed/traffic speed)
- Bård Nonstad, Norwegian Public Roads Administration, E-mail: bard.nonstad@vegvesen.no. mob: +47 97654306

Measurement wheel ASTM E524 (Slicks). Normal ground pressure 460 kg (Variable from 300-600 kg). Measurement mode: Fixed slip (0-90 %) and also variable slip. Standard in Norway is 18 % fixed slip. Water tank 1000 liters, water film 0.5 mm as a standard. Dynamic at high speed (normally 60km/h). Longitudinal Method.


**Locked-wheel**

- surface texture, friction
- dynamic (slow speed)
- Hamzeh Zakeri

The Coefficient of friction (μ) is computed by measuring the restrictive drag force and the wheel load applied to the pavement. Friction is reported as friction number (FN) or skid number (SN). It contains user friendly systems with relatively simple and non-time consuming performance.


**IRI measuring with smartphone app**

- longitudinal evenness
- dynamic (high speed/traffic speed)
- Mehis Leigri

Roadroid Smartphone app for Road Surveys. Roadroid offers also Road Data Management System for collected data (video upload, data viewing and analyzing on) map. This app measures IRI (estimated IRI and calculated IRI) Best measuring speed is 70-80 km/h. It’s
accuracy is at Information Quality 3 (IQL3) level. It’s a response type survey system that measures vibration with internal accelerometer. It also captures photos/videos with GPS coordinates. You can calibrate it for small car, medium car or for 4WD car (like Hilux).

More info from Prague working group meeting:

- http://www.roadroid.com/Home/About
- in-vehicle technologies: smartphones (Google, be-mobile, asfinag ?, ...), probe vehicles (Volvo, Landrover, ...), fleet management companies (automile, ...), navigation systems, ...
- calibration for different vehicles
- privacy issues - insurance companies
- data quality, statistical evaluation
- cfr. SURF2012 paper https://vtechworks.lib.vt.edu/handle/10919/50472

Automated road profile monitoring system based on the use of probe vehicles equipped with low-cost sensors

- longitudinal evenness, potholes, surface defects, other than cracking or potholes
- dynamic (high speed/traffic speed)
- Fabien MENANT & Jean-Marc MARTIN (Org. IFSTTAR, France)

This system is based on the use of a fleet of probe vehicles equipped with low-cost sensors on board (e.g. smartphones). With this method, a large amount of raw data could be collected on real-time, at high frequency and on the entire road network (including minor roads). The raw data are sent to a server where there are automatically processed in order to provide road indicators. At the end, this information is entered into a database and can be easily and quickly visualized with a GIS software.


(X-ray) Computed Tomography and Digital Image Processing

- other (specify in the description)
- static
- Hamzeh Zakeri (contact Iran PIARC members for contact information)

Microstructure and features of asphalt concrete (AC) can be captured from X-ray computed tomography images.

UAV (unmanned aerial vehicle)

- transverse evenness, longitudinal evenness, surface texture, friction, cracking, potholes, surface defects, other than cracking or potholes, other (specify in the description)
- dynamic (high speed/traffic speed)
Recently, scientists have made wide applications in the field of the UAV system for the unmanned aerial vehicle (UAV) for the monitoring of structures and maintenance controls. The potential of UAV is recognized by modern photogrammetry and remote sensing. The UAV systems provide a new platform for data acquisition. These systems are tested in autonomous surveillance, photogrammetric for 3D modeling, remote-sensing, monitoring of bridges and super structures, infrastructures like pipelines, bridges and roads. This is mainly due to the low cost, fast speed, high maneuverability, and high safety of UAV systems for collecting images. UAVs are already replaced over satellites and manned vehicles. Moreover, they have overcome the disadvantage of low flexibility and high cost of aerial imagery.

More info from Prague working group meeting:

- HR image devices
- moving away from the road
- in quality chapter?

Remote Sensing

- transverse evenness, longitudinal evenness, surface texture, cracking, potholes, surface defects, other than cracking or potholes
- dynamic (high speed/traffic speed)
- Hamzeh Zakeri

These tools opens a new door for fast surveys of infrastructure.

More info from Prague working group meeting:

- See fiber optics

Rolling resistance test trailer

- rolling resistance
- dynamic (high speed/traffic speed)
- Hamzeh Zakeri

The new device employed for testing the rolling resistance, to detect and quantify the resistance to forward motion of a vehicle due to the rolling resistance.

More info from Prague working group meeting:

- extension of report
- ROSANNE project
- MIRIAM project

roadscout or pavescout
- transverse evenness, longitudinal evenness, surface texture, cracking, potholes, surface defects, other than cracking or potholes
- dynamic (high speed/traffic speed)
- vincent Baltazart, IFSTTAR

stereophotometry

Other ideas

- Margo
  - condition bicycle paths - eveness (and distresses)
    - Dutch device
    - Martyn: visual inspection
    - report in Sweden
    - Leif: comfort with smartphone
  - fiber optics (Fiber Bragg grating) - stresses, temperature
  - RFID
  - sensors
  - WIM + BWIM

- Leif
  - methods, techniques and sensors that can be used as reference for quality approval of routine equipment
cfr. EVEN project
  - cfr. HiSPEQ project
  - 3D heat cameras
  - winter friction = same devices, no water, other procedures

- Johan
  - Footway profilometer (measurement longitudinal evenness of cycle tracks)
    - also lasers on buggies
  - Dynaplaque (rapid checks of the bearing capacity of soils or subgrades with a maximum particle density Dmax smaller than 200 mm)
  - FWD measurement of structural road characteristics
  - PFT (portable friction tester) friction measurement
  - Rolling resistance trailer, based on angle & force measurement

- SURF 2012
  - papers: https://vtechworks.lib.vt.edu/handle/10919/50416

- smartphones
- probe vehicles - INTRO project
● outsourcing data, lessons learnt
theme for SURF2018
● asphalt vs. concrete
● summary table
● new vs. old equipment, what's the truth? to be mentioned in the general introduction
● Light-weight deflectometer for unpaved roads
Report

General structure

- Surface evenness
- Vehicle/road interaction characteristics
- Surface defects
- Structural condition
- Positioning (or part of introduction)
- Multifunctional measurements (or part of introduction)
- Case studies

Family of characteristics

- transverse evenness
- longitudinal evenness
- surface texture
- friction
- traffic noise
- rolling resistance
- cracking
- potholes
- surface defects, other than cracking or potholes
- structural condition
- other

Article structure

- definition
- measurement method(s)
- indicator(s)
- reference(s)