ARCADIS Design & Consultancy for natural and built assets

DIGITAL INSPECTION AND AUTOMATED PREDICTION OF ROAD DEFECTS AND DETERIORATION

IAM Annual Conference 2019 Liverpool

25 June 2019

The Institute of Asset Management

Content

1. Introduction
2. Operate & Maintain, Asset Management Roads, motivation
3. Digital Road inspections
4. Development of Data analytics
5. Automated recognition of defects
6. Regulations and requirements
7. Predictive model of asphalt deterioration
8. Other assets
9. Questions

1. Introduction

Introducing myself

ARCADIS Design & Consultancy for natural and built assets

Robert van de Krol

Head Advisory Asset Management Roads

QUALIFICATIONS

- Business Administration
- Civil Engineering

Certificate in Asset Management

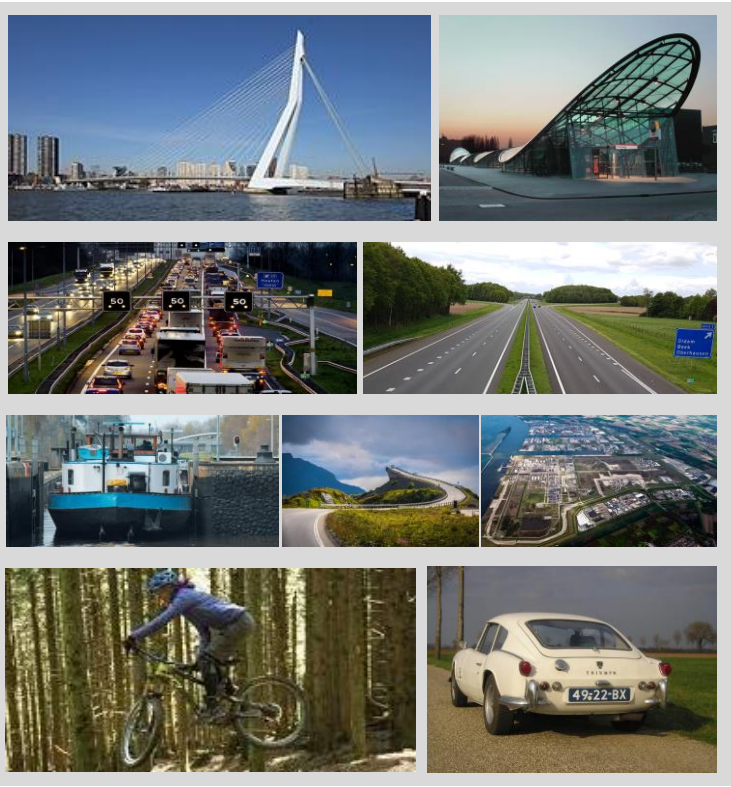
Diploma Safety for Operational Supervisors VCA

EXPERIENCES

- 1995-2001 Municipality of Rotterdam
  Consultant in civil structures: Erasmus Bridge Rotterdam, Metro line tunnel, High Speed Rail
- 2001- 2010 Arcadis
  Project manager in Urban infrastructure, Area and Site development, Water, Dikes and Sewers
- 2007-2012 Arcadis
  Team manager Urban Infrastructure, Water hydraulics, Site Development
- 2013-now Arcadis
  Head advisory Group Asset Management Roads

WHAT I LIKE

- Mountainbiking in a country without hills
- Driving an English classic car left hand drive



Arcadis Global – At a Glance

Global market position: Top-3 in Design & Consultancy

Recognized in Buildings – Environment – Water – Infrastructure

€ 3.3 bn

2018 GROSS REVENUE

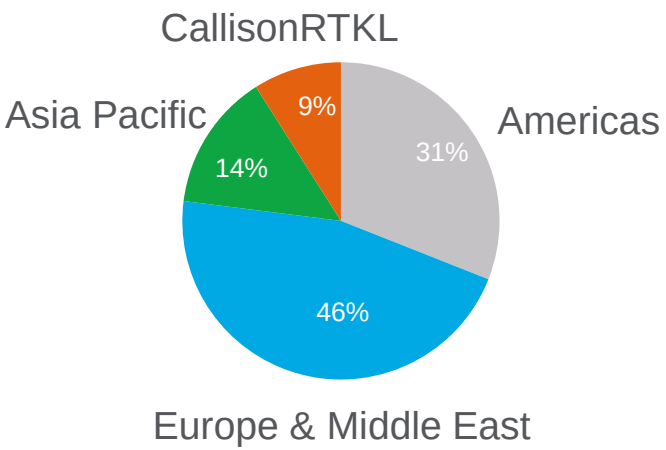
~ 28,000

PEOPLE WORLDWIDE

70+

COUNTRIES WHERE ARCADIS DELIVERS PROJECTS

GROSS REVENUE BREAKDOWN BY SEGMENT



ARCADIS Design & Consultancy for natural and built assets

Business in Operate & Maintain – 3 service delivery models

1 Consulting & Technical Advise

- Working as a trusted consultant or technical advisor for clients on the basis of a fixed fee, time & material or on the basis of value (success fee)

***Consulting**:*
Invest portfolio for airports (TotEx)
Value framework for ports

Technical advise
Multi-year program for bridges including inspection, risk analysis, programming, planning of maintenance and long-term investments

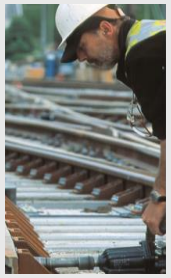


2 Partnering with contractors

- Collaborate with contractors in a joint venture for O&M related work, with focus on the asset management part
- Contract time frame 3-10 years

AssetRail:
Performance-based maintenance contract for ProRail (rail system, landscape)

Sherpa:
Performance-based maintenance contract for Rijkswaterstaat (bridges, locks, barriers)



3 As delegated asset manager

- Take (full) responsibility or act as an asset manager between the asset owner and the contractor, including contracting the work to subcontractors
- Contract time frame 3-10 years

Waterwolf Tunnel:
Performance-based contract for operation and maintenance of 3 tunnels in the province of Noord-Holland


2. Operate & Maintain, Asset Management Roads, motivation

Start development digital inspections

- Asked by client (Contractor) for Performance based contract of motorway maintenance.

- good position at client's side on 4 Performance Based Maintenance Contracts of motorways (> 1000 km)

- to determine road surface quality could be a giant job

- usual way was inspectors on the road: *expensive and safety issue*

- to be cost effective → use footage and utilize our Global Excellence Center

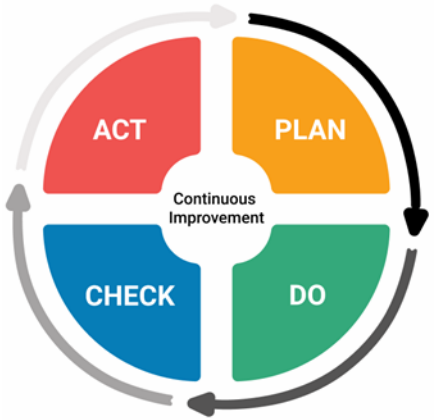
Our journey

- Challenge: learn deterioration skills to foreigners

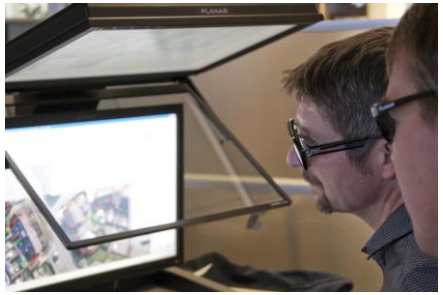
- instruct - educate – procedures – ameliorate – travel - redefine

- after 4 years: experienced team, 6 fte, 8 months a year.

- consistent and efficient product



- contributes to our asset management approach → asset condition is the base for programming maintenance



digital road inspections

3. Digital Road inspections

1) Guard rails
- Crooked position
- Corrosion
- Sag
- Deformation
- Surface damage
- Obstacle
- Parts missing
- Function absent

2) Asphalt
- Ravelling
- Cracks
- Crackles
- Rutting
- Unevenness
- Edge damage
- Potholes
- Surface damage
- Weed growth
- Sag
- Puddles
- Fauna victim
- Pollution
- Function absent

3) Markings
- Marking incorrect

4) Portals
- Corrosion
- Posters
- Graffiti
- Surface damage
- Parts missing
- Algae
- Obstacle
- Deformation

5) Shoulders
- Dense growth by tree/bush
- Holes
- Obstacle
- Puddles
- Driving tracks
- Wash-out
- Pollution by litter
- Damage by wildlife
- Grass vegetation damaged

6) Road signs and furniture
- Posters
- Function, absent
- Graffiti
- Surface damage
- Crooked position
- Dirt
- Lamp posts

Road defects

ARCADIS

4. Development of Data analytics

Moving on

- a perfect structured approach and procedures

- upward trend of machine learning

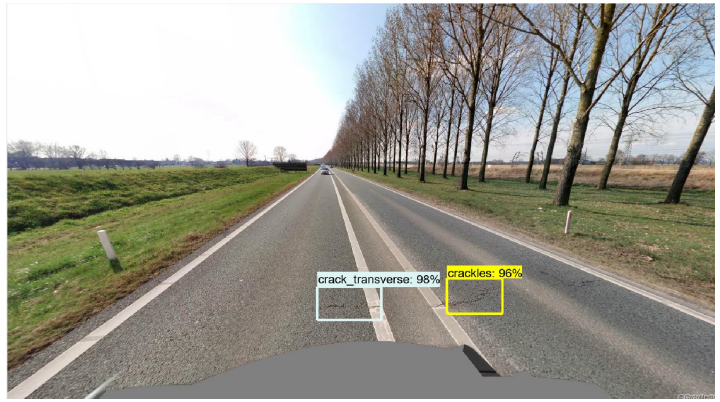
→ lets combine it!

Start → progress → machine learning

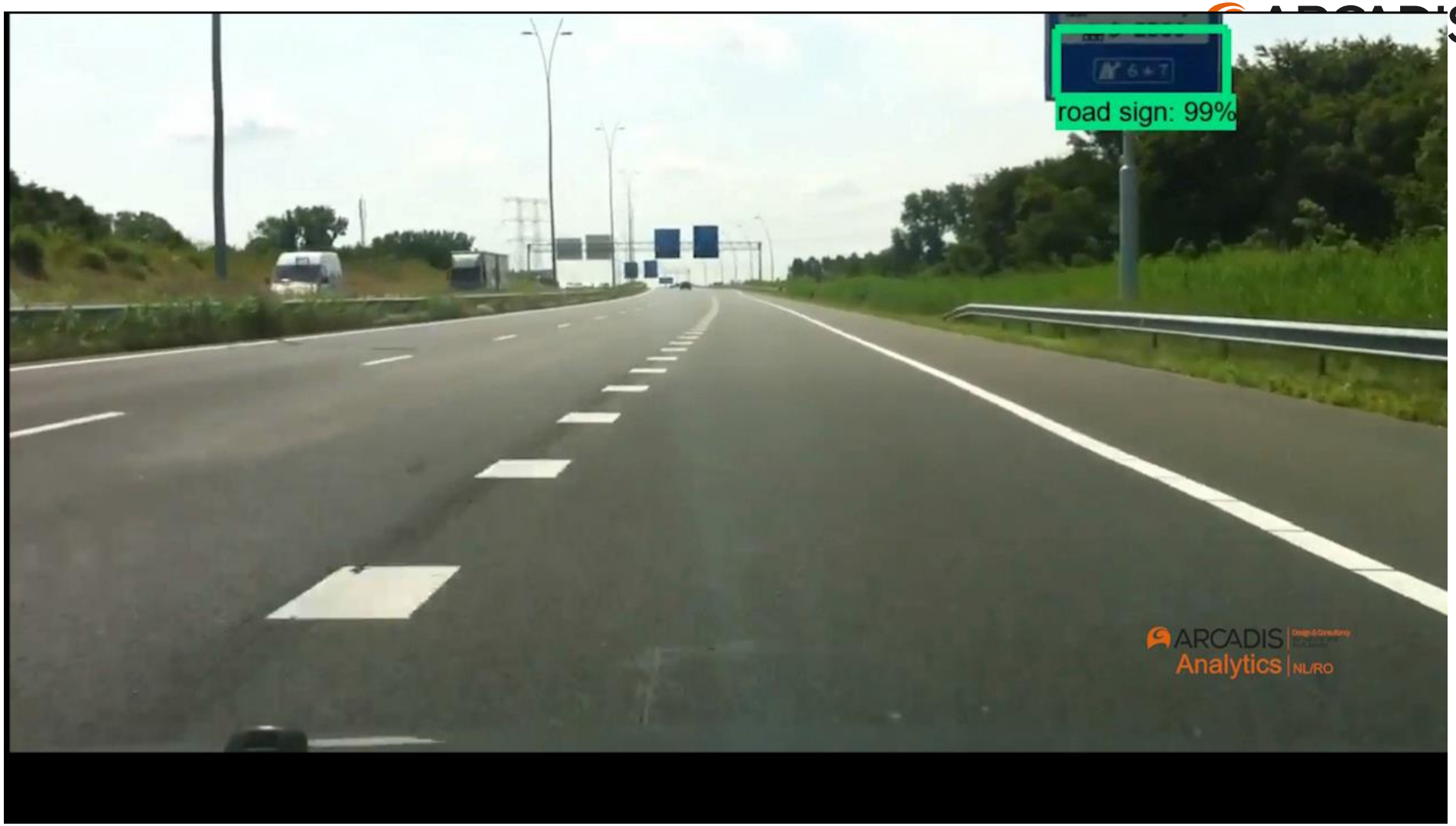
First step with a Youtube movie

Result of second step

Second step with own car and GoPro-camera

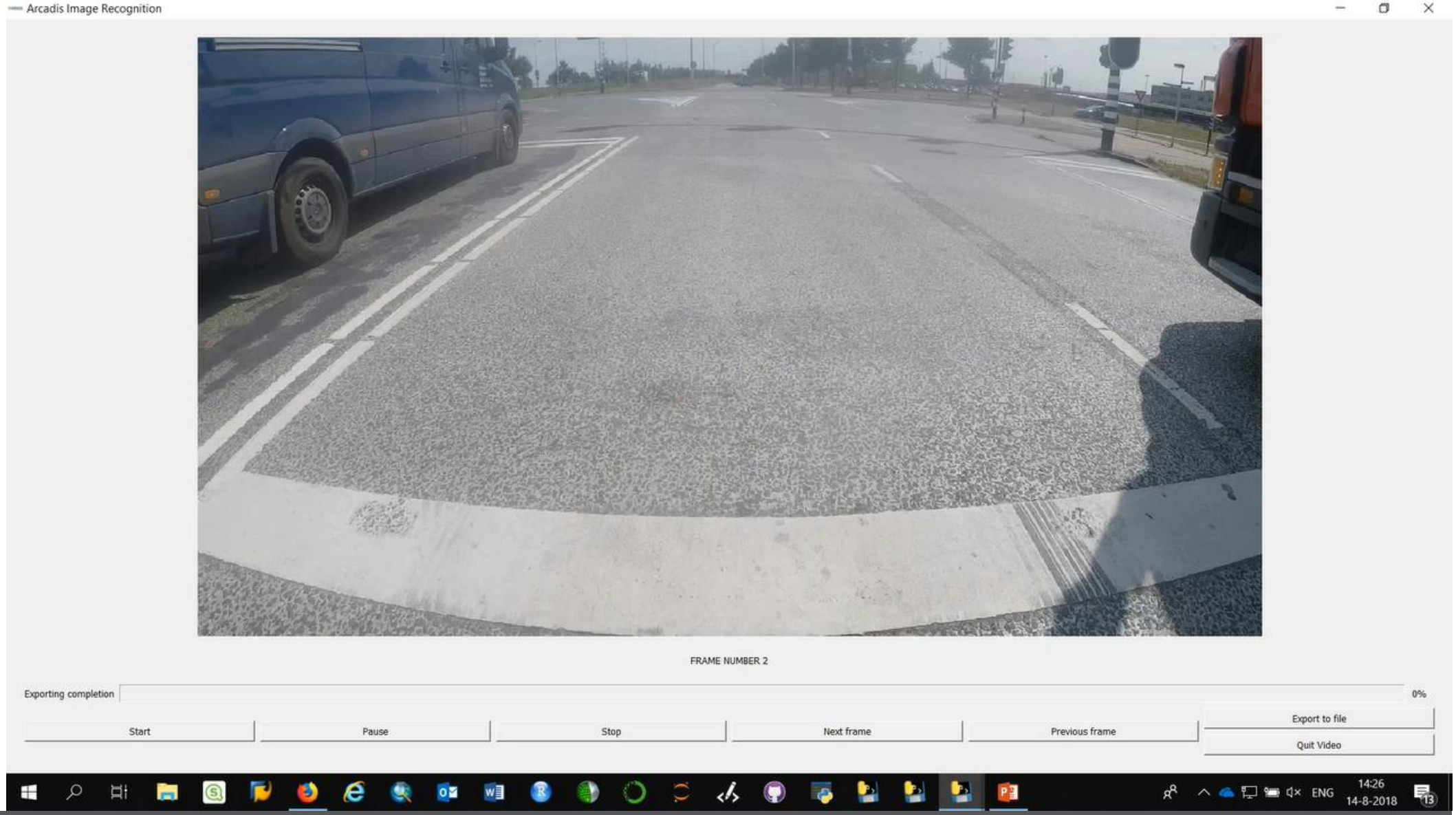


Result of second step with professional footage

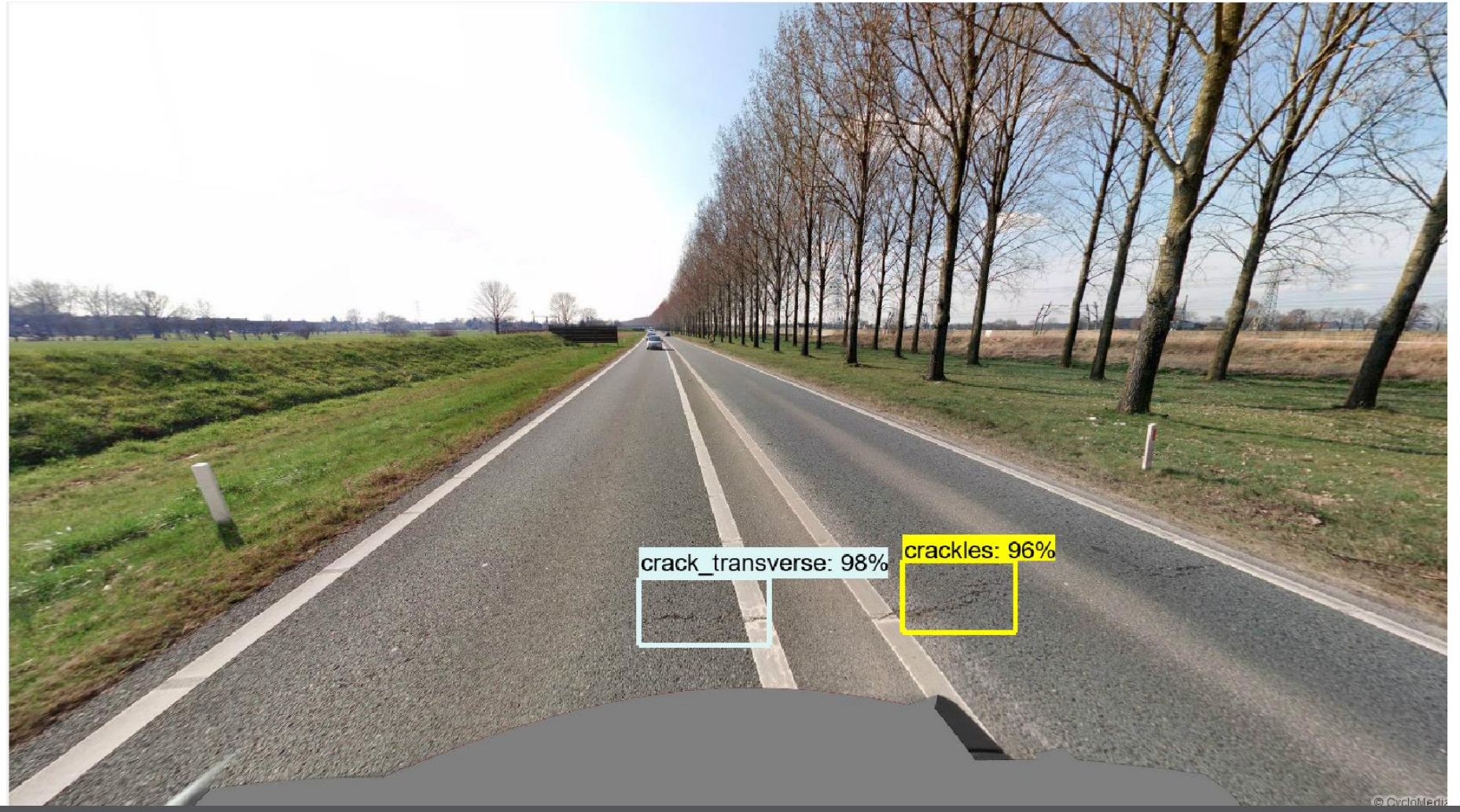


Step 1. with a Youtube movie

Step 2. With own car and GoPro-camera



Step 3. Result of second step



Step 4. Result of second step with professional footage

Train the model

- Data Augmentation (>25000 pictures)
- Labelling the defects by hand

Defect in normal image

Rotate image

-1°, -2°, -3°, >°, +1°, +2°, +3°, >

Flip image

horizontal

Crop image

Random cropping and zooming

Add blur

Gaussian blur, add noise

Machine learning

Labeling example

5. Automated recognition of defects

NOW| Image recognition & object detection

ravelling
379 • 1419

Ravelling is the progressive disintegration of a toplayer from the surface downwards as a result of the dislodgement of aggregate stone particles

crack_longitudinal
160 • 1284

A crack is a defect which manifest itself in de form of a crack in the longitudinal or transverse direction. Longitudinal cracks are following a course approximately parallel to the road direction.

crack_transverse
114 • 1008

A crack is a defect which manifest itself in de form of a crack in the longitudinal or transverse direction. Transverse cracks are following a course roughly perpendicular to the road direction.

weld
222 • 726

Welds are normally situated nearby a road marking or in the middle of a traffic line.

road_sign
44 • 319

Road signs are signs erected at the side of or above roads to give instructions or provide information to road users.

rim
29 • 282

Rims look like welds, but are normally bending towards the emergency lane or rush lane.

crackles
53 • 235

Crackles is attained when discontinuous longitudinal and transversal cracks begin to interconnect to form a series of small polygons. Crackles is the next stage after single cracks.

Automatic detection up to 7 classes of defects for a single asset

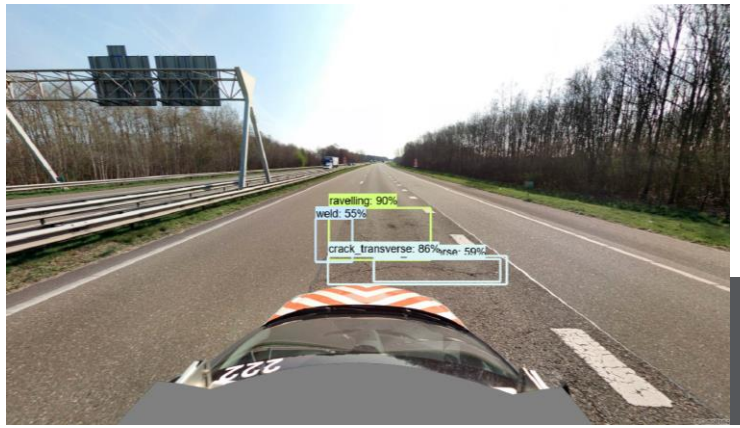
NOW| Image recognition & object detection

Automatic detection other asset classes

6. Regulations and requirements

Automatic recognition of defects

- sort
- position
- size
- severity



Regulations and requirements

Dutch regulations for local authorities

kennisplatform CROW

Dutch regulations for highways

NEN 2767-4 / NPR 4768 Conditiemeting infrastructuur

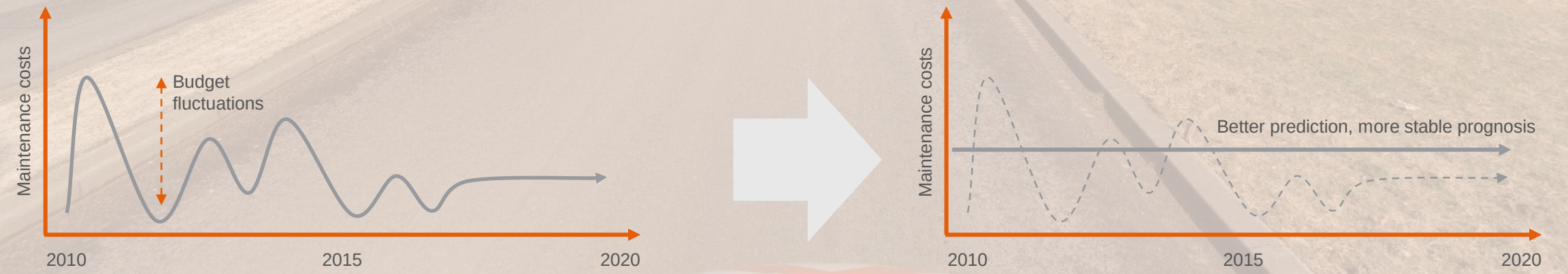
Combine process and content

7. Predictive model of asphalt deterioration

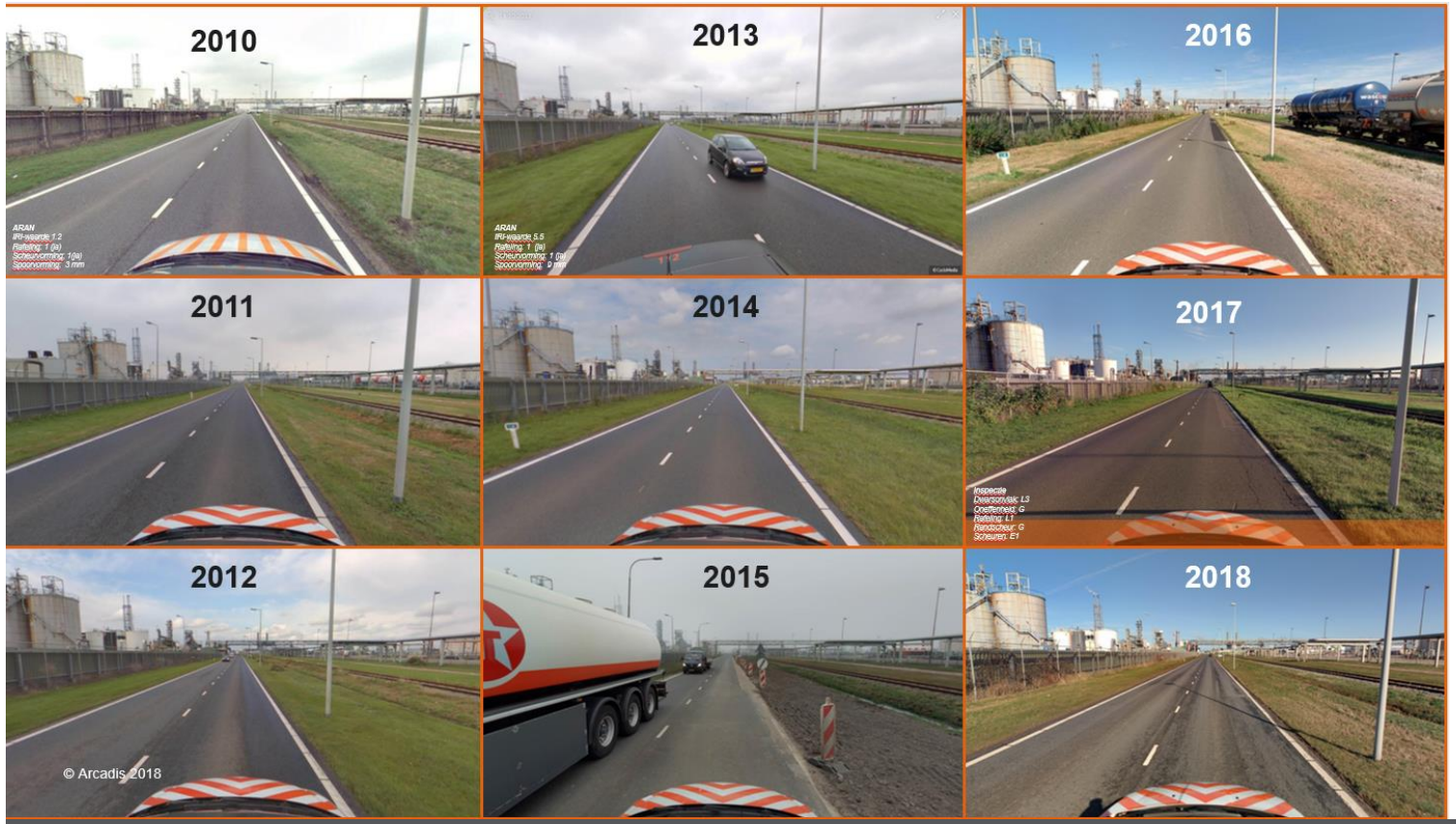
Next step with acquired knowledge

- Main goal: the client's management needs a substantiated and stable prognosis of the required costs for capital maintenance in the coming years.

a. It appears to be difficult to schedule capital maintenance tasks in an early and reliable manner
b. Existing degeneration models are insufficiently location-specific and to high level
c. Inspection results are inconsistent and contradict each other ("self-healing ways"?)
d. Many measurements are performed and require large investments, the added value is not always clear. Which measurements can be remediated?



Predict deterioration



Available data wasn't consistent. Too many distinctions in types and ways of measuring, non-consecutive years.

Using multiple years of footage provides consistent insights of surface defects

Image recognition

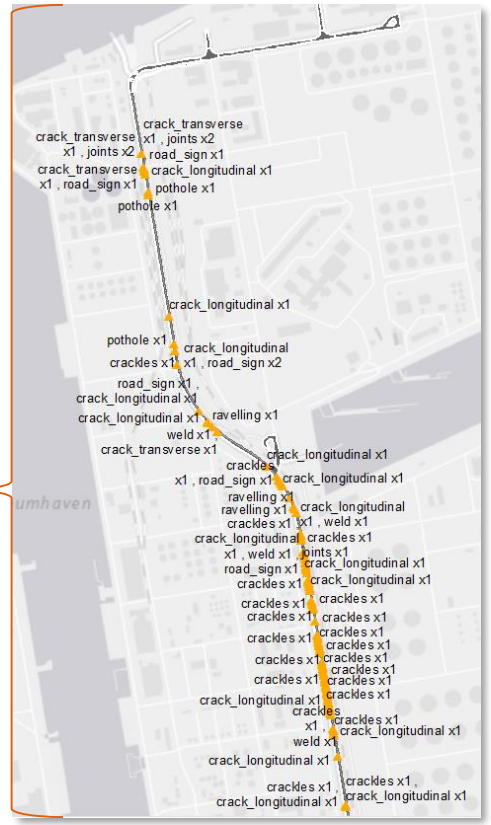
IR for the Visual Condition and Maintenance

ARCADIS Design & Consultancy for natural and built assets

Many data sources added with 9 years of detected surface defects

Databron	Compleetheid	Uniciteit	Timeliness	Accuraat	Consistent	Valide
Wegvakken	Geen missende waarden of outliers	Geen dubbele registraties	Na aanpassing nieuwe functieplaats	Ja	Geen verschillen tussen bronnen	Geen onrealistische combinaties
Verhardingslagen	Tussen 10%-20% missende waarden	Geen dubbele registraties	Geen bijzonderheden	Ja	Geen verschillen tussen bronnen	Geen onrealistische combinaties
Meting bovenlaag (ARAN)	Tussen 80%-90% missende waarden	Geen dubbele registraties	Alleen 2008, 2010 en 2013 beschikbaar	Ja, belangrijke voorspeller onderhoud	Ja, komt overeen met visuele inspectie (1%)	Structureel lager in 2010
Meting constructie (VGD)	Tussen 30%-40% missende waarden, grote outlier(s)	Geen dubbele registraties	Alleen 2007, 2012, 2013 en 2015	Ja	Komt voor 2/3 overeen met de ARAN meting	Grote verschuivingen tussen meetjaren
Meting opbouw (radar)	Rond 10% maar 100% in 2017	Geen dubbele registraties	Alleen 2017 (2008 andere opbouw)	Niet te toetsen	VGD van 2017 nodig, onderhoud pas in 2018	Niet te toetsen
Stroefheid	Geen koppeling door kilometrering	Geen dubbele registraties	Alleen 2007, 2013 en 2017(?)	Niet te toetsen	Niet te toetsen	Niet te toetsen
Visuele inspectie (schadebeelden)	Tussen 60%-80%,	Geen dubbele	80% (2007, 2008, 2014, 2015, 2016, 2014, 2015 en 2017)	Ja maar subjectiviteit bij	Komt overeen met klein	Geen onrealistische
Klein onderhoud	Meer dan 90% missende waarden, dan geen melding	Geen dubbele registraties	Alleen 2017	Ja	Komt overeen met de visuele inspectie	Geen onrealistische combinaties
Groot onderhoud	Meer dan 90% missende waarden, dan geen melding	Geen dubbele	Alleen 2009 en 2015	Ja, voor zover alles	Direct link met de ARAN	Geen onrealistische
Verkeersintensiteit	Tussen 10%-20% missende waarden	Geen dubbele registraties	100% (extrapolatie op 20% van de data)	Ja	Slechts één bron beschikbaar	Geen onrealistische combinaties
Omgeving (greppel, kolk, boom)	Geen missende waarden of outliers	Geen dubbele registraties	Geen bijzonderheden	Ja, lijken wel meer bomen te staan	Geen verschillen tussen bronnen	Geen onrealistische combinaties
Locatie (hoogte, verzilting, grondsoort)	Geen missende waarden of outliers	Geen dubbele registraties	Geen bijzonderheden	Ja	Geen verschillen tussen bronnen	Geen onrealistische combinaties

Visual defects road 2018

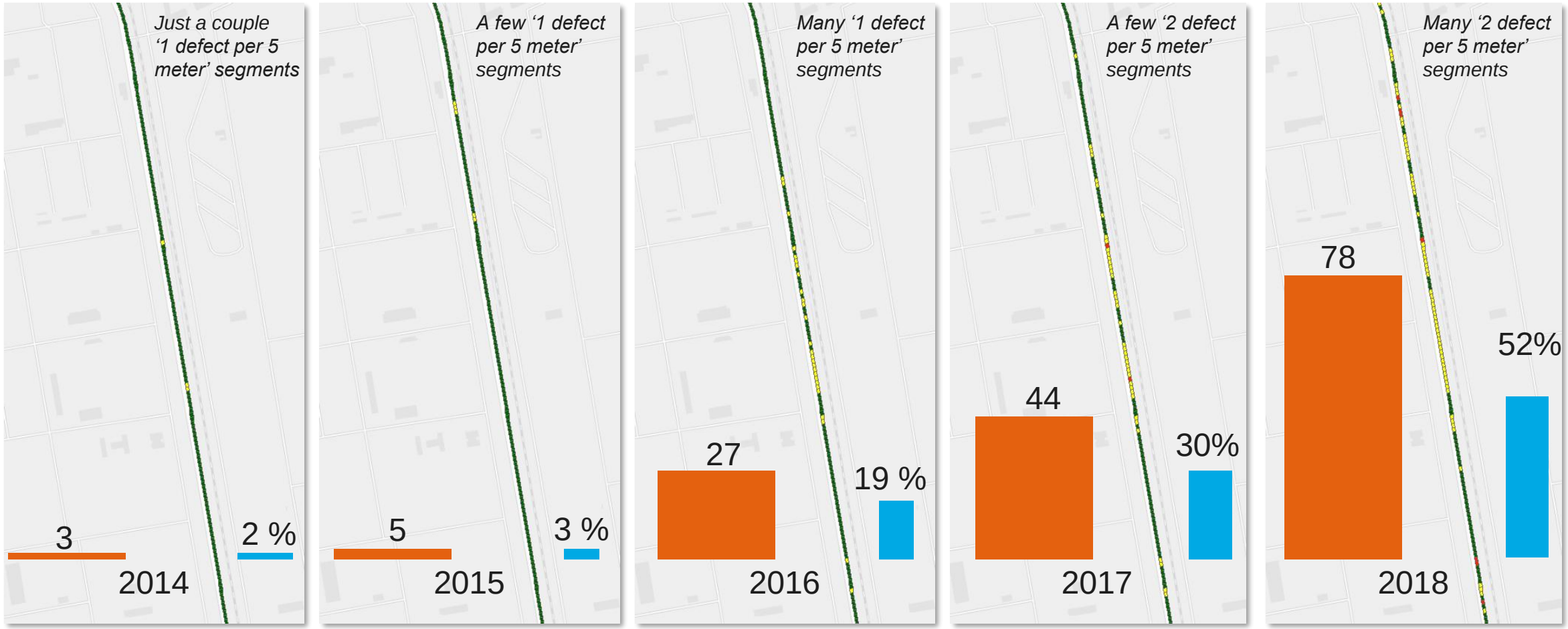


Visual repairs road 2018

Easy to determine moments of completed maintenance:
- when no/less defects and new repairs: small maintenance took place,
- when no/less defects and no repairs capital maintenance took place

VISUAL DEGENERATION

ARCADIS Design & Consultancy for natural and built assets



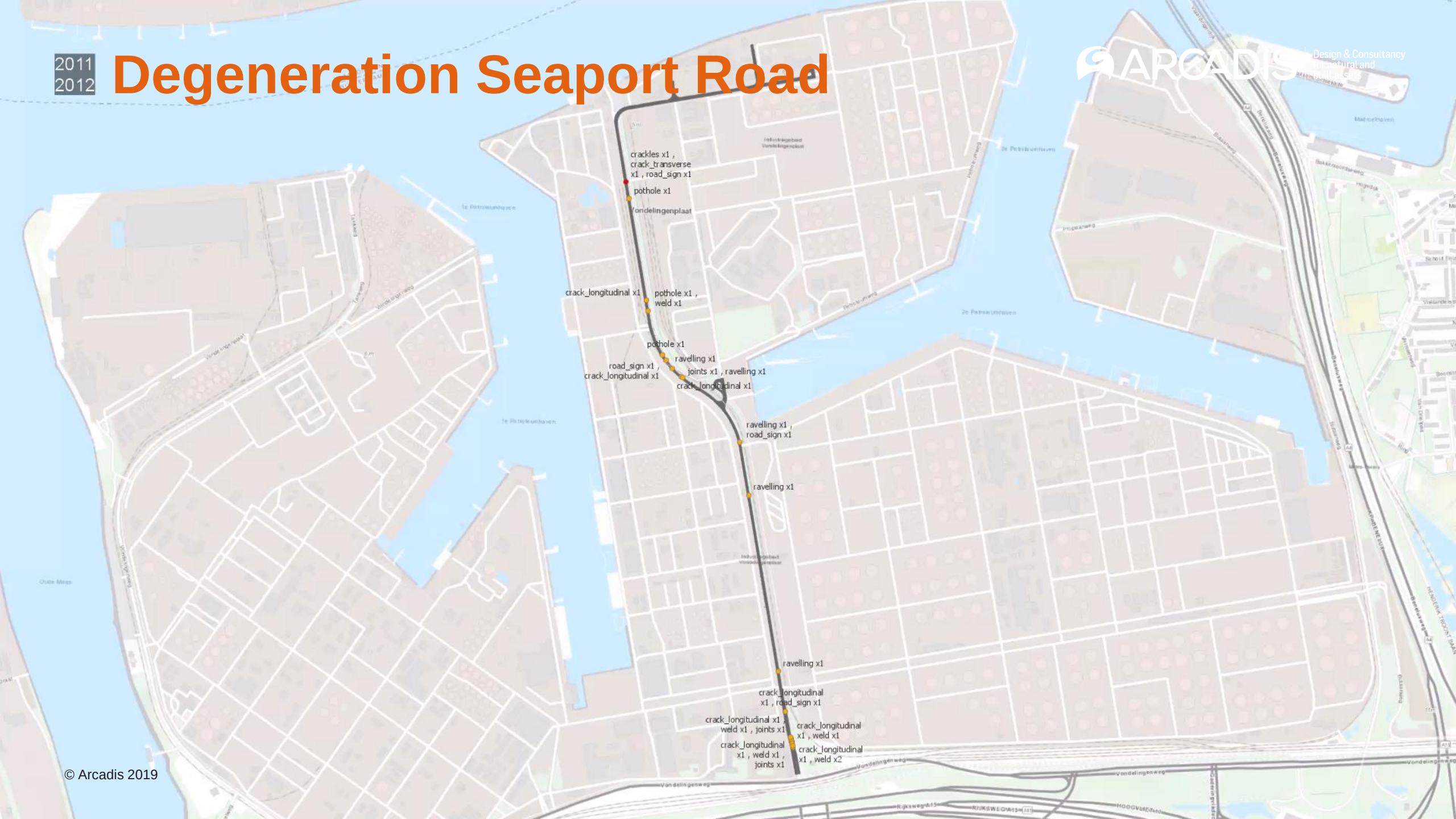
Visual defects by year visualized in ArcGIS to assess visual condition

Amount of defects

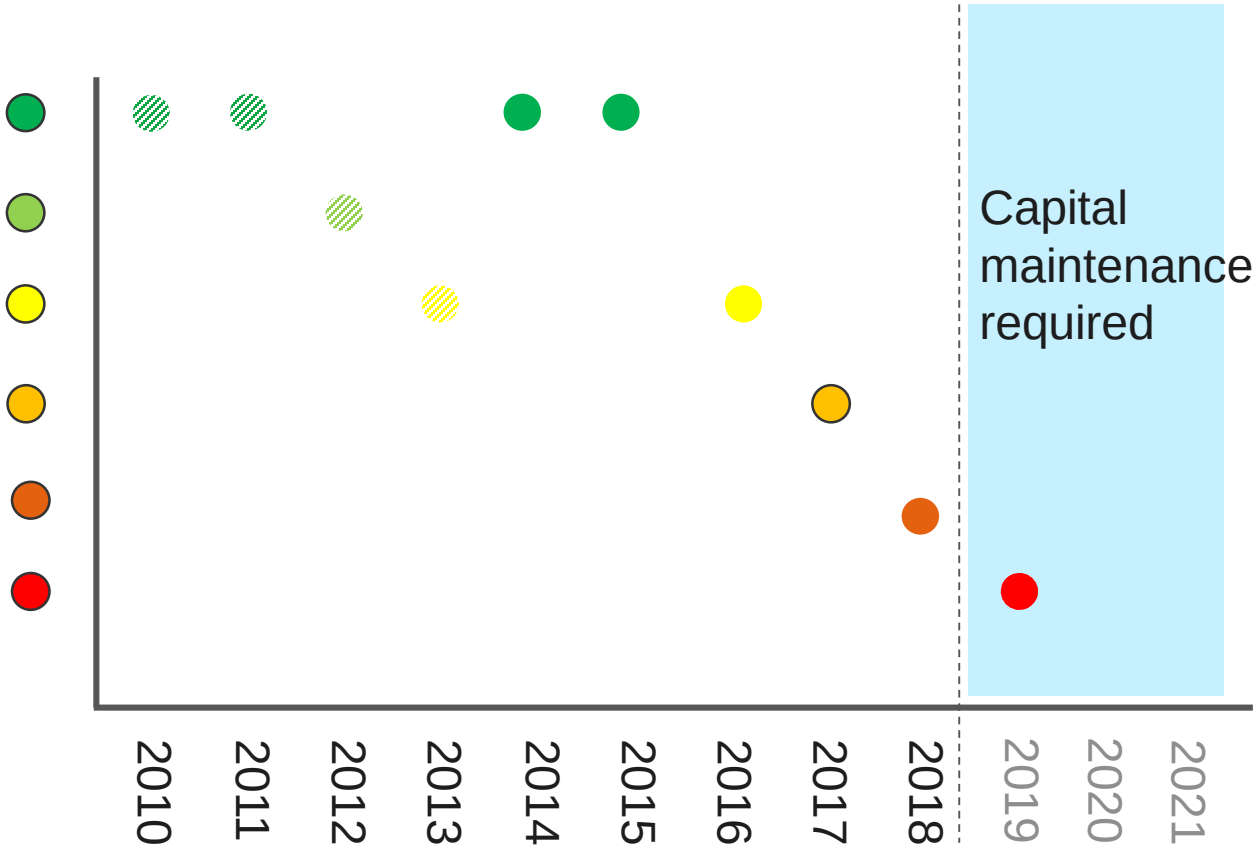
% segments with defects

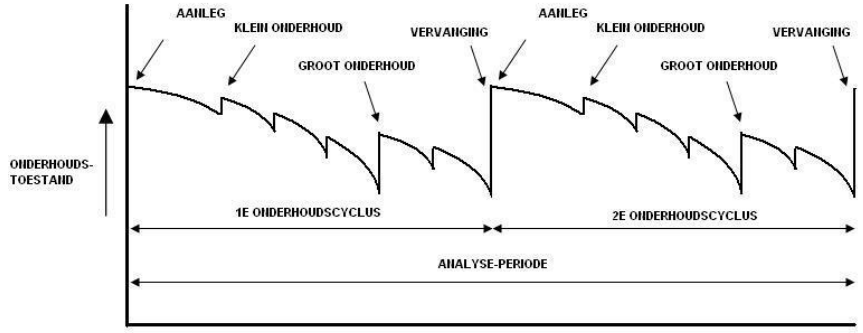
2011
2012

Degeneration Seaport Road

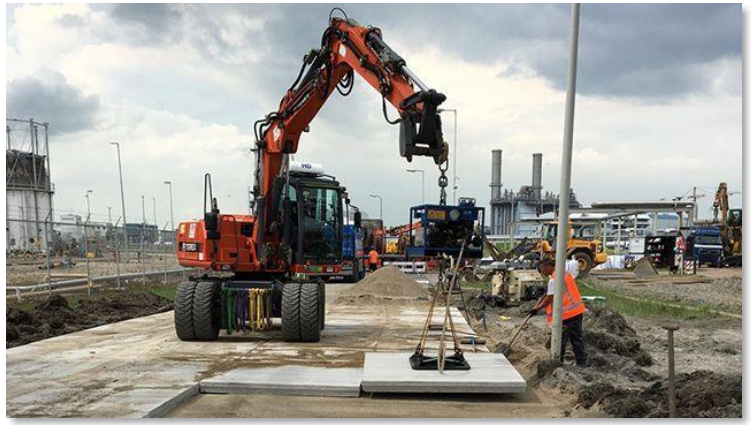


Model predicts when maintenance is needed





theory



Reality 2019

Capital maintenance project is conducted indeed

What we have learned

1. Image recognition can be used in addition to other data sets.
   Data sets are multivariable and have to be consistent, otherwise garbage in = garbage out.

2. Predicting deterioration and required maintenance is possible.

3. Gives quick insights, no road investigations needed. Many cost savings.

4. Safety risk of human inspections eliminated.

5. Predicting the moment of small and capital maintenance - in combination with a risk based maintenance approach - ensures a stable forecast of the required costs

automated prediction of road defects and deterioration

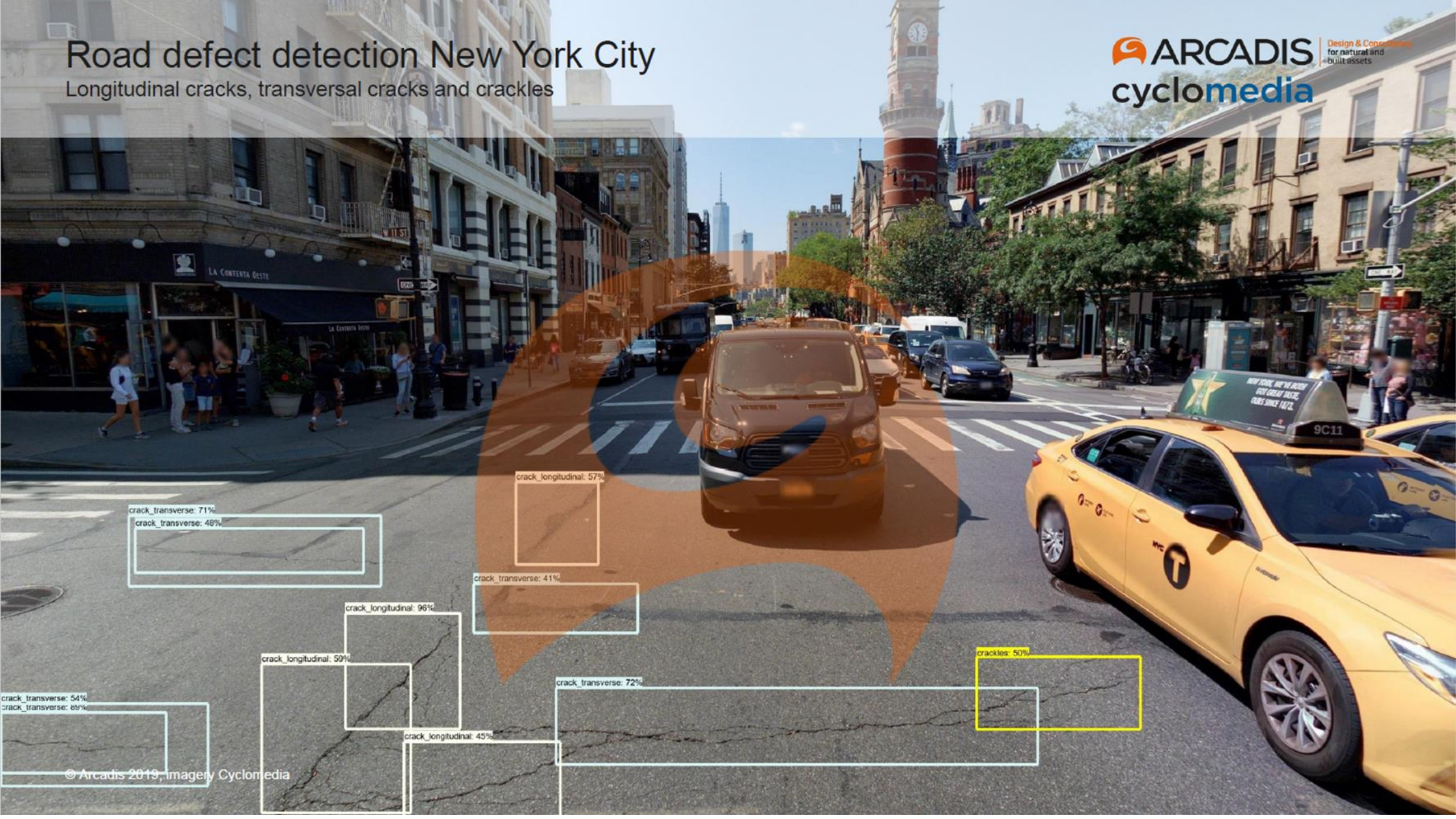
8. Other assets

Road defect detection New York City

Longitudinal cracks, transversal cracks and crackles

ARCADIS Design & Consultancy for natural and built assets

cyclomedia



Automated Image Recognition of Rail Assets in the USA

Wildspotter

9. Questions

Arcadis.
Improving quality of life