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Sustainability through road materials, technology and evaluation

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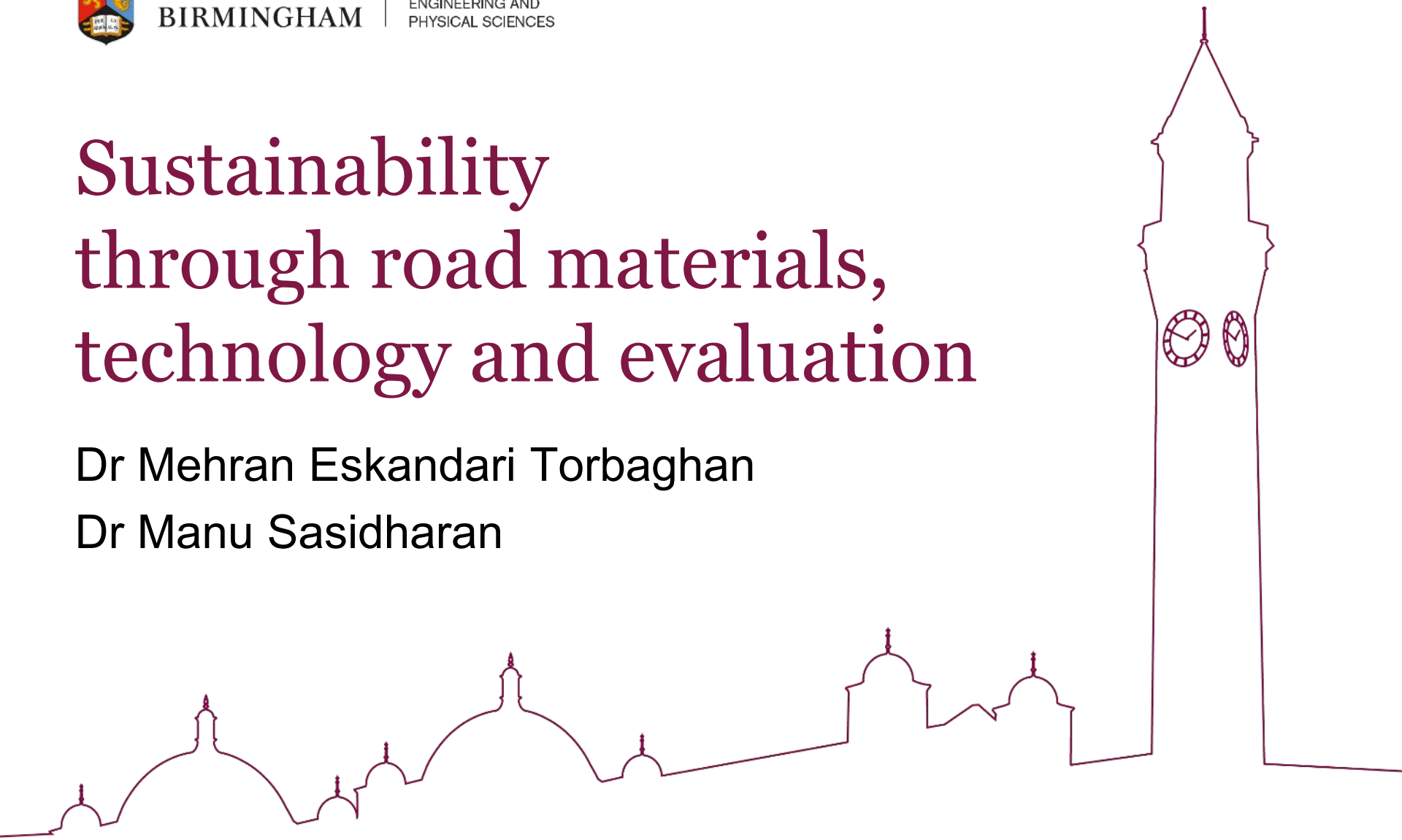

Sustainable Highways and Street Lighting
31 July 2020

Sustainability through road materials, technology and evaluation

- Using waste plastics in road construction
- Robotics and autonomous systems for managing infrastructure
- Sustainability evaluation of road infrastructure

Waste plastics in road construction

Department for International Development | K4D Knowledge, evidence and learning for development

Laboratory tests have shown positive results when a small amount (5-10% by weight) of plastic is incorporated in bituminous mixes

Evidence of improved pavement stability, strength and durability

~700,000 plastic bottles can be used to make a one kilometer stretch of road

- MacRebur (www.macrebur.com)

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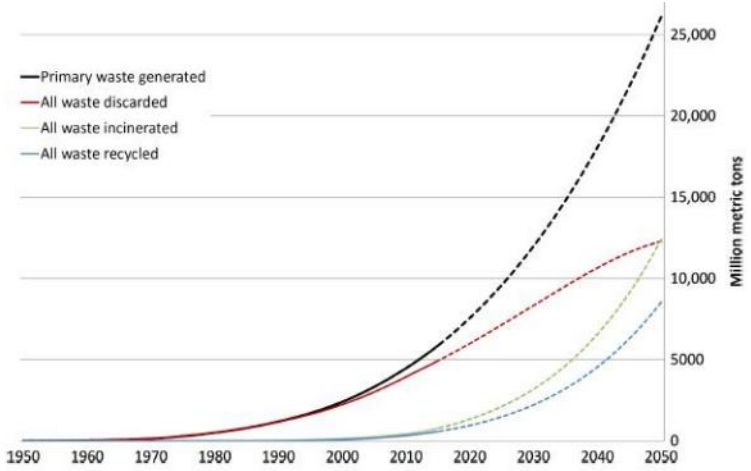
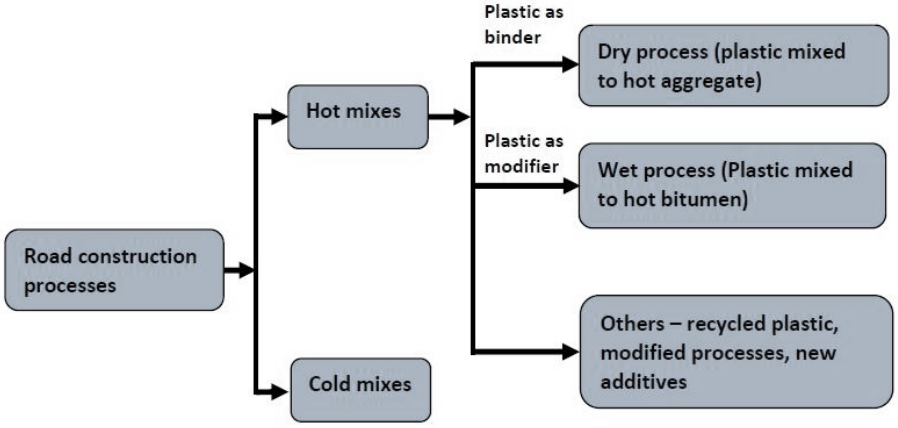
Waste plastics in road construction

Department for International Development | K4D | Knowledge, evidence and learning for development

Global generation and disposal of waste plastic



Source: Geyer et al. (2017)



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Waste plastics in road construction

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Plastic Waste	Origin	*Advantages*	*Disadvantages*	*Uses*	*Approximate Cost ($/t)*
Polyethylene (PE)	Carry bags, sacks, milk pouches, bin lining, bottles etc.	– High-temperature resistance – Ageing resistance – High Modulus – Low cost	– Hard to dispense in the bitumen – Instability problems – High polymer contents are required to achieve better properties – No elastic recovery	– Industrial uses – Few applications in road sector	420.83 - 1,403.86
Polypropylene (PP)	Bottle cap and closures, wrappers, food packaging and storage containers	– Ease of handling and layout – Low penetration – Widens the plasticity range and improves the binder's load resistance	– Separation problems – Low thermal fatigue and cracking resistance	– Isotactic PP is not commercially applied – Atactic PP is used for roofing	513.23 - 1,403.28
Polystyrene (PS)	Disposable cups, food trays, egg packs, foamed polystyrene	– Reusability – Inert and decreases construction time	– Vulnerable to petroleum solvents – Fire hazards	Used in road embankments	-
Polyvinyl Chloride (PVC)	Water bottles, credit cards, toys, pipes, electrical fittings, furniture, folders and pens, medical disposables	– Lower cracking – PVC disposal	Acts mostly as a filler	Not commercially applied	472.04 - 1170.07

Waste plastics in road construction

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India has the most experience with using waste plastics in roads and have constructed 2500km+ of national highways and rural roads

These roads are reportedly functioning well without potholes, ravelling and rutting up to 10 years later

In India, 1 tonne of waste plastic was used for every 1 km of road constructed, reducing CO_2 emissions by 3 tonnes/km

Cost savings of ~$670/km in India

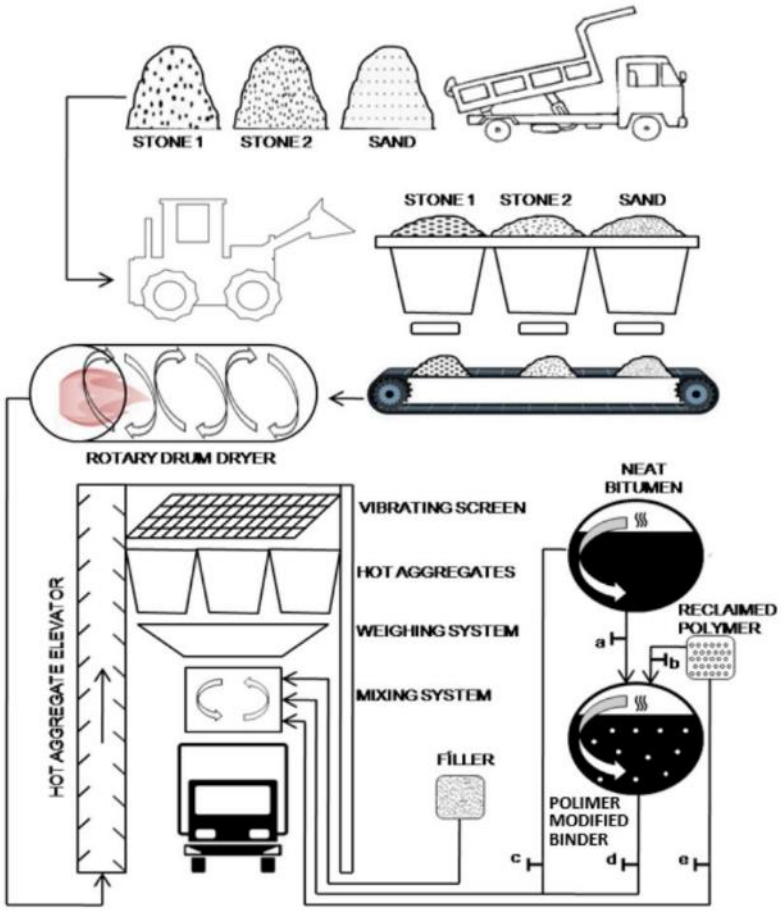
Road constructed in India using waste plastics

Road		Year laid	Unevenness (mm/km)	Skid number	Texture depth (mm)	Field density (kg/m³)	Rebound deflection (mm)
Design standard (acceptable values)		–	<4000	<65	0.6–0.8		0.5–1
Typical construction method: plain bitumen road		2002	5200*	76*	0.83*	2.86	1.55*
Roads constructed using waste plastics	Jumbulingam Street	2002	2700	41	0.63	2.55	0.85
	Veerabadhra Street	2003	3785	45	0.70	2.62	0.60
	Vandiyur Road	2004	3005	41	0.66	2.75	0.84
	Vilachery Road, Mai	2005	3891	45	0.50	2.89	0.86
	Canteen Road, TCE	2006	3100	45	0.65	2.86	0.86

*Values outside acceptable design parameters shown in red
Traffic data was not available

International Journal of Pavement Research and Technology, 2010, p:39

Sketch of the wet and dry process in an asphalt plant



Source: Brasileiro *et al.* (2019)

MacRebur, a UK based company has developed a solution to use waste plastic within asphalt for road construction and surfacing

MacRebur's recycled waste plastic was incorporated into asphalt instead of traditional bitumen and used by Durham County Council in the UK for resurfacing a section of A689 near Sedgefield and for resurfacing the runways at Carlisle Airport

The UK government recently announced the investment of £23 million into plastic road technologies by setting up real-world tests across eight local authorities

Waste plastics in road construction

Department for International Development

K4D Knowledge, evidence and learning for development

Challenges

Health and Environmental hazards
- Leaching of toxic components during the cleaning process
- Generating hazardous chlorine based gases during road construction

Collecting and sorting waste plastics

Training for construction workers

An adequate regulatory and technical framework for the use of waste plastics in road construction

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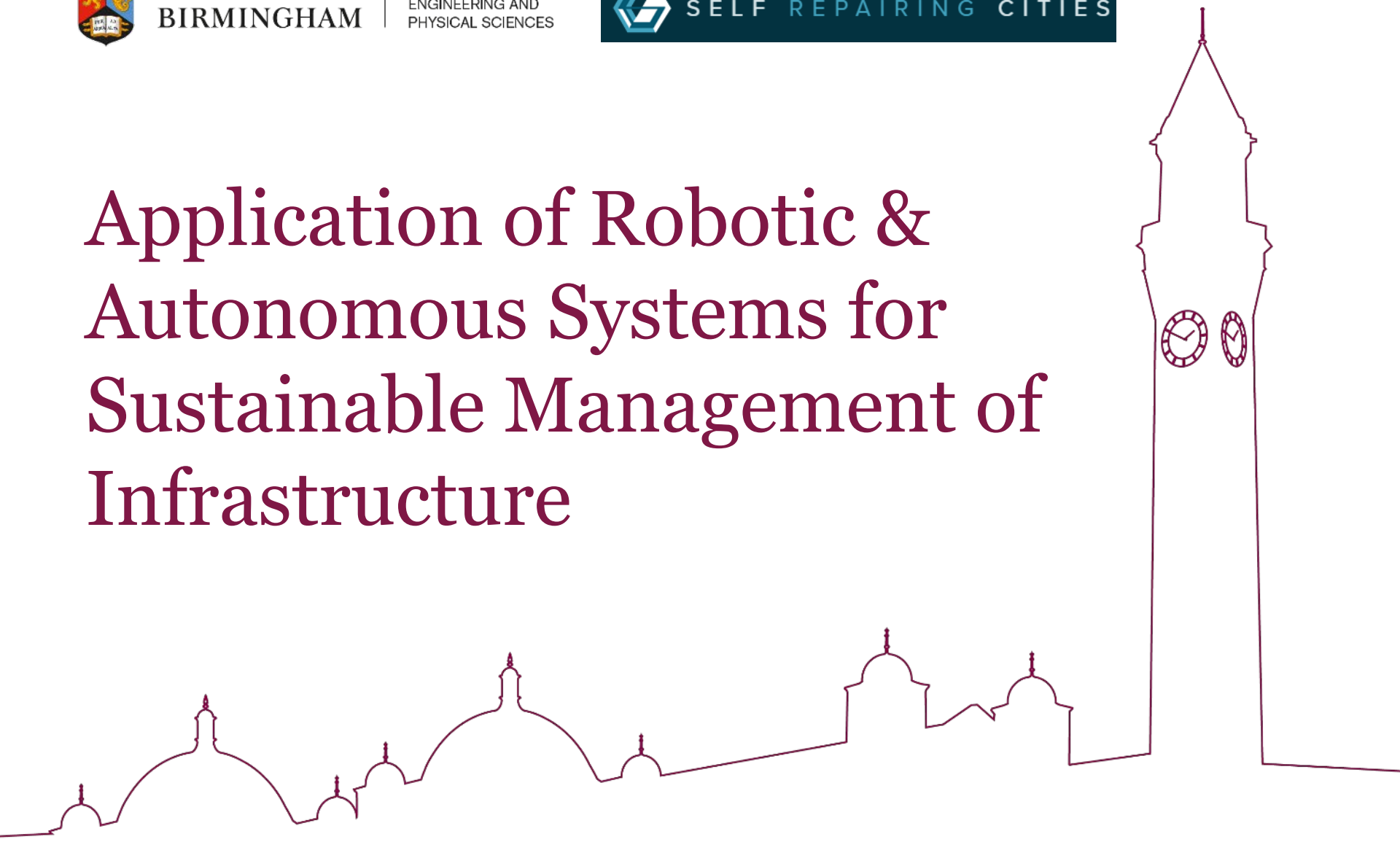
SELF REPAIRING CITIES

Application of Robotic & Autonomous Systems for Sustainable Management of Infrastructure



The Problem

- *A pothole is filled every **21 seconds** in the UK*
- *Poor road condition costs **£22.8 million** in compensation in England and Wales in 2018*
- *Costs of streetworks disruption > **£600** million per year*
- ***14** road workers were killed and over **300** were seriously injured between 2006 and 2016*
- *Congested traffic, such as that caused by streetworks, emits **4** times as much pollution as free-flowing traffic and contributes to ~**40,000** premature deaths*

*Is this **sustainable**?*

SELF REPAIRING CITIES

- *Funded by Engineering and Physical Science Research Council (EPSRC)*
- *Grand Challenge: Balancing the impact of City Infrastructure Engineering on Natural systems using Robots*

- *Vison:* **ZERO DISRUPTION FROM STREETWORKS BY 2050**

Project Partners:

UNIVERSITY OF LEEDS

UNIVERSITY OF BIRMINGHAM

UCL

UNIVERSITY OF Southampton

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Self-Repairing Cities

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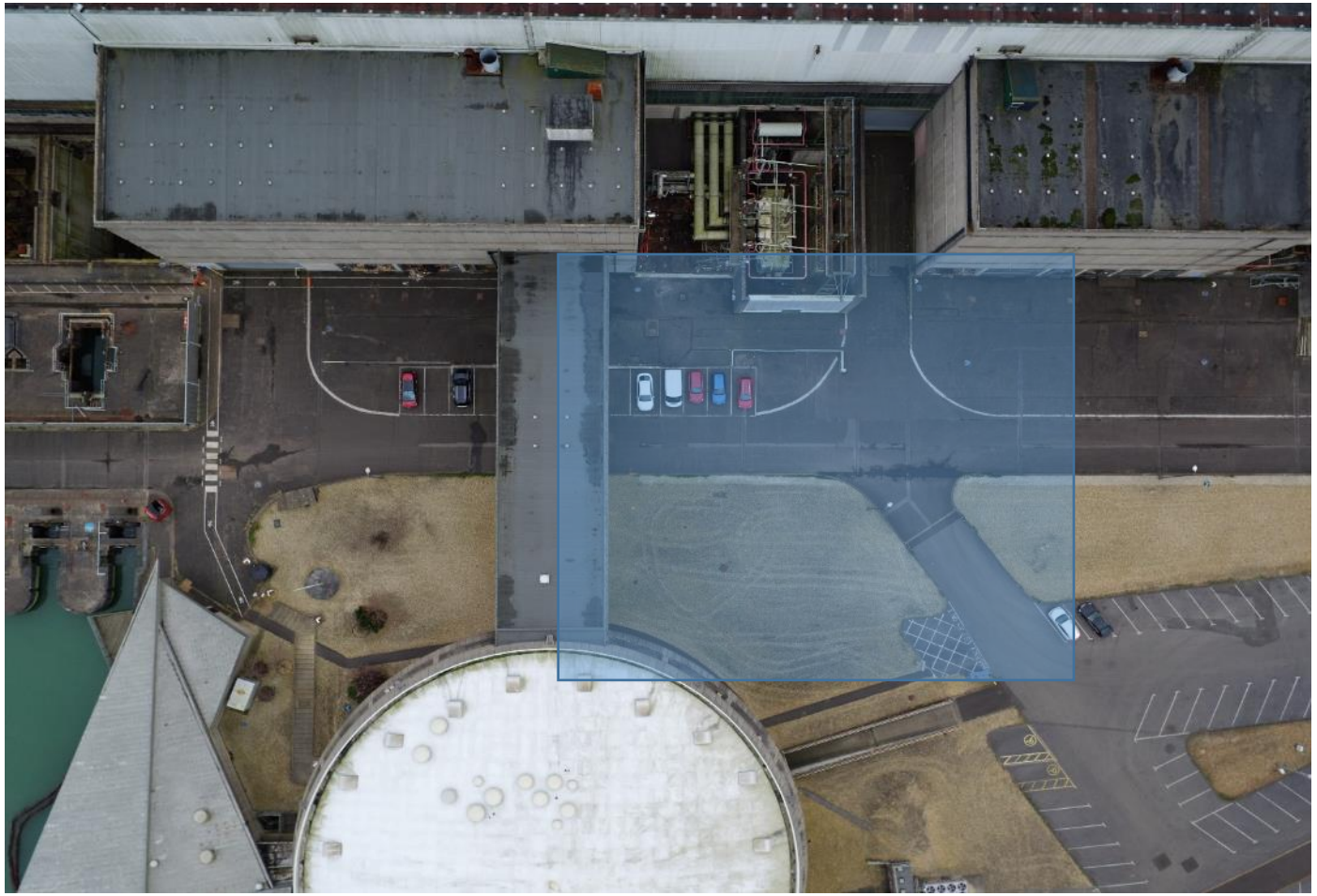
SELF REPAIRING CITIES

Inspection Drone

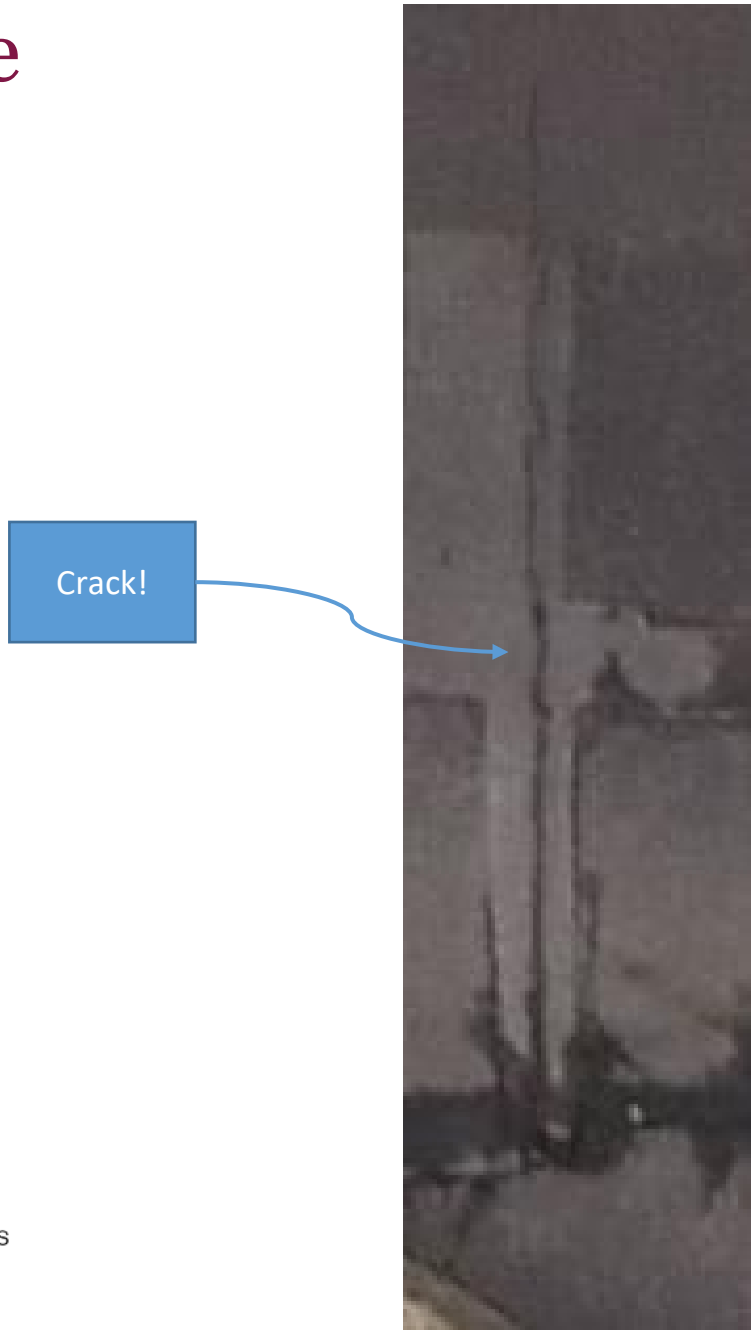
- *Installation of a visual inspection system based on hyperspectral and normal cameras*
- *The system has the ability to detect crack and potholes and build a 3D model of the detected anomaly in real-time.*
- *Allows inspections of high structures.*
- *The drone has the ability to detect defects as part of an autonomous infrastructure maintenance operation.*

Inspection Drone



Inspection Drone

Inspection Drone



Deployment of ground inspection robot

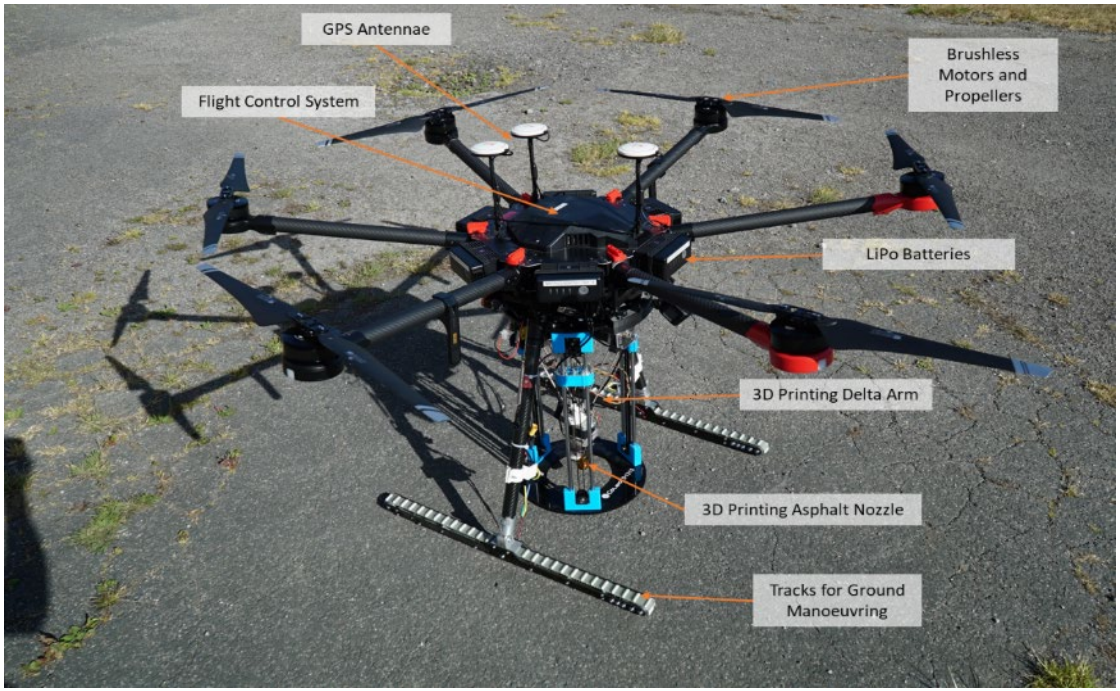
- *Rapid deployment of ground rover*
- *Designed for rover deployment and retrieval*
- *Allows inspection for long periods of time*
- *Provides a detailed inspection platform*
- *Allows inspection where UAVs cannot fly*

Drone Delivery of Metal Bridge Inspection Robot

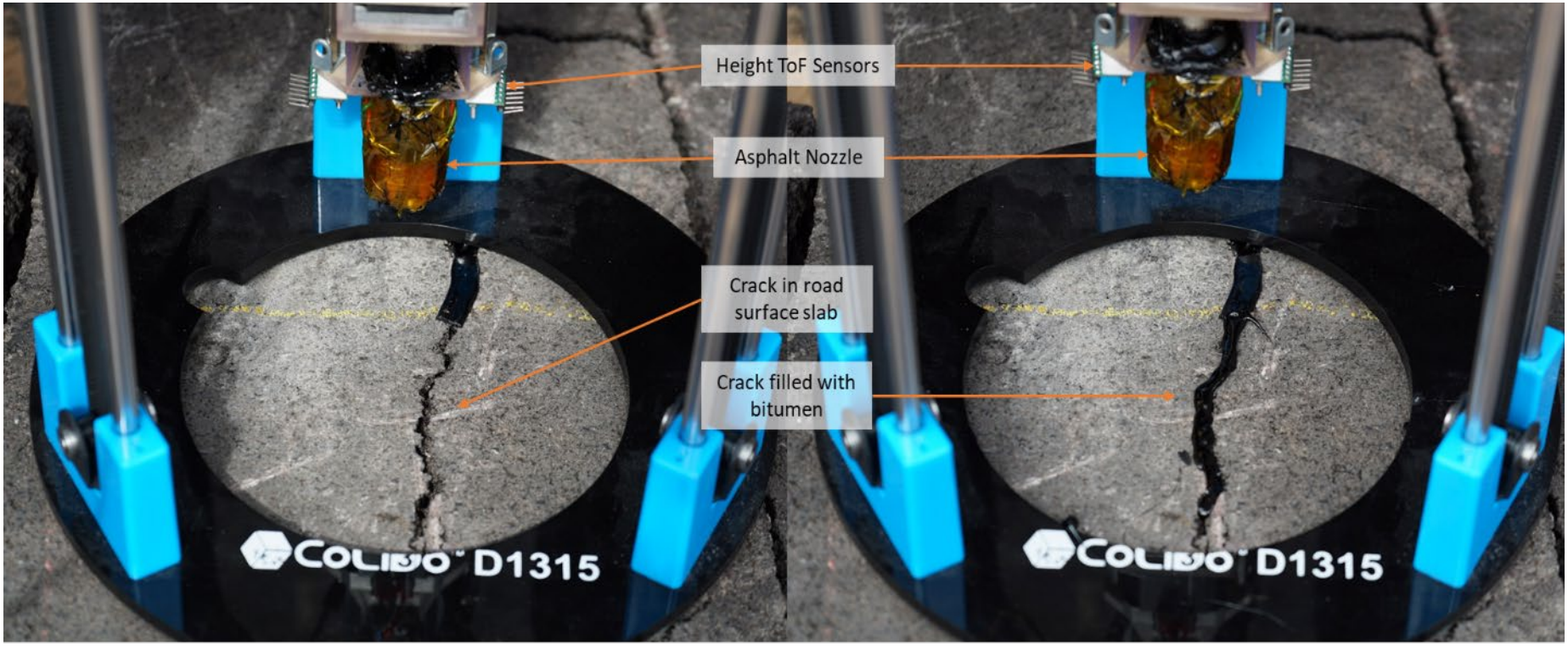
- Aims:
  - Reach obstructed areas under the bridge
  - Assess the damages to bridge bearings from all sides
  - Perform non-destructive tests
- Proposed solution:
  - Use a drone to deliver and retrieve an inspection robot to the bridge underside

3D Printing Drone

- Installation of a 3D printer on a drone.
- Ability to fill-up holes/cracks as part of an autonomous infrastructure maintenance operation.
- Why Drone?
- Working on using multiple material (pothole repair)
- Robotic and Larger Platform



3D Printing Drone



(a) (b)

- (a) Irregular crack to be filled (b) Crack autonomously filled with asphalt

Perching and Manipulation on a Street Lamppost

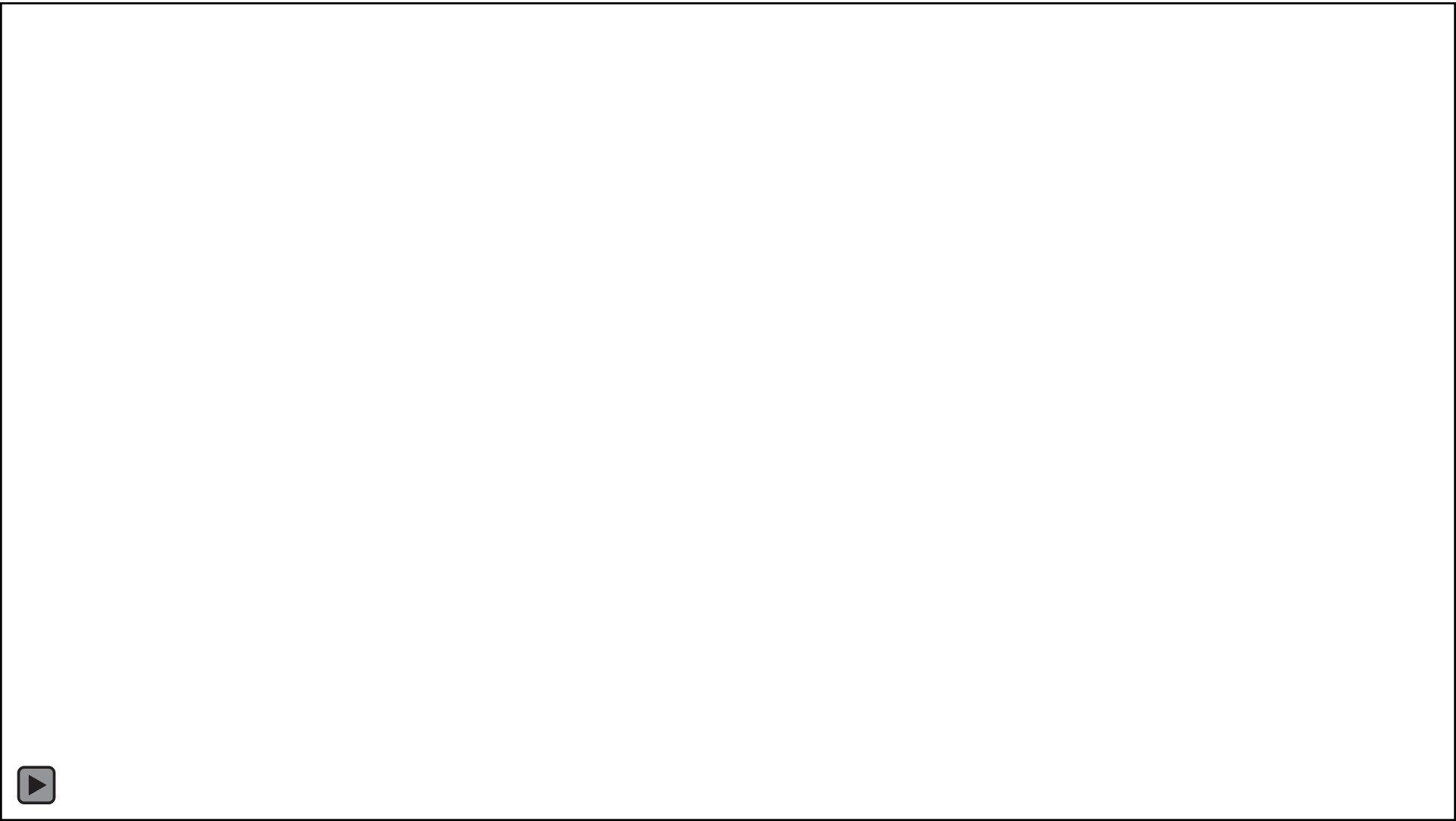
- *Autonomously perching on a street lamppost,*
- *Performing sensor (camera)*
- *(Un-)installation on the lamppost with its on-board robotic arm*
- *Disaster response*

Source: University of Southampton

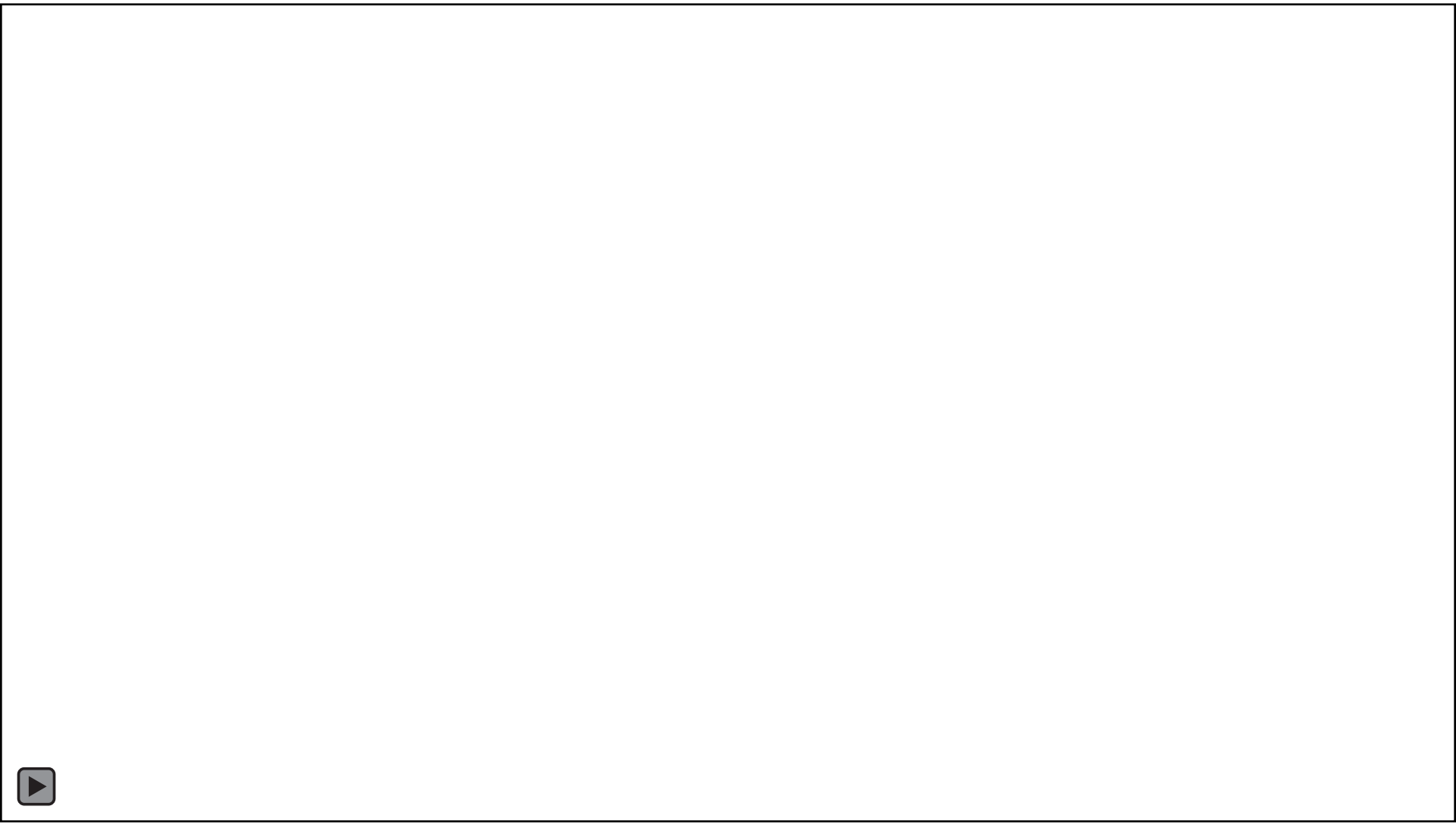
Self-Repairing Cities Project

- *Aiming at a resilient infrastructure where autonomous robots will maintain the crucial infrastructure that we rely on in our daily life.*
  - *Reduce downtime*
  - *Reduce disruption to services*
  - *Reduce risk on the safety of the workforce*
  - *Reduce cost of inspection and maintenance*
  - *Increase quality and reliability of infrastructure services*
  - *Better quality of life*

Automatic Perching on Lamppost



Manipulation / sensor installation



3D Printing Drone

Challenges for Automation

- *Localisation in urban environment due to degraded GPS signal*
- *Image processing and object identification*
- *Autonomous path planning and inspection planning*
- *Power*
- *Big Data and information management*
- *Legislation, Regulations and Rules !*
- *People Perception*

Sustainability evaluation of road infrastructure

Green Infrastructure Corridors

wider context of delivering urban transport justice through principles of sustainability

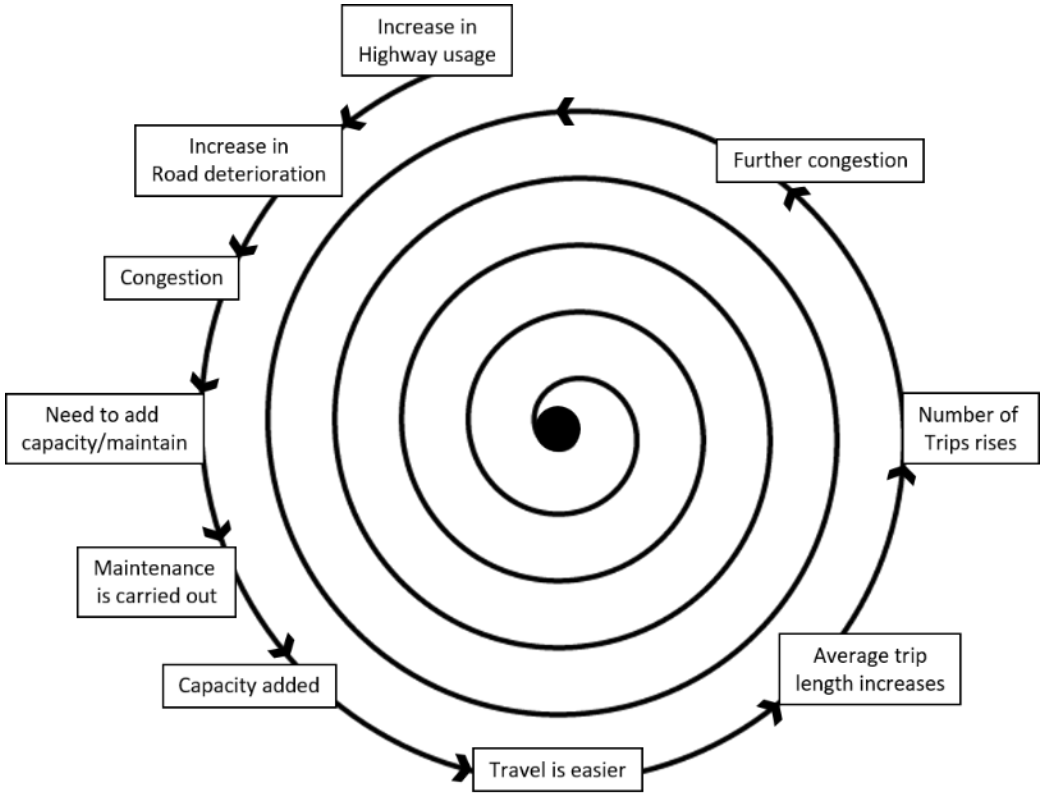
Smart Motorways

evaluate whether such schemes are sustainable for a nation-wide rollout

Sustainable Transport?

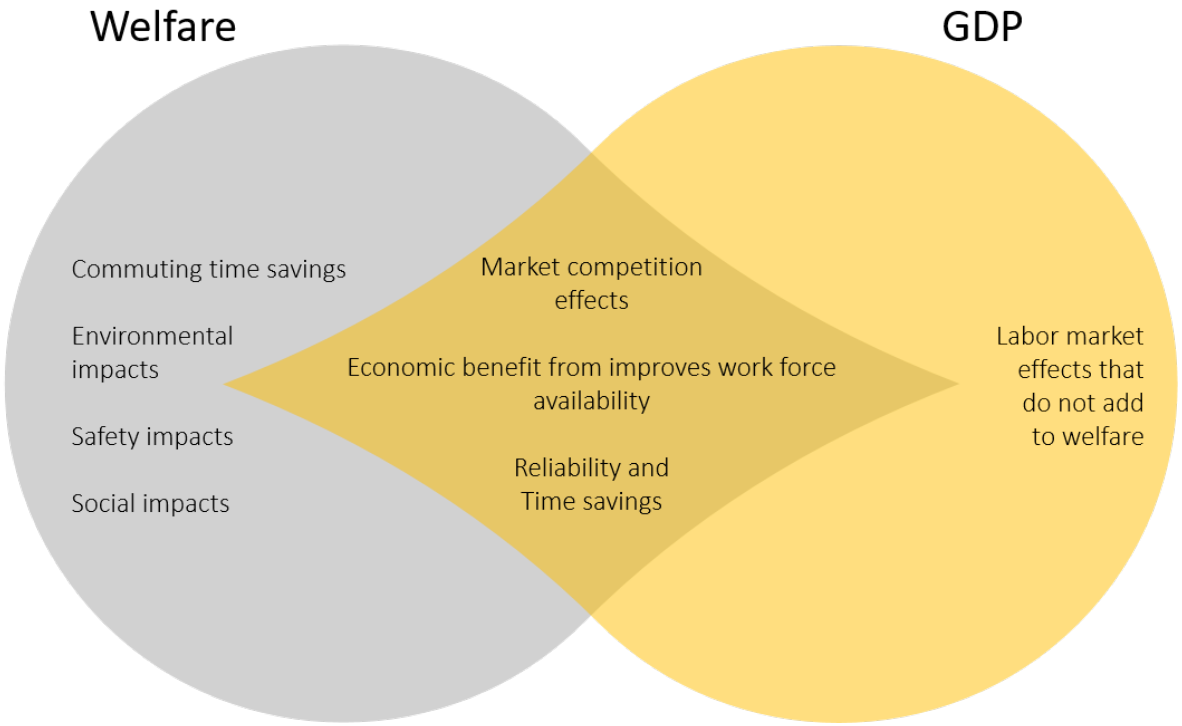
- *"that meets the current transport and mobility needs without compromising the ability of future generations to meet these needs"*
- *"transport and mobility with non-declining capital, where capital includes human capital, monetary capital, and natural capital"*
- Decision makers when carrying out the transport investment appraisals should consider impacts associated with the depletion of non-renewable fuels, climate change, air pollution, fatalities and injuries, congestion, noise, low mobility, biological damage, and lack of equity

Sustainability evaluation of road infrastructure

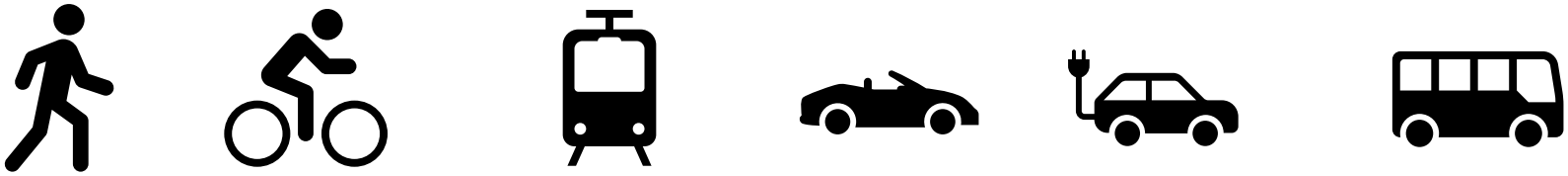


Investment on increasing capacity on the highways adapted from the Black Hole Theory (Plane, 1995)

Sustainability evaluation of road infrastructure



Wider economic benefits of transport investments



What would be the sustainable combination of urban transport modes for a city?

Sustainability evaluation indicators for Green Infrastructure Corridors

Transport Objectives	Sustainability		
	Economic	Social	Environmental
Reducing greenhouse gas emissions			✓
Reducing noise		✓	
Reducing congestion	✓		✓
Reducing exclusion		✓	
Improving air quality		✓	✓
Improving transport safety	✓	✓	
Improving access	✓	✓	
Creating wealth	✓	✓	
Supporting the local economy	✓	✓	
Protecting landscapes and biodiversity			✓

Would a national roll-out of Smart Motorway schemes be a sustainable choice?

Sustainability evaluation indicator for Smart Motorways

Indicator	Sub-Indicator	Project Stage		
		Construction	Operation	Maintenance
Economy	GDP		✓	
	Productivity		✓	
Social	Safety		✓	✓
	Noise		✓	
Environment	Embodied energy	✓		
	Air pollution	✓	✓	

Collaborate with us!

- Green infrastructure corridors
  - To work with city councils or urban transport stakeholders for identifying sustainable urban transport strategies

- Smart Motorways
  - To collect data or use expert opinion for evaluating sustainability of the scheme for a nation-wide rollout

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