ITRC mistral
multi-scale infrastructure systems analytics

Newcastle University

EPSRC
Engineering and Physical Sciences Research Council

Urban strategies for reducing flooding impacts in cities

Maria Pregnolato

EPSRC Fellow

School of Engineering, Newcastle University (UK)

UK-China joint workshop

Xi'an, China | 11-13th September 2018

EPSRC
Engineering and Physical Sciences Research Council

ITRC mistral
multi-scale infrastructure systems analytics

Infrastructure & the city

Infrastructure as backbone of cities

- ROADS
- RAIL
- POWER SYSTEM
- ICT

EPSRC
Engineering and Physical Sciences Research Council

ITRC mistral
multi-scale infrastructure systems analytics

Hazard & the city

Impact of natural hazards on cities

- ACCESSIBILITY
- SERVICE DISRUPTIONS
- POWER CUT-OFF
- CASUALTIES

EPSRC
Engineering and Physical Sciences Research Council

ITRC mistral
multi-scale infrastructure systems analytics

Infrastructure & Hazards

Socio-environmental issues

- CLIMATE CHANGE
- DEMAND
- AGING

EPSRC
Engineering and Physical Sciences Research Council

ITRC mistral
multi-scale infrastructure systems analytics

Flooding impact on bridges

REDUCED PRACTICABLE SERVICE: Eamont Bridge (2015)

NO PRACTICABLE SERVICE. Calva bridge (2009)

COLLAPSE. Tadcaster bridge (2015)

HUMAN LOSSES. Northside bridge (2009)

EPSRC
Engineering and Physical Sciences Research Council

ITRC mistral
multi-scale infrastructure systems analytics

CAT (catastrophe) modelling

Current method for direct damages to buildings

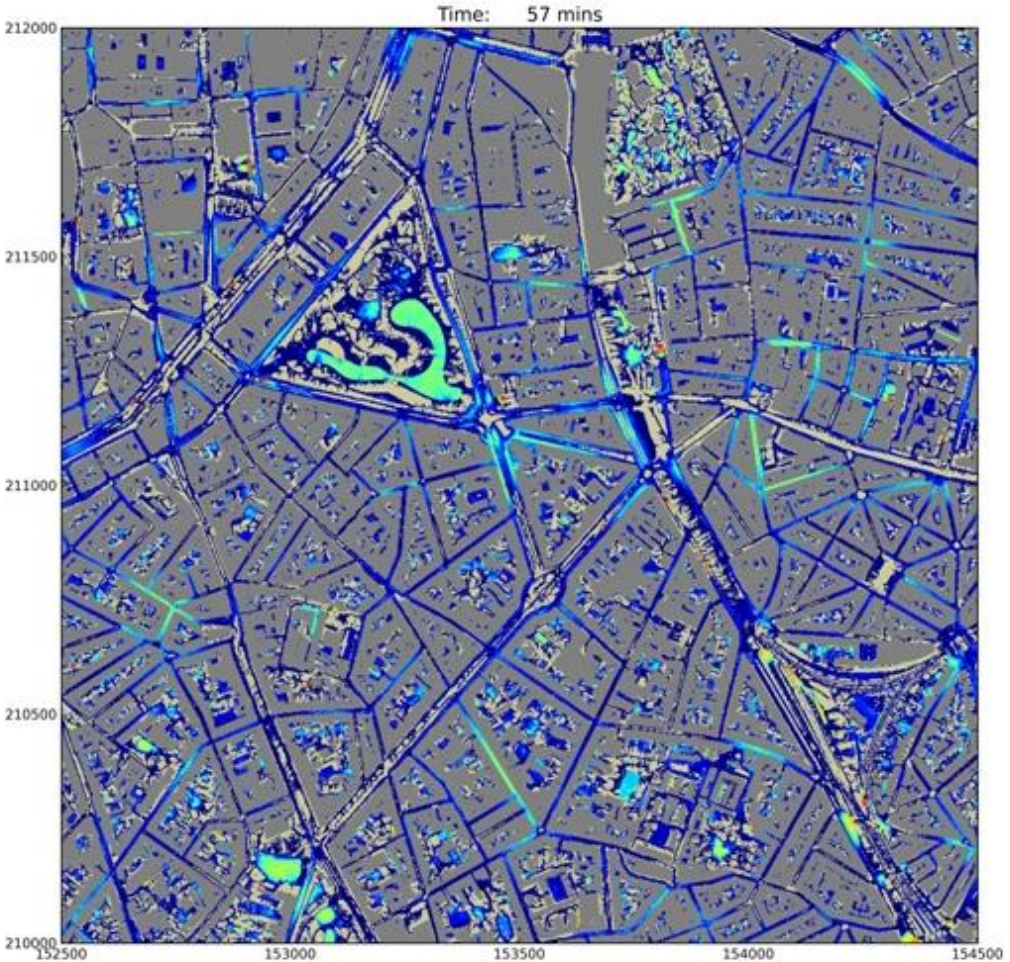
→ No indirect damages to infrastructure

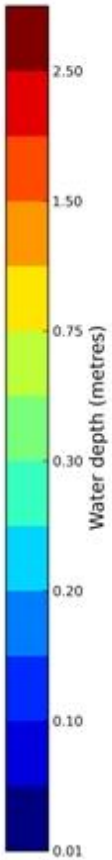
EPSRC
Engineering and Physical Sciences Research Council

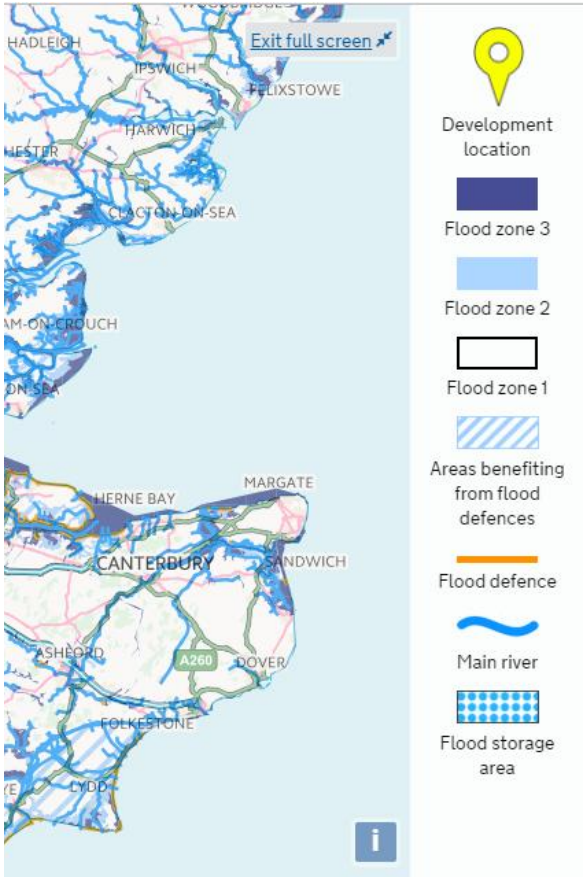
Hazard modelling

- Analysis of hazard scenarios
- Flood intensity measures
- Hazard maps

HAZARD

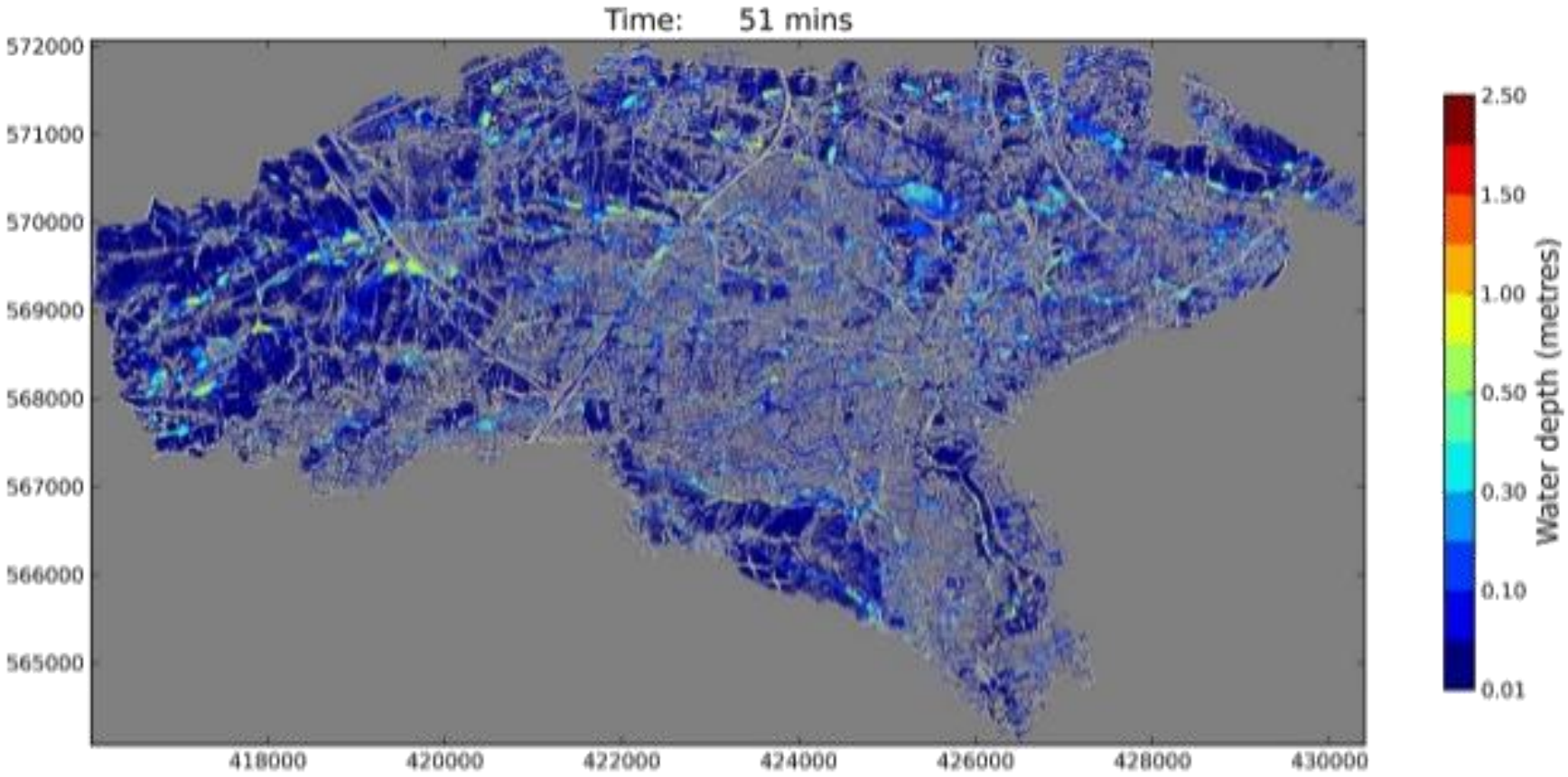






Hazard modelling

CityCAT flood model



Water depth map of **Ouseburn catchment** (area = 120km^2 , cell size = 2m, cells = 30million). Storm event = 60 minutes, 100-year return period

Exposure assessment

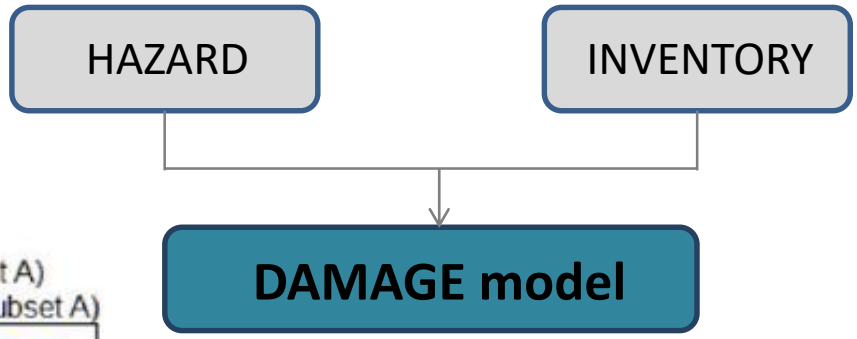
- Build a geo-referenced database
- Merging data into one inventory
- Technical and engineering information

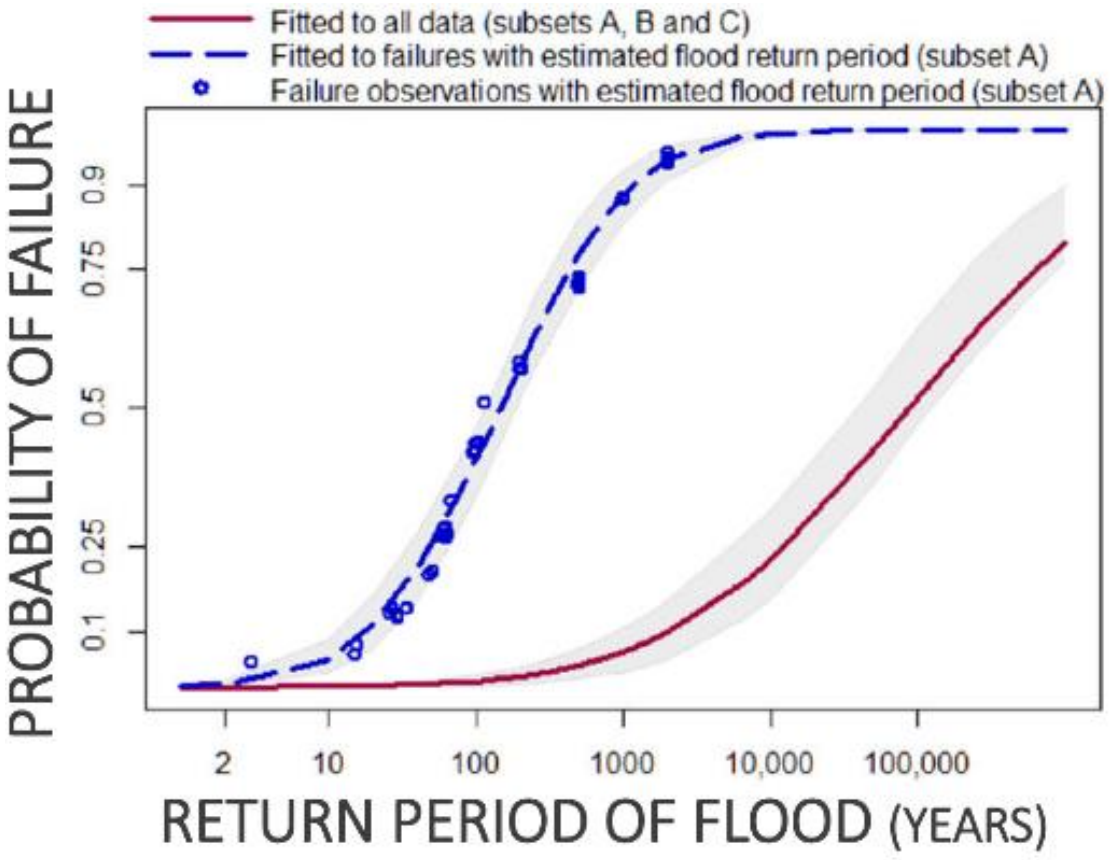
Data Source	Description of source	Accuracy and reliability of source	Owner of source	Comments
Scour, assets, failures				
Railways Archive	Failure reports	Not all incidents included	Railways Archive	
News Reports	Internet searches for news reports	Not all incidents included		
New Civil Engineer (NCE) magazine	Incidents included as news items	Not all incidents included		
Weather and Rainfall Data				
EA/NRW	Rainfall and river flow data	Good		
Hi-Flows UK	Flood peak data	Good		
NRFA	River flow data	Good		

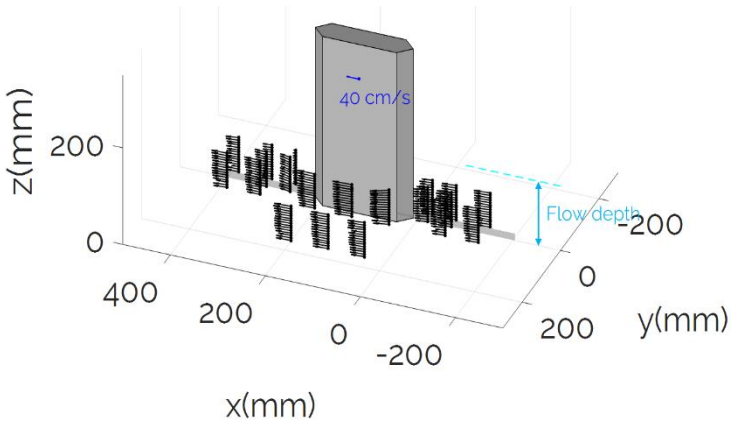
Date DD/MM/YYYY	River	Location	Type of Structure	Use
Road/Foot bridges				
21/11/2009	Derwent	Northside Bridge, Workington, Cumbria	Bridge	Road
??/11/2009	Derwent	Northside Foot Bridge	Bridge	Foot
01/11/2009	Derwent	Calva Bridge, Workington, Cumbria (road bridge)	Bridge	Road
21/11/2009	Derwent	Camerton bridge, Workington, Cumbria (foot bridge)	Bridge	disused railway/ footbridge
??/11/2009	Cocker	Lorton Bridge, near Cockermouth	Bridge	Road

Damage modelling

- Assess the damage
- Hazard loading vs damage Functionality loss metrics

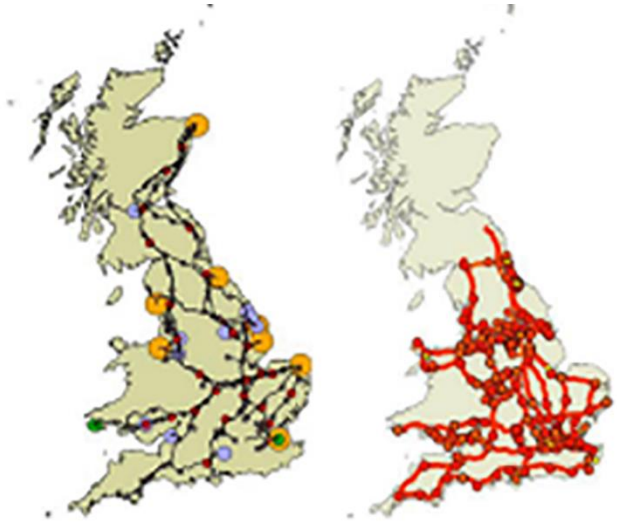


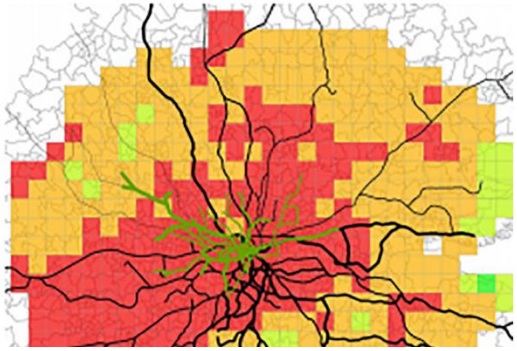


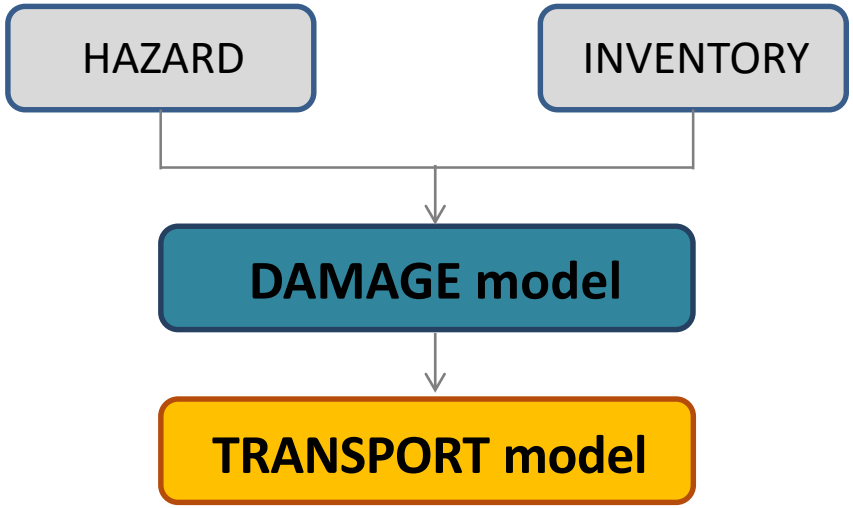


Consequences

- Model network flows and accessibility
- Flood-transport integration
- Identify bridges and routes at risk

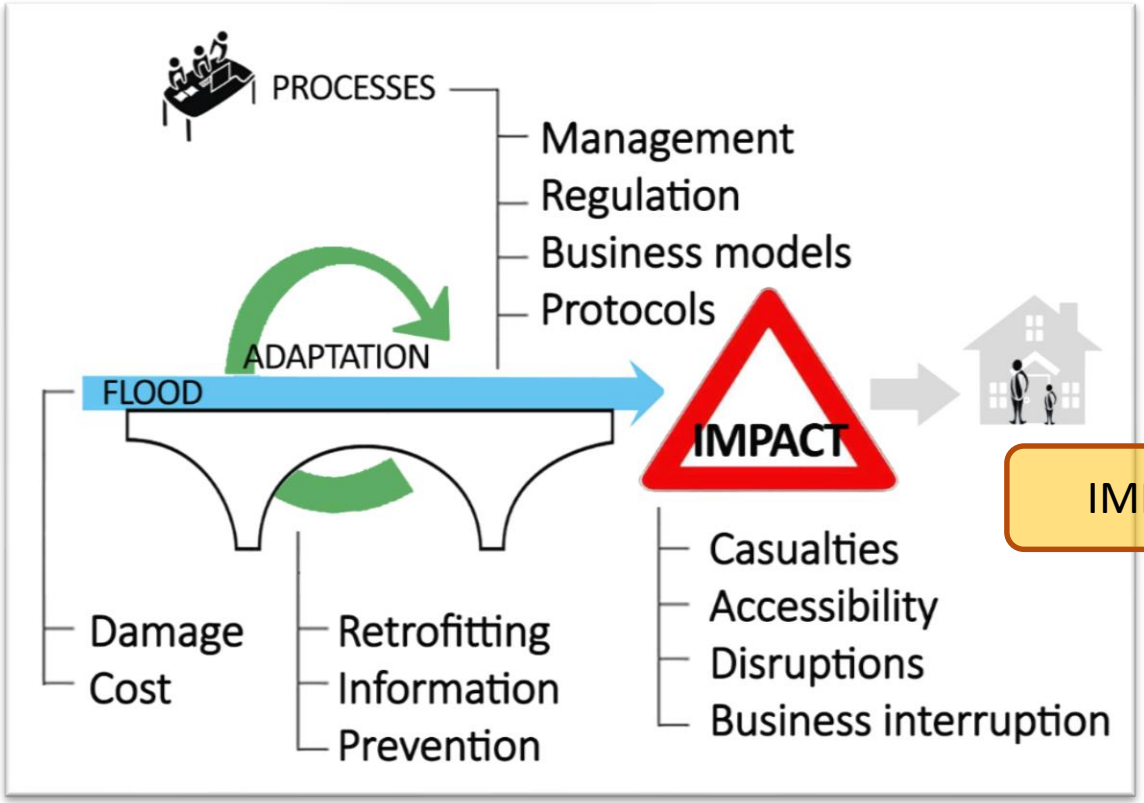


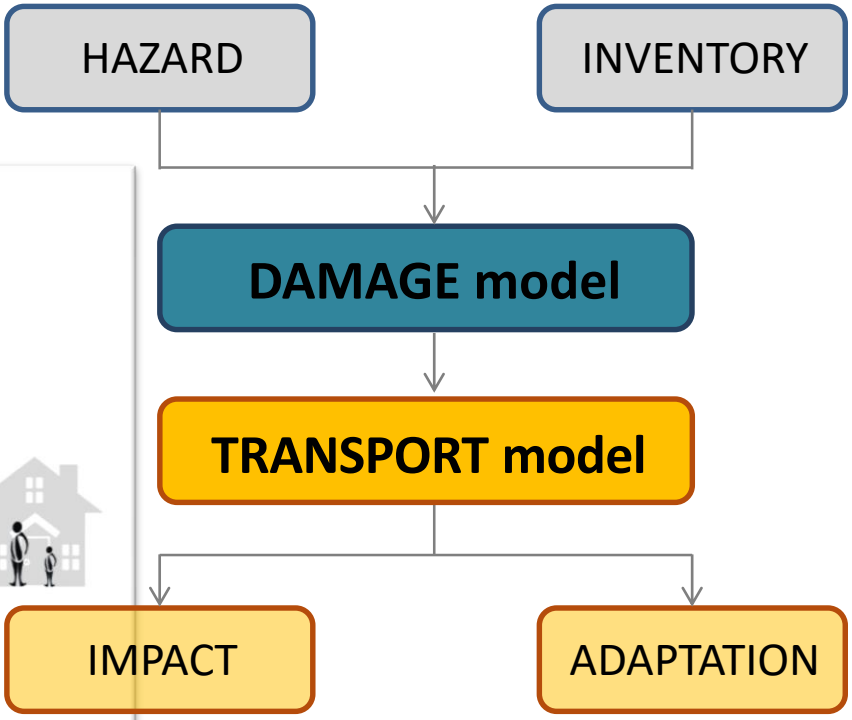




Consequences

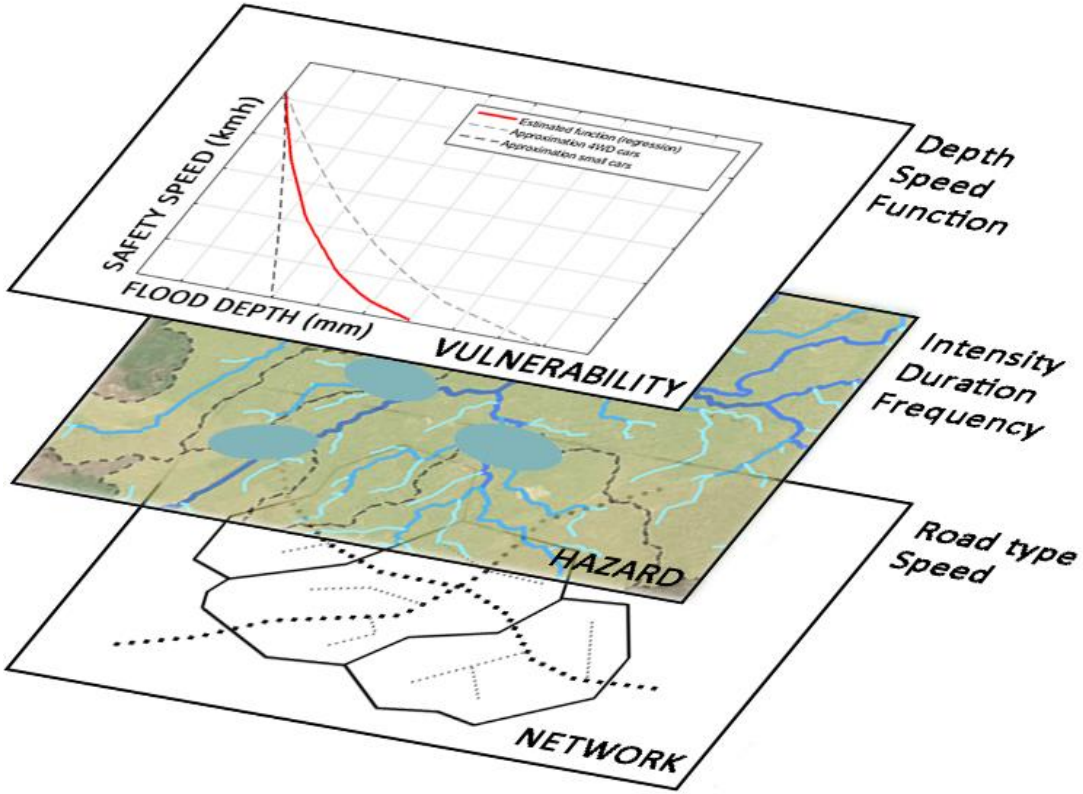
- Societal and economic impact
- Target interventions
- Quantify returns and payback

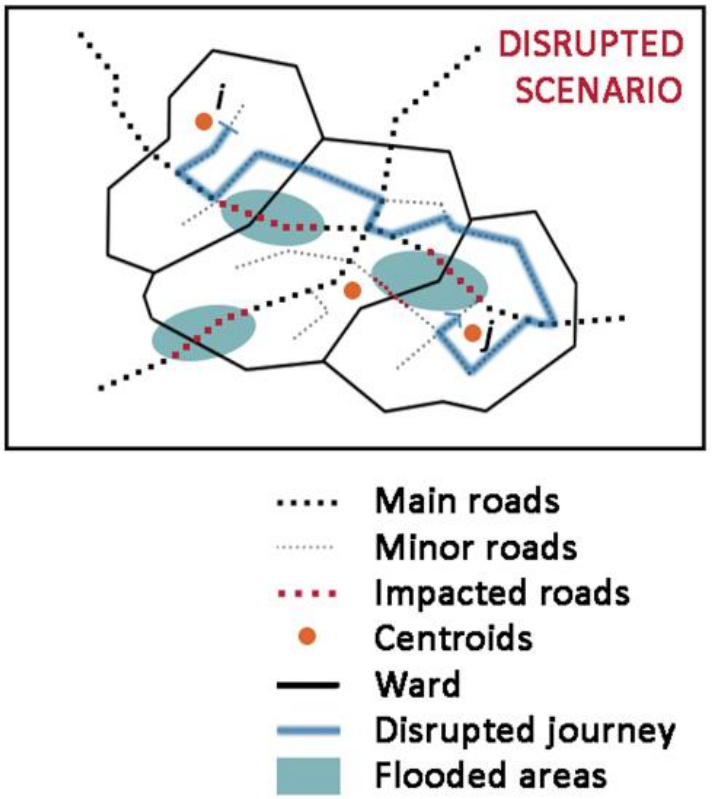




Impact

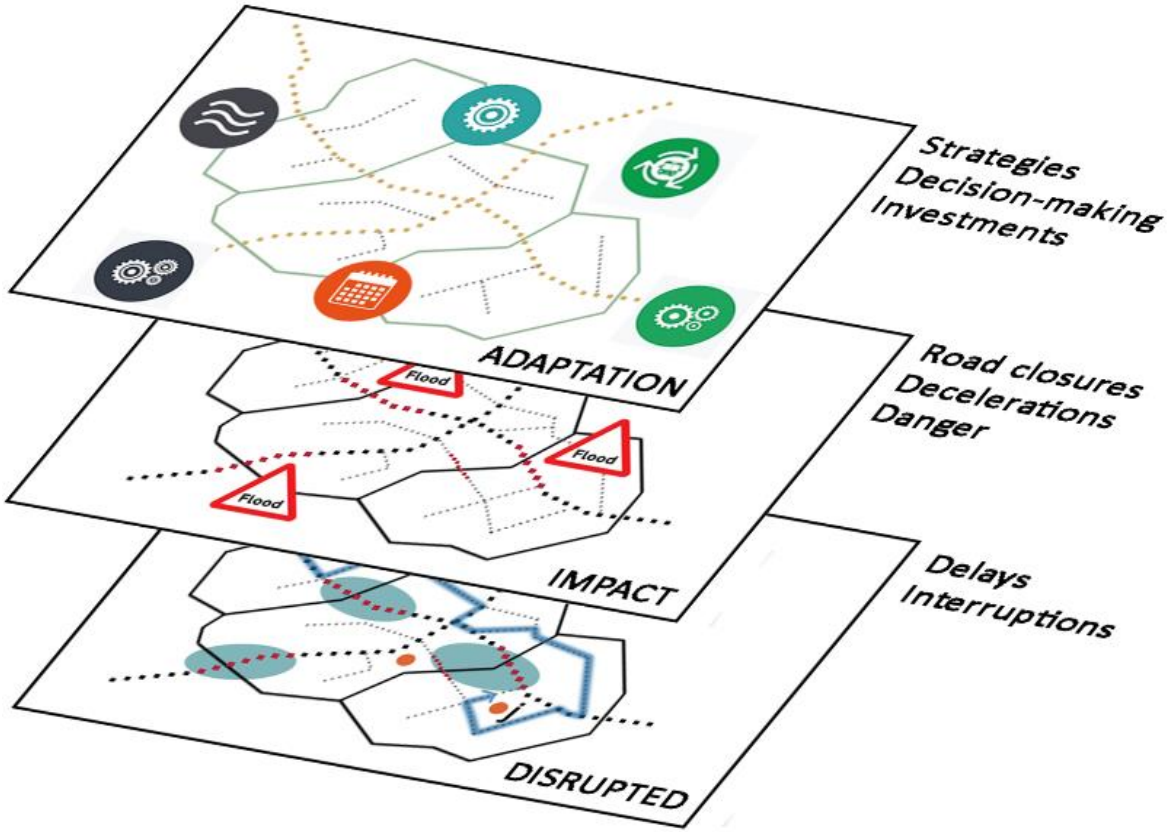
Flood impact on road networks

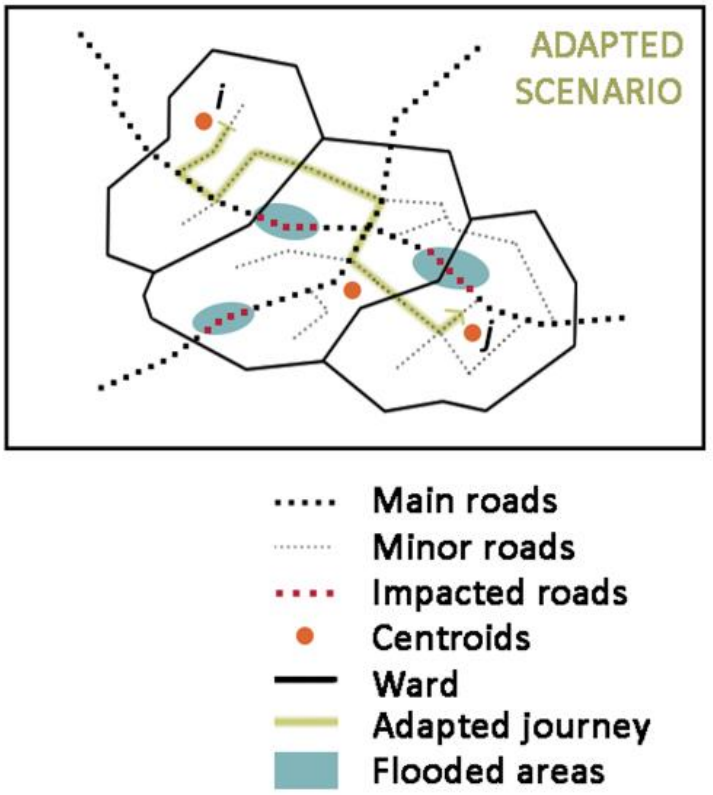




Adaptation

Adaptation on road networks





ITRC mistral
multi-scale infrastructure systems analytics

Adaptation

Grey adaptation

Green adaptation

EPSRC
Engineering and Physical Sciences Research Council

ITRC mistral
multi-scale infrastructure systems analytics

Adaptation

BASELINE COST

Damage cost of hazard impact WITHOUT ADAPTATION

ADAPTATION COST

Damage cost WITH ADAPTATION + Adaptation intervention cost - Co-benefits from adaptation

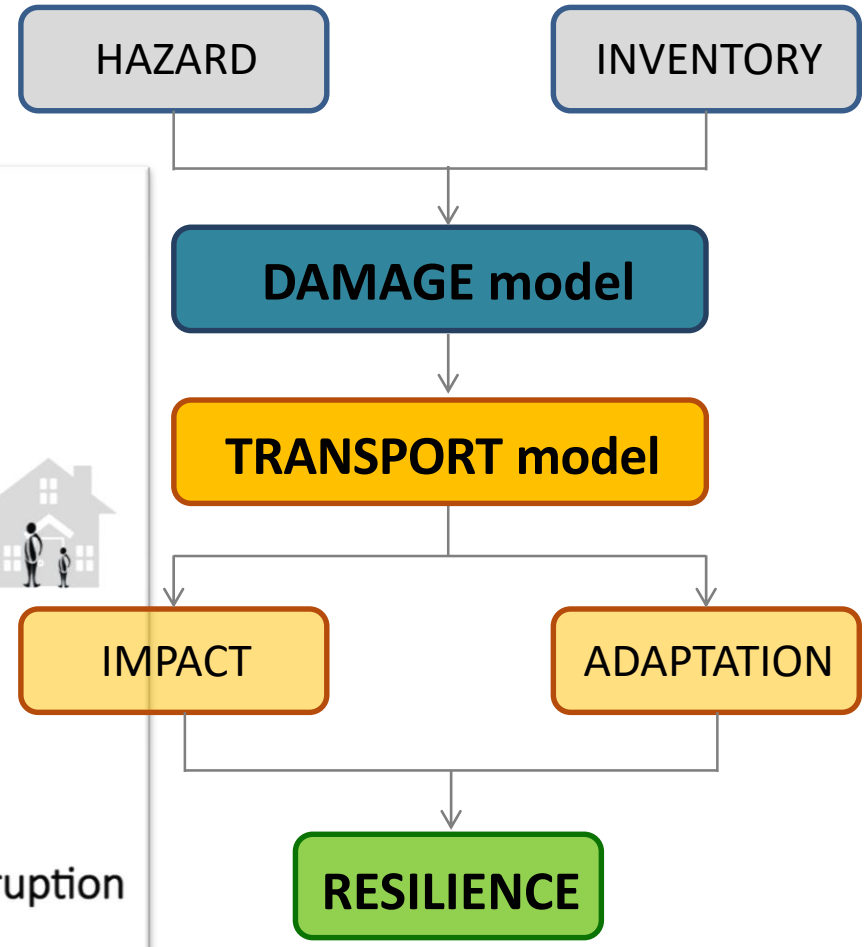
COST-BENEFIT

BASELINE COST - ADAPTATION COST

ITRC mistral
multi-scale infrastructure systems analytics

Consequences

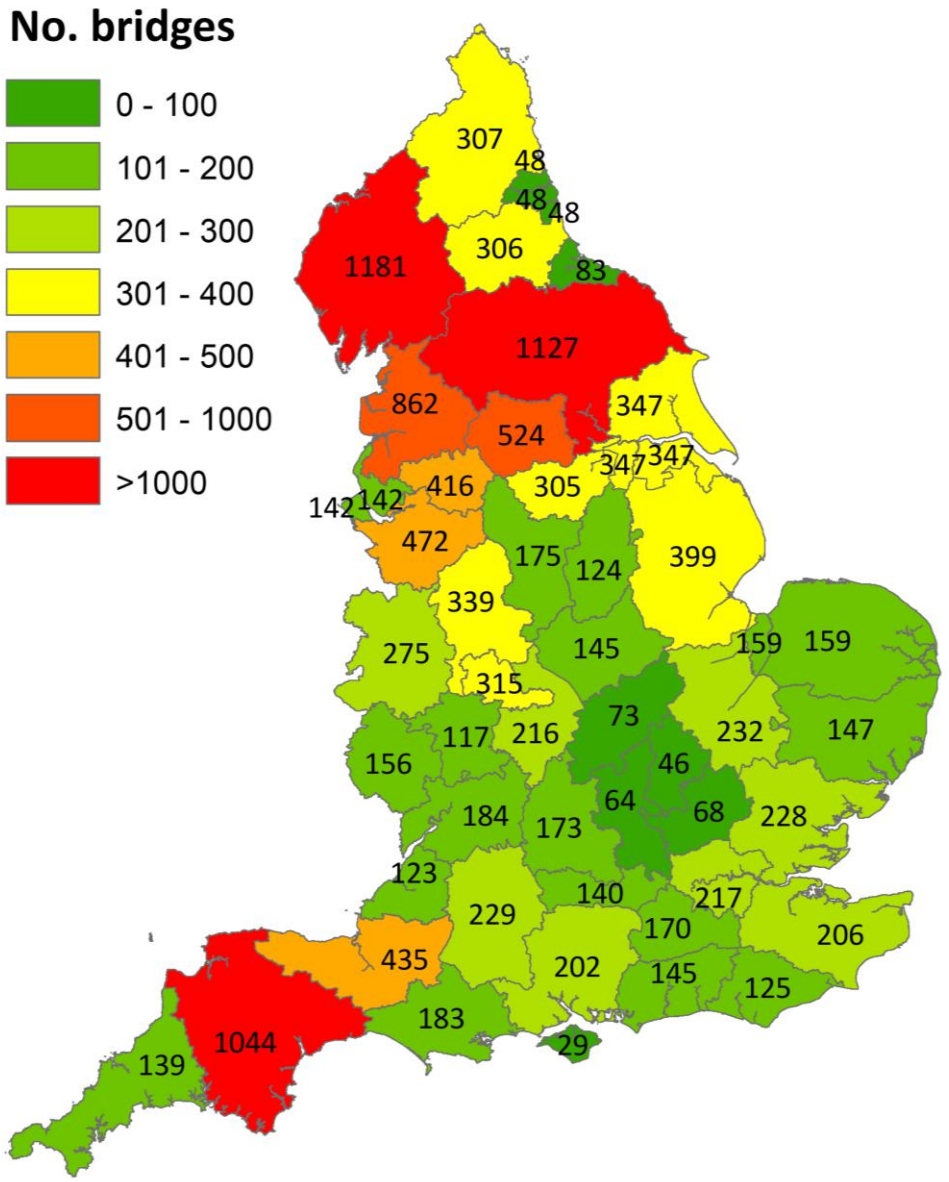
- Societal and economic impact
- Target interventions
- Quantify returns and payback



National analysis

BRIDGE TAXONOMY

- Topography (catchment)
- Type of bridge
- Type of foundations
- Age
- Maintenance
- Type of load/mean



ITRC mistral
multi-scale infrastructure systems analytics

Key points

- CITIES ALONG RIVERS
- BRIDGE CRITICALITY
- DISCONNECTION COST
- NATIONAL BRIDGE DATABASE

EPSRC
Engineering and Physical Sciences Research Council

ITRC mistral
multi-scale infrastructure systems analytics

Future research

- FLOOD-BRIDGE DAMAGE MODEL
- INVENTORY PILOT
- UK CASE STUDY
- RETROFITTING
- SMART BRIDGES

EPSRC
Engineering and Physical Sciences Research Council

ITRC mistral
multi-scale infrastructure systems analytics

Talk to me! 跟我说说话!

THANK YOU
谢谢

Questions?

maria.pregnolato@ncl.ac.uk

Interested in?

- **CAT modelling**
- **Flood impact**
- **Urban adaptation**
- **Bridge engineering**

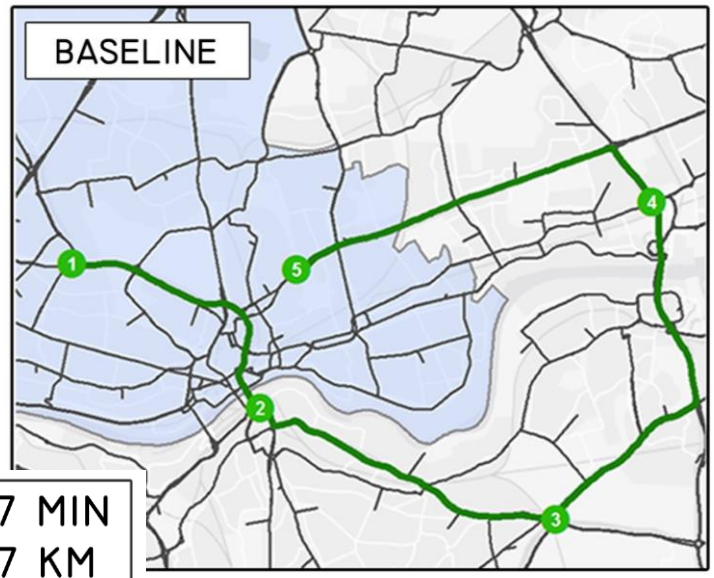
Pregnolato M. and Dawson D. (2018). "Adaptation investments for transport resilience: trends and recommendations". International Journal of Safety and Security Engineering (in press).

Pregnolato et al. (2017a). "Impact of flooding and urban adaptation in a changing climate". Journal of Infrastructure Systems, Special Issue "Infrastructure Resilience to Climate Change", 23(4), 1-13

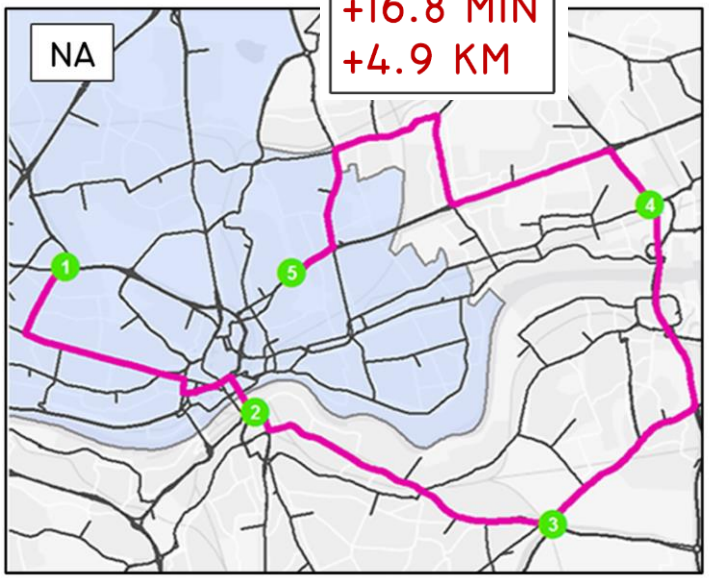
Pregnolato et al. (2017b). "The impact of flooding on urban transport sector - an integrated depth-disruption function". Transport Research Part D: Transport and Environment, 55, 67-81.

Pregnolato et al. (2016). "Assessing Urban Strategies for Reducing the Impacts of extreme Weather on Infrastructure Networks" Royal Society Open Science, Special Issue "City Analytics" 3(5), 1-15

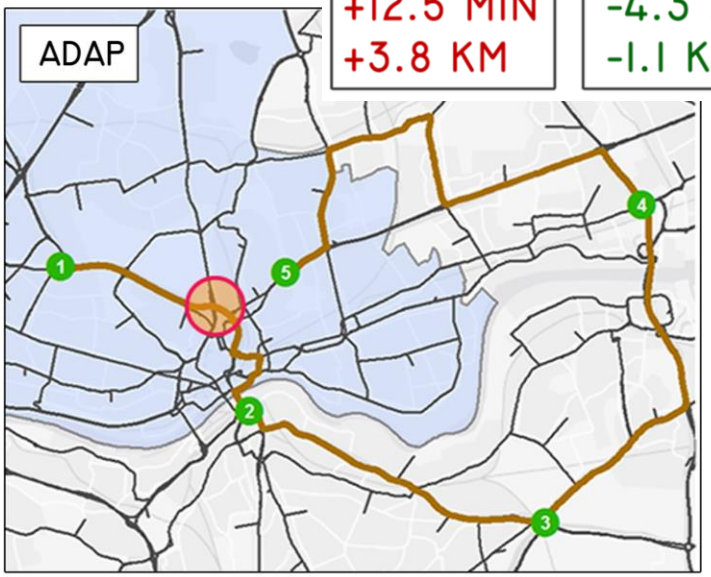
Example (Newcastle)



23.7 MIN
26.7 KM



+16.8 MIN
+4.9 KM



+12.5 MIN
+3.8 KM

-4.3 MIN
-1.1 KM

Protection of one node

EPSRC
Engineering and Physical Sciences Research Council

ITRC mistral
multi-scale infrastructure systems analytics

Critical links

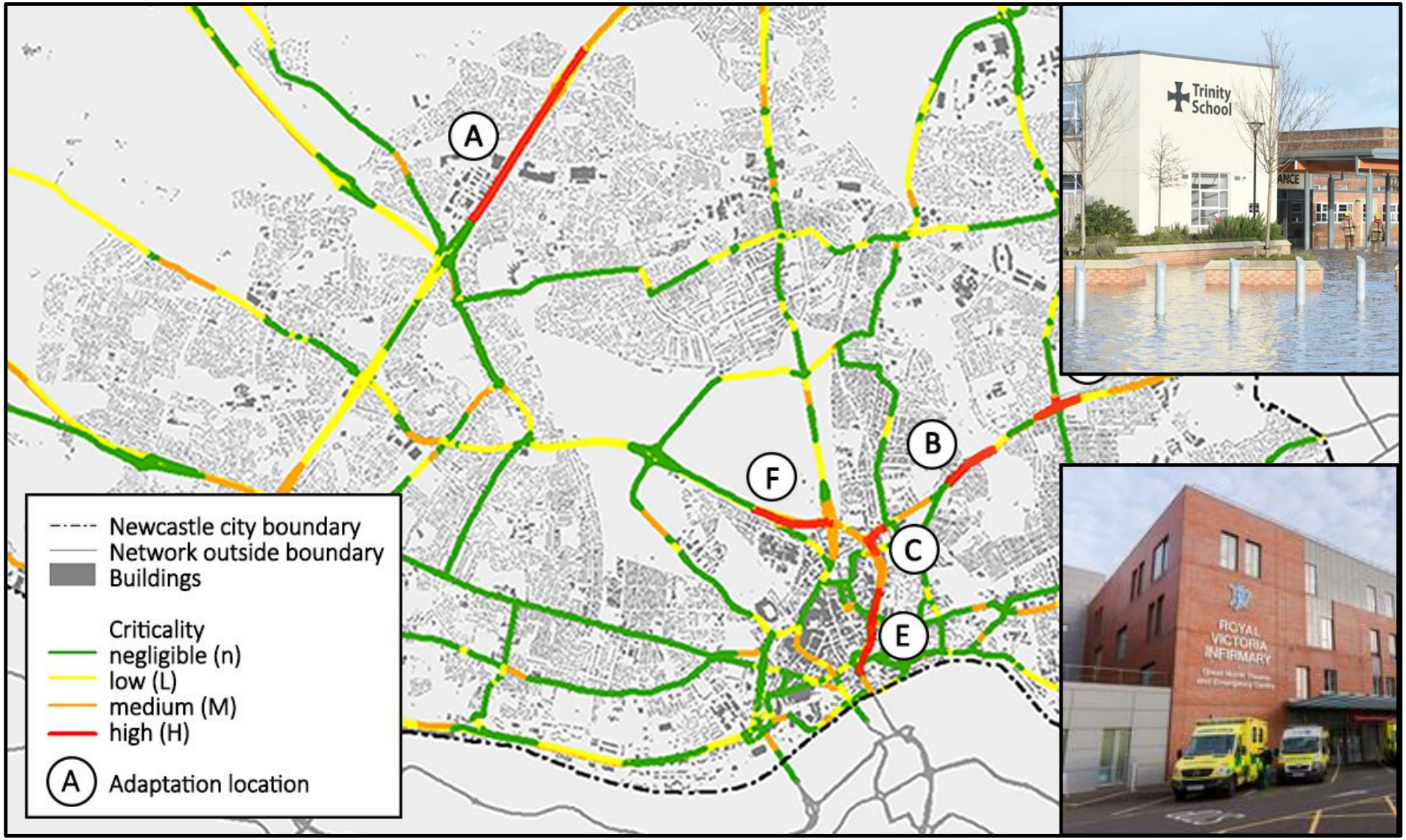
[MM] FLOOD DEPTH / [CAR/HR] FLOW		EXPOSURE			
		MINOR 0-500	MODERATE 501-1500	MAJOR 1501-2500	SEVERE >2500
HAZARD	MINOR 0-100	LOW	LOW	LOW	MEDIUM
	MODERATE 101-300	LOW	MEDIUM	MEDIUM	MEDIUM
	MAJOR 301-1500	LOW	MEDIUM	MEDIUM	HIGH
	SEVERE >1500	MEDIUM	MEDIUM	HIGH	HIGH

IMPACT
LOW
MEDIUM
HIGH

EPSRC
Engineering and Physical Sciences Research Council

ITRC mistral
multi-scale infrastructure systems analytics

Hotspots



EPSRC
Engineering and Physical Sciences Research Council

….OTHER QUESTIONS??

- How infrastructure can be made SMART?
  - Smart in its usage
  - Smart in its robustness
  - …
- Main barrier to use so much technology?
  - Costs vs benefits
  - Being reliant on technology
  - …