Institution: Lancaster University
Unit of Assessment: 11, Computer Science and Informatics
Title of case study: SmartWater: Harnessing the power of the Internet of Things to transform the UK transport network's flood management.
Period when the underpinning research was undertaken: 2013-2020
Details of staff conducting the underpinning research from the submitting unit:

Name(s):	Role(s) (e.g. job title):	Period(s) employed by submitting HEI:
Professor Nigel Davies	Distinguished Professor	01/08/95-present
Mike Harding	Research Fellow	01/04/07-present

Period when the claimed impact occurred: 2013-2020
Is this case study continued from a case study submitted in 2014? N

1. Summary of the impact

Collaborative research carried out at Lancaster University has resulted in a first-of-a-kind data-driven drainage management service (SmartWater) used across the UK to help reduce surface water flooding. SmartWater, a commercial service implemented by InTouch Ltd is available in the UK with patents pending in Europe, the US and Hong Kong. It currently supports the management of **over 643,142 drainage assets**, accounting for approximately **4.6% of all roadside drains (gullies) in the UK**. Highway maintainers estimate that using SmartWater they accrue **cost-savings totalling over 20% annually**, with a **25% reduction in emergency callouts across contracts**. Lancaster's research contribution in the design of IoT drainage analytics and understanding issues of mistrust amongst asset maintenance stakeholders has underpinned the user-centred design of SmartWater and has been pivotal in the adoption and user acceptance of SmartWater within a domain that has traditionally been slow to innovate.

2. Underpinning research

The SmartWater system builds on two distinct sets of underpinning research - the development of a set of techniques for helping establish trustworthy data systems in the highways sector and the creation of an IoT platform for precision surface water management.

Lancaster's work on trustworthy data systems drew on an initial collaboration with Carillion PLC and InTouch Ltd as part of the OurTravel **[G1]** project (Real-Time Context Sensitive Travel Information for Communities' (2009-2011) that developed the world's first travel information system capable of reporting context-sensitive highway maintenance information through journey-based social networks, similar to how Google's Waze service provisions travel information today. Lancaster's findings highlighted the need to address emerging upstream maintenance information reliability issues and more critically, the deep-rooted mistrust issues that negatively affect highway maintenance data exchange between local authorities and highways maintainers **[3.3]**, along with its use by travellers. InTouch Ltd exploited this new understanding of emerging trust challenges within the transport maintenance sector by developing a UK leading mobile works orders management platform (WOMs). WOMs created a mobile inspection data capture system that integrated trusted highways maintenance information with social travel network feeds. It enabled the direct dissemination of context-sensitive maintenance information to personal travellers and workers in the field undertaking infrastructure management tasks. As a leading highways maintainer at the time, Carillion PLC acted as a conduit for the research, providing access to drainage operatives that allowed Lancaster to examine their work practice and use of WOM technology within a real-world setting.

Building on the insights from OurTravel, FAITH: Building Trust Between Citizens, Local Authorities and Contractors (2011-2013) **[G2]** set out to investigate more broadly the role of trust in highway maintenance, developing new tools and guidance for the sector (including both academic publications and industry white papers) that provided actionable guidance on how greater levels of trustworthiness can be designed into digital solutions **[3.2]**. In collaboration with Carillion PLC, InTouch Ltd, and Redcar & Cleveland Council, Lancaster worked with local management authorities to investigate and mitigate mistrust amongst highway maintenance stakeholders. Consequently, new guidelines were developed to inform the future design of civic transport management technologies that aimed to facilitate greater transparency and trustworthiness by

design **[3.1]**. InTouch were able to utilise these findings to inform the product development of new drainage inspection capabilities.

In parallel with underpinning research on trustworthy data systems, Lancaster also began to explore the use of open IoT data in highways maintenance. In particular, Lancaster facilitated workshops that brought together industry leaders (i.e. Carillion, Balfour Beatty, Amey) to explore barriers to data accessibility and interoperability. Based on the requirements identified from industry, Lancaster's was able to contribute to new industry data standards [e.g. PAS 212:2016 - Automatic resource discovery for the Internet of Things] and tools (i.e. SmartStreets IoT Hub **[G3]**). These developments lowered the cost of provisioning and integrating highway related datasets. This work led to a focus on drainage management – addressing the need for the sector to comply with new UK Government legislation (Flood & Water Management Act 2010) that created greater expectations for transport infrastructure maintainers to improve the management of roadside drainage and mitigate the impact of flooding. In collaboration with InTouch and Mott MacDonald as part of the SmartClean: Data-driven Precision Surface Water Management for Urban Environments (2015-2017) project **[G4]**, Lancaster developed 1) a novel IoT sensor that is now at the heart of SmartWater, along with 2) the supporting statistical models to monitor and predict roadside drainage conditions. Lancaster's research into the use and configuration of LoRa **[3.5]**, which is a low-power, long-range wireless communications medium, has underpinned the transformative capabilities of SmartWater as an end-to-end drainage decision-support solution.

Together these two strands of underpinning research have led to the development of a system that transforms manual, reactive transport infrastructure maintenance practices through the curation and development of new forms of data to support more informed, proactive maintenance decision-making. Following the recent commercial impact of the SmartClean research within the highways sector, Lancaster and InTouch partnered with Network Rail as part of the TrackWater: Supporting High-Value, Low-Cost Rail Network Drainage Asset Management (2017-2019) **[G5]** and TrackWater2.0 (2019-2020) **[G6]** projects to assess and evaluate the feasibility of utilising SmartWater in track-side drainage management. Lancaster applied previous learning in highways maintenance to increase understanding of the sociotechnical implications of leveraging predictive drainage analytics **[3.4]** and inform organisational changes and technical adaptations to meet the needs of rail operatives.

3. References to the research

3.1. HCI, Civic Engagement & Trust. **M. Harding**, B. Knowles, **N. Davies**, M. Rouncefield. 2015. In Proceedings of the 33rd Annual ACM Conference on Human Factors in Computing Systems (CHI '15). ACM, New York, NY, USA, 2833-2842 https://doi.org/10.1145/2702123.2702255

3.2. Trustworthy by design. B. Knowles, **M. Harding,** L. Blair, **N. Davies,** J. Hannon, M. Rouncefield, J. Walden. CSCW '14 Proceedings of the 17th ACM Conference on Computer Supported Cooperative Work & Social Computing. New York: ACM, 2014. p. 1060-1071 https://doi.org/10.1145/2531602.2531699

3.3. Experiences with a social travel information system. **M. Harding,** J. Finney, **N. Davies**, M. Rouncefield, J. Hannon. 2013. In Proceedings of the 2013 ACM International Joint Conference on Pervasive and Ubiquitous Computing (UbiComp 2013). ACM, New York, NY, USA, 173-182 https://doi.org/10.1145/2493432.2493475

3.4 Maintainer perspectives on data-driven transport asset management and the future role of the Internet-of-Things. **M. Harding**, M. Rouncefield, **N. Davies**. In Proceedings of the ACM on Human-Computer Interaction - CSCW, Vol. 3, 112, 13.11.2019.
https://doi.org/10.1145/3359214

3.5. IoT Enabled Highways Maintenance: Towards an Understanding of Emerging Cyber Security Threats. L. Trotter, **M. Harding,** M. Mikusz, **N. Davies**. IEEE Pervasive Computing, Vol. 17, No. 3, 07.2018, p. 23-34. https://doi.org/10.1145/MPRV.2018.03367732

[G1] OurTravel, Innovate UK, 400066, Aug 09 - Oct 11, GBP847,421
[G2] Faith: Building Trust Between Citizens, Local Authorities and Contractors, Innovate UK, (May 2011 - Jan 2014), GBP653,369
[G3] SmartStreets IoT Hub, Innovate UK, 972152, (Apr 2013 - Mar 2014), GBP799,966
[G4] SmartClean, Innovate UK, 131556, (Mar 2014 - Mar 2015), GBP156,915
[G5] TrackWater: Supporting High-Value, Low-Cost Rail Network Drainage Asset Management,

Innovate UK, 103957, (Oct 2017 - Mar 2019), GBP636,078
[G6] TrackWater 2.0, Innovate UK, 971702, Dec 2019 - Nov 2020), GBP348,885

4. Details of the impact

Lancaster University's research into the design and implementation of trustworthy data systems and its application to drainage and gully management has had significant impacts in three key areas: 1) on the working practices, business models and commercial success of the partner organisation InTouch Ltd.; 2) cost-savings through the introduction of more efficient monitoring systems for local authorities, contractors and Highways England resulting in improvements to local and national road infrastructure maintenance; and 3) the application of these systems to national rail infrastructure through collaborations with Network Rail.

4.1 Impact on the working practices, business models and commercial success of InTouch Ltd.

InTouch Ltd are a software development and telecom company based in **Morecambe** in the North West of England.   Until the early 2000s, the company specialised in managed radio communications solutions for the construction industry but seeing a shift in their markets to more digital platforms, InTouch partnered with Lancaster University to innovate. That partnership has resulted in an entirely new area of business for InTouch in drainage asset management and flood prevention. The positive impact this partnership has had for both InTouch and the local economy was lauded by David Morris MP (Morecambe and Lunesdale), who stated that: *"The benefit of having a world leading University on the doorstep facilitates SME's such as InTouch Ltd to take advantage of this incredible resource to allow them to work in markets which they could not hope to achieve without them. InTouch Ltd is a fine example of a long-established business which needed to move with the times and move into being a research led business to be able to maintain and develop new markets."* He goes on to note how *"Having a world leading solution to an ever-increasing flooding problem in the Morecambe and Lunesdale constituency is exactly the type of business we strive for – high quality jobs, high quality solution and great opportunities for expansion"* **[5.1]**.

This *"blossoming"* partnership **[5.1]** has reached maturity within the audit period, resulting in the creation of SmartWater (2015) an innovative, market-leading drainage management and flood prevention solution. SmartWater uses IoT sensor technologies and real-time weather information to monitor gullies, predict flood risk and facilitate more proactive drainage maintenance. This shift in maintenance practice has seen a reduction in maintenance costs among key maintenance providers and clients **of up to 50% [5.2]**.

InTouch has successfully taken SmartWater products to market and the company has seen significant growth as a consequence. During the REF impact period, InTouch expanded its workforce to accommodate for this strand of its business provision, **hiring 13 highly skilled members of staff** and restructuring a further **3 existing roles** to support the management and rollout of related products and services between 2013 and 2021. The SmartWater system is responsible for the management of over **643,142 gullies** and accounts for around **4.6% of all gully drains in the UK**. The value of the company has grown by **65% between 2013 and 2020**, and it now works with **22 local authorities and road maintenance contractors**, with the list of clients continuing to grow **[5.2]**. John Walden, Managing Director of InTouch, sees a direct link between his company's success and its engagement with Lancaster University research: *"Our collaboration with Lancaster University and highways maintenance companies such as Carillion, Amey and Balfour Beatty has totally transformed our company. We knew that if we were to take a long-term strategic look at the data and communications industry and predict the likely advances in innovation, we needed academic input and our working with Lancaster University in consortiums has helped to strengthen the long-term viability of the company. I'd urge 'more small companies to take advantage of how universities have opened up their fantastic resources to businesses like ours"* **[5.2]**.

4.2 Cost-savings for local authorities, contractors and Highways England arising from SmartWater and related products.
a) Local Authorities and Maintenance Contractors
Thanks to the introduction of adaptive data monitoring and asset management products developed in partnership with Lancaster University, impacts have been realised by InTouch's large and expanding client base. Drawing on data from across its portfolio, estimates suggest that the

introduction of SmartWater results in average cost-savings of **over 20% annually (and as high as 50%)**, including **a reduction in callouts by 25%**, and an estimated **reduction in flood incidents by 20% [5.2, 5.6]**. The deployment of these systems has helped local authorities and contractors to shift maintenance procedures from cyclical, annual cleansing to a more efficient and proactive approach, identifying and targeting specific gullies that are more prone to blockages. The system is able to learn and adapt to prevailing environmental conditions and thereby identify clusters of gullies that are at higher risk of flooding which can then be targeted with remedial work. For example, Knowsley MBC Highways & Transportation have stated that because of the introduction of SmartWater monitoring systems *"we are now able to target the high-risk gullies with an efficiency-driven approach"*. Similarly, the Asset Officer at Stirling Council has commented on how: *"The introduction of the InTouch Inspection software has improved the trust we have in our contractor, we now have the tools to see daily activity of the cleaning schedule and by viewing the photographs taken, we can reduce the number of on-site inspections of our gully assets. As a direct result of implementing this solution we have made a significant saving this year in emergency flooding callouts"* **[5.3]**.

Local authorities have also commented on the long-term transformational impact SmartWater has had on the way they manage their drainage systems. In a recent Highways Infrastructure Asset Management report (2018), Plymouth City Council described how: *"The SmartWater system produces focussed work schedules to target only those gullies that need attention, namely gullies that are blocked,* [or] *close to becoming blocked… In a first iteration of implementing the system, we would expect the three categories of gullies identified to equate to 20-25% of the gully stock based on empirical evidence of a number of years of research and implementation of this system in other local authorities. Subsequent iterations of the system should see the numbers of gullies that need to be targeted [for cleansing] reduce toward 10% and maybe even lower"* **[5.4]**. Reducing the number of gully visits required, naturally reduces the overall cost of system cleansing.

The savings accrued from the implementation of the SmartWater system are significant. Bristol City Council have recorded a significant **80% reduction in the number of callouts** due to flooding on its roads, a reduction in the prevalence of potholes due to reduced surface water, and **the number of blocked gullies in the city are down from 18% to 5%**. This has been realised in a fall in the budget required for highways flood prevention from **GBP431,000 in 2014**, to **GBP150,000 in 2018, a reduction of 65.2%** at a time when all local authorities are facing intense budgetary restraints **[5.5]**.

SmartWater has also provided highways maintenance companies with a novel platform offering richer and more transparent information to their clients. This has improved trust relationships between local authorities and the companies they hire to conduct maintenance and ultimately helped them address the legal responsibility placed on them to manage highways flooding. One such maintenance company with multiple cleaning subcontracts was Carillion. In 2018, Carillion commented on the benefits arising from SmartWater in their *"ability to build strong business partnerships"* with local authorities and were committed to continue supporting the rollout of SmartWater technologies, and to *"implement them further in different contracts"* **[5.7]**. This work has continued under other contractors, including Amey and Balfour Beatty, who combined, maintain thousands of miles of road and rail across the UK. Amey have emulated the SmartWater solutions to develop their own related products, helping them achieve several notable contract deals, including one with Yorkshire Water worth GBP100million **[5.8]**.

b) Highways England
Highways England, the UK government's road operations and maintenance agency, has funded in-field trials of SmartWater gully sensor and wireless communication infrastructure on the M25 motorway to assess the environmental, economic and societal impacts of real-time drainage asset monitoring in known flood hotspot areas **[5.2]**. A second Highways England trial on the M6 Smart Motorway (J21-26) has been undertaken with 54 sensors deployed in the first 12 months, demonstrating the applicability of the technology in different environmental conditions and to different types of assets.

These trials have been reflected in UK wide policy. The Department for Transport created an initiative to link SMEs developing innovative solutions in the highways sector with a network of relevant agencies, organisations and local authorities as part of the Connected Places Catapult

and this has fed into the work with InTouch Ltd. On the subject of gully management, Steve Berry OBE at Department for Transport has said, *"Since 2016, the Department for Transport has been encouraging all highway authorities and the wider sector to adopt a risk-based approach to their maintenance service. We are also encouraging all those who maintain highways to adopt new and emerging technologies as part of their highway service. This should include consideration of new ideas, methods of working and innovation in order to drive greater efficiency."* He goes on to note *"SmartWater, developed by InTouch, in collaboration with Lancaster University, is one example of a real problem being solved by utilising a robust technology solution.* ***The novel way of combining sensors, changing working patterns and large data analysis not only helps reduce risk and the number of flooding events, but also increases efficiency and can offer value for money****"* **[5.9]**.

InTouch have recently (2019-2020) partnered with The Highways Agency to carry out SmartWater trials on the M25. 55 sensors were integrated into existing smart lighting infrastructure to inform the cleaning regime of high value drainage assets. Positive results from the initial deployment has created confidence in the process and led to its wider implementation to include four junctions on the M6. The work has received positive comment from the Department of Transport *"At the last two LCRIG (Local Council Roads Innovation Group) events, I was pleased to see the early adopters praising the SmartWater solution in their presentations and allowing the audience to understand the benefits that can be achieved using this solution"* **[5.9]**.

4.3 SmartWater technologies for Network Rail
Between 2017 and 2020 InTouch deployed SmartWater in two collaborative R&D projects with Network Rail (TrackWater **[G5]** and TrackWater2 **[G6]**). Network Rail's lead R&D Programme Manager stated "The first phase [TrackWater] went so well that we decided to do another phase funded entirely by us. TrackWater 2.0 is the second phase within Network Rail trialling SmartWater in three different regions at flood prone sites" **[5.10]**. The project has already seen improvements to drainage efficiency, reduced disruption to rail traffic and improved rail worker safety, as manual inspections of trackside catch-pits in hazardous 'red zones' were needed less frequently. **[5.10]**. The success of these trials has seen TrackWater shortlisted as **one of only five projects (out of 130) to be presented as a leading R&D project for Network Rail,** and was given publicity in *Railway International*, where it describes how *"the use of real-time information and automation* [promoted through the TrackWater project] *will equip Network Rail with the ability to keep a tab on the rail infrastructure's drainage system and mitigate drainage-related issues on the tracks"* **[5.11]**. Application of this technology to the UK's national rail network is ongoing, but Network Rail have committed to the next phases of its implementation in the coming years **[5.10]**.

5. Sources to corroborate the impact
5.1 Letter from David Morris, MP (January 2020), corroborating the statement in the House of Commons in June 2019 (link: Hansard), confirming impact of Lancaster research on InTouch Ltd.
5.2 Letter from John Walden, MD, InTouch Ltd. corroborating efficiency savings and new technologies implemented resulting in new jobs, business practices and growth (2021).
5.3 Collated feedback from InTouch Ltd. customers corroborating impact that SmartWater solutions have had on maintenance procedures and efficiency savings.
5.4 Plymouth City Council, *Highways Infrastructure Asset Management* report (2018).
5.5 Presentation given at the *Local Council Roads Innovation Group* about impact of SmartWater on Bristol City Council road maintenance (2019).
5.6 Gateshead Council use of SmartWater to facilitate risk-based highway asset management. Highway Maintenance Plan 2018–2030: appendix 3 - Highway Drainage Strategy (2018).
5.7 Video testimonial by Carillion and others regarding the impact SmartWater has had on working practices and Carillion's commitment to continue roll out of the product (2018).
5.8 Evidence of Amey applying SmartWater processes of preventative flood maintenance and achieving a GBP100million contract with Yorkshire Water (2020).
5.9 Letter from Steve Berry from the Department of Transport (2020).
5.10 Presentation provided by Network Rail and partners reporting observed benefits of SmartWater technology arising from TrackWater projects.
5.11 News Article: 'Network Rail to trial technology to prevent flooding on tracks' *Railway International* (October 2018).