Institution: **Loughborough University**		
Unit of Assessment: **C13 Architecture, Built Environment and Planning**		
Title of case study: **Improving and Protecting the UK Government's largest asset – the Strategic Road Network**		
Period when the underpinning research was undertaken: **2006 – 2014**		
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:
Mohammed Quddus	Professor of Intelligent Transport Systems	2006 – current
Marianna Imprialou	Lecturer	01-Aug-12 – 31-Dec-16
Period when the claimed impact occurred: **1st Aug 2013 – 30th Dec 2020**		
Is this case study continued from a case study submitted in 2014? **No**		

1. Summary of the impact (indicative maximum 100 words)

In 2014 there were 1,472 deaths, 21,425 serious injuries and 175,029 slight injuries from 146,322 road collisions in England. Highways England (HE), responsible for the Strategic Road Network (SRN), was charged by the UK Government to reduce the number killed and seriously injured by 40% by 31 December 2020. To achieve this target, HE engaged with Loughborough University who deployed AI-based collision mapping and risk modelling to raw collision data provided by Department for Transport and improved this to 99% accuracy, leading to the following impacts: 1) Improved the safety of the SRN with 99% accurate accident data and models, giving HE the confidence to implement a new data-driven intelligence-led Safe Systems model; 2) A new Road Safety Delivery Programme was implemented to improve traffic safety across England, and 3) HE's business case to Government was supported with evidence of improvements, leading to the decision to invest **all** £27.4Bn vehicle excise duty into road improvements between 2020-2025.

2. Underpinning research (indicative maximum 500 words)

Geo-spatial data arising from an incredibly diverse and rapidly growing array of sensors and systems is fundamental to addressing translational challenges in road safety. However, analysing spatial data is extremely difficult, owing to indeterminate locational accuracy. For example, more than 1.2m traffic collisions reported by police forces across the UK between 2012-2018 are often inaccurate, unreliable, or inconsistent with respect to the absolute location of collision sites. Furthermore, collision data is likely to be erroneous as space is multi-dimensional, complicating the identification of collision hot-spots and high-risk road elements, especially in complex road configurations [**R1**].

Research conducted by Prof Quddus and Dr Imprialou revealed that traditional collision data are only mapped to the actual road network with ≈82% accuracy [**R2**] – neither convincing nor credible – with subsequent analysis and modelling often leading to inefficient, or even ineffective, safety interventions [**R1**]. The inaccuracies also caused commercial problems, with contracted road operators who are financially responsible for safety in their regions of the 4,300 miles strategic road network (SRN) in England consisting of motorways and major (trunk) roads. Therefore, essential work was needed to increase the quality of the national road accident data, known as STATS19. This data is used for collision analysis, mapping and modelling across the English network. This is to ensure that effective road safety countermeasures are deployed, and road operators are managed appropriately. For this purpose, *collision risk models* that consider traffic exposure, speed, road type and road users needed to be formulated. An in-depth literature review, however, revealed that such models were not available in the UK. Therefore, concerted research efforts were imperative to develop statistical techniques for modelling and analysing UK collision data.

Between 2006 and 2018, the research team developed innovative artificial intelligence (AI) based map-matching algorithms to accurately assign spatial collision data onto road segments. The precision of collision mapping across the SRN of England was substantially enhanced [**R3], [R4]**. Funding from Highways England (HE) enabled the team to customise Loughborough's map-matching algorithms to identify erroneous traffic collision records in the STATS19 database. Two AI-based collisions mapping algorithms achieved, *for the first time*, an accuracy of over 99% in locating collisions, across the entire SRN in England; a significant improvement on the raw data [**R1], [R5]**.

The mapping of high-risk routes and collision hotspots on the SRN demanded an in-depth analysis of the accurately mapped collision data. The team therefore developed advanced statistical models and GIS-based mapping techniques [**R6]** to analyse more than 70,000 traffic collisions occurred on the SRN from 2012 to 2018. The research produced more than 500 spatio-temporal safety risk maps identifying hotspots where people were killed or seriously injured. The research identified high-risk routes classified by road user, vehicle type and severity, which enabled Highways England to: (i) identify causal factors affecting the frequency and severity of traffic collisions and to develop effective countermeasures to save lives, (ii) introduce proactive and targeted traffic safety management and improvement and (iii) evaluate and measure the effectiveness of implemented safety measures to accurately quantify the number of lives saved and report back to UK Government.

3. References to the research (indicative maximum of six references)

R1: Wang, C, Quddus, MA, & Ison, S.G. (2009). Impact of traffic congestion on road safety: a spatial analysis of the M25 motorway in England, *Accident Analysis and Prevention*, 41(4), pp.798-808. DOI: 10.1016/j.aap.2009.04.002.

R2: Deka, L. & Quddus, M. (2014). Network-level accident-mapping: distance-based pattern matching using artificial neural network", *Accident Analysis and Prevention*, 65, 105–113. DOI: 10.1016/j.aap.2013.12.001.

R3: Quddus, M.A., Noland, R.B. & Ochieng, W.Y. (2006). Integrity of map-matching algorithms, *Transportation Research C: Emerging Technologies*, 14(4), 283-302. DOI:10.1016/j.trc.2006.08.004.

R4: Velaga, N.R., Quddus, M.A. & Bristow, A.L. (2009). Developing an enhanced weight-based topological map-matching algorithm for Intelligent Transport Systems, *Transportation Research C: Emerging Technologies*, 17(6), 672-683. DOI:10.1016/j.trc.2009.05.008.

R5: Imprialou, M., Quddus, M. and Pitfield, D. (2014). A high-accuracy generic method for automatic crash mapping using fuzzy logic, *Transportation Research Part C: Emerging Technologies*, 42, 107-120. DOI: 10.1016/j.trc.2014.03.002.

R6: Wang, C, Quddus, MA, Ison, SG (2011). Predicting accident frequency at their severity levels and its application in site ranking using a two-stage mixed multivariate model, *Accident Analysis and Prevention*, 43(6), 1979-1990. DOI: 10.1016/j.aap.2011.05.016.

The research was published following peer review in leading journals and supported by competitively-awarded grants in excess of £1.94M: (1) EPSRC £265K: *Real-time Intelligent Map-matching Algorithms for Advanced Transport Telematics Systems*; (2) EPSRC £372K: *DRT for DRT: Developing Relevant Tools for Demand Responsive Transport and BAE systems*, (3) EPSRC & BAE Systems £1M: *Towards More Autonomy for Unmanned Vehicles: Situational Awareness and Decision Making under Uncertainty,* and (4) EPSRC and Balfour Beatty £124K: *Estimation of a Risk Profile to Operatives and the Public from Motorway Hard Shoulder*. The work described in [R2] and [R5] was funded by Highways England through a competitive HE tender with AECOM between 2014-2018 (£176K to LU).

4. Details of the impact (indicative maximum 750 words)

In every year since 2014, Loughborough researchers have worked closely with Highways England and their technical advisors, AECOM, to produce over 110 safety risk models

covering the entire Strategic Road Network (SRN) [**S1**], [**S2**]. The SRN is the UK Government's largest asset (£128Bn), a network of over 4,300 miles, with more than four million journeys made per day and carrying 1/3 of all traffic and 2/3 of all freight**,** more than three times the rail network**.** The UK government's Department for Transport (DfT) collates unvalidated, inaccurate collision data (known as STATS19) for the UK road network annually. This data was provided to Loughborough as the only source of information upon which strategic safety decisions are made about changes and improvements to the 4,300 miles SRN across England.

The accurate data and models produced by LU helped HE to understand road safety holistically by looking at how vehicles, people and the design of the road infrastructure interact. For the first time, HE had accurate and intelligent information which allowed them to confidently consider a variety of intervention options – ranging from traditional engineering changes on the infrastructure, through to behavioural change campaigns and technology improvements to vehicle maintenance. Our collaboration with HE enabled a **pathway to the following impacts**:

Impact 1 Improved the safety of the SRN with 99% accurate accident data and models, giving HE the confidence to implement a new data-driven intelligence-led Safe Systems model.

Loughborough research on Artificial Intelligence (AI)-based algorithms to the UK government's Department for Transport collision data improved collision data to 99% accuracy [**R2**], [**R5**] and led to Highways England to adopt a new approach to road safety based on our research – a Safe System Model (SSM) [**S1**]. This enabled HE to meet its target to reduce the number killed and seriously injured on the roads by 40% by 31 December 2020. Since winning a competitive HE tender (Regional Delivery Partnership Technical Adviser Framework) with AECOM in 2014, our research has been applied across all regions in England ensuring any investment and intervention by HE is made at genuine collision sites across the SRN [**S1**], [**S2**].

Since 2014, HE has employed 99% precise collision data across the Safe Systems model of road safety improvements. The data and the risk models underpinned the compilation of the first set of more accurate Road Casualties on the Strategic Road Network [**S3**], Regional Road Safety Reports [**S4**], National Incident and Casualty Reduction Plan for HE for the SRN [**S5**]. Research findings compiled in these reports served as the primary input to the HE's Safe System approach to road safety management [**S1**]. Consequently, the investment decisions of £17Bn in interventions made on the SRN between 2014 – 2019 used LU data to determine the optimum intervention and subsequent evaluation of the success of the intervention. In 2016, LU identified that an upward trend in KSI (Killed and Seriously Injured) was emerging and HE had to implement further measures to achieve its strategic outcome set by UK Government of a 40% reduction in killed or seriously injured casualties by the end of 2020 **[S3]**.

Stuart Lovatt, Head of Strategic Road Safety at Highways England stated that [**S1, S6**]:

> *"The partnership between Loughborough University, AECOM and Highways England has been an essential piece of our strategic development for over 8 years….we have been able to develop some strategic policies and procedures by looking in more detail at the in-depth analysis of collisions and casualties on the Strategic Road Network*."

Impact 2: A new Road Safety Delivery Programme (RSDP) was implemented to improve traffic safety across England.

LU research [**R1**], [**R6**] enabled the nationwide mapping of collision risk to identify KSI hotspots, high-risk routes and road users at risk of death and injury (e.g. motorcycle riders) across England. In addition, LU's data and risk models were employed to develop a KSI forecasting tool which identified safety performance of the SRN over time and any shortfall in meeting the 40% KSI. This allowed HE to identify which regions required additional Interventions, how these should be best implemented and at what cost to meet the identified

shortfalls [**S3**]. Consequently, HE implemented a new approach to road safety, which is at the core of its Road Safety Delivery Programmes (RSDP) **[S1], [S7].** Based on the 99% accurate collision data and over 110-regional safety-risk models created by LU every year throughout the current REF period [**S4**], HE along with AECOM developed an intervention toolkit termed as 'Guide to Road Safety Route Treatments' [**S8]** to determine and deliver the optimum and most cost-effective engineering, educational marketing campaigns and enforcement interventions to maximise incident and casualty reduction at the regional level [**S1**], [**S2**]. This facilitated the allocation and re-location of public budgets to where they would be most effective. The accuracy of the data and safety risk models provided to HE by LU allowed evidence-based intervention selection and subsequent evaluation, to monitor and review the changes made.

This richer understanding of the causal factors of a collision hotspot allowed effective interventions to be selected, implemented, and evaluated over time by HE. For example, it was estimated that the South West (SW) region required an additional level of investment of between 150-275M (£3 million per KSI saved, 200 new road schemes) to deliver a programme of targeted interventions to meet the 2020 target set by Government [**S1], [S7]**. The intervention toolkit is flexible and adaptable and currently consists of 220 engineering and non-engineering-based interventions.

Stuart Lovatt asserted that [**S6**]:

> "*LU research has enabled us to look at what kind of infrastructure improvements, as well as all kind of campaigns and behavioural change initiatives we need to develop*."

Taking the South West region as an example, a 19% reduction in personal-injury road casualties (from 1,593 in 2016 to 1,289 in 2018) was achieved in 2018 compared with 2016 owing to the targeted road safety schemes implemented during 2016-2017 **[S4].** The accurate modelling and analysis of collision data by LU underpinned the identification of challenging sites, realised an understanding of the causal factors leading to the collision hotspot, enabling evidence-based intervention selection. These actions and initiatives had a wider impact than just safety improvement. Reduced injury collisions meant reduced associated costs including human, reduction in resulting congestion, road closure and improved journey time resulting in less impact on the road asset **[S7].** Subsequent evaluation of the intervention was conducted through the analysis of accurate collision data and models year on year by LU. Implemented interventions in the South West region resulted in 304 less collisions in 2018, equivalent to a saving of £42.7m from the prevention of road closure (see cost of closures to the economy, i.e., £140.6K per collision that resulted in two-lane being closed for two hours for moderate traffic, [**S7**]). Similarly, there were 20% less collisions (i.e., 3,568 collisions) on the entire SRN between 2014 and 2018 despite an increase of 8% in total vehicle miles travelled **[S3]**. This equates to a saving of £501m from the prevention of road closure.

The accuracy of the data allowed causal factors to be identified for the first time. For example: In the South West of England on the M48, there were 27 incidents/deaths between 2006-2016. But following the implementation of the improved data, (2013-2016) it was shown that 21 out of the 27 incidents were deaths caused by suicide NOT traffic related. Hence, HE implemented a suicide prevention strategy rather than introducing any changes to the road network [**S7**]. This differentiation would not have been possible without LU's accurate data and reporting.

Impact 3: Provided evidence to support the HE business case to Government to invest all vehicle excise duty (worth £27.4Bn) into road improvements from 2020-2025 for the first time.

The implementation of accurate collision prediction models in HE's Safe Systems Approach has allowed any improvement to the SRN to be quantitatively evaluated over time and absolutely records the change in number of KSIs from 2014-2019.

Through the continued improvement and application of LU research **[R2], [R5]**, HE was enabled to immediately identify and quantify the effectiveness of an intervention. Collision

risk was measured and represented by colour on the map of the road network – so transition from a black to an amber hotspot represents an 85% reduction in KSI rates over the period. Improved data and risk models developed by LU were directly fed into HE's safety risk guidelines termed as '**GG 104 Requirements for Safety Risk Assessment**' to address potential risks of further collisions [**S9**].

This evaluation of the road safety interventions made has been fundamental in illustrating the return on the investment made by Government through Road Investment Strategy 1 worth £17Bn, (RIS 1) e.g., for every £1 invested in the SRN brings a £2 benefit to the economy and UK PLC. The quantitative evaluation also confirmed that HE met the Government's target of 40% reduction in personal injury road casualties between 2014-2019 on the SRN.

As a consequence of meeting this target, Treasury made the fundamental decision in 2019 to invest all vehicle excise duty collected in England (£27.4Bn) in future road improvements for the first time **[S10].** The £27.4Bn RIS 2 (Road Investment Strategy 2) programme managed by HE will run from 2020-2025 and will rely on accurate collision data and models **[R6]** provided to them by LU. This illustrates the importance of this research in enabling HE to measure, record, improve and protect the SRN across England - the Governments largest asset.

Senior Road Safety Policy Advisor - Anne-Marie Penny of HE stated that [**S1**]:

> *"Improved data accuracy developed by LU has enabled us to strengthen our evidence-based strategies to delivery targeted road safety interventions with greater confidence. It also allowed us to evaluate the effectiveness of the intervention."*

The decision to adopt the delivery plan for HE 2020-25 **[S10]** represents a £27.4Bn investment decision by the Government that depends upon LU data and evidence, enabling HE to spend the investment wisely and innovatively, and continue to improve the government's biggest national asset.

Loughborough University will continue to work with AECOM, after winning a place on Highways England's Regional Delivery Partnership Technical Adviser Framework for the delivery of RIS 2 2020-2025.

5. Sources to corroborate the impact (indicative maximum of 10 references)

S1: Testimonial from Stuart Lovatt, Highways England (18/03/2020)
S2: Testimonial from AECOM (08/01/2021)
S3: Highways England: reported road casualties on the strategic road network (SRN) 2018 (June 2020)
S4: Regional road safety reports – Highways England, AECOM and Loughborough University (2014 - 2018)
S5: National Incident and Casualty Reduction Plan (NICRP)
S6: Stuart Lovatt – Head of Strategic Road Safety of Highways England: Promotional video Impact Award competition (Winner of 2019)
S7: A report produced by Highways England on Road Safety Delivery Programme – South West (July 2017)
S8: Highways England - Guide to Road Safety Route Treatments (June 2018)
S9: Highways England - GG104 Requirements for Safety Risk Assessment (June 2018)
S10: Road Investment Strategy 2: 2020-2025 (March 2020)