Institution: Coventry University		
Unit of Assessment: 12		
Title of case study: Efficient processes to support Tyre Modelling in Vehicle Design		
Period when the underpinning research was undertaken: 2014 to 2018		
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:**
Mike Blundell	Professor	1991-present
Period when the claimed impact occurred: 2016 to 2021		
Is this case study continued from a case study submitted in 2014? No		

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

The tyre remains one of the most challenging areas of computer modelling. The state-of-the-art modelling procedure described here, follows 20 years of research into the modelling of tyre behaviour to support computer-based design simulation. This has involved collaborations with the automotive and aerospace sectors. The main impact is based on a research project carried out with Jaguar Land Rover (JLR) between 2014 and 2017. This work investigated efficient methods for tyre testing and has resulted in a significant reduction in overall tyre test duration in the order of 72% and a saving in the order of £800k per annum. The procedure is the first of its kind and is now firmly established in the design and development process at JLR.

2. Underpinning research (indicative maximum 500 words)

Greater automotive industry commitment to active safety, Advanced Driver Assistance Systems and the development of autonomous vehicles with on-board computational vehicle dynamics algorithms, demands evermore use of tyre models. In turn, this drives the need for expensive laboratory testing to understand tyre behaviour and to generate data for computer models. The testing modelling of the tyre is one of the most scientifically challenging areas for the virtual design of both aircraft and automotive vehicles.

Professor Blundell's investigations into the computer simulation of automotive vehicle dynamics tests, began at Coventry University (CU) in 2000. Collaborative work with Rover and Dunlop, explored how tyres are tested in a laboratory to obtain data and parameterise tyre models for use in a vehicle dynamics simulation (R1).

Between 2003 and 2006, Blundell collaborated with Harty at Prodrive and published a new low parameter tyre model (R2), used to simulate the Subaru Rally car in race conditions. The model was shown to be accurate, when compared with measured test data, and is now globally available after being implemented in the commercially available Optimum-Tire http://www.optimumg.com/software/optimumtire/ toolkit.

Between 2008 and 2014, Blundell worked on collaborative projects with the aerospace sector, where his automotive knowledge was transferred to develop aircraft tyre models to simulate take-off, landing, runway taxiing manoeuvres and hard emergency landings. Work involved a European funded FP6 project with Eurocopter (R3), an EPSRC funded project with Airbus (R4) and supervised PhD projects with Dunlop Aircraft Tyres and Augusta Westland (R5).

Blundell's work into tyre modelling culminated in 2015, with a collaborative project with JLR to address the problem of the large number of tyres and laboratory test procedures required to obtain the test data needed to populate tyre models, used in the vehicle dynamics simulation models, employed by JLR's design and project teams. These machines are typically large, expensive, laboratory-based installations, such as the Calspan flat-bed (shown in Figure 1) tyre test machine in Buffalo, USA, used in this study to investigate the efficient modelling and testing of tyres (R6).

This work supports the use of computer simulation models, or virtual prototypes, to analyse the performance of new vehicle designs before a physical prototype is built. Computer models are used to simulate the development tests carried out with real vehicles and prototypes, on or off road and at the proving ground. The design areas addressed are vehicle dynamics, ride comfort, safety and durability, an area of design simulation activity expanding rapidly, with the evolution of autonomous vehicles.

The new test procedure, used a novel approach that considered the time tyres spend in different conditions to optimise the test periods for these conditions, rather than traditional methods, that attempt to map the complete envelope of tyre behaviour. This streamlined approach, developed exclusively with JLR and used there for the first time, has proved highly impactful at JLR.

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

(R1) Blundell, M. V. (2000) 'The Modelling and Simulation of Vehicle Handling Part 3: Tyre Modelling'. Proceedings of the Institution of Mechanical Engineers, Part K: Journal of Multi-body Dynamics 214, 1-32 https://doi.org/10.1243/1464419001544115

(R2) Blundell, M. V. and Harty, D. (2006) 'Intermediate tyre model for vehicle handling simulation'. Proceedings for the Institution of Mechanical Engineers, Part K: Journal of Multi-body Dynamics 221, 41-62 https://doi.org/10.1243/14644193JMBD51

(R3) Vadlamudi, S., Blundell M. V., Zhang Y. (2011) ' A multi-body systems approach to simulate helicopter occupant protection systems'. International Journal of Crashworthiness 16, 207 – 218 https://doi.org/10.1080/13588265.2011.554203

(R4) Wood, G., Blundell, M., Sharma, S. (2012) ' A low parameter tyre model for aircraft ground dynamic simulation'. Materials & Design 35, 820-832 https://doi.org/10.1016/j.matdes.2011.03.041

(R5) Wang, Y., Blundell, M.V., Wood, G., Bastien, C. (2014) 'Tyre model development using co-simulation technique for helicopter ground operation'. Proceedings of the Institution of Mechanical Engineers, Part K: Journal of Multi-body Dynamics 228, 400-413 https://doi.org/10.1177/1464419314541638

(R6) Smith, G. and Blundell, M. V. [2016] ' A new efficient free-rolling tyre-testing procedure for the parameterisation of vehicle dynamics tyre models'. Proceedings of the Institution of Mechanical Engineers, Part D: Journal of Automobile Engineering, 231, 1435-1448 https://doi.org/10.1177/0954407016675216

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

Testing vehicles at the proving ground only takes place after extensive validation of the tyre design using computer-based virtual prototypes. The tyre models used are mathematically complex and can have a large range of parameters. In order to parameterise the tyre models used in simulations, an extensive range of physical tyre tests must be performed using specialised test rigs and laboratories. A typical test to parameterise just one tyre model, can degrade 18 prototype tyres and take 14.5 hours of rig time. A typical annual spend on tyre testing for JLR, would be in excess of £1.1million.

Like many leading manufacturers in the automotive sector, JLR is working to increase its use of computer simulations and virtual prototypes in the design and development of their vehicles. JLR's commitment to a virtual engineering-led approach is already defining how current and future models are being designed. Around 40 percent of the design and performance requirements for JLR vehicles are already verified using virtual simulation tools and have an aspiration to achieve100 percent virtual engineering. The novel approach to tyre-testing developed here is the first of its kind and represents a significant step towards achieving this aim, within one of the most challenging areas of computer modelling in car design- tyre testing.

The pathway to impact was established through a direct collaboration between Coventry University and JLR. JLR approached Blundell due to his long-established and respected background in empirical tyre modelling, extending back over 30 years. The JLR tyre modelling group make regular use of Calspan to carry out the challenging testing required to parameterise the tyre models needed by the design and development groups at JLR.

As a direct result of the findings of this research collaboration, JLR changed its design processes to adopt the novel and significantly more efficient approach to tyre testing. This change enabled JLR to reduce the volume of experimental testing required to parameterise tyre models, carried out using the Calspan tyre test facility in the USA. Consequently, this led to a substantial reduction in the costs involved in this testing process. JLR have acknowledged the fundamental role that Coventry University played in this research (S1). The ability for JLR to generate more tyre models and to expand the use of simulation, which has resulted from the impact of this work, has enhanced the design process and led to safer and higher performing vehicles. On completion of the programme, it was clear that the novel process would deliver a significant and ongoing commercial impact at JLR.

"The work you carried out with us has produced efficient tyre lab test methods for JLR that are now in use, yielding excellent results with a reduction in overall tyre testing duration in the order of 72%. Financially, the output from this work has had the biggest impact on JLR of any of our collaborations, due to the huge cost savings in the order of £800k per annum that the work produced. This means that we are able to obtain more test data and to improve the amount and quality of our tyre models." (S1)

These savings – £0.8M per year – represent a major breakthrough in JLR's mission towards a total virtual design environment, that reaps the commercial advantage of lower testing costs, whilst continuing to improve vehicle performance and advance safety standards.

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

[S1] Testimonial letter from Technical Specialist for Tyre CAE and Modelling at Jaguar Land Rover, Banbury Road, Gaydon, Lighthorne Heath, Warwick, CV35 0RG