Foreword: Road profiles: measurement, analysis, and applications

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Biographical notes: Dr Gillespie is a Research Professor at the University of Michigan Transportation Research Institute. He joined the University in 1976 after working at Ford Motor Company as a design analyst and development engineer. Over the years he has conducted research in road roughness characterisation, road-vehicle interactions, and modelling and simulation of vehicle dynamic behaviour. The work in road roughness led to the development of the International Roughness Index. His experience in vehicle dynamics is largely reflected in the book, *Fundamentals of Vehicle Dynamics*, published by the Society of Automotive Engineers. In the late 1980s Dr Gillespie served as a Senior Policy Analyst in the White House Science Office for the Reagan Administration. Upon returning to the University he served as the Director of the Great Lakes Center for Truck and Transit Research. Currently, he teaches courses in the subject areas of vehicle dynamics, automotive engineering, and integrated vehicle systems design.

Understanding and characterising road roughness is a science that has developed in parallel with the automotive industry for the last century. The parallelism is no coincidence. Although road quality, as quantified by its roughness, was an annoyance to road users prior to the existence of the motor vehicle, it became a critical concern with the dramatic increase in speed afforded by use of the internal combustion engine.

Roads paved with unbound rocks, stones, bricks and gravel, which date as far back as 4000 BC, required constant maintenance to deal with the effect of wheels, weather and water. In the 1800s road-building technology was experimenting with mixtures of gravel and bituminous cements that we currently think of as asphalt roads. By the early 1900s, asphalt cement concrete (ACC) and Portland Cement Concrete (PCC) paving methods were available to support the demands of a public newly enamoured with the mobility provided by motorised vehicles.

With the road building boom that began in the early 1900s highway engineers became acutely aware of the need to create smooth pavements. From the outset, simple devices were used to gauge roughness. The simple straight edge, used to measure a mid-chord deviation, evolved to a rolling straight edge and other variants. While these simple geometric measurements of unevenness in the road were useful, by the 1920s it was recognised that the appropriate measure of roughness was how it affected vibrations of a fast-moving vehicle. It was in that timeframe that the State of New York devised the first 'road meter' by installing a mechanical device at the front

axle of a passenger car to measure the stroking of the suspension while traversing the road. This was the genesis of the 'inches per mile' roughness metric representing the inches of suspension stroke per mile of travel of the motor vehicle.

The technology in the highway community for measuring road roughness largely centred on this approach for nearly 50 years as various devices based on this principle were developed under familiar and historic names such as the BPR Roughometer, TRRL Bump Integrator, and various road meters and ride meters. However, this simple measure of road roughness was not adequate for automotive engineers to characterise the road system on which their vehicles were to operate. Thus, in the 1960s two engineers from the General Motors Research Laboratories – Elson Spangler and Bill Kelly – announced the development of an instrumented vehicle that could dynamically measure the vertical profile of the wheel tracks as it drove along a road. Their invention became known as a profilometer. The foresight of these inventors is noteworthy in that they eventually incorporated into the profilometer the ability to simulate the movements of a quarter-car model on the road profiles and calculate an 'inches/mile' metric comparable to that used by the highway engineers.

By the late 1970s the problem of obtaining consistent measurements of road roughness with vehicle-based systems was frustrating efforts by the highway community to achieve standardisation of practices. Research to solve this problem was sponsored by the National Cooperative Highway Research Program in the USA, and then internationally by the World Bank. These efforts led to the International Road Roughness Experiment conducted in Brazil in the early 1980s from which emerged the International Roughness Index (IRI) as a standard scale for quantifying road roughness. In effect, the IRI scale was based on measurement of the road profile, which was processed through a quarter-car model, to obtain the 'in/mile' or 'm/km' metrics, currently used worldwide.

Although measurements from the vehicle-based systems could be correlated to the IRI scale, the handwriting was on the wall that the most reliable and consistent methods for measuring road roughness would be profile based. Subsequently, numerous companies developed and marketed profiling devices that are currently used by virtually every major highway agency in the world, and even by some private firms.

While these historic developments have contributed much to the technology for measuring and quantifying the roughness of roads in a meaningful way, the story is not yet complete. The papers contained in this journal make additional, rich contributions, exploring the many dimensions of road roughness characterisation and assessment. Despite our progress, many questions remain that are addressed here, such as – how to best describe the mechanics of tyres enveloping road profile features, how to measure the three-dimensional aspects of roughness rather than a two-dimensional line along the wheel track, and how the tyre loads the pavement in response to roughness features.

While these papers make their contribution, our search for new insights and understanding is nowhere near complete. It is always helpful to remember that despite our personal familiarity with one of the most difficult road roughness problems – the ubiquitous pothole – as researchers we still have not come up with a universal method to describe the severity of this simple road feature. Keep up the good work!