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Original Research Paper

# Approaches for a 3D assessment of pavement evenness data based on 3D vehicle models

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ABSTRACT

Pavements are 3D in their shape. They can be captured in three dimensions by modern road mapping equipment which allows for the assessment of pavement evenness in a more holistic way as opposed to current practice which divides into longitudinal and transversal evenness. It makes sense to use 3D vehicle models to simulate the effects of 3D surface data on certain functional criteria like pavement loading, cargo loading and driving comfort. In order to evaluate the three criteria mentioned two vehicle models have been created: a passenger car used to assess driving comfort and a truck-semitrailer submodel used to assess pavement and cargo loading. The vehicle models and their application to 3D surface data are presented. The results are well in line with existing single-track (planar) models. Their advantage over existing 1D/2D models is demonstrated by the example of driving comfort evaluation. Existing "geometric" limit values for the assessment of longitudinal evenness in terms of the power spectral density could be used to establish corresponding limit values for the dynamic response, i.e. driving comfort, pavement loading and cargo loading. The limit values are well in line with existing limit values based on planar vehicle models. They can be used as guidelines for the proposal of future limit values. The investigations show that the use of 3D vehicle models is an appropriate and meaningful way of assessing 3D evenness data gathered by modern road mapping systems.



## 1. Introduction

Pavements are 3D in their shape. However, current practice in most countries is to measure and assess pavement evenness in terms of two dimensions: the longitudinal and transversal profile. The only reason for this is a technical one: the measurement equipment has not been sufficient enough in the past to gather 3D road surface data with the efficiency and accuracy needed to assess pavement evenness.

In recent years measurement techniques have come up, for the first time, to allow for an effective and sufficiently accurate acquisition of 3D road surface data. On one hand this represents a challenge; on the other hand it opens opportunities of assessing pavement evenness in a more comprehensive and realistic way in the future. This paper covers

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approaches for a 3D assessment of pavement evenness data. Basically, there are two opposing approaches to assess pavement evenness, one evaluating the dynamic effects of the road on passengers, vehicles and the road itself; the other one focusing on the evaluation of the geometrical properties of the pavement surface. The first approach has been chosen for the 3D assessment of pavement evenness and presented in the paper. To begin with, a short review on existing approaches to evaluate longitudinal evenness shall be given.

## 2. Existing approaches to evaluate longitudinal evenness

Existing approaches to the evaluation of longitudinal evenness may roughly be divided into equipment-specific methods and numerical methods based on the measured longitudinal elevation profile (Fig. 1). Equipment-specific methods include, for example, rolling straightedge, slopemeter and profilograph.

For monitoring purposes on a net-wide level, measuring the "true" longitudinal elevation profile using a non-contacting profilometer is preferred, followed by the calculation of suitable indicators of longitudinal evenness from the measured profile. These can be either "geometrical" indices calculated directly from the elevation profile or its 1st, 2nd (Bruscella et al., 1999; Hudson et al., 1985; Rouillard et al., 2000) and even 3rd (Schniering, 1998) derivatives respectively, e. g. mean, median, standard deviation, root mean square, variance, range, etc., or indices inferred indirectly by means of wavelet decomposition (Shirakawa et al., 2005, 2006; Wei et al., 2005), and Fourier transforms (Andrén, 2006; Braun, 1969; Houbolt, 1962; Sayers et al., 1986). Besides that diverse filtering techniques (moving average, Butterworth, Chebyshev) are used to pre-process the profile data and to calculate unevenness indices with respect to different wave bands (e.g. short, medium and long waves) as described in prEN 13036-5 (2004).

An alternative is to deduce the dynamic response of measuring devices or vehicle components (axles, bodywork, seats, and cargo load) and/or the perception of driver/passengers from the measured elevation profile by appropriate filters and to express the output in terms of indicators giving a statistical and/or peak rating for a given evaluation length (response-type indicators). Approaches of this kind include, amongst others, the international roughness index (IRI) (Sayers, 1986, 1996), the half-car roughness index (HRI) (Sayers, 1989), even a full-car roughness index (Capuruco et al., 2005), and the ride number (RN) (ASTM E 1489-98, 2003), which is defined as an exponential transform of the profile index (PI). The profile index, in turn, uses the same quarter car filter as the IRI, but with other coefficients. The

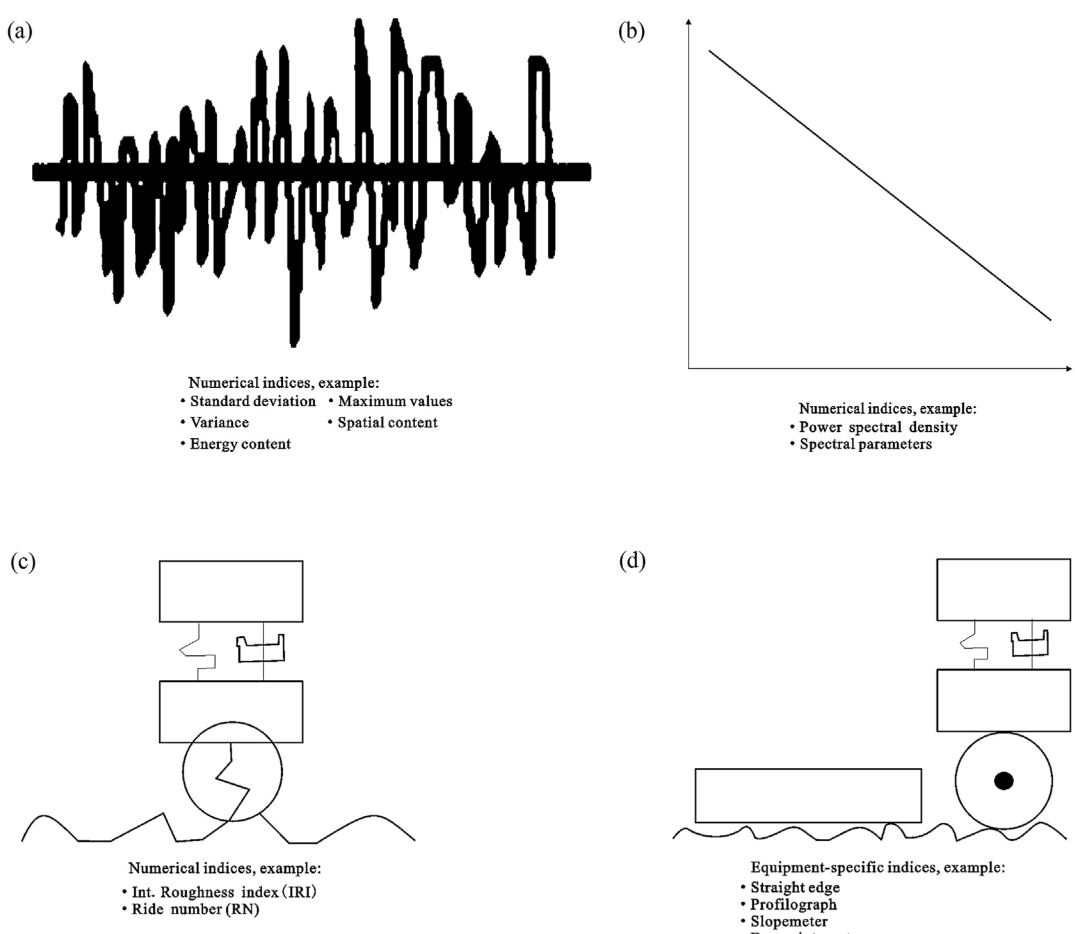


**Fig. 1 – Existing approaches for the evaluation of longitudinal evenness. (a) Geometry in distance domain (longitudinal profile). (b) Geometry in spectral domain. (c) Effect in distance domain. (d) Geometry and effect in distance domain.**