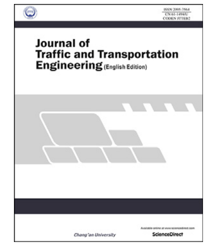
JOURNAL OF TRAFFIC AND TRANSPORTATION ENGINEERING (ENGLISH EDITION) 2016; X (X): 1–14

Available online at www.sciencedirect.com

ScienceDirect

journal homepage: www.elsevier.com/locate/jtte



Original Research Paper

Measuring and evaluating of road roughness conditions with a compact road profiler and ArcGIS

Nueraihemaitijiang Abulizi [a,*], *Akira Kawamura* [b], *Kazuya Tomiyama* [b], *Shun Fujita* [c]

[a] *Graduate School of Engineering, Kitami Institute of Technology, Hokkaido 090-8507, Japan*
[b] *Department of Civil and Environmental Engineering, Kitami Institute of Technology, Hokkaido 090-8507, Japan*
[c] *Hokkaido Regional Development Bureau, Ministry of Land, Infrastructure, Transport and Tourism, Hokkaido 090-8507, Japan*

ARTICLE INFO

Article history:
Available online xxx

Keywords:
Road engineering
Road roughness
Mobile compact profiler
ArcGIS
Ride quality
Wheel path

ABSTRACT

With a wide range of requirements throughout the world, high-quality road management is subject to increasing demand from a perspective of customer-oriented levels of service. In recent years, road administrators are requested to create a visual map of a road network to monitor conditions. To fulfill these requirements, this study conducted as follows. Firstly, this paper introduces a new compact road profiler to collect the profile data at ease. Using the international roughness index (IRI) to assess public roads in local cities of Japan's Hokkaido prefecture, this study also provides real-time monitoring of pavement roughness conditions. Moreover, this study deals with an effective method for visualizing collected IRI data as an attribute in a geographic information system (GIS) and the database of Japan digital road map (DRM). Secondly, the authors present the measurement results of IRI at two different cities during different seasons by using GIS to compare the road conditions. According to the results clarified on different statistical characteristics of road profiles, this study recommends that it is necessary to establish pavement management system (PMS) in consideration of road class, network of local city, and evaluation and management of road conditions in winter quantitatively. Finally, the authors measure and evaluate ride quality by assessing differences between the inner wheel path (IWP) and outer wheel path (OWP) of the vehicle into account, using the previously mentioned profilers and the driving simulator, which is called KITDS. Results show that information from both wheel paths contributes to improve current monitoring process regarding pavement surface, and expects to construct a high level of PMS for road administration in the future.

* *Corresponding author*. Tel.: +81 0157 269516.
E-mail addresses: ahmat_abliz@yahoo.co.jp (N. Abulizi), kawamuak@mail.kitami-it.ac.jp (A. Kawamura), tomiyama@mail.kitami-it.ac.jp (K. Tomiyama), fujita-s22ac@mlit.go.jp (S. Fujita).

Peer review under responsibility of Periodical Offices of Chang'an University.
http://dx.doi.org/10.1016/j.jtte.2016.09.004

1. Introduction

Nowadays, systematic pavement management has become increasingly important as pavements continue to age and deteriorate while funding levels have decreased due to reduced funding or increased competition for funds. PMS provides roadway managers with a systematic process for generating solutions to many of their pavement management questions (Wolters et al., 2011). The roughness of the road surface can affect the ride quality (RQ) and vehicle operating costs. Rough surfaces considerably impacts vehicle speed, fuel consumption, tire wear, and more and increase maintenance costs of road surface. Thus, it is necessary to gather the roughness data of road network to operate PMS accurately (Flintsch et al., 2012). According to the present conditions of the municipal roads in Japan, the Ministry of Land, Infrastructure, Transport and Tourism (MLIT) has promoted a strategy for the full-inspection of road stocks and an implementation guide for municipal roads since 2013 (MLIT, 2013). Based on monitoring road surface conditions of municipal roads, this strategy has motivated local road administrators to develop and improve their PMS in order to provide a better ride environment. During a half century of development, engineers and researchers have invented several techniques and methods for measuring road roughness. The measurement devices can be divided in to four general types: response-type road roughness measuring systems (RTRRMS), direct profile measurements, indirect profile measurements, and subjective rating panels (Sayers et al., 1986a, 1986b). Most highway agencies collect IRI data using a laser sensor or high speed profiler. This equipment measures surface profiles at normal traffic speeds and provides excellent results for use in network analysis for PMS. However, because these devices are mounted on a full-size van, auto mobile, or trailer, they are difficult to use on roadways for short periods of time. In addition, these devices are rather expensive and delicate (Du et al., 2014). In order to satisfy these requirements, the authors have provided a low-cost road surface profile measuring system. The profiler consists of two small accelerometers set up to a vehicle suspension system, while conventional high-speed profilometers which use laser sensors (ASTM, 2004). This system enables the measurement of surface profiles using the back calculation method, which is based on the measured acceleration of a vehicle without empirical correlations between roughness profiles and vehicle motion. Then, the measured profile data in the proposed system can be immediately converted into a summary roughness index such as the IRI. The roughness information is instantaneously displayed on an onboard computer in real time, unlike with a conventional RTRRMS (Tomiyama et al., 2011). This study focuses on a method for providing basic information about road roughness and IRI on municipal roads, which may assist and improve the implementation of PMS in municipalities. The overall objectives of this study are as follows.

(1) To introduce the principle of a new compact road profiler to measure IRI and roughness condition of municipal roads in different cities during different seasons.
(2) To introduce the use of GIS and Japan digital road map (DRM) so as to visualize the survey results linking land-use and road classification.
(3) To develop statistical analyses and evaluation methods based on a comparison study using local cities, road classes, road directions, wheel paths and different conditions of road roughness.
(4) To analyze and evaluate the ride quality of the road surface, the KITDS and ISO standard 2631 are applied, respectively (ISO, 1997).

2. Monitoring and evaluation of road profile

2.1. *Basic knowledge of quarter-car model to measure IRI*

The IRI was developed in 1986 using the results from the International Road Roughness Experiment performed in Brazil in 1982 (Sayers et al., 1986a, 1986b). Since then, it has become a well-recognized standard for the measurement of road roughness.

The main advantages of the IRI are that it is stable over time and transfer able throughout the world. The IRI is an index defined by applying the algorithm proposed by Sayers (1995) to a measured realization of the longitudinal profile. The IRI is a mathematical model applied to a measured longitudinal road profile. The model simulates a quarter-car model is shown in Fig. 1 (Kawamura, 2011). The quarter-car model predicts the spatial derivative of a suspension stroke in response to a profile using standard settings for speed and the vehicle dynamic depicted in Fig. 1.

2.2. *Compact mobile profiler in pavement monitoring*

The conventional profilers are not used to collect profile data frequently (every day or week), because data collection requires too much cost and time for operation. In recent years, with the development of pavement survey technology, a lot of countries have their own high-speed profilers, which are mainly used as laser sensor technology. These profiles have grown more powerful and become easy to operate, but the response-type profilers are still difficult to maintain the

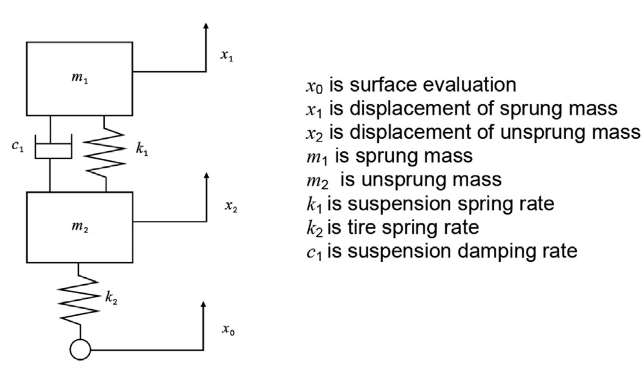


Fig. 1 – Quarter-car model.

Please cite this article in press as: Abulizi, N., et al., Measuring and evaluating of road roughness conditions with a compact road profiler and ArcGIS, Journal of Traffic and Transportation Engineering (English Edition) (2016), http://dx.doi.org/10.1016/j.jtte.2016.09.004