IRI ROUGHNESS INDEX REQUIREMENTS FOR HIGHWAY FUNCTIONAL CLASSIFICATION

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Abstract

The paper reviews the role of highway functional classification in pavement management. Predominantly, technical classification is used in pavement management in CIS countries. The paper raises importance of highway functional classification in pavement maintenance in order to efficiently manage road network. IRI roughness index is widely used to monitor, assess road condition, analyze life cycle of the pavement. Authors proposed IRI values according to highway functional classification.

Key words: Highway functional classification, IRI, pavement management.

The role of highway functional classification play an important role in road asset management. While in planning stage many factors are uncertain, and based on prediction assumption that traffic volume increases due to new business opportunities in the area. In analyzing existing roads transportation planners and engineers have to pay attention to how heavily road is used by different type of vehicle and their purpose. Technical classification doesn’t answers key questions such as how a road section is used by road users, what is the purpose. Contrarily, highway functional classification approach let to study two main transportation functions such as mobility and access.

Two primary transportation functions of roadways, namely mobility and access, and describes where different categories of roadways fall within a continuum of mobility-access. In addition to mobility and access, other factors that can help determine the proper category to which a particular roadway belongs — such as trip length, speed limit, volume, and vehicle mix. The concept of functional classification defines the role that a particular roadway segment plays in serving this flow of traffic through the network. Roadways are assigned to one of several possible functional classifications within a hierarchy according to the character of travel service each roadway provides. Planners and engineers use this hierarchy of roadways to properly channel transportation movements through a highway network efficiently and cost effectively [1].

Based on literature review, the following highway functional classification was recommended in CIS countries [2]:

- Arterial:
  - Major Arterial;
  - Minor Arterial;
- Collector:
  - Major Collector;
  - Minor Collector;
- Local

As a road technical category is primary principle for designing and maintaining roads it would be appropriate to introduce functional classification in line with it.

![Figure 1. Highway Functional Classification in relationship to road technical category](image)

Highway functional classification serve not only for identifying what function is playing certain road section but also importance of that section. As one of the performance
indicators AADT (Annual Average Daily Traffic) or VKMT (Vehicle Kilometers Traveled) plays significant role in budget spendings.

Figure 2 shows how existing and recommended technical category and functional classification play role in pavement life circle in Uzbekistan. Existing technical classification is used in whole pavement life circle. Recommended classification suggests that in maintenance highway functional classification should be used in order to properly assess the importance of road section. Highway functional classification might be used along with technical classification during planning and design period.

International road roughness experiment (IRRE) led to the development of international roughness index (IRI), which was held in Brazil, and it was conducted by research groups of several countries [3]. IRI is widely adopted as a main assessment tool or reference tool for evaluating longitudinal road profiles in many nations around the globe in order to obtain preliminary calculations and assessments of road condition, maintenance costs and quality of newly constructed roads. Even though the quarter car model approach type – IRI is widely used and adapted. Apart for the quarter car model approach type – IRI, half car roughness index [4], full car roughness index [5] and the ride number [6] approaches are also developed and studied. There are several advantages of the quarter car - IRI approach. This method is simple and easy to use, fast and cost efficient in evaluations.

The IRI is a mathematical model applied to a measured longitudinal road profile. The model simulates a quarter-car model is shown in Figure 3. 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.

From the quarter-car model shown in Figure 3, we derive equations of motion of the two mass bodies, which are unsprung mass (half of axle mass and one wheel) and sprung mass (quarter car body mass). The equations of motion of the system are as follows:

\[
\begin{align*}
    m_s \ddot{z}_s + c_s (\dot{z}_s - \dot{z}_u) + k_s (z_s - z_u) &= 0 \\
    m_u \ddot{z}_u + c_u (\dot{z}_u - \dot{z}_s) + k_s (z_u - z_s) + k_z z_u &= k r
\end{align*}
\]

(1)

Figure 3 Quarter-car model according to the IRI [8].

Figure 2. Role of technical and functional classification in pavement life circle.
Where are displacement, velocity and acceleration of the sprung mass, respectively; are displacement, velocity and acceleration of the un-sprung mass (half of axle mass and one wheel), respectively; damping coefficients of suspension; and stiffness of suspension and tire; and are mass of the sprung (quarter car) and axle + tire; is terrain roughness (road irregularities) dependent of a vehicle’s speed on the direction.

IRI is the reference average rectified slope (RARS80) of a simulated standard quarter-car traveling at a speed of 80 km/h, which yields a ratio of the accumulated motion of the quarter-car’s suspension to the distance traveled during the test. More specifically, the IRI is based on following quoted from [7]:

- IRI is computed from a single longitudinal profile. The sample interval should be no larger than 300 mm for accurate calculations. The required resolution depends on the roughness level, with finer resolutions being needed for smooth roads. A resolution of 0.5 mm is suitable for all conditions.
- The profile is assumed to have a constant slope between sampled elevation points.
- The profile is smoothed with a moving average whose base length is 250 mm.
- The smoothed profile is filtered using a quarter-car simulation, with specific parameter values (Golden Car), at a simulated speed of 80 km/h.

The simulated suspension motion is linearly accumulated and divided by the length of the profile to yield IRI. Thus, IRI has units of slope, m/km. The IRI value is calculated according to following equation [8]:

\[ IRI = \frac{1}{L} \int_0^L \left| \dot{z}_s - \dot{z}_u \right| dt \]  

Where:

- \( L \) = Traveling distance (m) 
- \( v \) = Vehicle speed (m/s).
- \( \dot{z}_s \) = Velocity of the sprung mass, \( \dot{z}_u \) = Velocity of the un-sprung mass, \( dt \) = time increment.

Measurement of reference road surface profile for IRI calculation is perform in fig. 4. IRI roughness index is widely used in international projects financed by international financial institutions WB, ADB and others. Road agencies across the globe annually prepare road condition reports presenting IRI. One of the reasons is that IRI is versatile pavement condition indicator. The same value of IRI represents the same meaningful interpretation in any road section in any place. Although IRI is sensible to several factors such as equipment type (accuracy class), measurement speed and calibration. But if properly planned and correctly performed IRI roughness survey would result adequate output.

**Figure 4. Generalized reference road profile measurement procedures [9].**

**Table 1. Recommended values of IRI for highway functional classification**

<table>
<thead>
<tr>
<th>Highway functional classification</th>
<th>IRI, m/km</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Arterial roads</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Major arterial roads</td>
<td>1.6</td>
<td>New construction or after repair</td>
</tr>
<tr>
<td>Minor arterial roads</td>
<td>1.8</td>
<td>Critical value, trigger intervention</td>
</tr>
<tr>
<td>Collector roads</td>
<td>2.2</td>
<td>Critical value, trigger intervention</td>
</tr>
</tbody>
</table>

| | | |
It’s logical that developed countries set higher standards compare to developing counterparts. For example, in Canada IRI varies from 0.65 to 2 m/km depending on road class, in Australia from 1.6 to 1.9 m/km, in Italy from 1.8 from 2.5 m/km, in Norway from 2 to 2.5 m/km, in Portugal from 1.5 to 3.5 m/km, in Spain from 1.5 to 2.5 m/km, in Sweden from 1.1 to 2.4 m/km [10]. An interesting trend can be observed in this study, for instance in some developing countries such in Belarus IRI varies from 1.5 to 2.5 m/km, in Bosnia and Herzegovina from 1.2 to 4.6 m/km, in Estonia from 1.6 to 2.6 m/km, Hungary from 1.2 to 2.2 m/km, in Poland from 1.3 to 4.6 m/km, and in Ukraine from 1.7 to 2.8. These developing countries set minimal IRI values in some cases higher than developed countries which is challenging to achieve due to certain constraints such as construction quality, expertise, and financial limitation. Therefore it’s recommended to set IRI values taking account local standards and technical capabilities.

Reference