ESSAYS ON ISSUES
THE FEDERAL RESERVE BANK OF CHICAGO
JULY 2009
NUMBER 264

Chicago Fed Letter

The state of our interstates

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President Obama's budget proposal emphasizes the importance of infrastructure investments for the nation's economic health, so now seems a good time to assess the condition of our country's major roads.

Investments to increase further the smoothness of interstate highways without targeting them to the roughest areas are unlikely to yield a substantial direct benefit.

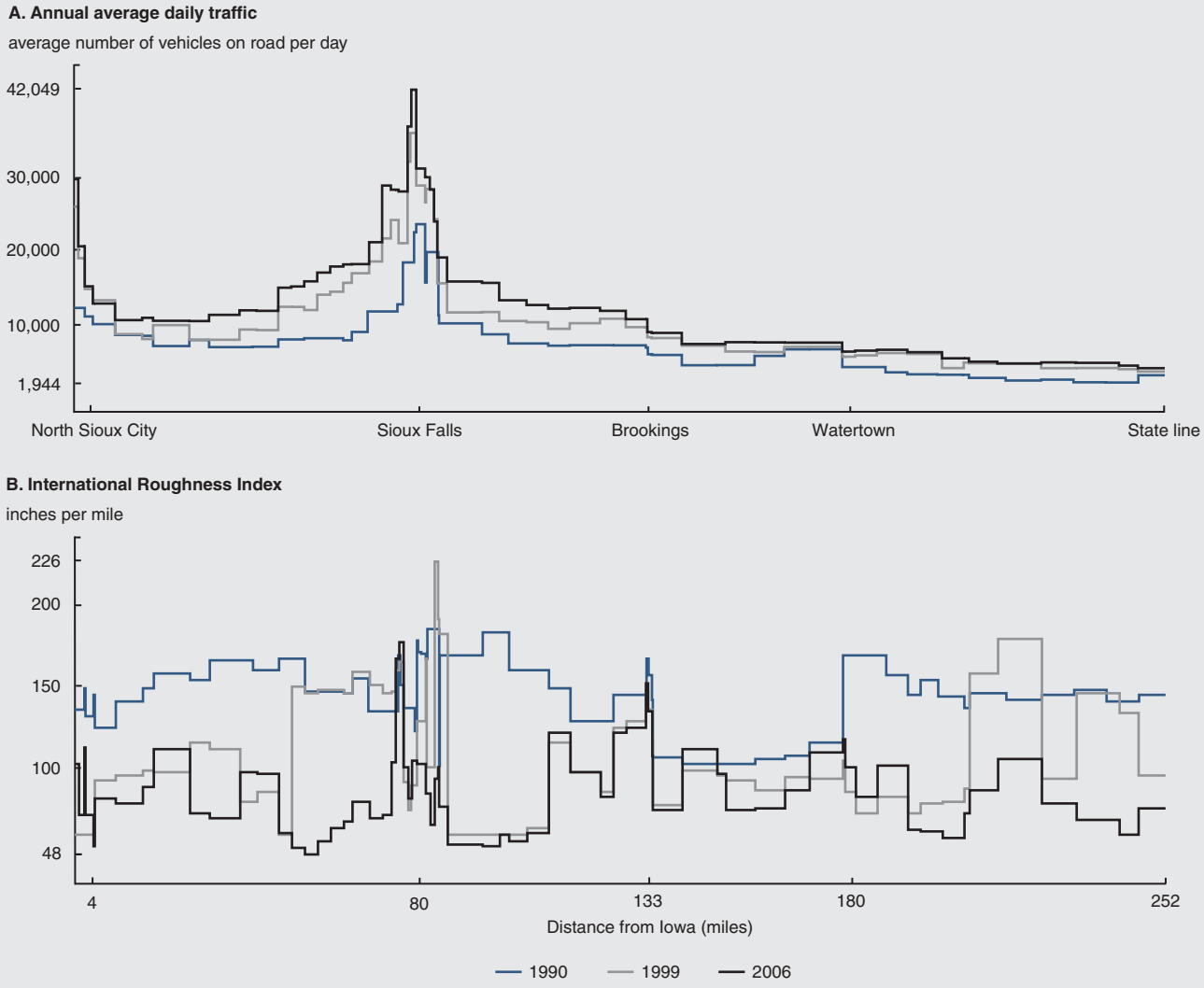
Our nation's economy depends on its roads for low-cost movement of goods and people, so their deterioration could have a substantial impact on macroeconomic performance. In this *Chicago Fed Letter*, we measure the state of our interstate highway system, using data on road deterioration collected from state highway agencies by the U.S. Department of Transportation's Federal Highway Administration (FHA). For each year from 1980 through 2006, these data indicate the average daily vehicle traffic and surface roughness of each interstate highway segment in the country.[1] We summarize these data with the average and median roughness levels for each year. Plotting the resulting statistics over time reveals a strong *favorable* trend. Since the mid-1990s, our nation's interstate highways have become indisputably smoother and less deteriorated. Indeed, the *surface* of the median interstate highway mile is suitable for superhighway speeds not typically permitted in the United States. Thus, investments to increase further the smoothness of interstate highways without targeting them to the roughest areas are unlikely to yield a substantial direct benefit.

Measurement of road roughness

A road can serve its purpose well only if its users can drive on it in comfort at a reasonable speed, so civil engineers have devoted considerable energy to the measurement of road roughness. Carey and Irick[2] pioneered a four-step procedure for measuring this. First, take groups of users on rides across trial road segments and ask them to subjectively rate each one's roughness. Denote these with S_i. Next, take objective measurements of each segment's physical characteristics, such as cracking and deformation. Denote these with M_i. Third, fit a linear model such as $S_i = \alpha + \beta M_i$ to these data. This can be done by choosing α and β to minimize the average squared difference between S_i and its predicted values based on M_i. Finally, collect observations on M_i on all road segments of interest and use the model to predict how the panel of users would have rated it. Carey and Irick called the resulting measure the Present Serviceability Index (PSI).

The dependence of the PSI on subjective impressions and on ad hoc modeling of them limited its reproducibility across time and space. This motivated the World Bank to create a replacement, which uses only data on the longitudinal profile of a road (typically collected with a spring-mounted laser atop a single wheel pulled by a truck) to calculate the suspension movement of an ideal reference car over any given interval. This movement, measured either in inches per mile or centimeters per kilometer, is the International Roughness Index (IRI).[3] In the United States, civil engineering practice moved away from the PSI to the IRI in the early 1990s.

1. Highway Performance Monitoring System data for Interstate 29 in South Dakota



SOURCE: Authors' calculations based on U.S. Department of Transportation, Federal Highway Administration, Highway Performance Monitoring System data.

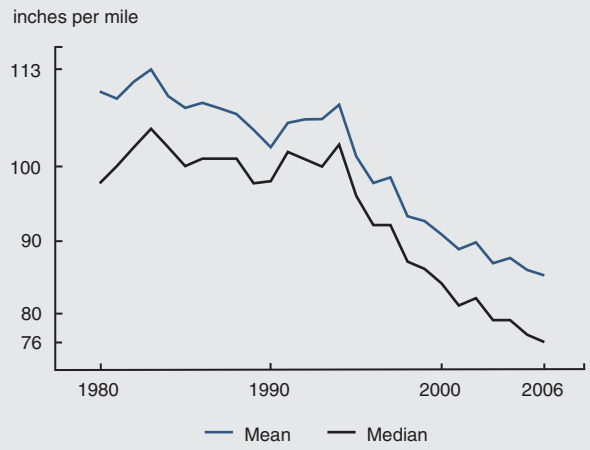
The Highway Performance Monitoring System

Since a road's roughness is the primary indicator of the benefits from its maintenance, state highway agencies measure the roughness of interstates and other arteries annually. They report these and other observations (such as road use) to the FHA, which assembles them into the Highway Performance Monitoring System data. We have these data beginning in 1980 and extending through 2006. Throughout the 1980s, state highway agencies tended to report roughness using the PSI, but the FHA required them to add the IRI beginning in 1989. These observations lie at the heart of our work.

Figure 1 presents a portion of these data for an arbitrarily chosen corridor—Interstate 29 in South Dakota—for three years, 1990, 1999, and 2006. Each panel's horizontal axis measures distance along the highway from the point it enters South Dakota from Iowa. Panel A plots annual average daily traffic (AADT), the average number of vehicles using the road on a given day. The data set reports this by *segment*, which is a portion of the road defined by starting and ending mile markers. Since nearly all of these segments' boundaries coincide with exits, they are longer in rural areas. As expected, these data clearly show high highway utilization in the urban areas of North Sioux City and Sioux Falls. They also show that highway utilization has risen substantially over time, particularly near the urban areas.

Panel B of figure 1 plots the IRI measured in inches per mile. In 1990, the average IRI equaled 144. The road was somewhat better than this on the 50 miles between Brookings and Watertown. Sayers and Karamihas[4] give IRI ranges for different classes of road, which provide some perspective on the measures for Interstate 29. The range 25 to 100 covers airport runways and superhighways (those with speeds higher than typically permitted in the United States), while 100 to 200 covers new pavements suitable for typical interstate speeds. So Interstate 29

2. Mean and median International Roughness Index



SOURCE: Authors' calculations based on U.S. Department of Transportation, Federal Highway Administration, Highway Performance Monitoring System data.

in South Dakota fell right into the middle of the new pavements range in 1990. By 1999, maintenance and improvements had brought this average down to 125. There was no improvement and some deterioration in Sioux Falls and the area to its immediate south, but the rest of the interstate's condition became comparable to or better than the best segments in 1990. As of 2006, the average IRI equalled 111. Although the area around Sioux Falls continues to have trouble spots, its worst areas would have been considered average in 1990. This particular road improved greatly over these 17 years.

Evolution of interstate roughness

As we noted before, the FHA began requiring state highway agencies to report the IRI only in 1989. Most of the road roughness observations available before then are expressed with the PSI, which uses the "one-to-five" scale familiar from survey questions. So that our series of mean and median IRI would cover the most time possible, we converted these observations to the IRI. For this, we first fitted a model relating IRI to PSI, using observations from 1995 through 1999 that reported *both* roughness measures. The model fitted was

$$IRI = \alpha + \beta \times PSI + \delta \times PSI^2 + \gamma \times I\{\text{Road is Asphalt}\}.$$

Here, $I\{\text{Statement}\}$ equals one if the statement in brackets is true and zero otherwise. We chose the parameters α, β, δ, and γ to minimize the average squared difference between the IRI measures and their predicted values from the model. We then used the fitted model to predict what each segment's IRI would have been in the years 1980 through 1989. With these and the original IRI observations from later years, we can then calculate the mean and median IRIs across interstate segments for each year. For this, we weighted each segment by its length so that each mile of interstate highway contributes equally to the sample.

Figure 2 plots the results of this exercise. Both the mean and median start the sample period somewhat below the levels for Interstate 29 in South Dakota. They stay roughly at that level until 1994. In that year, the mean and median IRI equalled 108 and 103, essentially equal to their values in 1980, 110 and 97. Then they began a dramatic decline. By 2000, the mean and median IRI equalled 93 and 86, and the sample finishes in 2006 with them equal to 85 and 76. Apparently, our interstate highways were smoother in 2006 than in any other year since 1980.

Conclusion

One might raise a number of objections to our conclusion that the interstate highway system has become much better maintained. First, we have summarized the data, treating each mile of interstate highway as of equal interest. As figure 1 highlights, the utilization of interstate highway miles varies dramatically across the system. One might wonder if we would get the same answer if instead we focused our attention more on the most heavily used highway miles. We have recalculated the means and medians in figure 2 after first weighting each segment by the number of vehicle miles traveled upon it (calculated as the product of a segment's length with its AADT). The resulting average and median roughness measures modestly exceed those displayed in figure 2, but their dynamics are identical. Another possible objection to our results is that drivers care more about the worst road they use than they do about the average or median road. To investigate that, we calculated the 90th percentile of the IRI for each year. This is defined to equal the IRI that equals or exceeds exactly 90% of the measured IRIs. The quality of this typical "bad road" also improved dramatically from 1980 to 2006, although the improvement occurred throughout the period rather than only since 1994.

From these results, we conclude that the surface of our interstate highway system is in good shape relative to its past condition. The economic value of improvements to road surfaces remains to be determined. In view of this finding, accelerated expenditures on improving road surfaces are unlikely to yield significant direct benefits unless they are carefully targeted to specific interstate segments that are in need of improvement.

ISSN 0895-0164

[1] Unfortunately, these data contain no information about the state of the interstate system's bridges, so we have nothing to say regarding their state.

[2] W. N. Carey, Jr., and P. E. Irick, 1960, "The pavement serviceability–performance concept," *Highway Research Board Bulletin*, No. 250, pp. 40–58.

[3] Details on the IRI's initial creation and current implementation can be found in W. D. O. Paterson, 1986, "International Roughness Index: Relationship to other measures of roughness and riding quality," *Transportation Research Record*, No. 1084, pp. 49–59, and M. W. Sayers, 1995, "On the calculation of International Roughness Index from longitudinal road profile," *Transportation Research Record*, No. 1501, pp. 1–12.

[4] M. W. Sayers and S. M. Karamihas, 1998, *The Little Book of Profiling: Basic Information about Measuring and Interpreting Road Profiles*, University of Michigan Transportation Research Institute, unpublished manuscript, p. 48.