Chapter 1
Predictive Analytics for Infrastructure Performance

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ABSTRACT

A predictive analysis methodology was designed for application to the Transportation Performance Index, which was first released in September 2010 through the U.S. Chamber of Commerce to benchmark and measure changes in the performance of US infrastructure over time. This article starts with a summary of the development and use of the Index in order to present the performance indicators that were the foundation of the predictive analysis. A new methodology was developed to generate prospective values for the Index by applying elements of the improvement plans from US Metropolitan Planning Organizations (MPOs) that paralleled the performance indicators used in the Index. The results show that over a 24 year period (2011 to 2035) the plans developed by MPOs can slow the decline in infrastructure over a baseline scenario. In addition to forecasting changes in the performance of the infrastructure that undergirds all economic activity, the results serve to further validate the Index as a methodology that captures important performance functions of transportation infrastructure. The original purpose of the Index was to capture trends, making it well-suited to the application of predictive analysis.

INTRODUCTION

A predictive analysis methodology was designed for the Transportation Performance Index ("TPI" or "Index"), which was first released in September 2010. The Index was developed in a rigorous way, applying standard methods, including taking a representative sample. Because it is impossible to measure every inch of road, bridge, airport, marine terminal, etc. in the nation, a sample of Metropolitan Statistical Areas (MSAs) is selected that is representative of the economic, demographic and geographic configuration of the US. The sampling method is not unlike that applied to the Dow Jones Industrial

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Average (DJIA) which consists of only 30 stock prices, each selected to be representative of economic activity in the US industrial sectors. One could make predictions for the stock price performance of the individual component companies, apply the DJIA formula to those predictions (which includes price-weighting, scaled averaging, etc.) and arrive at a valid prediction for the DJIA. These results would be interpreted as predictions for the performance of the US economy (or the US stock market). Similarly, our methodology makes informed predictions of changes in the individual components of the TPI to arrive at predictions for changes in the national performance of US transportation infrastructure. We found no similar methodologies for measuring the overall performance of US transportation infrastructure. The application of predictive analytics in the field of transportation is generally limited to predicting traffic flows (e.g., Andrienko, Andrienko & Rinzivillo 2015) or equipment maintenance. Many are offered by private consulting firms; therefore, without transparent methodologies or publically available results.

The Index itself is a rigorous, formula-generated methodology employing measurements made possible by the big data sets routinely generated from observations of the conditions of transportation infrastructure throughout the more than 3 million square miles of the United States. In order to use the Index to forecast changes in the future performance of infrastructure, we add the business-intelligence supplied by individual metropolitan planning organizations that are responsible for selecting improvement projects to be completed in their jurisdictions. Every urbanized area with a population greater than 50,000 is required to form a metropolitan planning organization (MPO) for the purpose of channeling federal transportation funding to projects and programs in their regions. MPOs in the US are required to produce and make publicly available regional transportation plans that cover at least 20 years into the future. Since enactment of the Intermodal Surface Transportation Efficiency Act in 1991, these plans must also meet federal financial constraint requirements, where "federal regulations are explicit that funds must be balanced" to the money provided by the Federal Highway Administration and Federal Transit Administration (Atlanta Regional Commission, 2010). A constrained financial plan is one that includes only projects that can be implemented using current revenue sources while the existing transportation system is adequately operated and maintained. To be most realistic, we limit our predictive analysis to consideration of the fiscally constrained proposals as we take advantage of those published plans for transportation projects to predict the future of infrastructure performance in the United States.

In the next section we provide a summary of the development and use of the Index in order to present the performance indicators that are the subject of the predictive analysis. (Interested readers are referred to the Technical Report (US Chamber of Commerce 2010) which documents the complete development of the Index and includes an analysis of the results for the initial time periods.) The description of the Index and the indicators is followed by a complete presentation of our predictive analysis. We include the methodology, a demonstration of the procedure used to gather and incorporate human intelligence into the statistical analysis and the result of our predictive analysis.

BACKGROUND: THE TRANSPORTATION PERFORMANCE INDEX

By design, the Transportation Performance Index is generated from publicly available data. The transparent process has been reproduced in Brazil and the Netherlands to benchmark and measure changes in the performance of transportation infrastructure over time. The Index was designed to bring a rigorous, quantitative, and repeatable methodology to the assessment of infrastructure performance. In the past, studies that attempted to relate infrastructure to economic growth and prosperity largely had to rely on