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History of rail traffic volumes in the evaluation of fatigue consumption in steel bridges

M. Ralbovsky[1], A. Vorwagner[1], S. Lachinger

[1]AIT Austrian Institute of Technology, Vienna, Austria

Abstract

More and more railway steel bridges are near the end of their lifetime and are affected by material fatigue. To optimize the maintenance cost plans, fatigue life assessment can be updated using estimates of traffic development of bridge's lifetime.
A concept for adjusting fatigue traffic load models with respect to past traffic data was created. It provides a rough estimate of traffic volume development from the point-of-view of bridge fatigue. The method uses the relative change of network-aggregated traffic volumes of the past in relation to the present. The data for the past is either directly available from country's statistics, or it can be estimated from country's macroeconomic indicators. The relation between traffic volume and macroeconomic indicators was established using simple linear regression, applied separately on data of each country. The estimates derived from macroeconomic indicators require plausibility check and are generally less reliable. The estimated history of traffic volume development is then used to update the number of train passages of all train types in the traffic model for the past years.
Of course, the estimates depend on the assumptions that the distribution of country's rail traffic to different routes is uniform and that the past wagon material and its load utilization is same as present.
This approach provides rough estimates and is open to inclusion of more accurate data, such history of regional (section-specific) traffic volumes, which may differ from the network-aggregates.
The proposed method was implemented with the aim to get an improvement of knowledge level of fatigue consumptions and to provide a better basis for

improvement of life-cycle analysis of steel bridges, and therefore help to renew these bridges in a more economic way.

Keywords: steel bridge, fatigue, traffic volume, history.

1 Introduction

Aging and deterioration due to fatigue are issues of paramount importance of steel railway bridges. The structures are essential network components which cannot be replaced without considerable financial investments and interruption to railway operation. More and more railway steel bridges are near the end of their lifetime. Infrastructure owners must guarantee that the bridges are safe to operate and strive to maintain and renew these bridges in the most economic, socially and environmentally sustainable way without compromising the reliability of the structures. These tasks were addressed within the Shift2Rail-project “Assets4Rail”, which shares the view of having an ageing European railway infrastructure that needs to cope with the expected traffic increase in the future. Both goals rely on a proactive and cost-effective maintenance and intervention system in the assets. A contribution of Assets4Rail [1] to these aims is development of a dedicated information model (BIM), which is the keystone of the infrastructure part of this project. A Bridge Information Module integrates sensor data and analysis algorithms for evaluation of fatigue consumption, noise and vibrations.

Fatigue consumption of structural components is estimated from train load histories, structural response and fatigue-resistance of structural steel. The assessment should be done using load history estimates that are accurate as possible in order to optimize the maintenance cost plans. However, to assess the load history from the point of bridge construction, it is necessary to estimate past traffic volumes. Rail traffic changes over time and older bridges might have been exposed to different traffic volumes decades ago. Therefore, it would be helpful to have the traffic information not only for the present traffic, which can be collected using wayside monitoring. However, data availability regarding past traffic is limited. Main reasons are:

- Traffic data was not recorded in the past, or was recorded with less detail
- Data was archived as hardcopy and is difficult to retrieve
- Data was destroyed or is missing

Although data (timetable, historic train data etc.) is possibly available in archives, the extraction of relevant information from there might require significant resources. Therefore, alternative approaches are needed which may vary depending on which data about the past is available. This short paper deals with the use of network-aggregated values of rail traffic, as well as macroeconomic data to improve the load history estimates for bridge fatigue evaluations.

2 Methods

Network-aggregates of traffic volumes provide information about total rail traffic volume in a country. Besides railway operators, this information is available at institutes that concentrate on country-statistics like Eurostat [2] or the World Bank [3]. Figure 1 shows the World Bank data with unfiltered outliers. Plotted passenger-km mean the number of transported passengers multiplied by transport distance; ton-km mean weight of transported goods multiplied by transport distance.

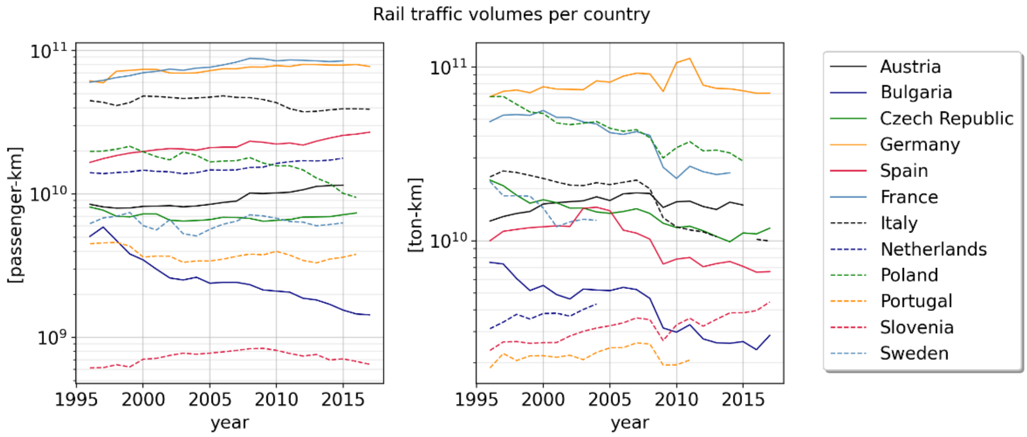

Figure 1: Rail traffic volumes of passenger traffic (left) and freight traffic (right) of selected European countries based on [3].

The basis for estimating actual load histories is a section-specific model of the present traffic, which can be derived for example using wayside monitoring data. From this, models for past traffic are estimated. In case if information on past composition of trains is available, the model for present traffic can be adjusted accordingly. However, this information is often missing or difficult to retrieve. In the simplified approach presented here, we assume constant composition of the wagon material. The amount of traffic volume in past years is then used to update the number of train passages ascribed to particular train types in the model of present traffic.

However, the traffic volume data do not reach far into the past. For most European countries, the data start in 1996. For bridges older than 26 years, traffic volumes before this date are necessary. To this end, traffic volume estimates are generated from economic indicators, which summarize the basic economic indicators of a country. The World Bank provides data of Gross Domestic Product, population, energy use per capita, and many other indicators. The traffic demand is given by needs of the industry and the population. Development of industry and population is reflected in macroeconomic indicators, therefore a correlation between these indicators and rail traffic is expected. The relation between macroeconomic indicators and rail traffic was already used to predict future traffic needs, as presented by Lazarević et.al. [4]. Here, the macroeconomic indicators are used to estimate the traffic volume of the past. From the many available indicators, the GDP and the country's total energy use (Figure 2) were chosen for establishing a relation to traffic volume. Data from the time period where both the traffic volume as well as the economic indicators are available was used to establish a relation between the two.

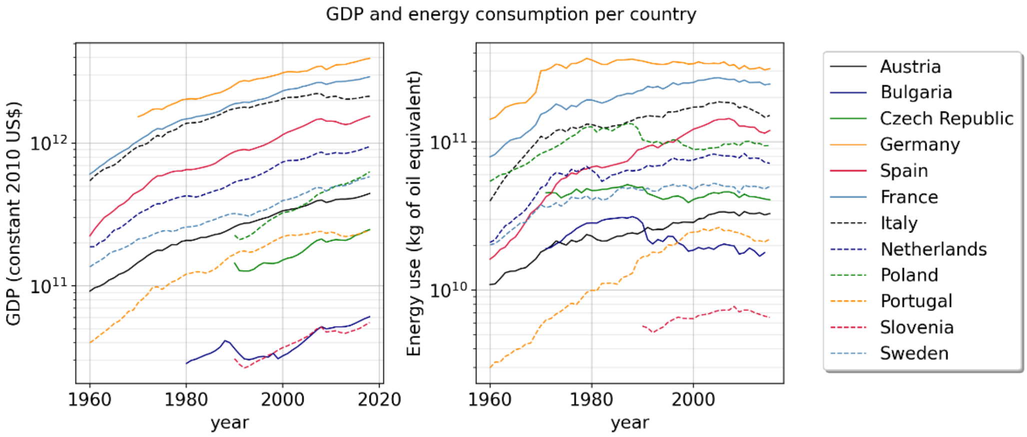

Figure 2: Macroeconomic indicators of selected European countries based on [3].

3 Results

The relation between traffic volume and macroeconomic indicators was established using simple linear regression, applied separately on data of each country. The use of functions of higher order (instead of linear) was explored but did not lead to improved results. The purpose of the established relation is to calculate an estimate of traffic volume for past years, before traffic volume data was available. A result example is shown in Figure 3 where the traffic volumes predicted from macroeconomic indicators are compared to actual traffic volumes, for the country of Austria.

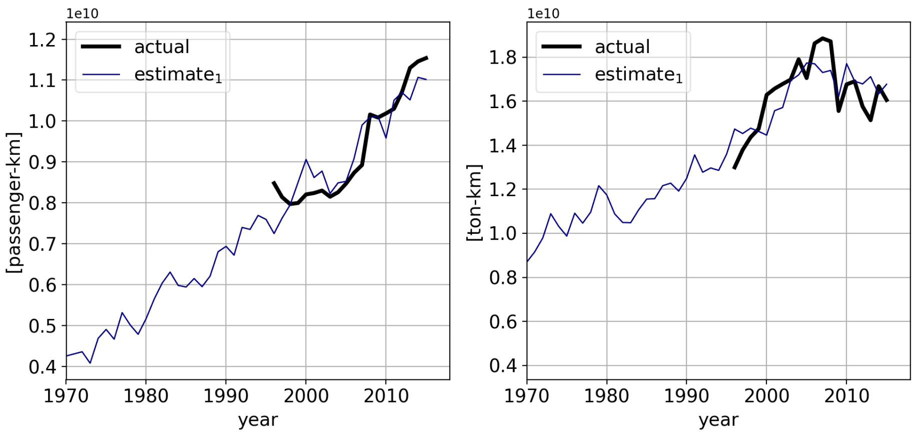

Figure 3: Net traffic volumes of passenger (left) and freight (right) traffic, as estimated from macroeconomic indicators (thin blue line), compared to actual volumes (thick black line). Country: Austria.

The estimated history of traffic volume development is then used to update the number of train passages in past years. In the present study, a section-specific traffic model was derived from current traffic management data and consisted of more than 100 train types, each with a defined number of passages. The change of the number of passages in past years was then estimated using the ratio of traffic volume in a given year to the current traffic volume, separately for freight and passenger traffic. Thus, all train types receive the same relative change of passage numbers (Figure 4).

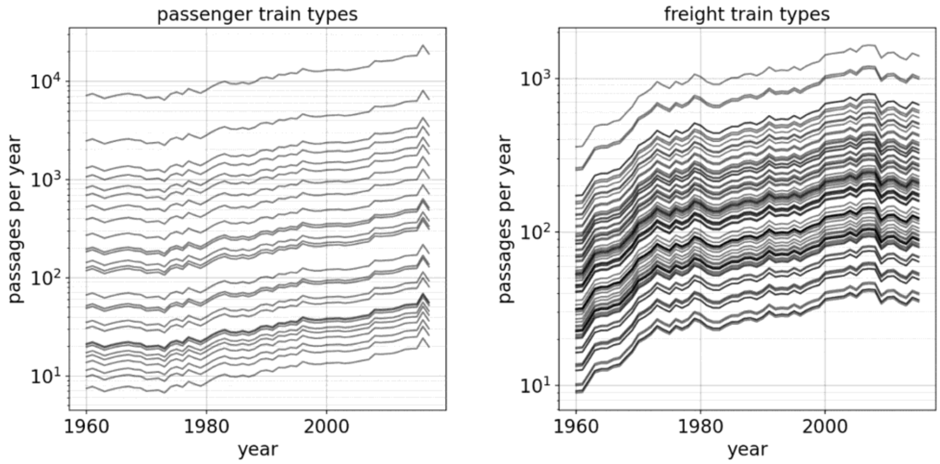

Figure 4: Estimated development of yearly number of passages in the section-specific traffic model. Each curve represents one train type.

The use of network-aggregated data implies following assumptions:

- the distribution of country's rail traffic to different track sections / routes is constant,
- past wagon material and their load utilization is same as present.

The accuracy of the result depends on how well these assumptions correspond with reality. The distribution of overall rail traffic to different routes depends on regional traffic demands. These may change considerably if heavy industry emerges or declines in individual regions. The simple conversion proposed above could be adjusted to accommodate information on temporal changes of regional traffic demands, if such information would be available.

This approach intends to provide rough estimates in lack of more accurate data. Plausibility check must be done before using traffic volume estimates derived from macroeconomic indicators. In some cases, the results were not plausible. Especially when the linear regression results in negative correlation between traffic volume and macroeconomic indicator, their usage is not recommended

4 Conclusions and Contributions

A concept for adjusting fatigue traffic load models with respect to past traffic data was created. The goal is to provide an estimate (without safety factors) of traffic volume development from the point-of-view of bridge fatigue.

To estimate the traffic of the past, retrieval of actual traffic occurrences on specific track sections from archived records would be reliable, but very time-consuming method, given that archived records are not available in a format that allows machine-processing. Therefore, scaling of current traffic model to past traffic volumes was proposed here. The scaling method uses the relative change of network-aggregated traffic volumes of the past in relation to the present. The data for the past is either directly available from country's statistics, or it can be estimated from country's macroeconomic indicators. The macroeconomic indicators are available starting from 1960 for many European countries, for some countries later (1970 or 1980). Many countries of Eastern Europe experienced splitting and major political changes around 1990. Therefore, data of macroeconomic indicators start around 1990 for these countries. The overlap of country's traffic volume data and macroeconomic-indicator data enables to establish a relation between the two.

However, the estimates derived from macroeconomic indicators require plausibility check and are generally less reliable. Similarly, as in case of the past data, macroeconomic indicators can be used to estimate future traffic volumes, if prognoses of the development of macroeconomic indicators exist.

This approach provides rough estimates and is open to inclusion of more accurate data, such history of regional (section-specific) traffic volumes, which may differ from the network-aggregates.

This approach could help to get an improvement of knowledge level of fatigue consumptions and could provide a better bases for improvement of life cycle analysis of steel bridges, and therefore help to renew these bridges in a more economic way.

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