Modelling lifetimes in the Swedish paved road network with time-to-event analysis

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To be able to perform life cycle cost analysis (LCCA) of the Swedish road network, reliable predictions of maintenance intervals are needed. This interval is defined as the time from when a road is first maintained until the second maintenance. To keep track of the condition of the road network, the roughness (IRI) and rut depth of the road surface is measured every year for high traffic roads and every third to fifth year for low traffic roads.

Since it is not economically or practically possible to obtain surface measures on all roads every year, prediction models are implemented in the Swedish Transport Administration's application Pavement Management Systems (PMS) which cover all state roads in Sweden. These are linear models which lack in precision in the long run because the road wear is non linear. Normally, the rate of wear increases as the road ages. There is also a question of censored observations in the PMS database. These are roads which have only one registered maintenance treatment, i.e. the next treatment has not yet happened. If the censoring is not considered such a model is likely to be biased and misleading.

A method commonly used for non linear and censored data to predict lifetimes in mechanistic applications is time-to-event analysis. In medicine, this method is known as survival analysis. In previous research time-to-event analysis has been used to model lifetimes of roads, where 'lifetime' is commonly defined as the interval between two maintenance treatment (see e.g. Do 2011, Smith et al 2006, Smith et al 2005, Gharaibeh et al 2003, Hall et al 1994). The aim of this paper is to use time-to-event analysis to estimate lifetimes of paved roads in Sweden. Also, the impact on a road's lifetime of several different factors is analysed such as pavement type, road type, bearing capacity, road width, speed limit, stone size and climate zone.

Figure 1 shows the survival curves estimated from a model which is stratified by eight traffic classes. A stratified model is necessary since road construction mainly depend on the traffic load and hence all other covariates are correlated with the amount of traffic. The expected median lifetime is found where the survival equals 0.5. It varies from 28 years for roads with less than 250 vehicels per day down to 9 years for roads with 8000 or more vehicles per day. In this graph all other covariates are set to certain baseline values, but survival curves can be estimated for all combinations of covariates.

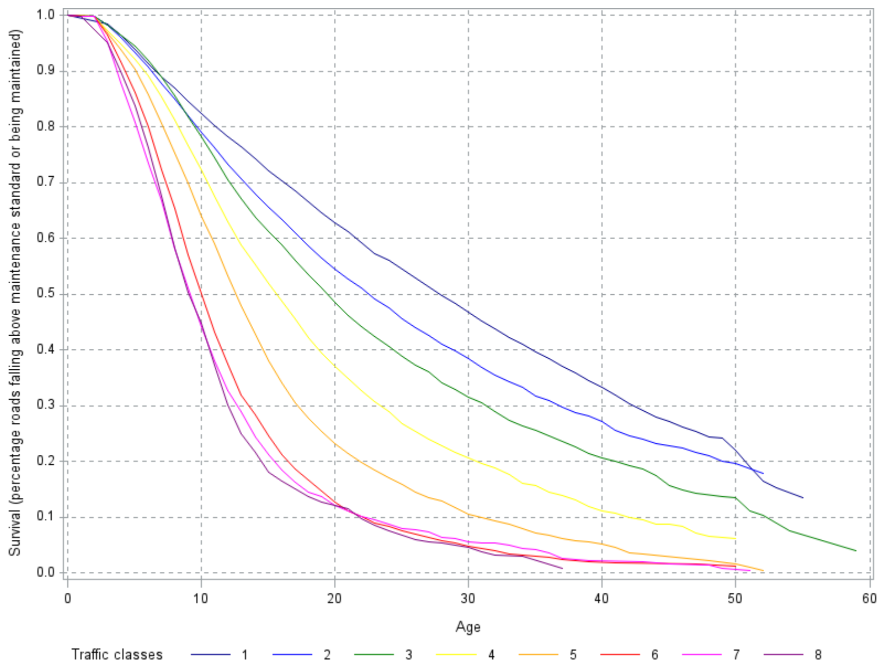

Figure 1: Survival curves for Swedish paved roads under different levels of traffic load.

Table 1: Definition of traffic classes.

Class	Vehicles/day
1	<250
2	250-499
3	500-999
4	1000-1999
5	2000-3999
6	4000-7999
7	8000-11999
8	>12000

A drawback of the definition of a road's lifetime being the time between two maintenance treatments is that the cause of maintenace is unknown. It might be that the road is maintained due to wear, but a specific road section in good condition might also be maintained because adjacent stretches are bad. To improve the analysis and obtain more accurate estimates of expected lifetimes information on the road surface measures is added to the model. In Sweden rut depth and IRI have been recorded since 1987. The Swedish Transport Administration has developed a maintenance standard stating apropriate levels of rut depth and IRI. This standard is a recommendation and not a necessity. All road sections in the material where a measure of surface condition is available (about 170.000 out of 280.000 road sections in total) were compared to the limits in the maintenance standard. If the measures of rut depth or IRI of a censored section exceeded recommended values, it was labelled as ”should have been maintained” and considered as non-censored in the analysis.

A model with an extended definition of a road’s lifetime was fitted to data. The lifetime of a road is either the time between two maintenance treatments as in the standard analysis, or; if the road has no second treatment registered; the time between the first maintenance treatment and the time when measures of rut depth or IRI exceeds the limits in the maintenance standard. In particular, the extended analysis showed some interesting results concerning the road type ”2+1 roads”. In 1998, the Swedish Transport Administration started to rebuild some wider ordinary roads and undivided motorways. A cable barrier was installed and the lanes alternate between one and two. 2+1 roads are considered safer than roads without a cable barrier. The oldest 2+1 roads in the data set are 13 years old and a lot of observations are censored. When road surface condtition of these roads were compared to the maintenance standard, censoring decreased from 57.3 to 52.1 percent. In total, 4.2 percent of the 2+1 roads which have not been maintained had measures of IRI and rut depth which exceeded the recommended limits in the maintenance standard. This information can be used in LCCA to account for the cost of maintenance of the increased number of 2+1 roads in Sweden.

References

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