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The (in)accuracy of travel demand forecasts in the case of no-build alternatives

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Abstract:

Impact appraisals of major transport infrastructure projects rely extensively on the accuracy of forecasts for the expected construction costs and travel time savings. The latter of these further depend on the accuracy of forecasts for the expected travel demand in both the build and no-build alternatives, in order to assess the impact of doing something rather than doing nothing. Previous research on the accuracy of demand forecasts has focused exclusively on the build alternatives, and revealed inaccuracies in the form of large imprecisions as well as systematic biases. However, little or no attention has been given to the accuracy of demand forecasts for the no-build alternatives, which are equally important for impact appraisals.

This paper presents what the authors consider the first and only ex-post evaluation of demand forecast accuracy for no-build alternatives, based on an empirical study of 35 road projects in Denmark and the United Kingdom. The sample is based on road projects for which traffic impact studies have been prepared for the no-build alternative, but where the projects had not yet been built at the time of the forecast target year. Data sources for expected travel demand have been decision-support prepared for policy makers, while data sources for actual travel demand have been observed traffic on the transport network.

The results show a tendency for systematic overestimation of travel demand in the no-build alternatives, which is in contrast to the systematic underestimation of travel demand observed in previous studies of build alternatives. These results indicate that the problem of systematic biases in travel demand forecasts for road projects have more problematic implications than previously assumed. The effect inflates rather than diminishes the problem of previously observed discrepancies between expected and observed travel demand, and the true magnitude of forecasting bias is thus greater than reported so far.

The main implication for planning practice is that impact appraisals of road construction as a means of congestion relief appear overly beneficial. Congestion in the no-build alternative is assumed to be unbearable if new capacity is not added to the road network, while actual travel demand is typically lower. This is problematic, since an overestimation of benefits for road projects will, ceteris paribus, make it more difficult to argue for other means of dealing with congestion problems, which might prove more sustainable and resilient in the long run.

1. Impact appraisals of transport infrastructure

In contrast to the large body of literature on ex-ante appraisals to inform decision makers of estimated uncertainty levels, there is a relatively sparse body of literature that deals with ex-post appraisals to inform decision makers about observed inaccuracy levels (Van Wee 2007). The issue is less problematic for cost estimates than for demand forecasts, since empirical studies of cost estimates are generally in ample supply, all of which seem to indicate a tendency for systematic cost overruns (Siemiatycki 2009). This tendency is not restricted to planning of transport infrastructure projects (see e.g. Hall 1980; Kharbanda and Stallworthy 1983), but due to the renowned studies by Flyvbjerg (2007) and colleagues it has perhaps received increased attention here compared to other fields of planning. However, large-scale ex-post appraisals of demand forecasts remain relatively rare, both in transport infrastructure planning and elsewhere. Data acquisition for such studies is cumbersome, and while there has been a surge of interest over the last decade, the number of comparable studies is still relatively modest. Further, such studies typically have a narrow focus due to the unavailability of data, and tend to focus on the specific project link while ignoring network effects or counter-factual scenarios. The latter issue is the focus of the present study, which is aimed at investigating the inaccuracy of demand forecasts in the case of the no-build alternative (a.k.a. business as usual, zero-alternative, do-minimum solution, etc.).

Decision-making in the field of transport infrastructure planning relies extensively on various types of impact assessments. The most common contemporary appraisal method is cost-benefit analysis (CBA) (Hayashi and Morisugi 2000; Mackie 2010; Odgaard, Kelly, and Laird 2005). A key aspect in this method of appraisal is the reliance on accurate forecasts for a range of impact categories, of which the most important for transport infrastructure projects are typically construction costs and travel demand. Construction costs are typically the biggest expense item for large public works projects such as transport infrastructure, while travel time savings are by far the biggest benefit category (Banister 2008; Nicolaisen 2012)[1]. The accuracy of cost estimates and demand forecasts are thus the most crucial factors to the validity of ex-ante appraisals of transport infrastructure, as both the magnitude of time savings and the amount of users benefitting from them are dependent on accurate forecasts of travel demand. More demand than expected can mean reduced benefits due to congestion, and less demand than expected can mean reduced benefits due fewer users benefitting from the project. As such, any deviations between expected and actual development for costs and demand propagate into subsequent appraisal tools such as CBA, although not necessarily in a linear manner for demand forecasts (Næss, Nicolaisen, and Strand 2012).

2. Ex-post appraisal of demand forecast accuracy

The forecasting potential of model-based decision support has long been subject to critical scrutiny, but typically the main academic focus has been directed at investigating levels of uncertainty related to model specification issues, calibration procedures, or data acquisition for necessary input variables (Ascher 1981; Clarke, Dix, and Jones 1981; De Jong et al. 2007; De Jongh 1998; Rasouli and Timmermans 2012; Walker et al. 2003; Zhao and Kockelman 2002). These are certainly important in and of themselves, but they are typically related to the issue of uncertainty rather than inaccuracy, if we define uncertainty as being "*any departure from the unachievable ideal of complete determinism*" (Walker et al. 2003, 8). Meanwhile, inaccuracy can be considered the actual deviation between predicted and observed values, which is only possible to measure after the true value is known. Uncertainty thus pertains primarily to ex-ante evaluations, while inaccuracy pertains mainly to ex-post evaluations. It is the latter of these concepts that is of interest in the present study.

Ascher (1978) addressed the accuracy of forecasts used in policy-making, concluding that both absolute inaccuracy and systematic biases were problematic for certain types of demand forecasts. The author pointed out the need for continued appraisal of forecast accuracy to improve decision-making. Sadly, the number of large-scale studies in this field remains limited, but from the current body of literature it seems fair to conclude that travel demand for new road infrastructure projects is generally underestimated on the new link (Flyvbjerg, Holm, and Buhl 2005; HA 2011; NAO 1988; Nicolaisen 2012; Parthasarathi and Levinson 2010; Welde and Odeck 2011). Conversely, travel demand forecasts for rail infrastructure projects appear to be overestimated (Button et al. 2010; DoT 2008; Flyvbjerg, Holm, and Buhl 2005; Fouracre, Allport, and Thomson 1990; Nicolaisen 2012; Pickrell 1990).

[1] An quick glance at assessments of transport infrastructure in Denmark over the last couple of years indicate that construction costs and travel time savings typically make up at least 80% of total costs and benefits respectively. For trivial road projects (capacity expansions, bypass constructions, junction widenings, etc.) the share is typically above 90%.

These observations have sometimes led planners to conclude that road projects benefits of road projects are underestimated, while benefits of rail projects are generally overestimated. If the project carries more traffic than expected, the societal benefit must be higher than expected as well (vice versa for rail). However, the when evaluating project benefits in a CBA framework the correlation between travel demand and benefits is not always linear, and such conclusions might be unwarranted. For example, Næss et al. (2012) found that a relatively small underestimation of traffic volume would lead to drastic overestimation of travel time savings when evaluating a new urban road project, since the additional traffic resulted in congestion. In addition to the evaluated economic effects are of course more adverse environmental and social effects caused by increasing traffic volumes in urban areas. Apart from the fact that increasing traffic volumes is not always a benefit, all studies of demand forecast accuracy have reported a large variation in accuracy for their sampled projects. It is thus difficult to apply observed aggregate biases to individual project appraisal, since deviations can occur both in a positive and a negative direction (i.e. road projects might be underestimated on average, but large overestimations are also common).

Reappraisal of projects based on ex-post evaluation of travel demand is beyond the scope of the present paper, but the brief discussion in the previous paragraph illustrates the complexity in interpreting the implications of these results. However, in order to perform an impact assessment, some ex-post scenario for a no-build alternative must be made for the sake of comparison. An implicit assumption in such reappraisals is often that the forecast for the no-build alternative is accurate, since this is a counter-factual scenario where no data exists for ex-post evaluation. The same base scenario is thus used for comparison with both the ex-ante and ex-post travel demand levels for the build alternative, but just like forecasts for the build alternatives the forecasts for the no-build alternatives can also be inaccurate. The consequences of inaccurate forecasts for the base alternatives are of course equally relevant when assessing the validity of decision support based upon these forecasts. However, so far studies of demand forecast accuracy has focused exclusively on build alternatives. To the best of the authors' knowledge, the present study is the first of its kind to assess the accuracy of no-build alternatives.

3. Methodology

Inspired by Flyvbjerg et al. (2005) "w*e follow common practice and define the inaccuracy of a traffic forecast as actual minus forecasted traffic in percentage of forecasted traffic*"[2].

$$I = \frac{O - E}{E}$$

This provides a simple measure of inaccuracy as the relative deviation between observed and expected values, where the central tendency will be used as an indicator of bias and the spread as an indicator of imprecision. Perfect accuracy is indicated by a measure of zero. Negative values indicate less demand than expected, while positive values indicate more demand than expected. A more sophisticated measure of inaccuracy would be desirable, since our chosen measure is a point estimate that is sensitive to fluctuations in the opening year. However, data availability rarely allows for more than this simple measure to be established for completed projects, and it has thus been the only realistic measure to employ across a larger sample.

In order to assess the accuracy of demand forecasts for no-build alternatives it is necessary to identify suitable units of observation as well as suitable reference points for the ex-ante and ex-post figures one seeks to compare. Since the purpose is to gauge the validity of

[2] I: inaccuracy, O: observed value, E: expected value

forecasts used for decision-making, the ex-ante reference point has been decided to be the forecasts included in the decision support documentation available to politicians immediately prior to forming a political decision on whether to go ahead with a project or not. This will typically be in the form of environmental impact assessments (EIA) or CBAs, but since the same demand forecasts are typically used in both documents, these sources can largely be considered interchangeable. The forecast target year for these forecasts has been selected as the ex-post reference point to allow the most straightforward comparison of expected and actual demand. For reasons of practicality, annual average daily traffic (AADT) levels on the planned project links have been selected as the unit of observation for the present study. Typically this will be the primary unit reported in decision support documents and also the most readily available in count databases.

Since data availability is typically a severely restricting factor in ex-post evaluations (Flyvbjerg, Holm, and Buhl 2005; Næss, Nicolaisen, and Strand 2012; Parthasarathi and Levinson 2010) it is unlikely that more detailed measures of demand can be accessed for both the ex-ante and ex-post reference points. In addition, the focus on no-build rather than build alternatives limits the amount of relevant projects to include in the sample. In order to make a useful comparison of expected and observed values for the purpose defined in the present paper projects must fulfil one of three criteria:

- A political decision to abandon or postpone the project must have been reached. This is basically the true no-build scenario that the baseline forecast was prepared for, and thus allows for an evaluation of the accuracy of the forecast.
- The project must have been significantly delayed so construction has not yet begun at the ex-post reference point. On the surface it might seem like this situation is identical for the purposes of the present study, but even if construction has been delayed it is still possible that land use changes in expectation of the future project has been initiated. This is not necessarily a critical issue but needs to be taken into account when comparing ex-ante and ex-post figures.
- The project is not expected to impact the transport network in a noticeable degree during the construction process. This essentially allows observed traffic levels one year prior to opening to be used as the ex-post reference point, since these would largely reflect the development in traffic in the baseline scenario. The same concerns of potential land use changes naturally apply here as well and need to be taken into account for the comparison.
- Traffic counts for the project must be available in the forecast target year and must be supplied by the respective transport authorities of each country.

Decision support documents for road projects planned in Denmark and the United Kingdom in the period 1970 to 2010 have been gathered as part a larger research project on demand forecast accuracy[3]. Among these, 35 projects meeting the four criteria listed above were identified; 15 from Denmark and 20 from the United Kingdom. These 35 projects were completed between 1985 and 2010. For a more elaborate discussion of the selection criteria and data collection process, see Nicolaisen (2012).

4. Results

Error! Reference source not found. displays the distribution of demand forecast inaccuracy for no-build alternatives observed in Danish and British road projects. A tendency to overestimate demand is clear already from visual inspection, with a normal distribution around a mean of -7 %. Some variation is present, but a standard deviation of 13 % must be considered relatively small. In comparison, must studies of demand forecast inaccuracy for build alternatives report standard deviations around 40 % (Nicolaisen 2012). The negative

[3] UNcertainties in Transport Project Evaluation (UNITE).

bias in the measure of inaccuracy is thus more robust than previously observed biases for build alternatives. **Error! Reference source not found.** displays basic descriptive statistics for the employed inaccuracy measure. The confidence interval indicates that the negative bias is statistically significant. The trimmed mean is close to the raw mean, meaning that the small skewness observed in **Error! Reference source not found.** has little actual impact on the magnitude of bias.

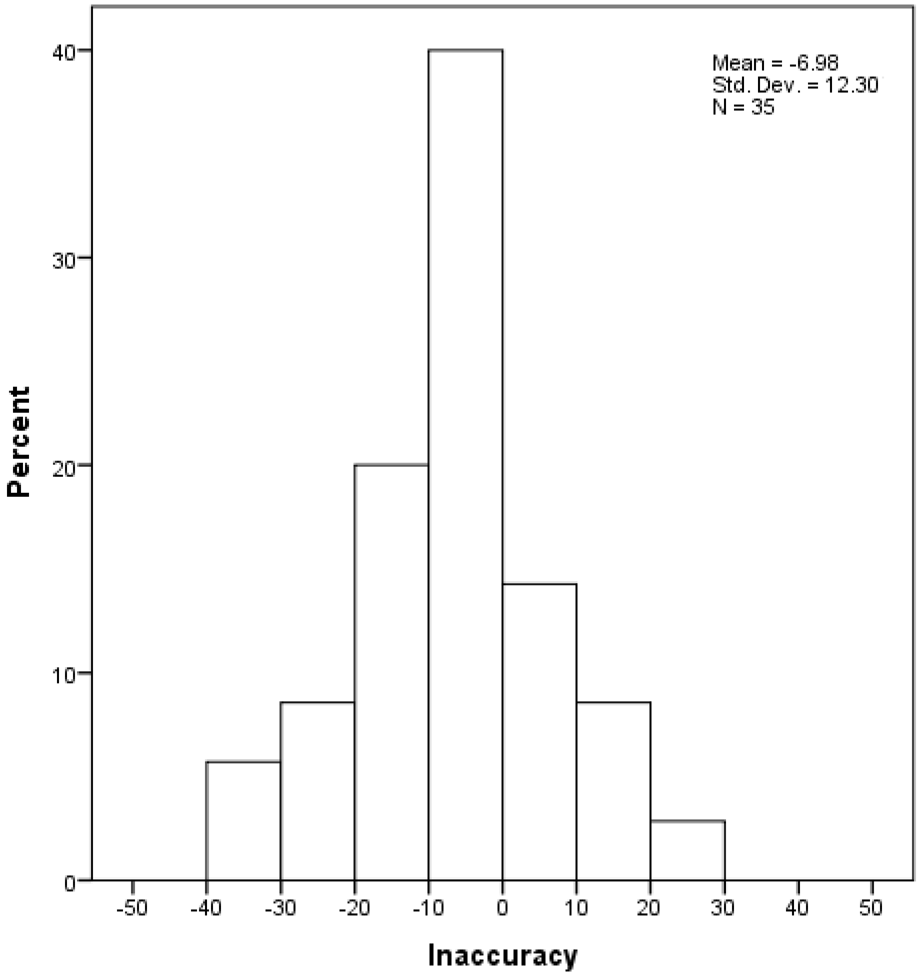

Figure 1: Observed distribution of demand forecast inaccuracy (%) in the no-build alternatives for planned road projects in Denmark and the United Kingdom.

Inaccuracy (%)	**Std. dev.**
Mean	-6.98
95% Confidence Interval for Mean	
Lower Bound	-11.21
Upper Bound	-2.76
5% Trimmed Mean	-6.85
Median	-5.84
Standard Deviation	12.30
Minimum	-34

Maximum	21
Interquartile Range	16

Table 1: Descriptive statistics of demand forecast inaccuracy in the no-build alternatives for planned road projects in Denmark and the United Kingdom.

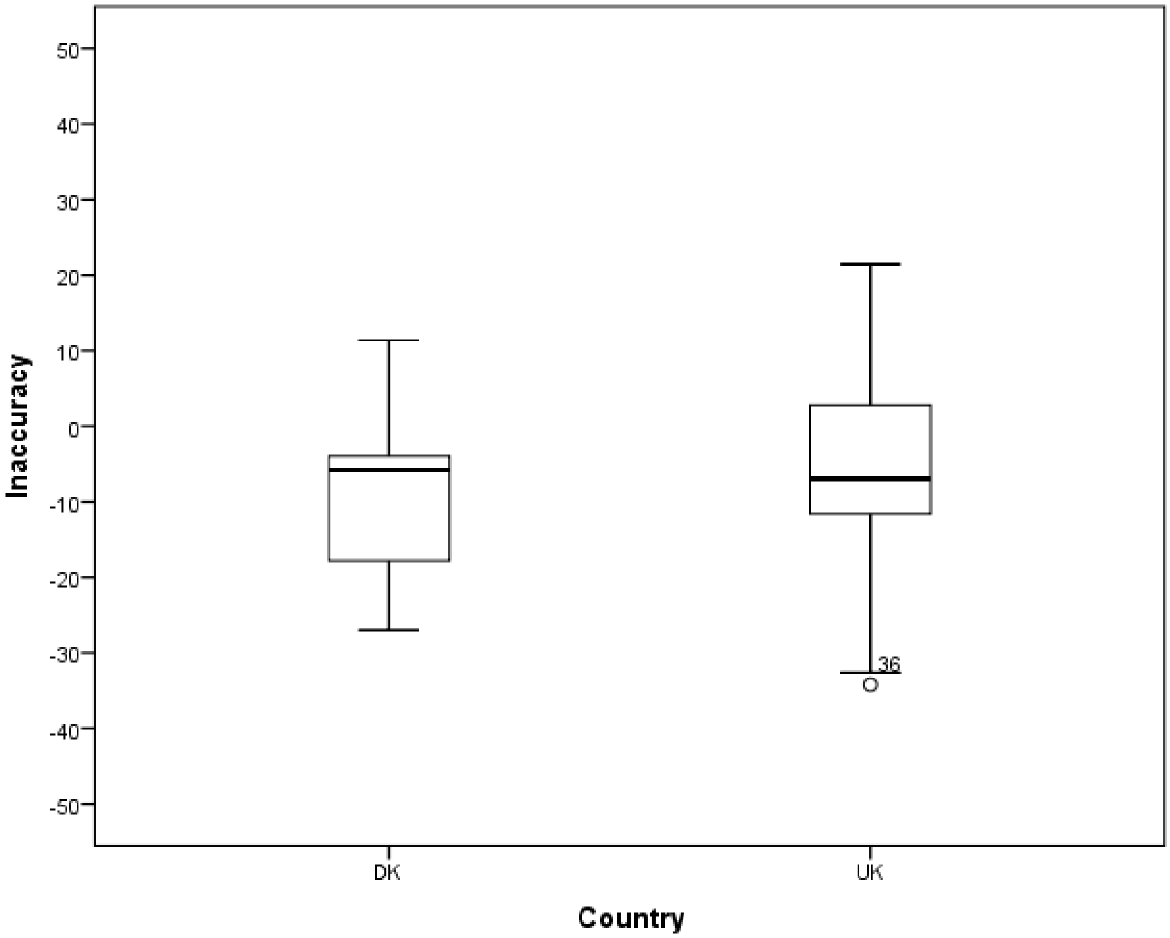

Figure 2: Boxplot of demand forecast inaccuracy (%) in the no-build alternatives for planned road projects in Denmark (DK) and the United Kingdom (UK).

Error! Reference source not found. displays a boxplot of the inaccuracy split by country. The biggest difference between Danish and British projects is a larger variation in Britain, but the negative bias observed in the aggregate sample persists at the national level.

5. Discussion

The results of the present study clearly indicate that travel demand has been systematically overestimated in the no-build alternatives for Danish and British road projects. On average, actual traffic volumes are 7% lower than those predicted in forecasts. While there is considerable variation between projects, the negative bias is statistically significant at the 0.05 level. It has not been possible to make a detailed inquiry into what the causes for this observed bias, but a possible reason could be that planners often assume traffic volumes to grow at a fixed annual rate for the no-build alternatives (this is also the case for most projects included in the present study). This growth rate is typically specified by national or regional forecasts for the overall traffic growth. Such an assumption disregards the deteriorating effect of congestion on future traffic growth, and will, ceteris paribus, overestimate actual traffic volumes. In the real world travelers will start seeking alternative solutions when faced with increasing levels of congestion rather than queuing for hours on end. Neglect of this effect in trip generation is likely to be a considerable contributing factor to the bias observed in the present study.

The bias might appear modest in comparison to that observed for certain types of build alternatives, such as demand forecasts for rail projects that typically overestimate patronage by 20-40% on average (Button et al. 2010; DoT 2008; Flyvbjerg, Holm, and Buhl 2005; Fouracre, Allport, and Thomson 1990; Nicolaisen 2012; Pickrell 1990). However, a comparison of the raw inaccuracy measures is a very simplistic way of evaluating the problem of forecast inaccuracy. First, the variation for no-build forecast inaccuracy is much smaller than ex-post evaluations of other project types. Some completed fixed link projects experience only one third of expected traffic, while others experience three times the traffic as expected. The same case can be made for rail projects, where some have massive patronage shortfalls and others quickly encounter capacity problems due to unexpected success. While the bias observed for both fixed links and rail projects is concerning, the general uncertainty involved in predicting the travel impacts of large, complex infrastructure projects is apparently so high that systematic bias might only be one of many issues that affect the validity of these forecasts. In comparison, the systematic bias observed for no-build alternatives appear to explain more of the total inaccuracy than for the build alternatives.

Second, the relationship between observed demand and the various impact categories of relevance to decision makers is rarely linear. For example, travel speed on motorways remains relatively unaffected at volume capacity ratios below 0.8 and congestion is rarely problematic until about 0.9 (Akçelik 1991). Above these ratios congestion becomes an increasing concern, where even small changes in traffic volume can traffic flow to a grinding halt. For a road with a capacity of 2000 vehicles/hour/lane (v/h/l), the difference in forecasting actual traffic volumes of 1900 and 1995 v/h/l is just 5%, but the resulting impact is a 21% and 43 % reduction of travel speed respectively[4]. Meanwhile, the difference between forecasting 1000 and 1050 v/h/l for such a road is also just 5%, but the resulting impact then only a 1.6 % and 1.7 % reduction of travel speed respectively. A 5% increase in traffic volume might therefore result in negligible or devastating flow disruptions depending on the existing capacity usage. The tendency to overestimate demand forecasts for no-build alternatives is thus highly important when evaluation networks that currently experience congestion or are expected to do so in the near future.

Travel time savings are by far the most dominant impact category when assessing the impacts of new transport infrastructure or policy initiatives aimed at improving mobility. In this perspective, future levels of congestion on road networks are systematically overestimated by overestimating the traffic growth trend in the no-build alternatives. The results of the present study are not surprising, but they confirm an often voiced criticism against a naïve use of demand forecasts in transport planning. Impact appraisals of road capacity expansion in urban areas overestimate benefits by neglecting, or outright ignoring, the effect of congestion on travel demand and thereby misrepresenting the impacts on travel time. This systematic neglect will, ceteris paribus, make it difficult to argue for alternative measures to combat congestion, since capacity expansions will often seem necessary. The issue can go unnoticed since the counterfactual scenario is rarely evaluated, and it is not possible to capture the full effect by merely performing ex-post analyses of completed projects. Increased attention need to be given to the assumptions embedded in the models used to evaluate no-build alternatives.

[4] Using the time-dependent travel time function specified by Akçelik (1991) and with identical parameter specifications.

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