ERROR AND OPTIMISM BIAS IN TOLL ROAD TRAFFIC & REVENUE FORECASTS

Robert Bain
RBconsult Ltd.
ERROR AND OPTIMISM BIAS IN TOLL ROAD TRAFFIC & REVENUE FORECASTS

Robert Bain
RB consult Ltd.

21st June 2011, Canberra
10,570 miles (from A to B)
Empirical Prediction Intervals

<table>
<thead>
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<th>Traffic Forecast Horizon</th>
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An Evidence-Based Approach
An Evidence-Based Approach

- Triangulation
An Evidence-Based Approach

- Triangulation
  - Convergence from multiple data sources...
    1. Past forecasting performance
    2. Survey of practitioners
    3. Evidence from related disciplines
1. Past Forecasting Performance
Bain (2005)

Standard & Poor’s Expanded Sample (2005)
Normal (0.77, 0.26), n = 104

Actual/Forecast Traffic
Others (selected examples)

- **JP Morgan (1997)**
  - 14 toll roads (US)
  - 1 exceeded its forecast; for 4 revenue was less than 30%

- **Flyvbjerg et al (2005)**
  - 183 tolled & toll-free roads (international)
  - Difference of over ±40% for ¼ of projects; no improvement in forecast accuracy over the years

- **US Transportation Research Board (2006)**
  - 26 toll roads (US)
  - “even with updated forecasts, only a small number are within ±10%”

- **Vassallo (2007)**
  - 14 toll roads (Spain)
  - “on average, traffic was overestimated by approximately 35%”

- **Li & Hensher (2009)**
  - 14 toll roads (Australia)
  - “on average, traffic levels of these [five] toll roads is 45% lower than predicted”

- **Bain (2010)**
  - 55 toll-free roads (UK)
90% of observed data lies between ±27.5% of the forecast (average age of forecasts = 5 years)
Past Forecasting Performance

- Traffic forecasting errors are common
  - ...and are commonly large

- Toll-free roads
  - Errors symmetrically distributed about the mean

- Toll roads
  - Errors skewed
  - Evidence of bias (optimism bias)
2. Survey of Practitioners
Survey of Practitioners

- Consultants, government officials & academics

- Australia, Bangladesh, Brazil, Canada, Chile, Hong Kong, Ireland, New Zealand, Sweden, UK & US

- Suggest likely error ranges (confidence intervals)
  - 2 scenarios:
    - exiting road and a new build
  - 4 horizons:
    - next day and 1 year, 5 years & 20 years ahead
## Survey of Practitioners

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<tr>
<td>5 Years</td>
<td>±15%</td>
<td>±25%</td>
</tr>
<tr>
<td>20 Years</td>
<td>±32.5%</td>
<td>±42.5%</td>
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Survey of Practitioners

- Clear evidence of over-confidence:
  - 5 respondents: ±0% for next day
  - 8 respondents: ±3% (or less) for 1-year
    - [30% respondents: μ = < 5%]
  - 10 respondents: ±8% (or less) for 5-years
    - [28% respondents: μ = < 9%]
  - 6 respondents: ±10% (or less) for 20-years
    - [32% respondents: μ = < 17%]

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Survey of Practitioners

- Prediction intervals grow as horizon extends
  - Non-linear

- Predictive capability stronger for existing (known) facilities
  - New assets introduce forecasting challenges of their own

- Traffic forecasters (significant %) exhibit over-confidence
  - Well-researched cognitive bias
  - Underestimate possibility of the future being different from that envisaged
  - In-line with other research (bankers, financial analysts, economic forecasters)

- Surprisingly under-researched field
  - Need to reflect on forecasting accuracy & communicate with the profession
    - Empirically derived (statistical) prediction intervals
    - Learn lessons to guide future traffic forecasting practice
3. Evidence from Related Disciplines
Method

- Majority of T&R forecasts incorporate growth

- Central proposition
  - Uncertainty associated with traffic growth
  - ...cannot be less than the uncertainty associated with its determinants
  - Determinants of traffic growth typically include projections of
    - Population
    - GDP
    - Car ownership
    - Households
    - Employment
    - Fuel price (and/or efficiency)
    - ...or some combination thereof
Method

- Majority of T&R forecasts incorporate growth

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  - Households
  - Employment
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  - ...or some combination thereof
Initial review of predictive accuracy was positive, but...

- Forecasting performance deteriorates rapidly:
  - ...as the forecasting horizon extends
    - linear?
  - ...as the study area contracts (national → subnational)
    - non-linear?
  - ...if population is changing rapidly, in urban areas, students/armed forces...
Small-Area Population Forecasts

<table>
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<tr>
<th>Prediction Interval (±%)</th>
<th>0%</th>
<th>10%</th>
<th>20%</th>
<th>30%</th>
<th>40%</th>
<th>50%</th>
<th>60%</th>
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<tbody>
<tr>
<td>Forecast Horizon (years)</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>6</td>
<td>7</td>
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Meta-Analysis Sources:
- Rayer et al (2009)
- Shaw (2007)
- Simpson et al (1997)
- Smith & Shahidullah (1995)
- Smith et al (2001)
Small-Area Population Forecasts

- Errors for 20-year small-area population projections
  - Average of approximately ±25%, yet
    - 1/3 of survey respondents said less than ±25% for 20-yr traffic forecasts

- Errors for 30-year small-area population projections
  - Between ±25% and ±55%
    - Average of approximately ±33%

- ...these are horizons frequently used in traffic forecasting!
A question and an appeal:

- How could the prediction intervals associated with traffic growth be narrower than the intervals associated with the determinants of traffic growth?

- Forecasting reports typically describe the determinants of growth:
  - Need to understand the uncertainties associated with these determinants individually and collectively
  - ...and the resulting implications for traffic forecasts
Conclusions
Empirical Prediction Intervals

Research
Conclusions
Empirical Prediction Intervals

Past Forecasting Performance

Research Conclusions

Survey of Practitioners

Evidence from Related Disciplines
**Empirical Prediction Intervals**

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<td></td>
<td>±2.5% * √n</td>
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* UK Department for Transport Percentages are rounded.

“The formula is based on experience with UK national traffic forecasts. Local traffic forecasts would be expected to be less accurate than this.”
# Empirical Prediction Intervals

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Government Office Region (GOR)
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“GOR level might be higher since they need to be aggregated together to get our ±15% (for Year 36) at national level.”
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Existing Road/Stable Conditions

Forecast Horizon (years)

Prediction Interval (±%)

Survey Responses
Survey Trend
Bain Approximation: ±7.5%*sqrt(n)
## Empirical Prediction Intervals

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New Road/Dynamic Conditions

Prediction Interval (±%)

0% 10% 20% 30% 40% 50% 60%

Forecast Horizon (years)

Survey Responses
Survey Trend
Bain Approximation: ±10%*sqrt(n)
HA Data (90% CI)
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"On discussion with colleagues, there is a feeling that even ±25% (for Year 35) might be too low when looking at individual area types or links"
**Empirical Prediction Intervals**

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"On discussion with colleagues, there is a feeling that even ±25% (for Year 35) might be too low when looking at individual area types or links”

\[±25\% \text{ @ Year 35 } = ±4.2\% * \sqrt{n}\]
Demographers Beat Us To It...

- By 40 years!

“Given the many uses of population projections, there is a need to provide a warning to users about the likely size of their errors.”

Keyfitz N (1972)
What Traffic Forecasts Look Like
What Traffic Forecasts Look Like
What Traffic Forecasts Look Like

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What Traffic Forecasts Look Like

![Traffic Forecasts Diagram](image)

Population assumptions:
- NM model's 'base' scenario
- NM model's 'low' scenario
- EIS/CDIMP model

Daily traffic forecasts:
- NM model's 'base' scenario
- NM model's 'low' scenario
- EIS/CDIMP model
What Traffic Forecasts Look Like

![Graph showing traffic transactions forecasted over fiscal years from 2010 to 2060. The graph indicates a steady increase in transactions over time.](image-url)
What Traffic Forecasts Look Like

FIGURE 7.3  OBSERVED AND FORECAST CAR REVENUE


Observed
Forecast
What Traffic Forecasts Look Like

![Traffic Forecast Graph]

Exhibit 8-1: VKT Forecast – peak model outputs
What Traffic Forecasts **Really** Look Like
What Traffic Forecasts Really Look Like

1990  2000  2010  2020  2030  2040  2050  2060

20,000  40,000  60,000  80,000  100,000  120,000  140,000  160,000  180,000  200,000

AADT

Columbia River Crossing (Oregon/Washington)

www.robbain.com
What Revenue Forecasts Really Look Like

www.robbain.com
A Word About Bias...
A Word About Bias...

- Why focus on error?

  - Error should be considered first
    - In the absence of a discussion on error, the temptation is to attribute all (or most) departures from expectations to bias
  - This would be convenient
    - Correct for bias and we have accurate forecasts!

- But, as we have seen, the role of error is significant

  - Correcting for bias is important, but
    - Correct for bias and we still have forecasts nesting within (potentially) large confidence intervals
A Word About Bias...

- Bias is what interested me about the current study

- The temptation is to believe that bias is entirely man-made

- But some elements of bias could be model-related

- That’s precisely what I want to examine in this study