ERROR AND OPTIMISM BIAS IN TOLL ROAD TRAFFIC & REVENUE FORECASTS

Robert Bain
RBconsult Ltd.

21st June 2011, Canberra

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10,570 miles (from A to B)

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Empirical Prediction Intervals

Traffic Forecast Horizon		
1 Year	10 Years	25 Years

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Empirical Prediction Intervals

Traffic Forecast Horizon		
1 Year	10 Years	25 Years
±?%		

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Empirical Prediction Intervals

Traffic Forecast Horizon		
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Empirical Prediction Intervals

Traffic Forecast Horizon		
1 Year	10 Years	25 Years
±?%	±?%	±?%

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An Evidence-Based Approach

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An Evidence-Based Approach

- Triangulation

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An Evidence-Based Approach

- Triangulation
  - Convergence from multiple data sources...

    1. Past forecasting performance

    2. Survey of practitioners

    3. Evidence from related disciplines

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1. Past Forecasting Performance

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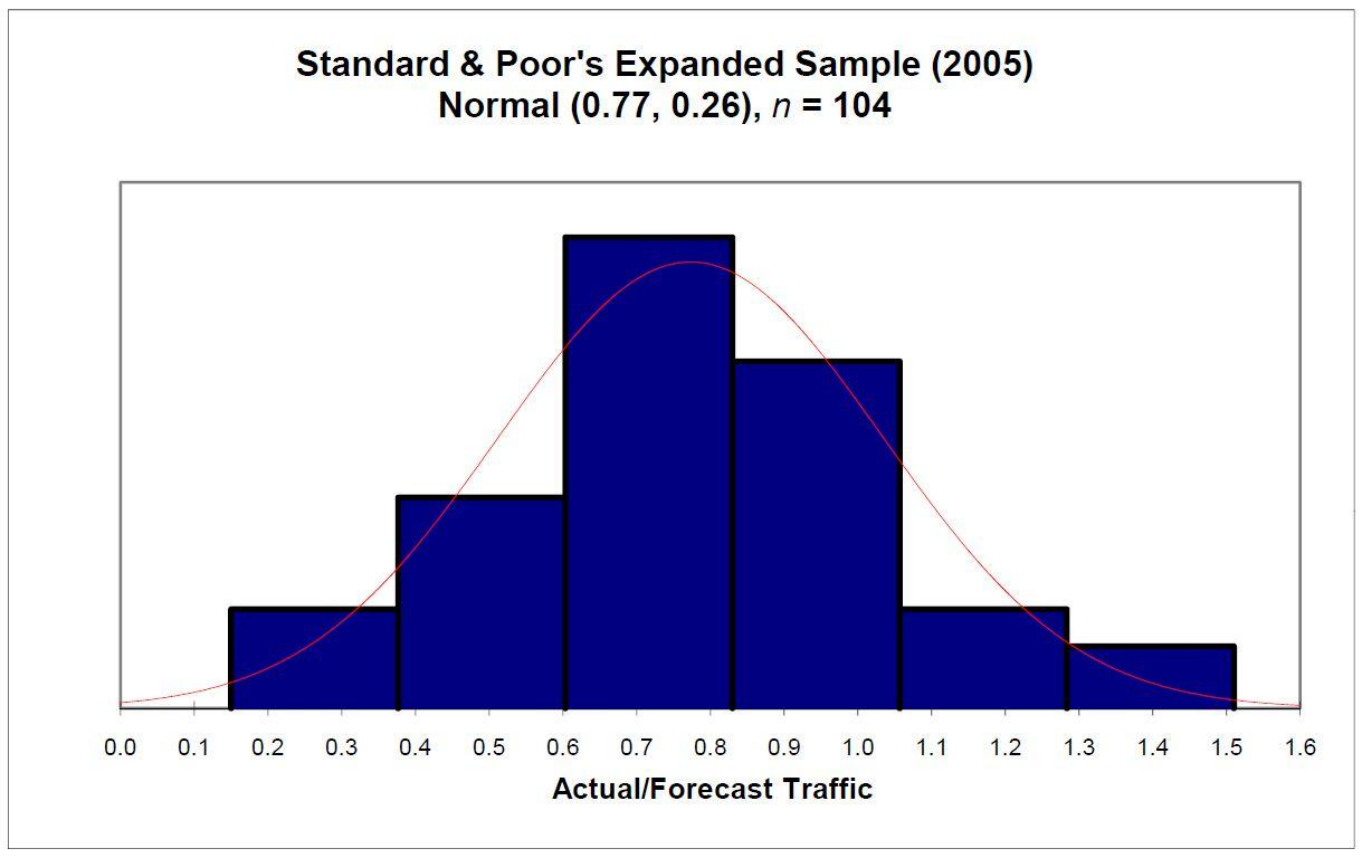
Bain (2005)



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)

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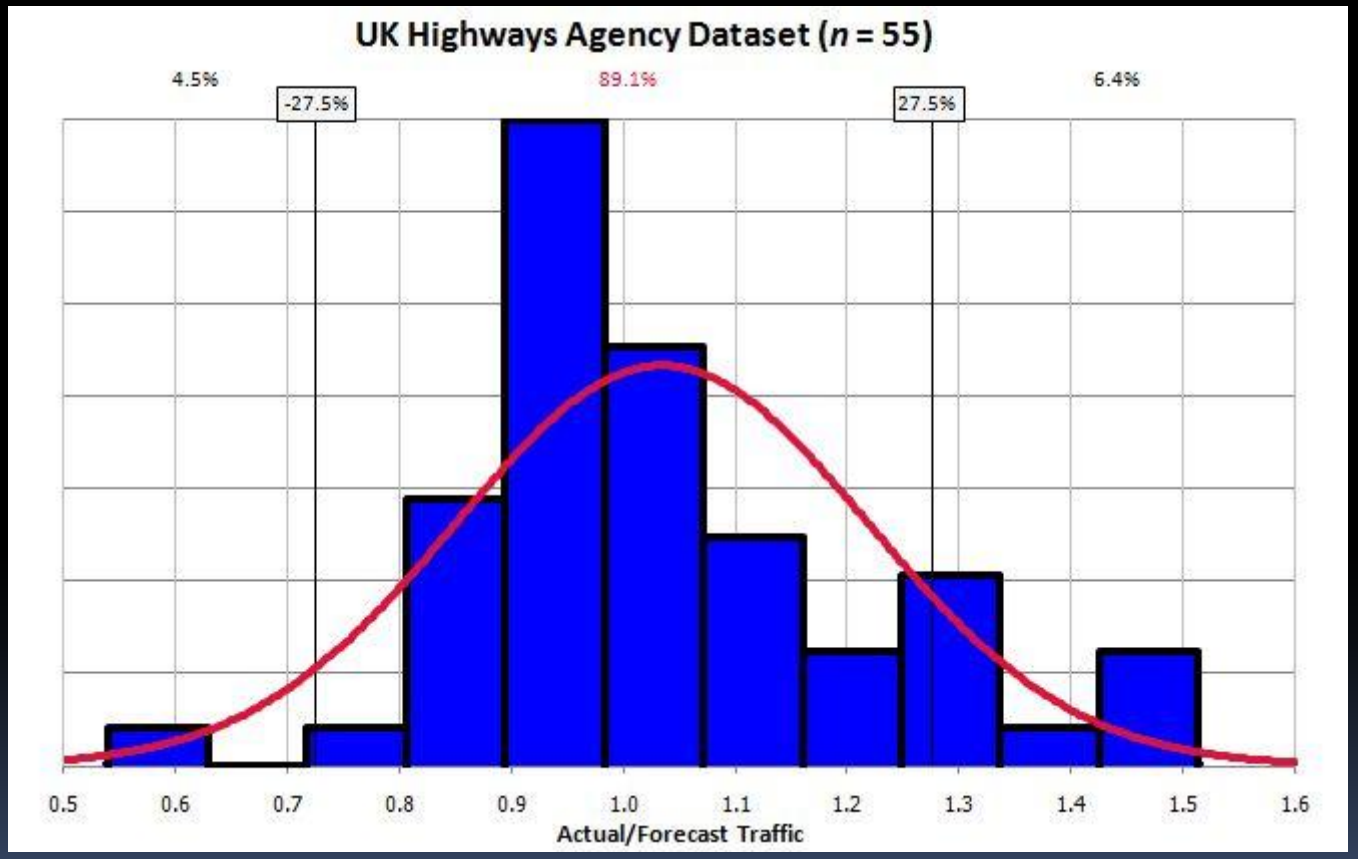
Bain (2010)



90% of observed data lies between ±27.5% of the forecast (average age of forecasts = 5 years)

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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)

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2. Survey of Practitioners

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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

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Survey of Practitioners

Traffic Forecast Horizon	Existing Road	New Road
Next Day	±7.5%	n/a
1 Year	±10%	±15%
5 Years	±15%	±25%
20 Years	±32.5%	±42.5%

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Survey of Practitioners

Traffic Forecast Horizon	Existing Road	New Road
Next Day	±7.5%	n/a
1 Year	±10%	±15%
5 Years	±15%	±25%
20 Years	±32.5%	±42.5%

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

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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

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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

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Method

- Majority of T&R forecasts incorporate growth
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    - Fuel price (and/or efficiency0
    - ...or some combination thereof

Population Forecasts

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- 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…
      - ??

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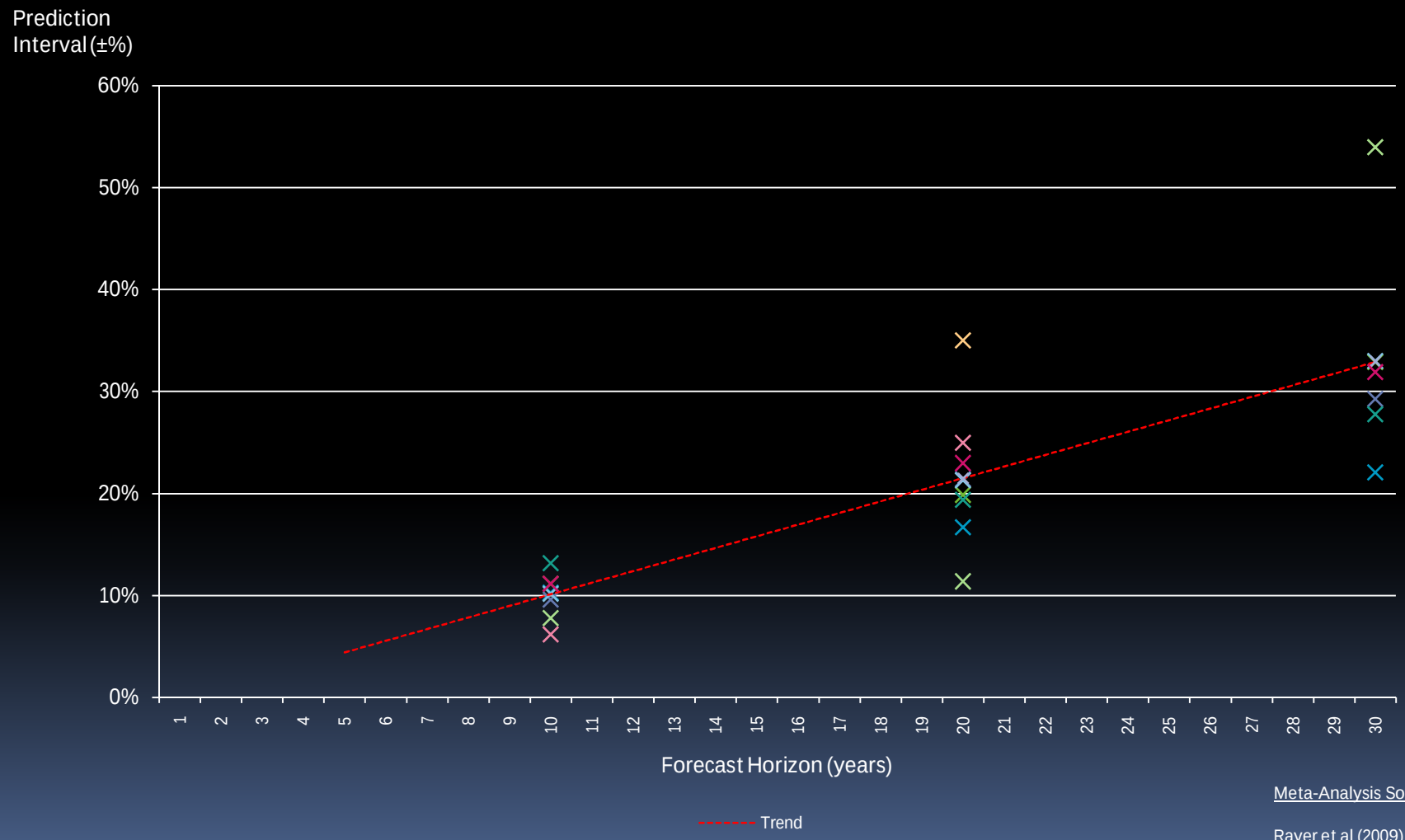
Small-Area Population Forecasts



Meta-Analysis Sources:

Rayer et al (2009)
Shaw (2007)
Simpson et al (1997)
Smith & Shahidullah (1995)
Smith et al (2001)

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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!

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Small-Area Population Forecasts

- 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

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Conclusions

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Empirical Prediction Intervals

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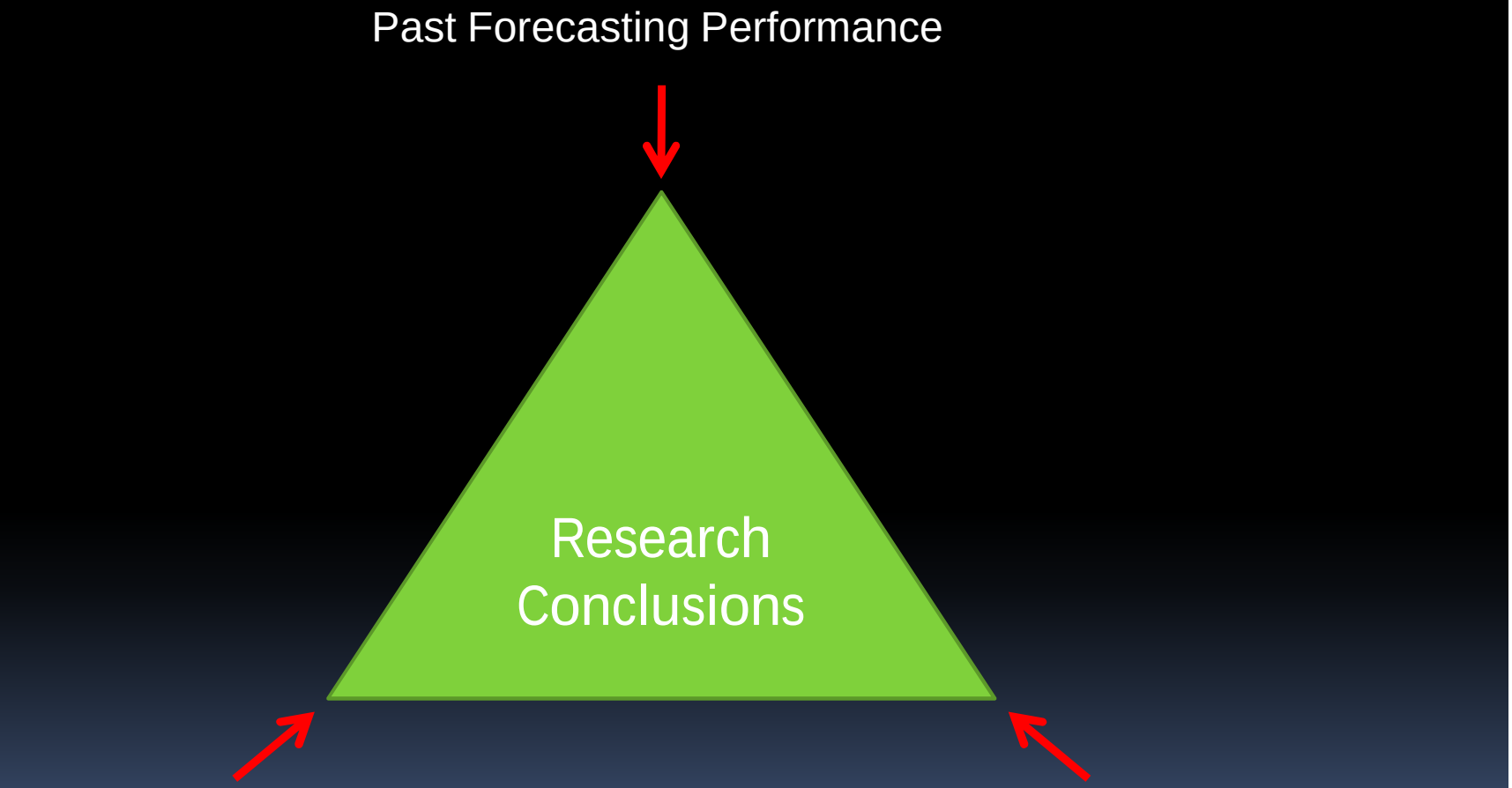
Empirical Prediction Intervals



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Empirical Prediction Intervals

Traffic Forecast Horizon		
1 Year	10 Years	25 Years
±?%	±?%	±?%

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Empirical Prediction Intervals

Study Level	Unpredictable? (Rapidly Changing?)	90% Confidence	Traffic Forecast Horizon		
			1 Year	10 Years	25 Years

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Empirical Prediction Intervals

Study Level	Unpredictable? (Rapidly Changing?)	90% Confidence	Traffic Forecast Horizon		
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National					

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Empirical Prediction Intervals

Study Level	Unpredictable? (Rapidly Changing?)	90% Confidence	Traffic Forecast Horizon		
			1 Year	10 Years	25 Years
National*		±2.5% * √n	±3%	±8%	±13%

** 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."

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Empirical Prediction Intervals

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National*		±2.5% * √n	±3%	±8%	±13%
Regional		?			

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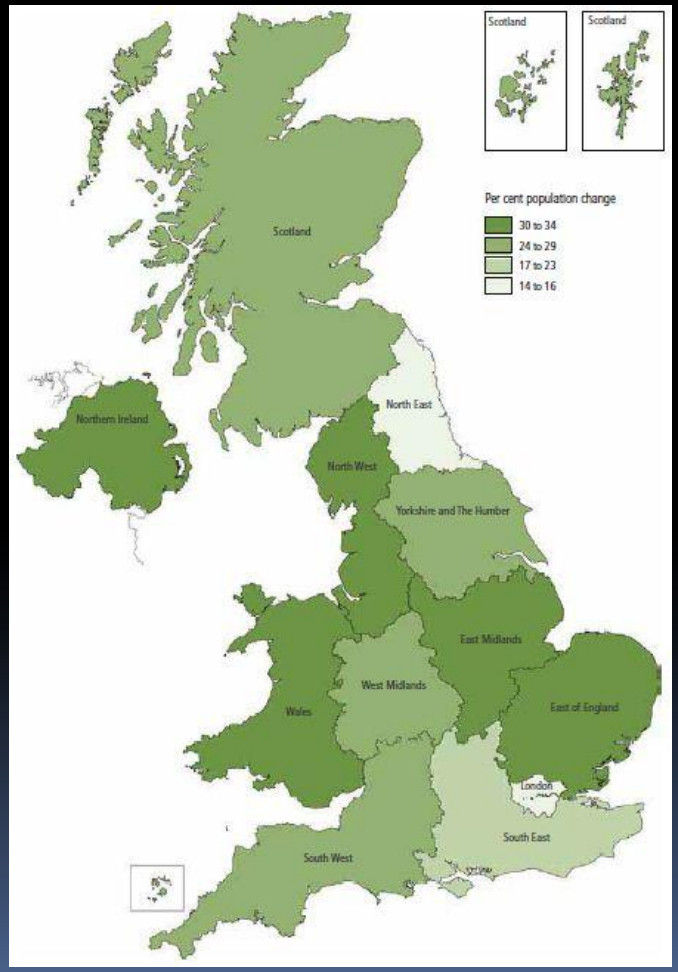
Government Office Region (GOR)



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Regional		?			

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Percentages are rounded.

"*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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Empirical Prediction Intervals

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Regional		> ±2.5% * √n			

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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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Local					

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Regional		> ±2.5% * √n			
Local	No				

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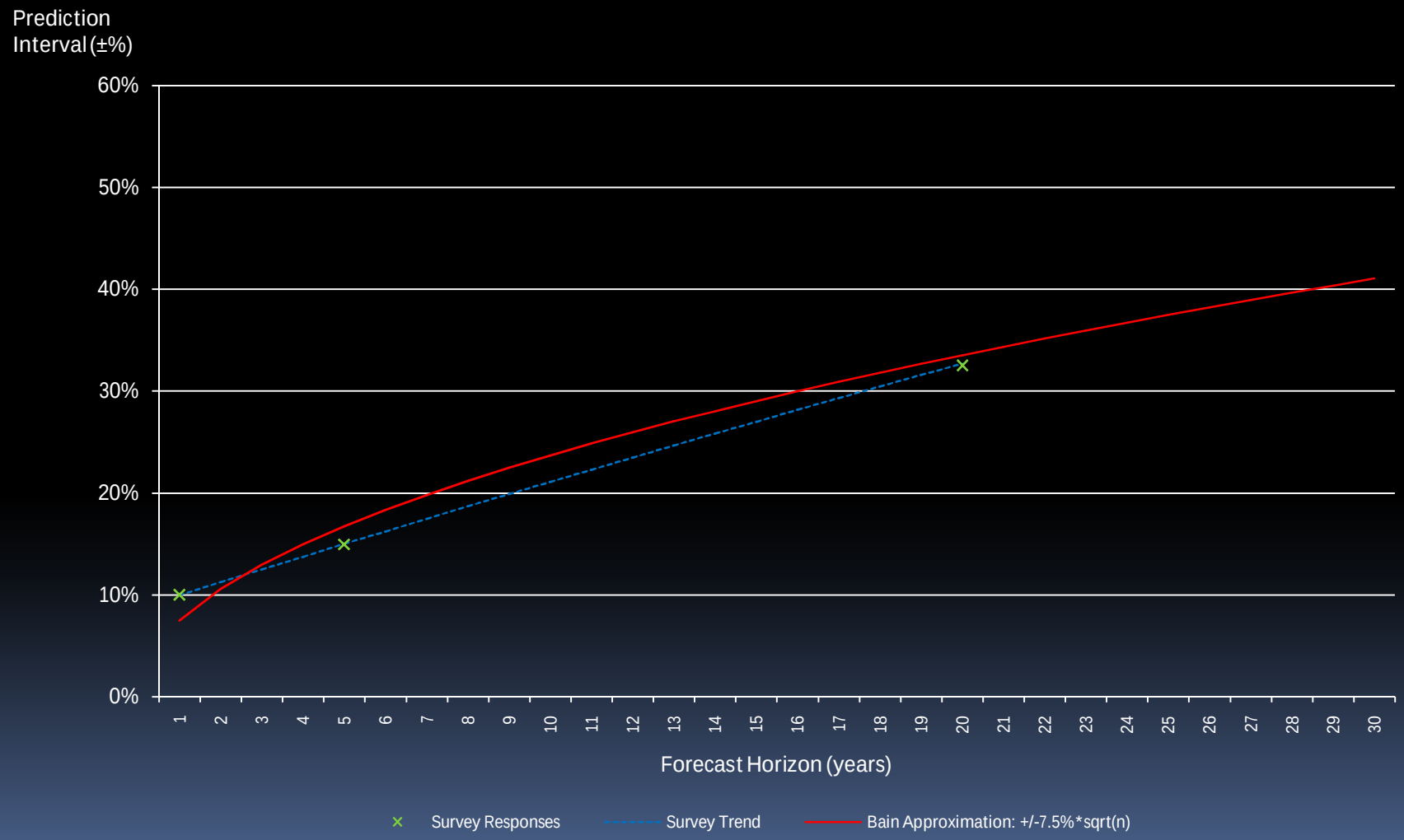
Existing Road/Stable Conditions



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Empirical Prediction Intervals

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			1 Year	10 Years	25 Years
National*		±2.5% * √n	±3%	±8%	±13%
Regional		> ±2.5% * √n			
Local	No	±7.5% * √n	±8%	±24%	±38%

** UK Department for Transport*
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Empirical Prediction Intervals

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Local	No	±7.5% * √n	±8%	±24%	±38%
	Yes				

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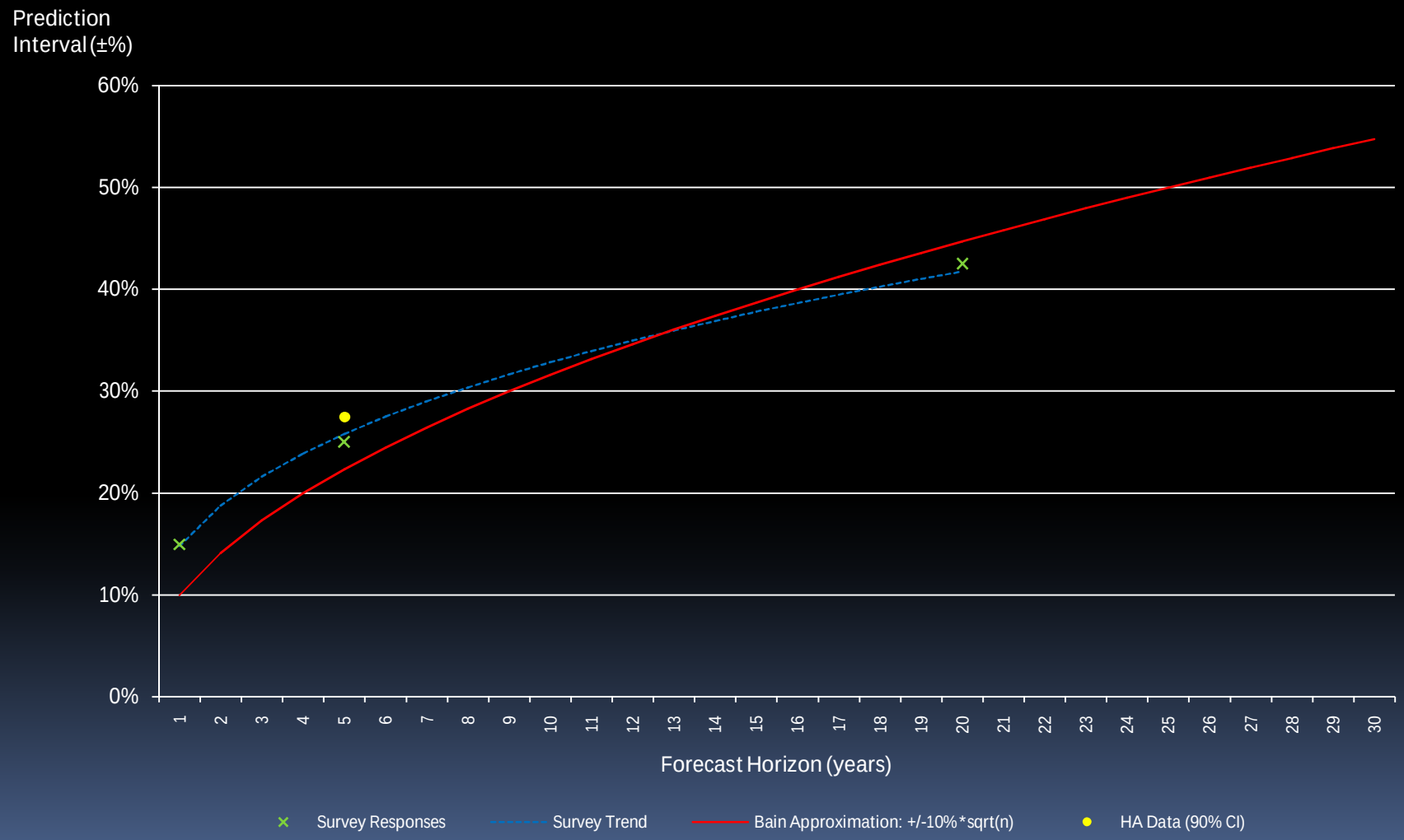
New Road/Dynamic Conditions



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Regional		> ±2.5% * √n			
Local	No	±7.5% * √n	±8%	±24%	±38%
	Yes	±10% * √n	±13%	±38%	±50%

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Percentages are rounded.

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Empirical Prediction Intervals

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			1 Year	10 Years	25 Years
National*		±2.5% * √n	±3%	±8%	±13%
Regional		±4% * √n	±4%	±13%	±20%
Local	No	±7.5% * √n	±8%	±24%	±38%
	Yes	±10% * √n	±13%	±38%	±50%

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Percentages are rounded.

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Local	No	±7.5% * √n	±8%	±24%	±38%
	Yes	±10% * √n	±13%	±38%	±50%

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Percentages are rounded.

"*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*"

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	Yes	±10% * √n	±13%	±38%	±50%

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Percentages are rounded.

"*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% @ Year 35 = ±4.2% * √n

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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)

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What Traffic Forecasts Look Like

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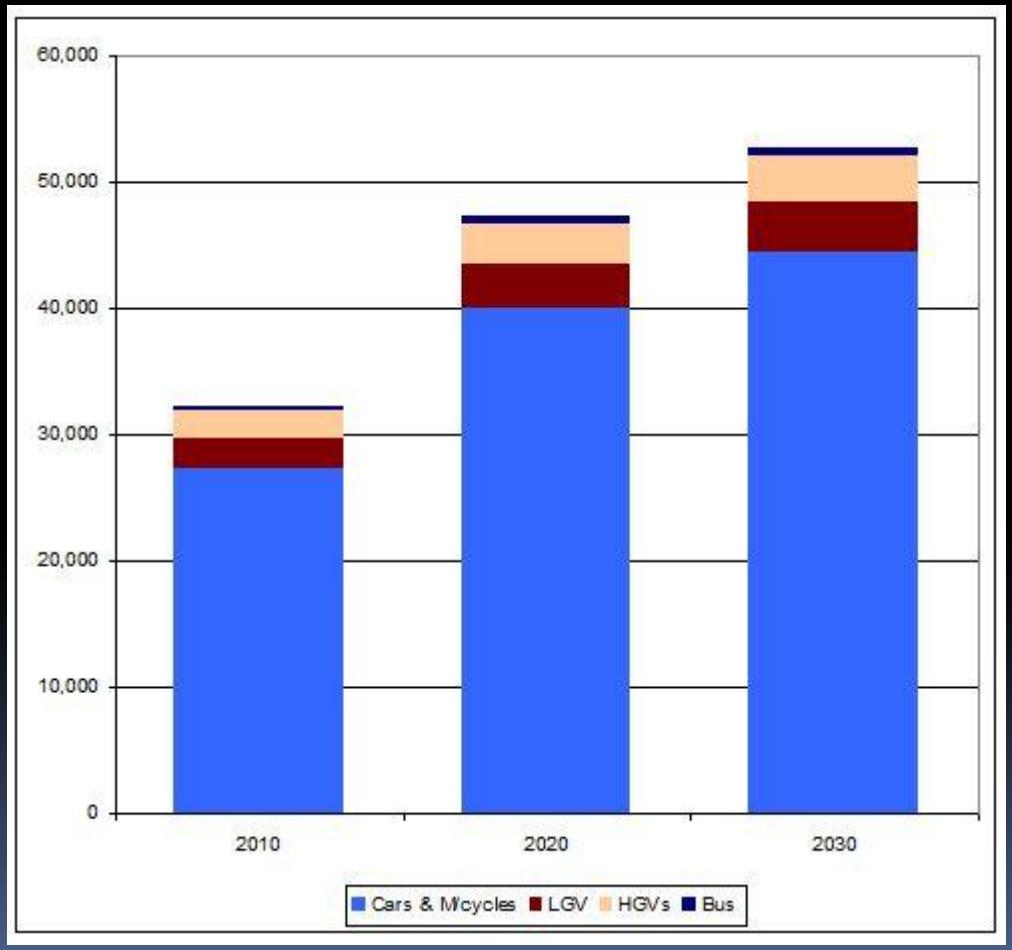
What Traffic Forecasts Look Like



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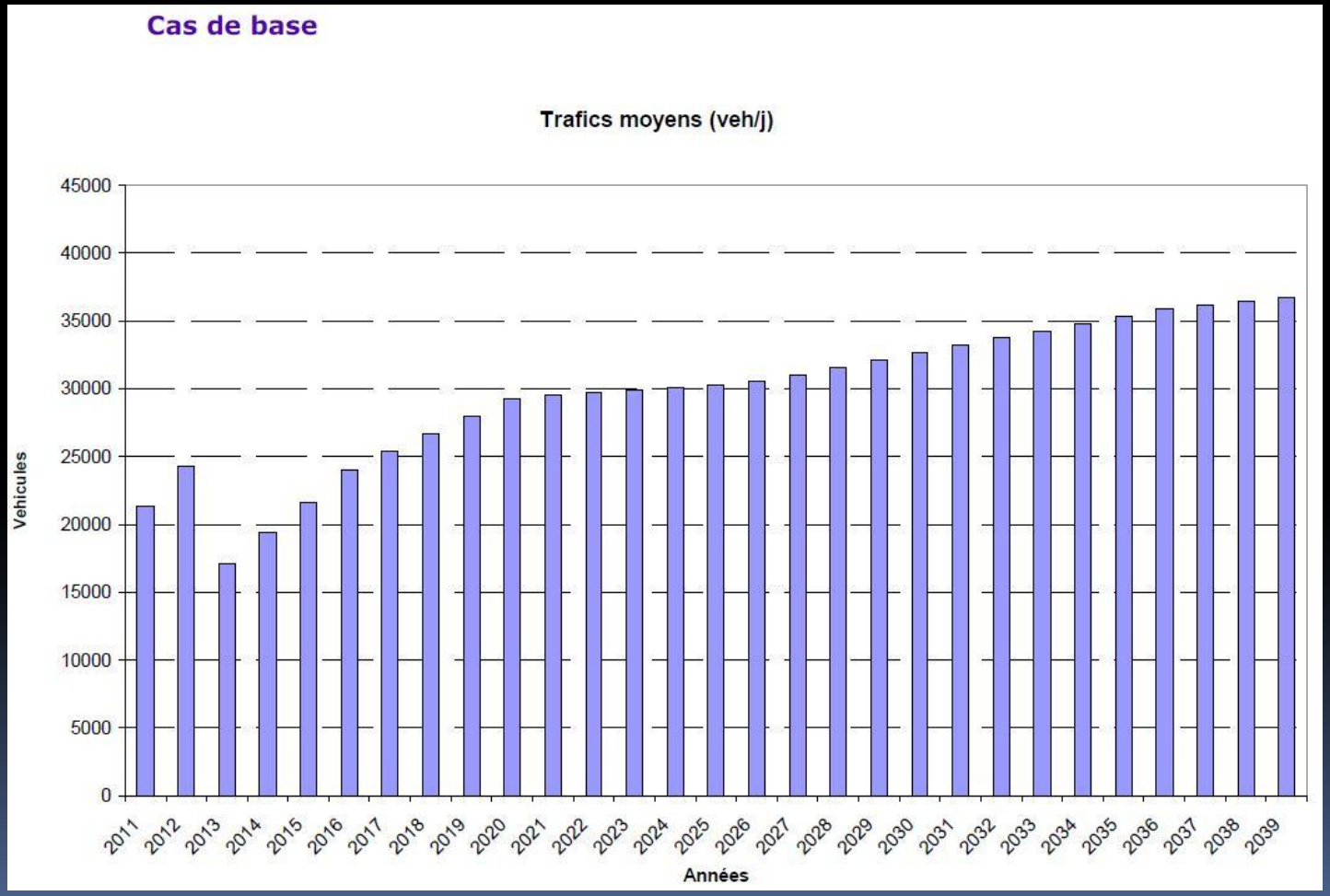
What Traffic Forecasts Look Like



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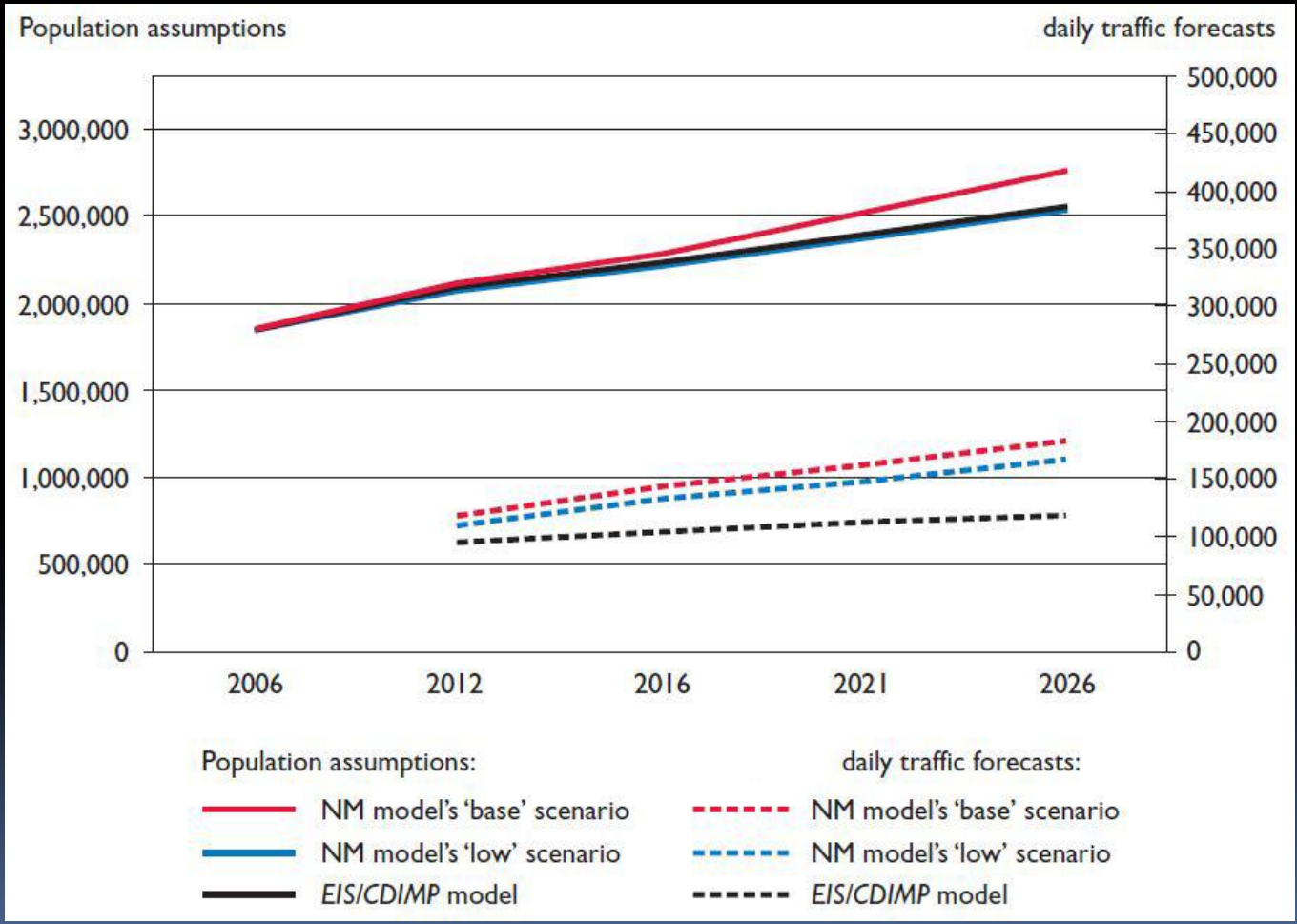
What Traffic Forecasts Look Like



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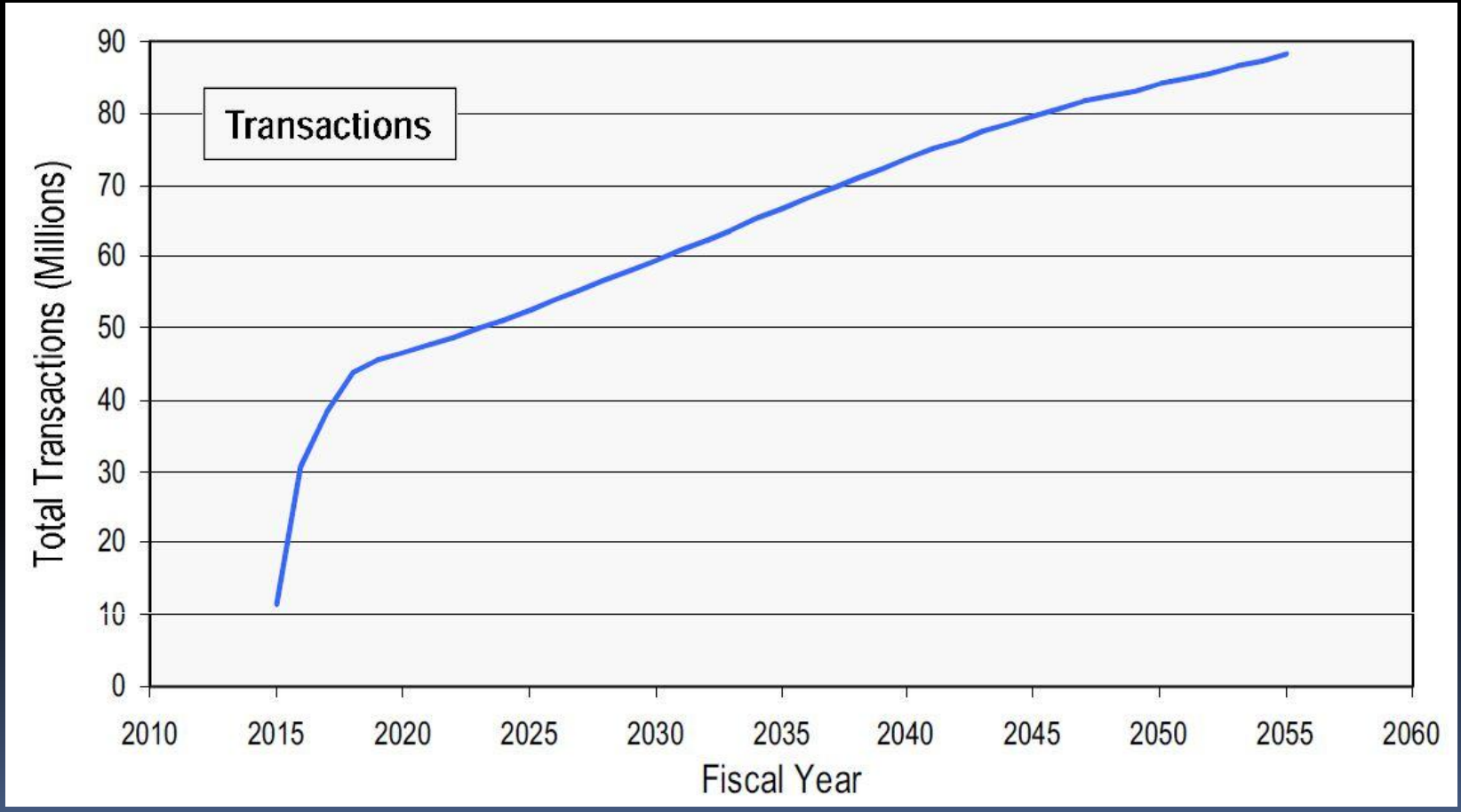

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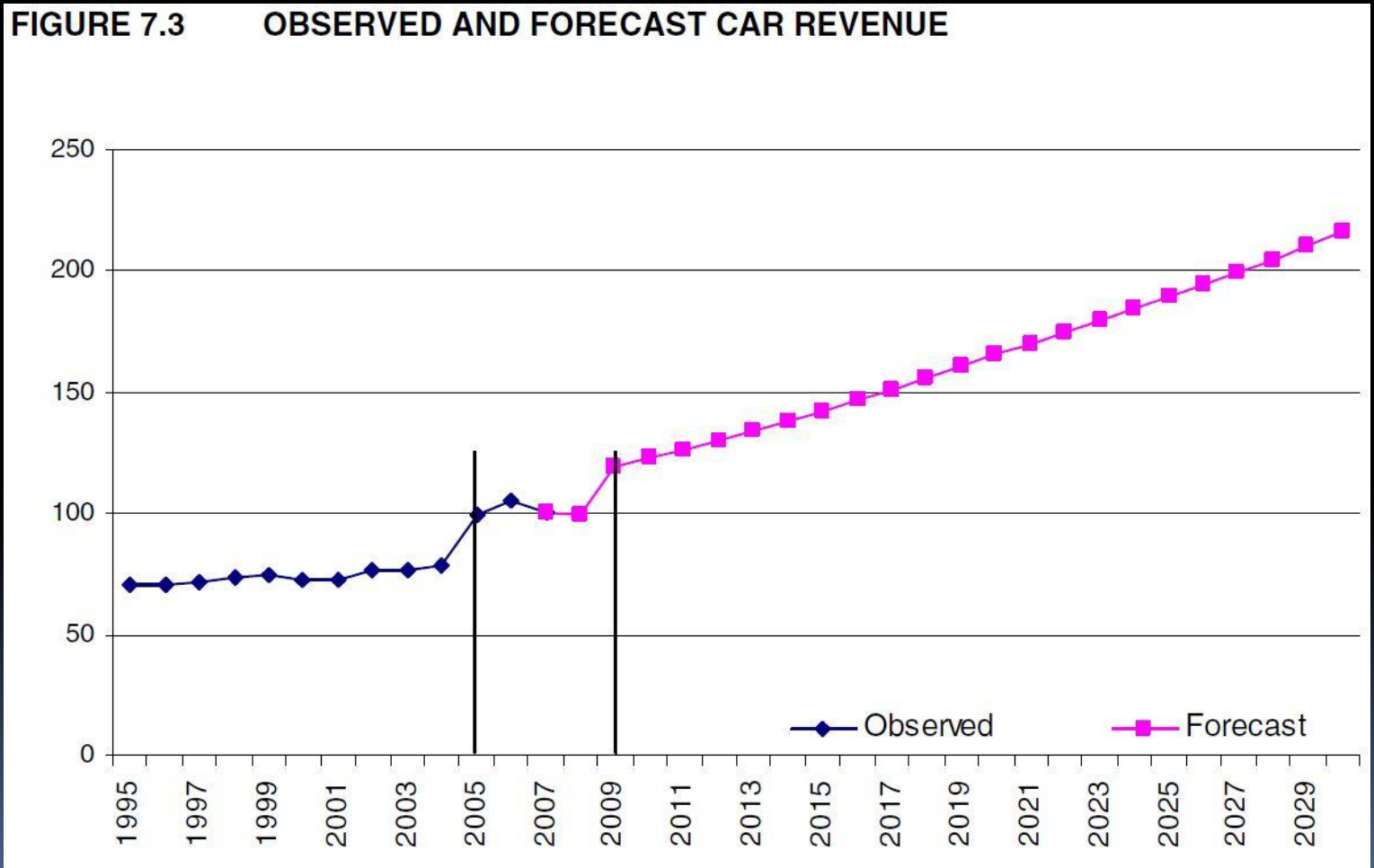

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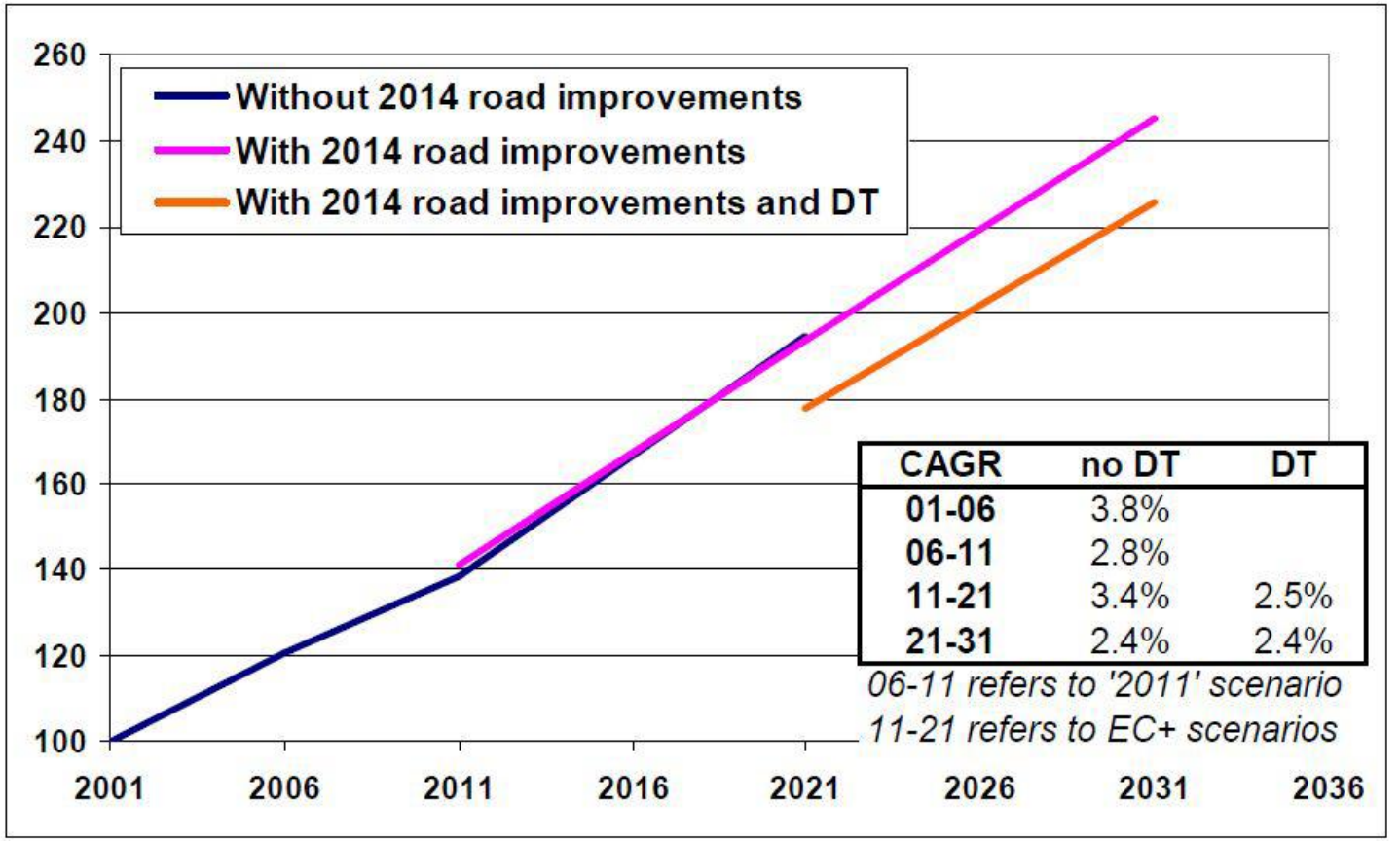

Exhibit 8-1: VKT Forecast – peak model outputs

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What Traffic Forecasts Really Look Like

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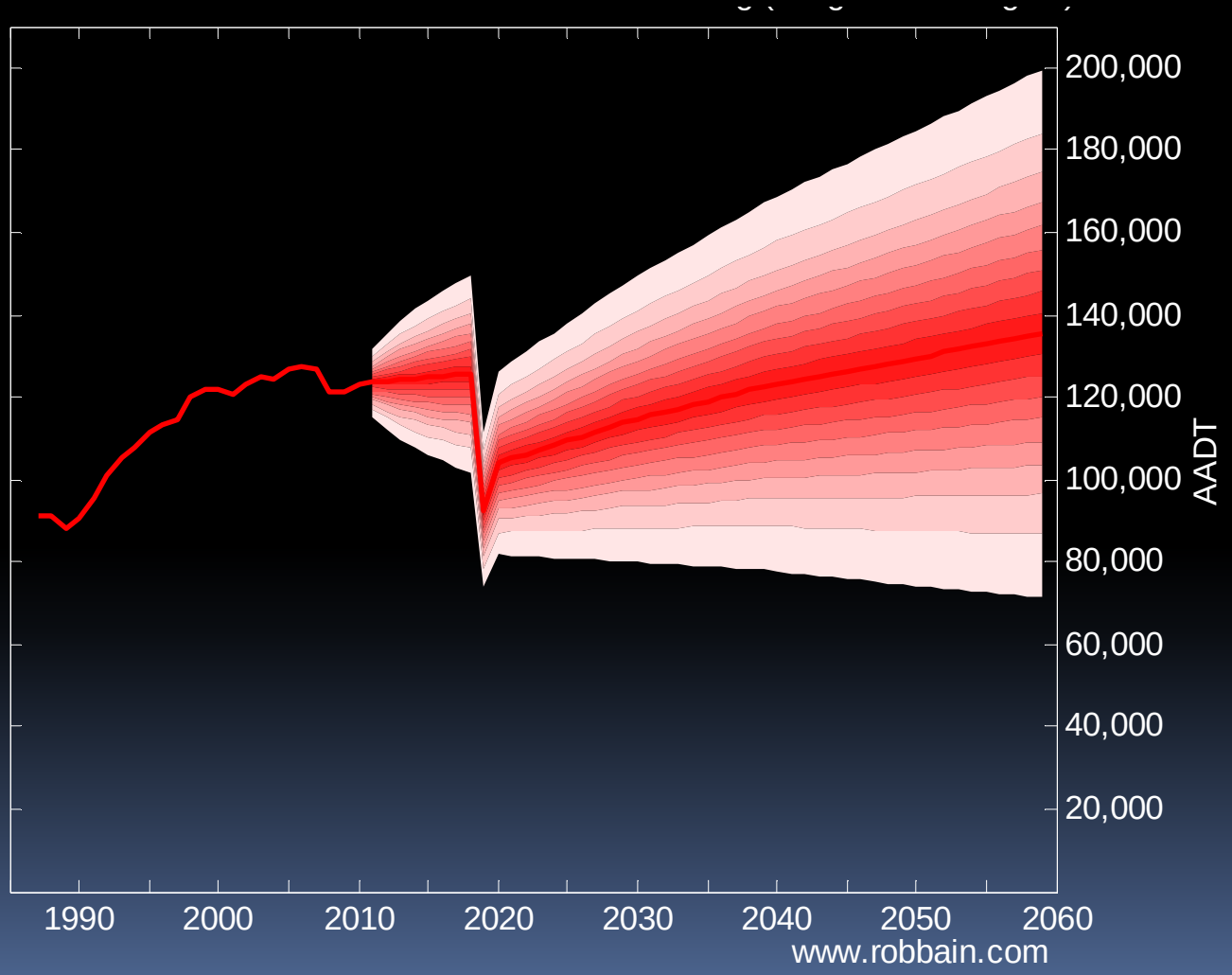
What Traffic Forecasts Really Look Like



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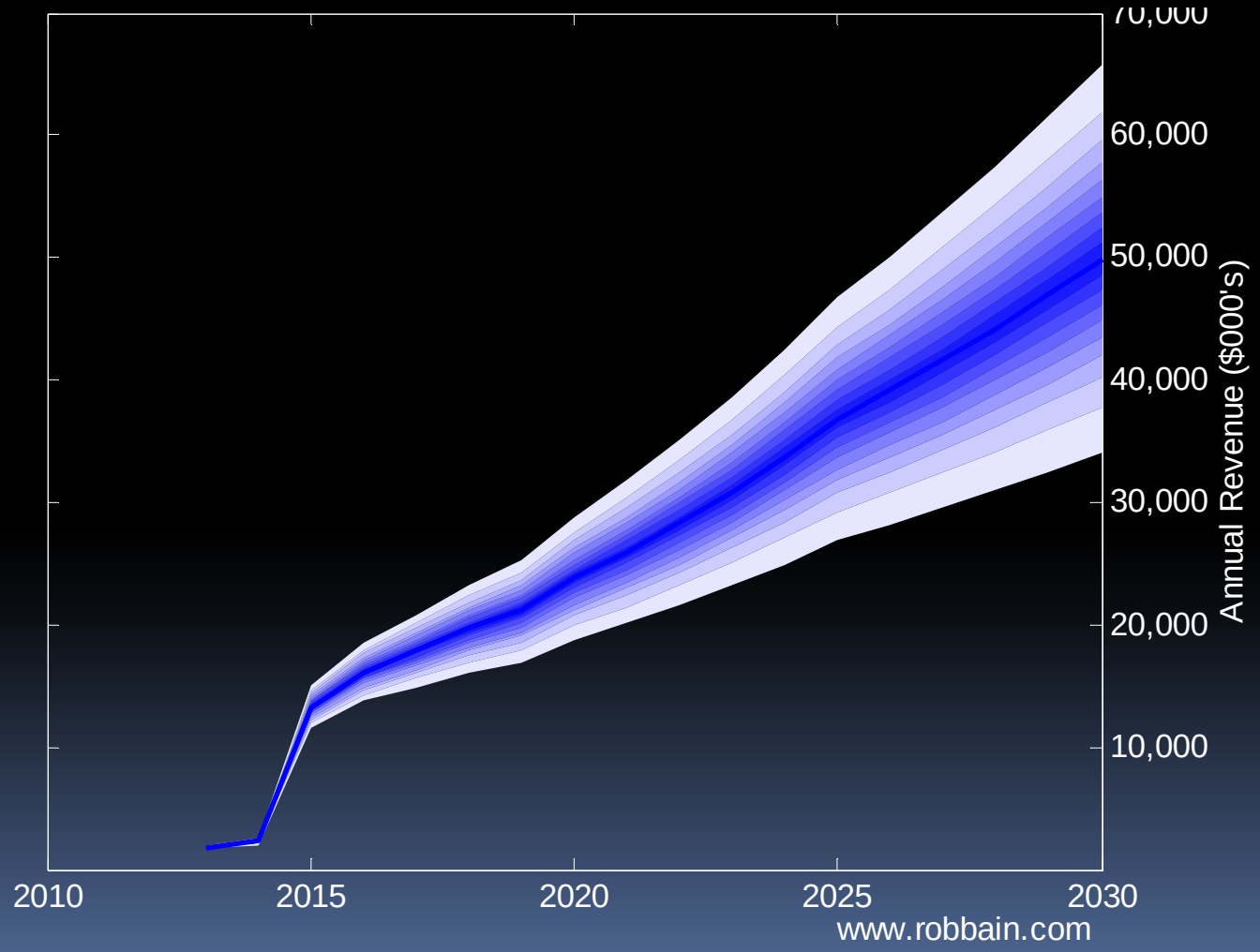
What Revenue Forecasts Really Look Like



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A Word About Bias...

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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

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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