Travel Demand Forecasts: Predictive Performance

Lessons from the International Toll Road Sector

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Topics

Focus on toll roads (but lessons for transportation generally)

Predictive Failure: Bias & Error

- Bias: Optimism Bias (or 'Strategic Misrepresentation'??)
  - Non-Random Error
- Error:
  - Random Error

Why Bias Before Error?

- Before you can consider/examine/assess/quantify error
- …you have adjust for bias

- Why?
  - Systematic error and random error have a hierarchical relationship

  - Random error is quantified through statistical tests, confidence intervals etc.
  - If an estimate is invalid in the first place, these quantifications (of the role of chance) are pointless
    - Statistical tests have little meaning in the face of systematic error

  - So systematic error (bias) is the place to start…

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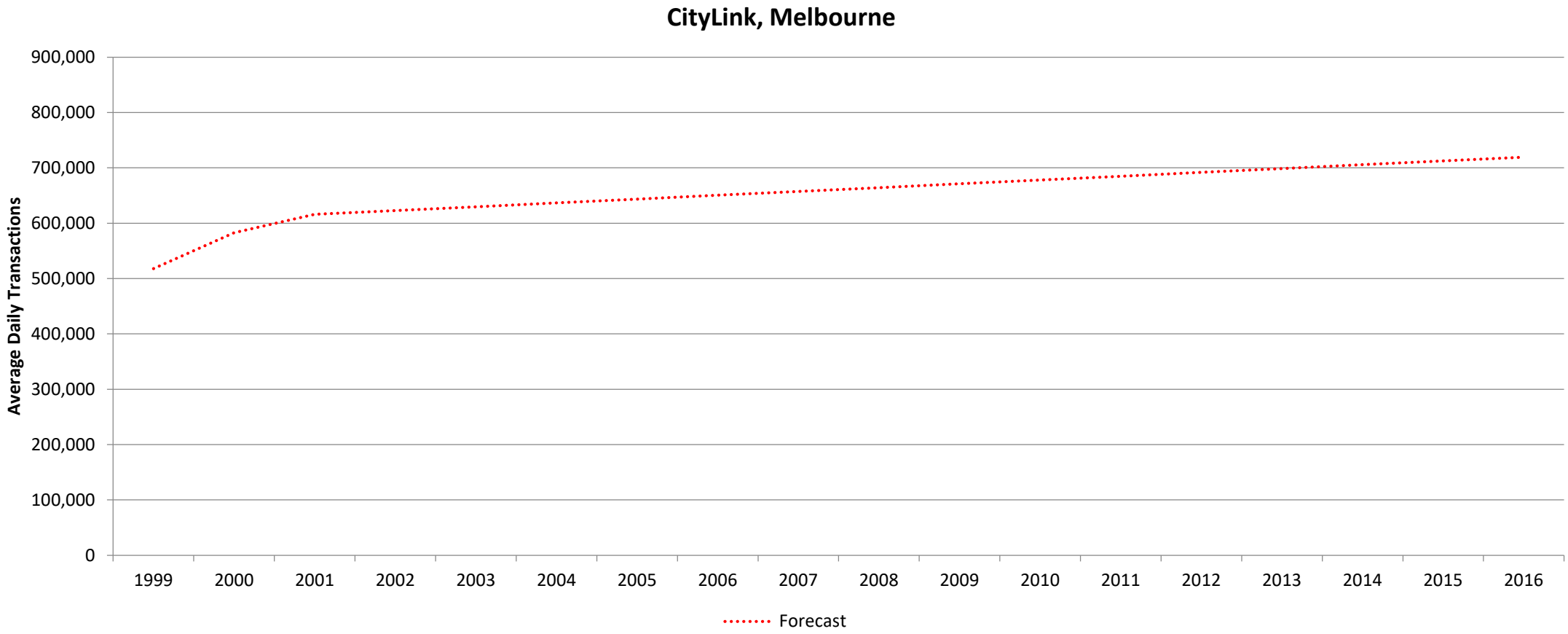
Optimism Bias / Strategic Misrepresentation

Lessons in Systematic Error (from Australia)

Lesson 1



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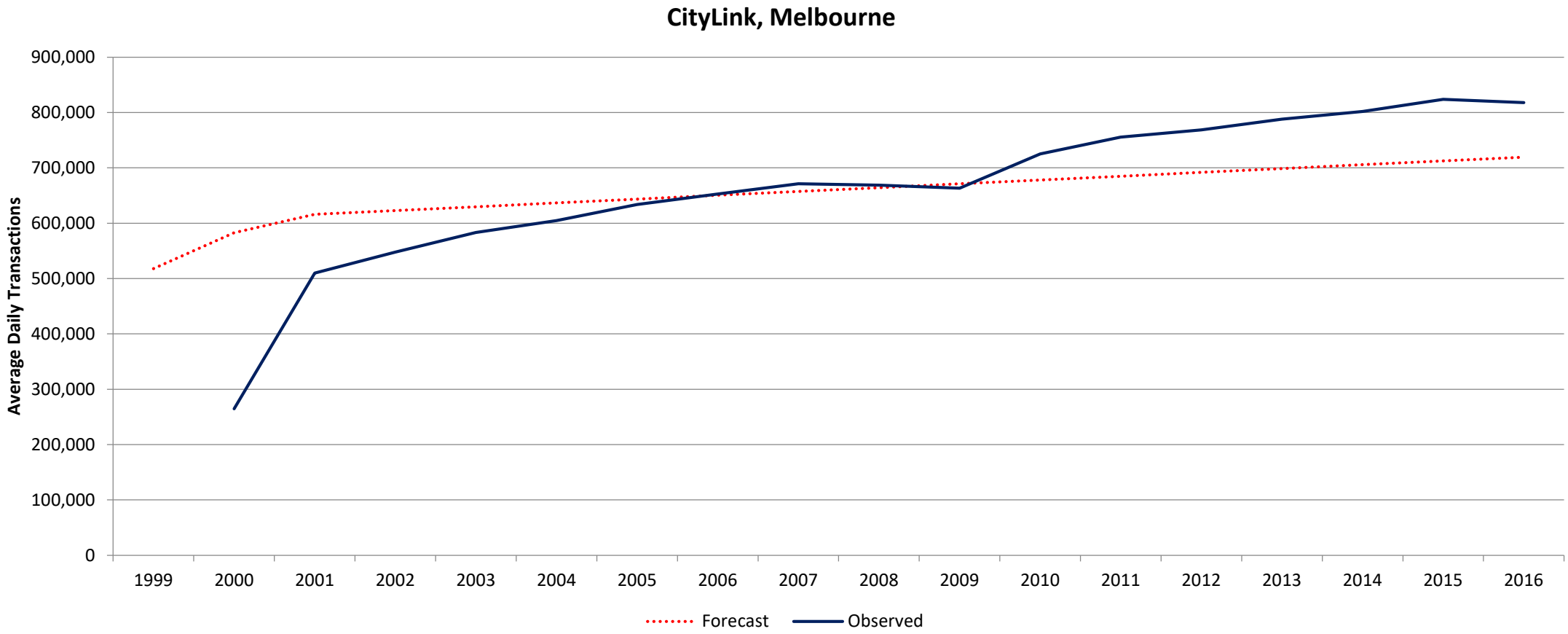

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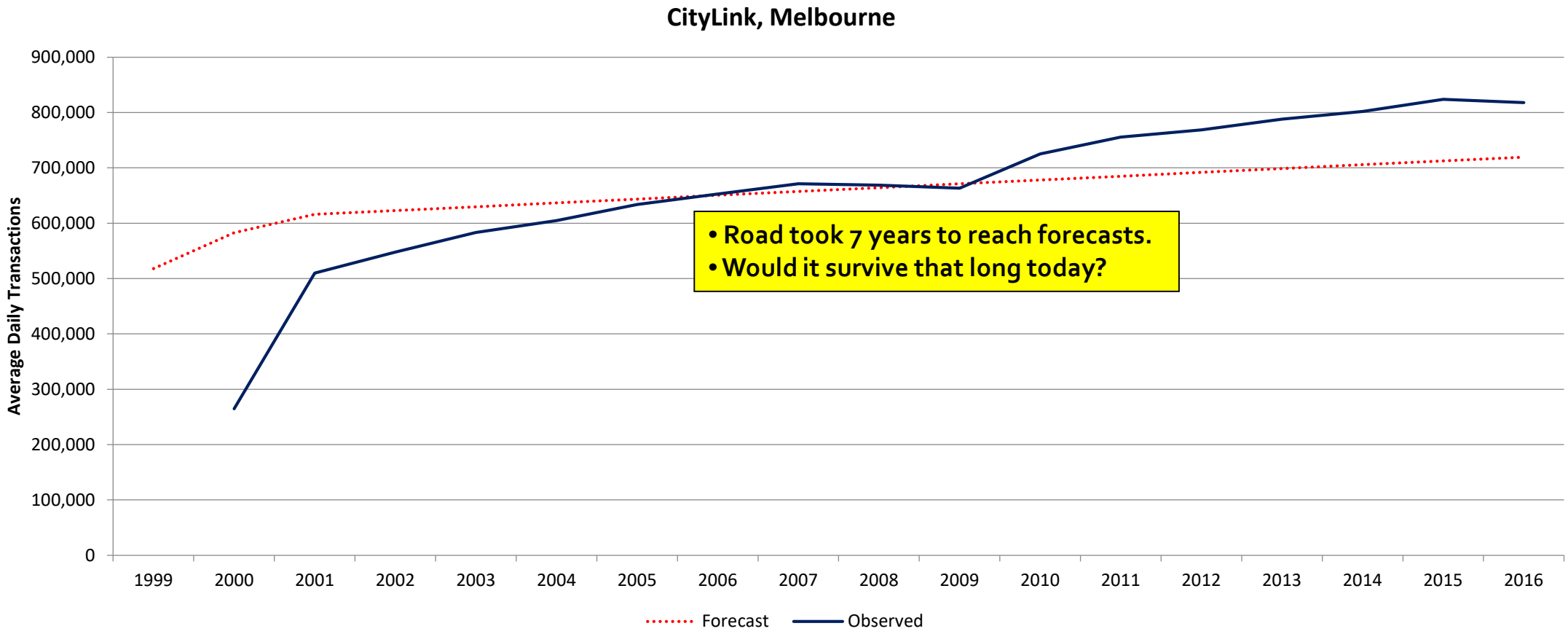

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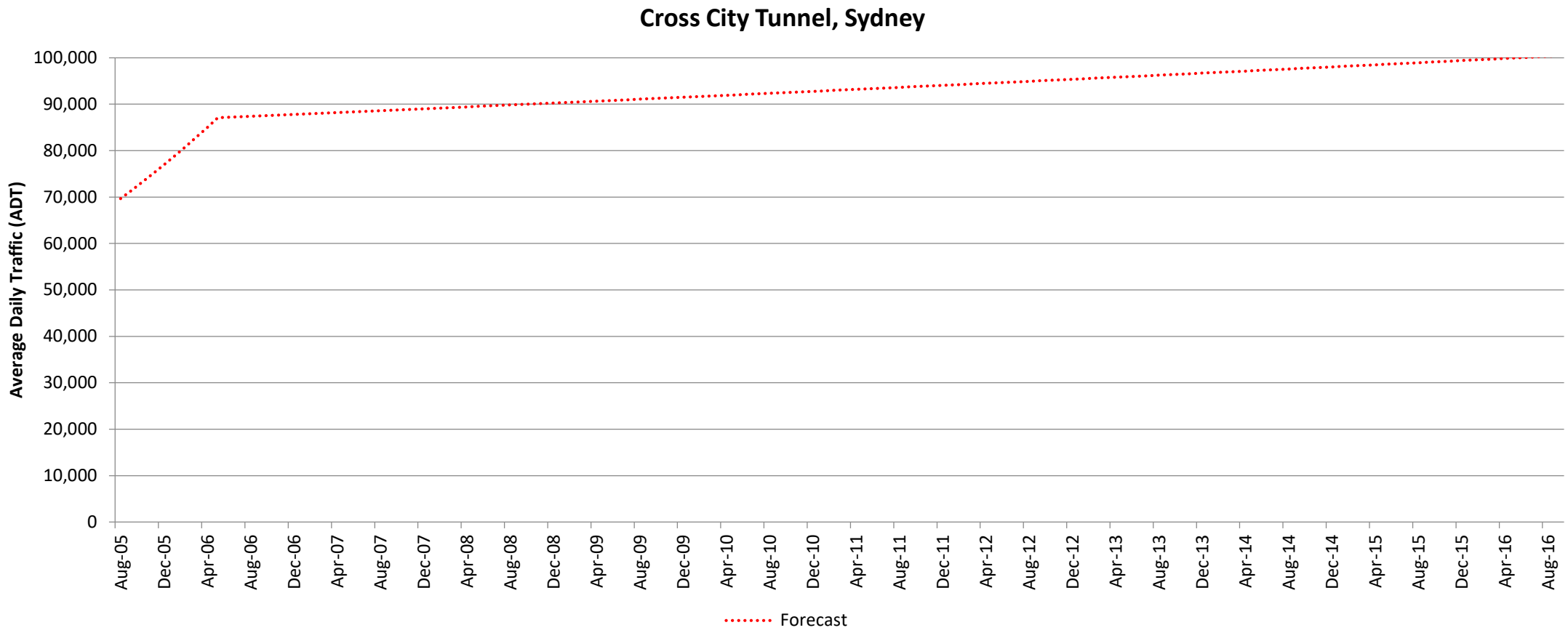

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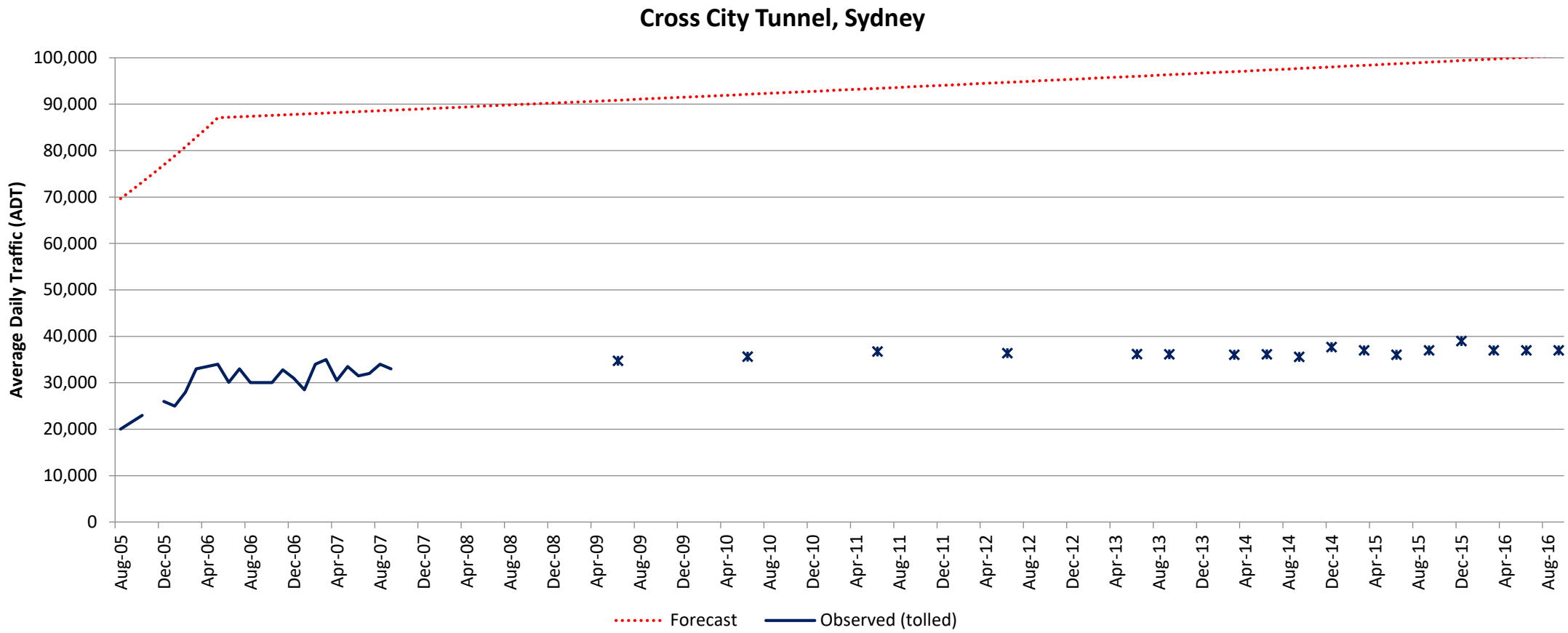

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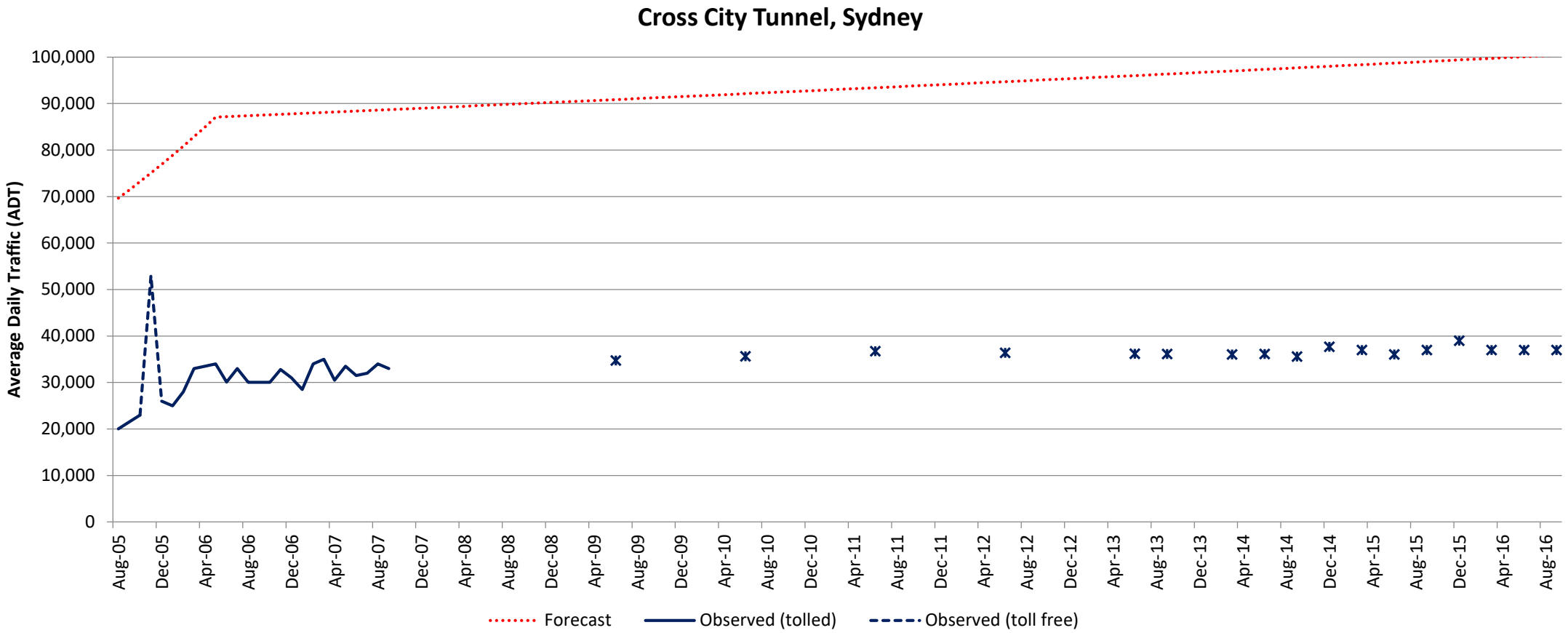

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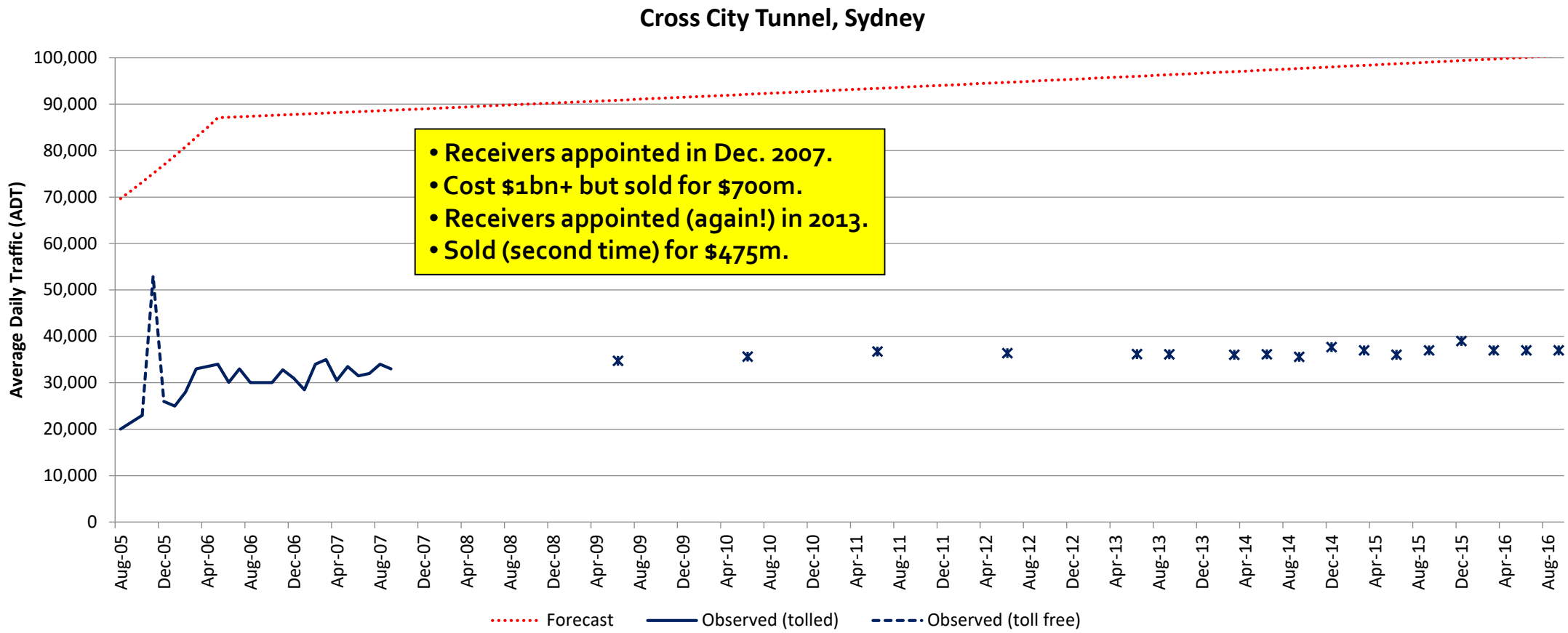

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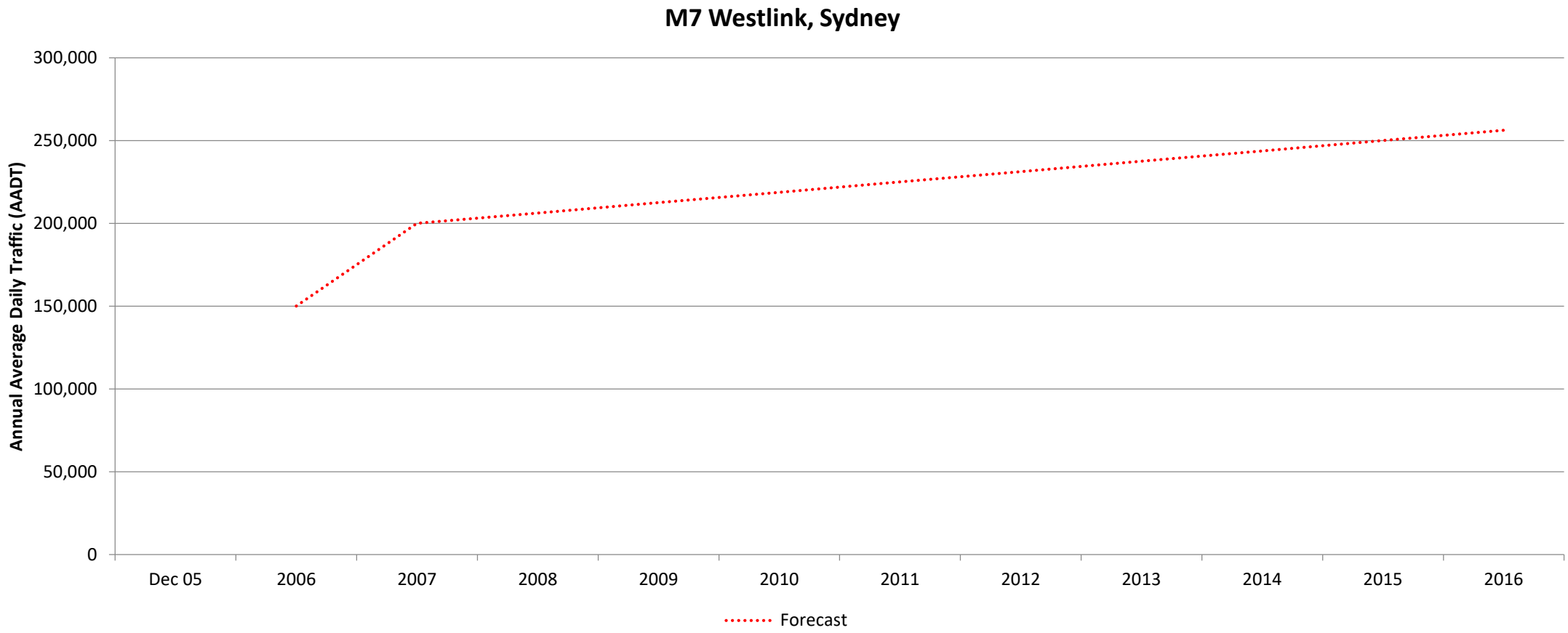

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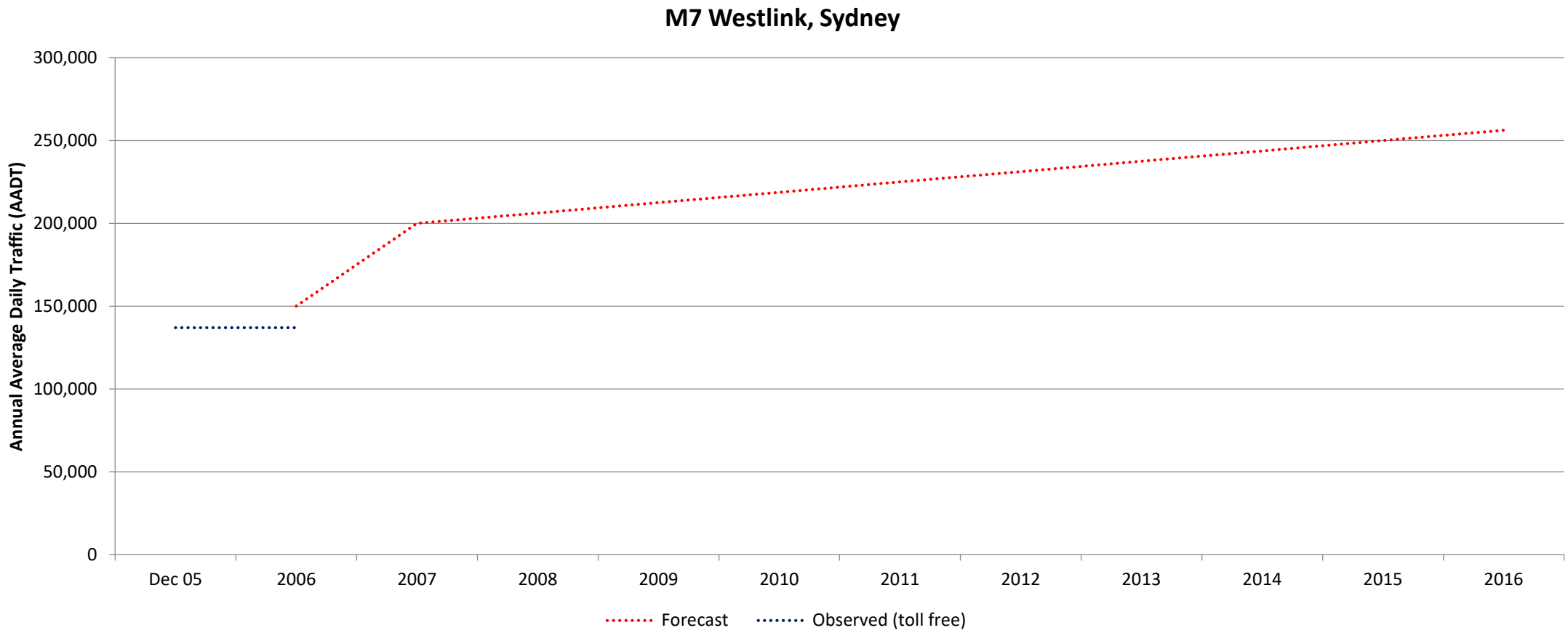

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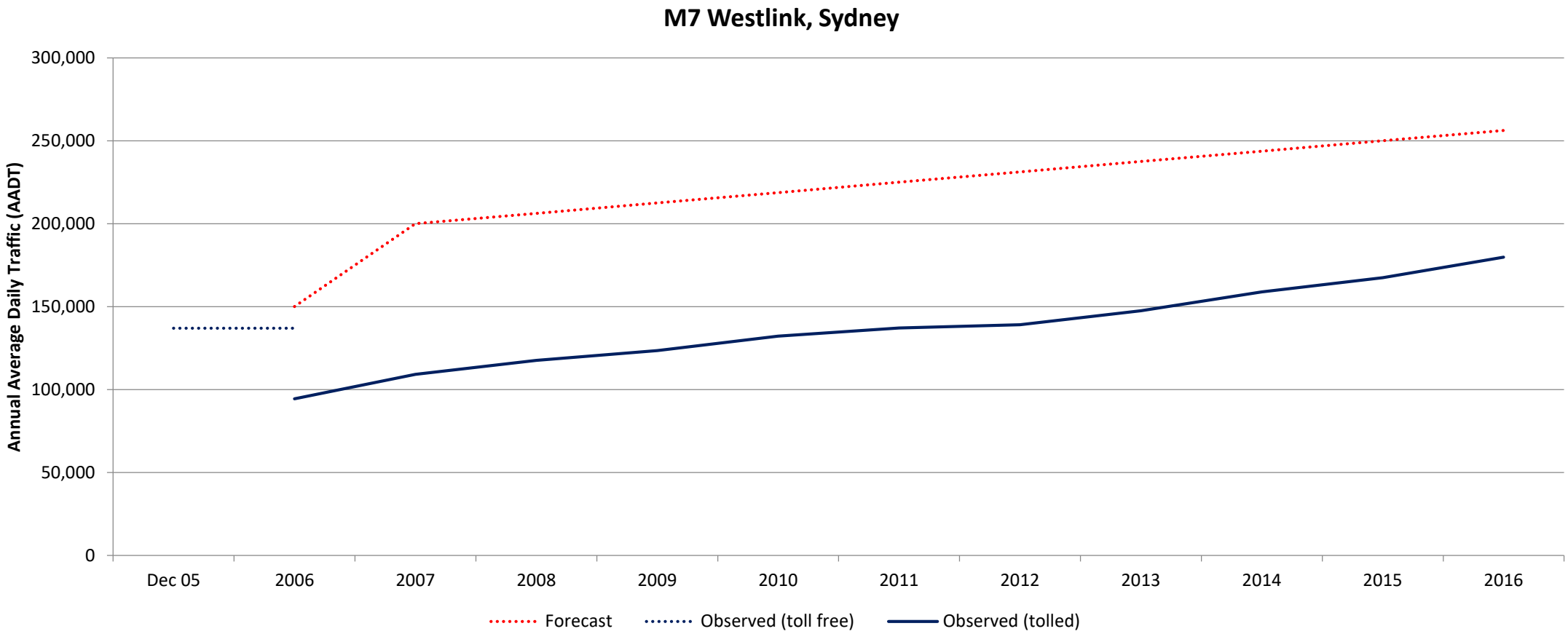

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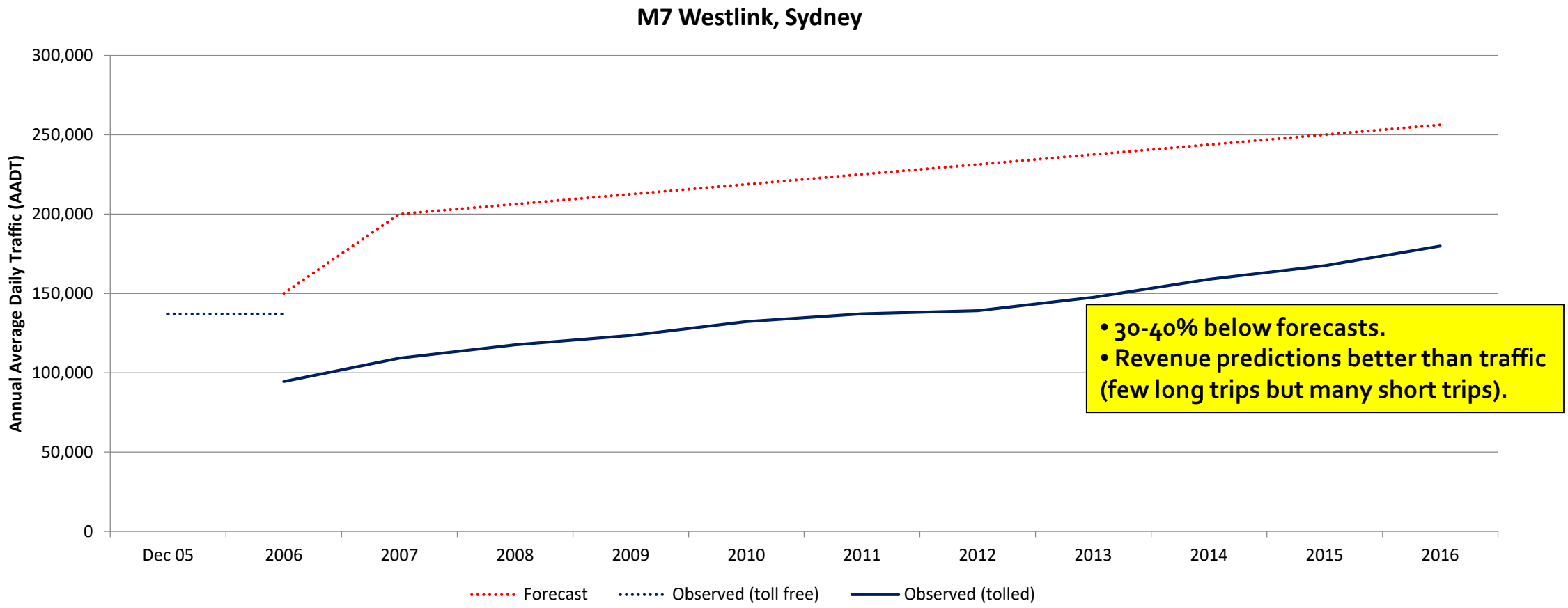

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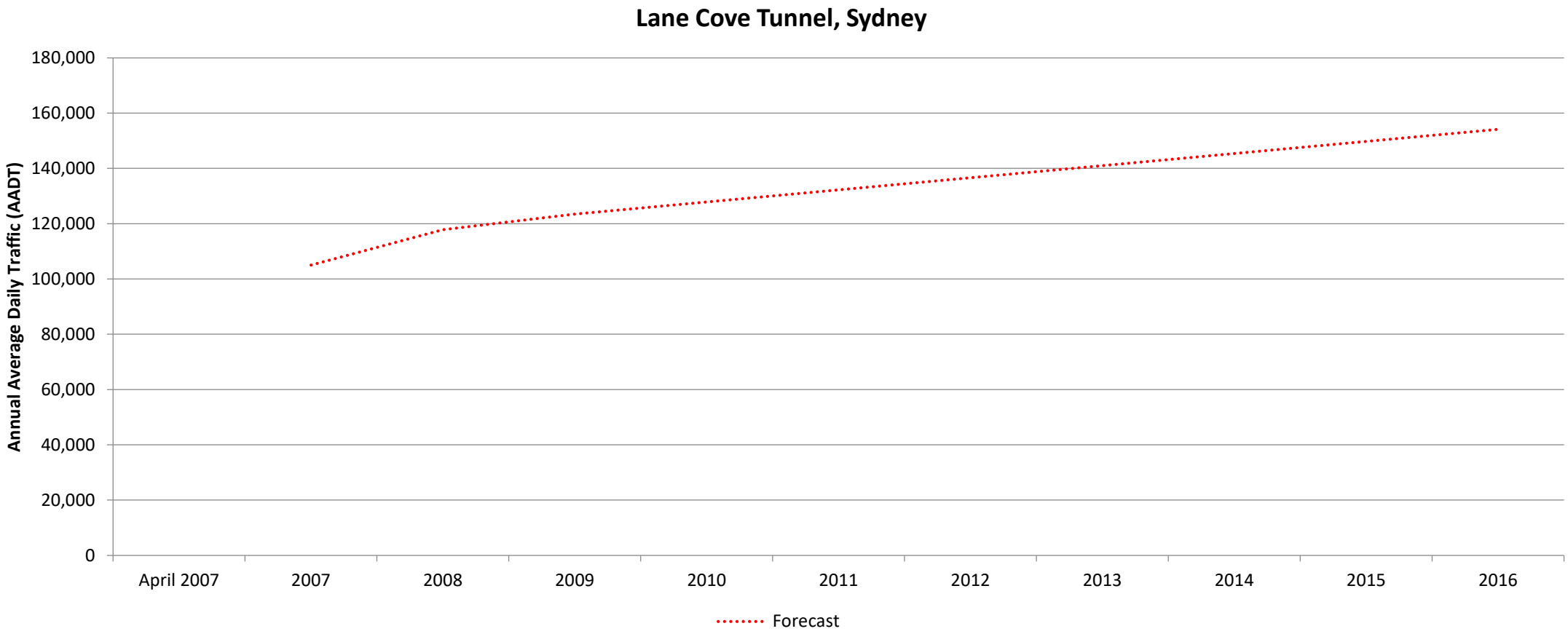

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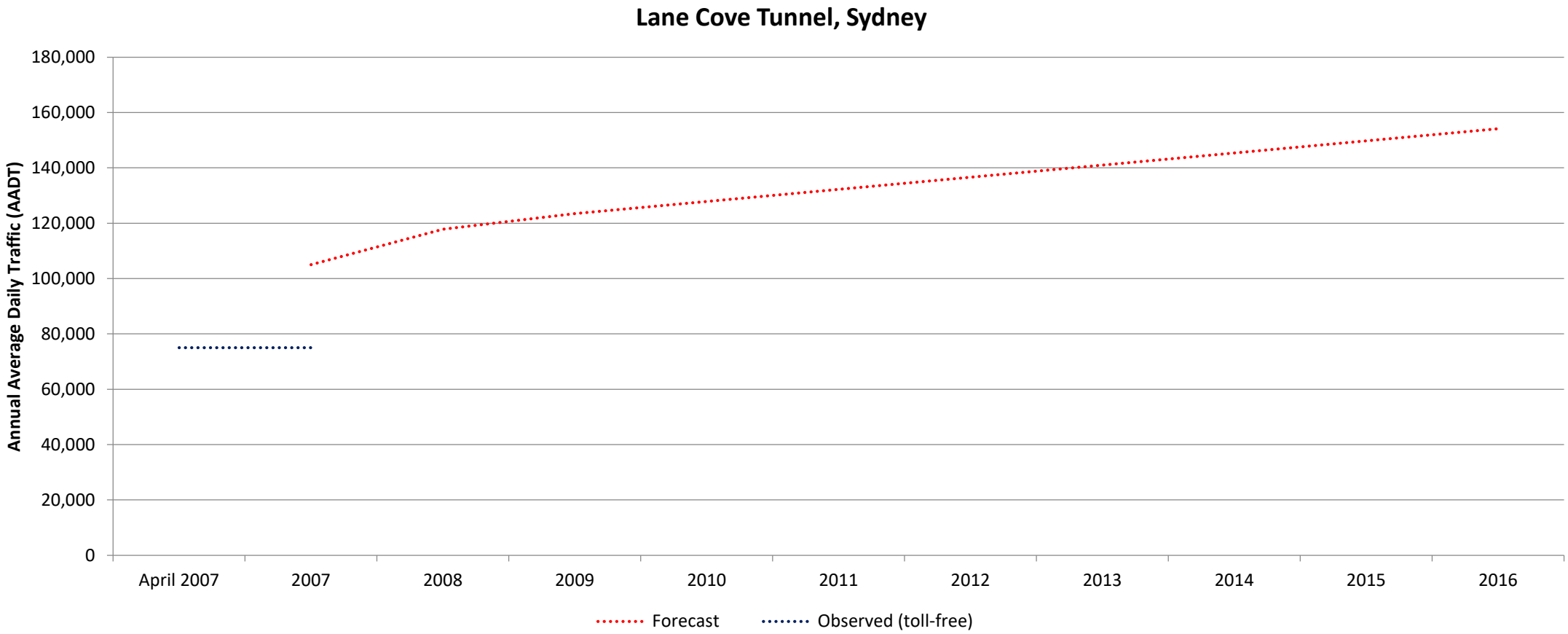

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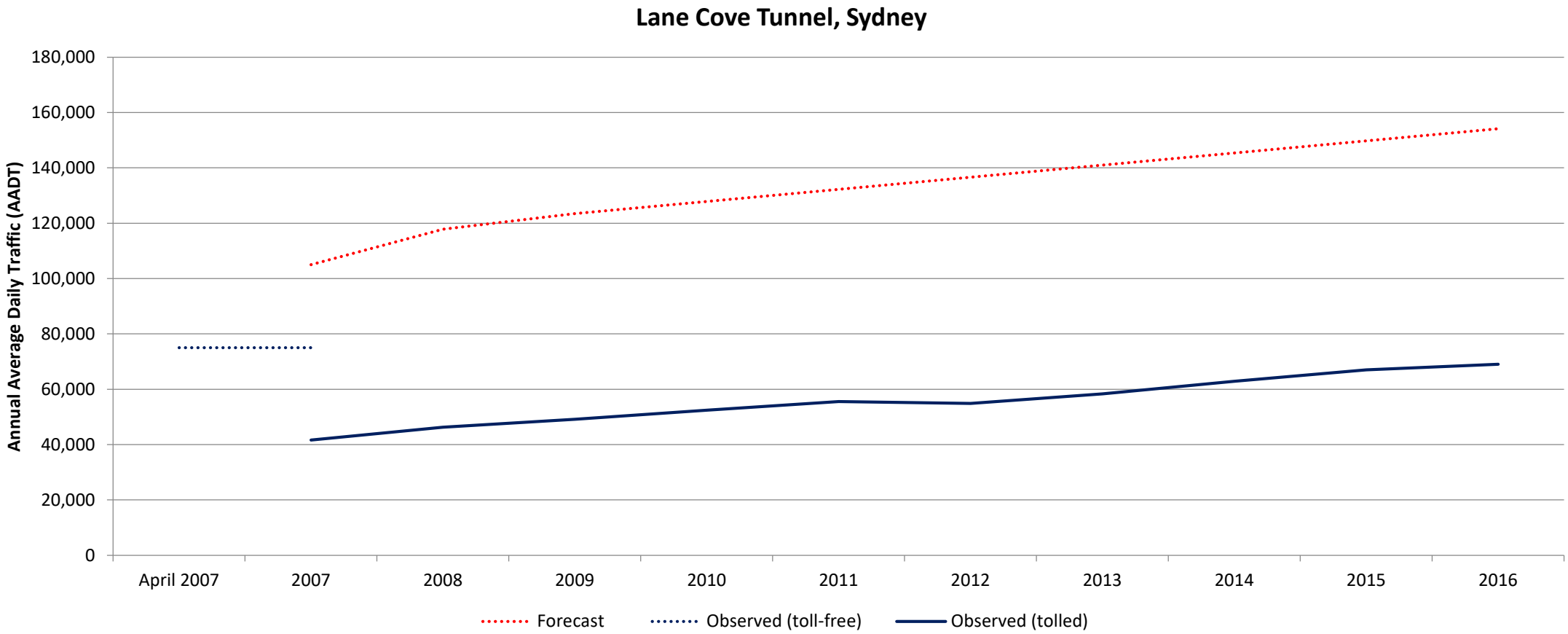

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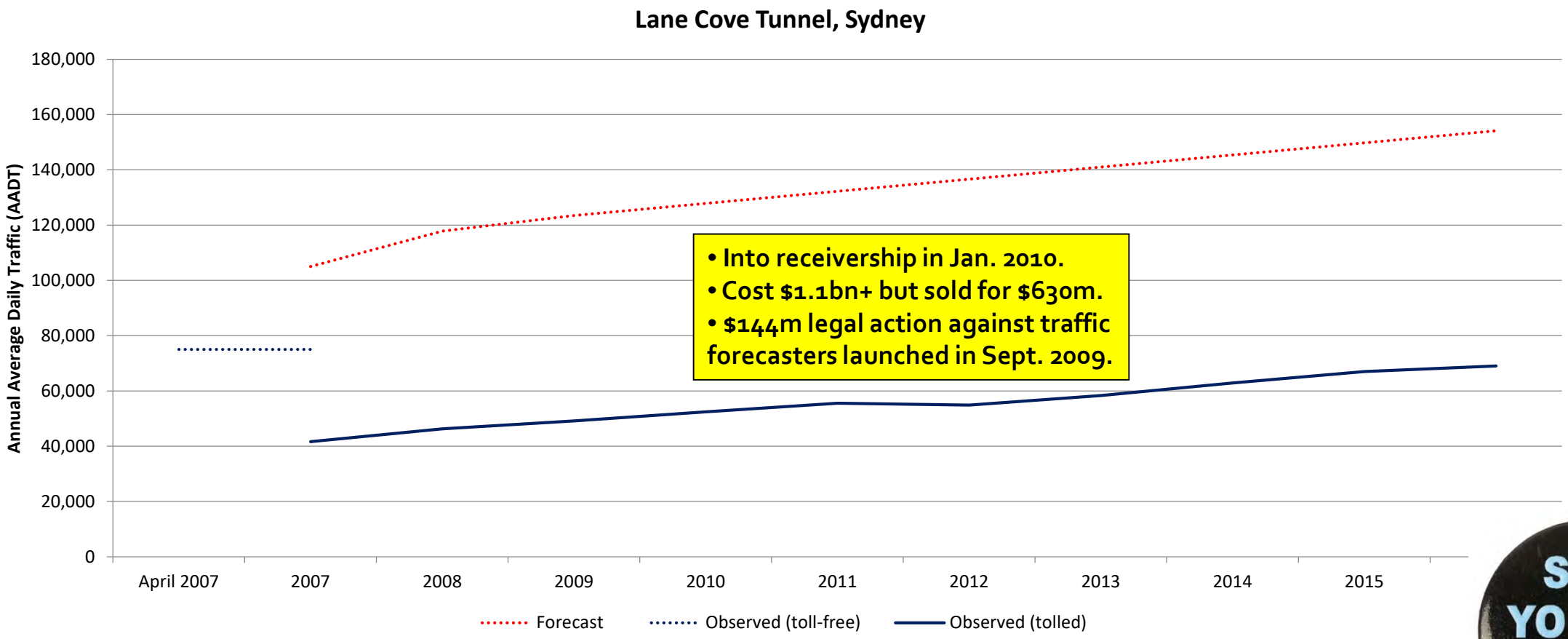

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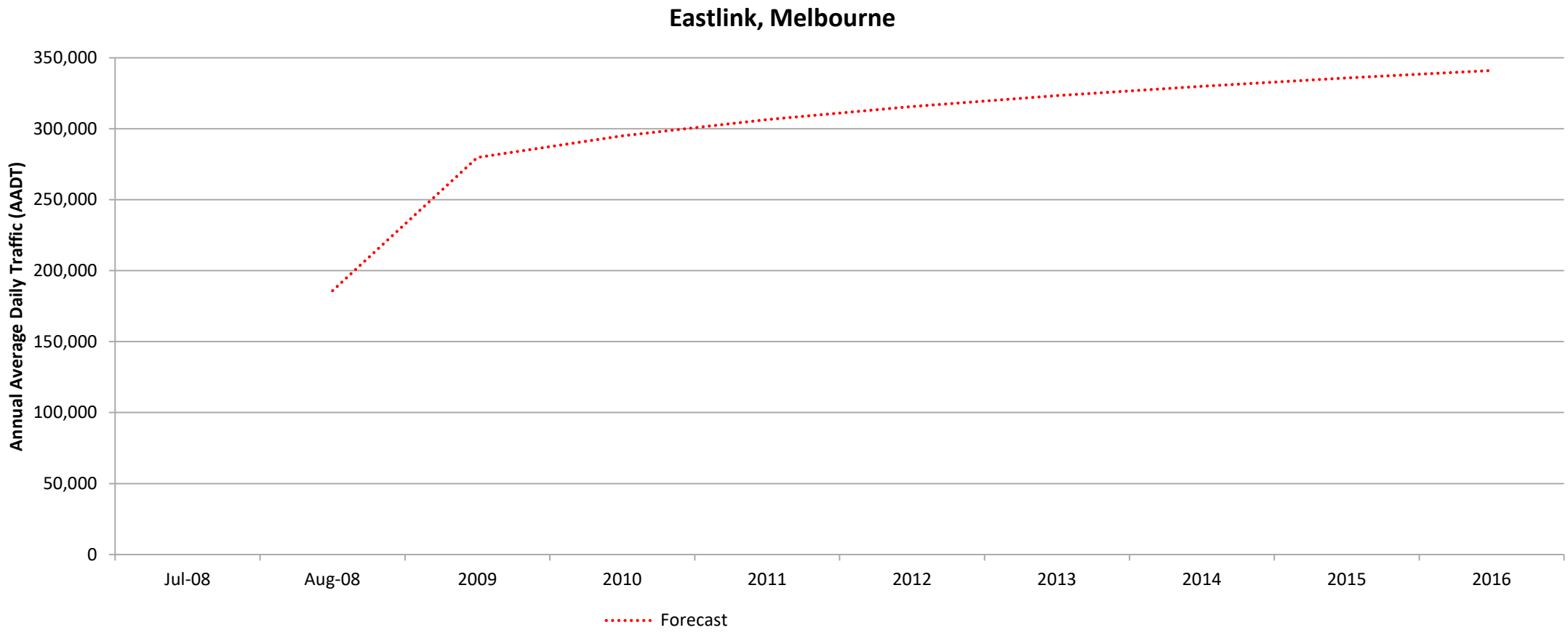

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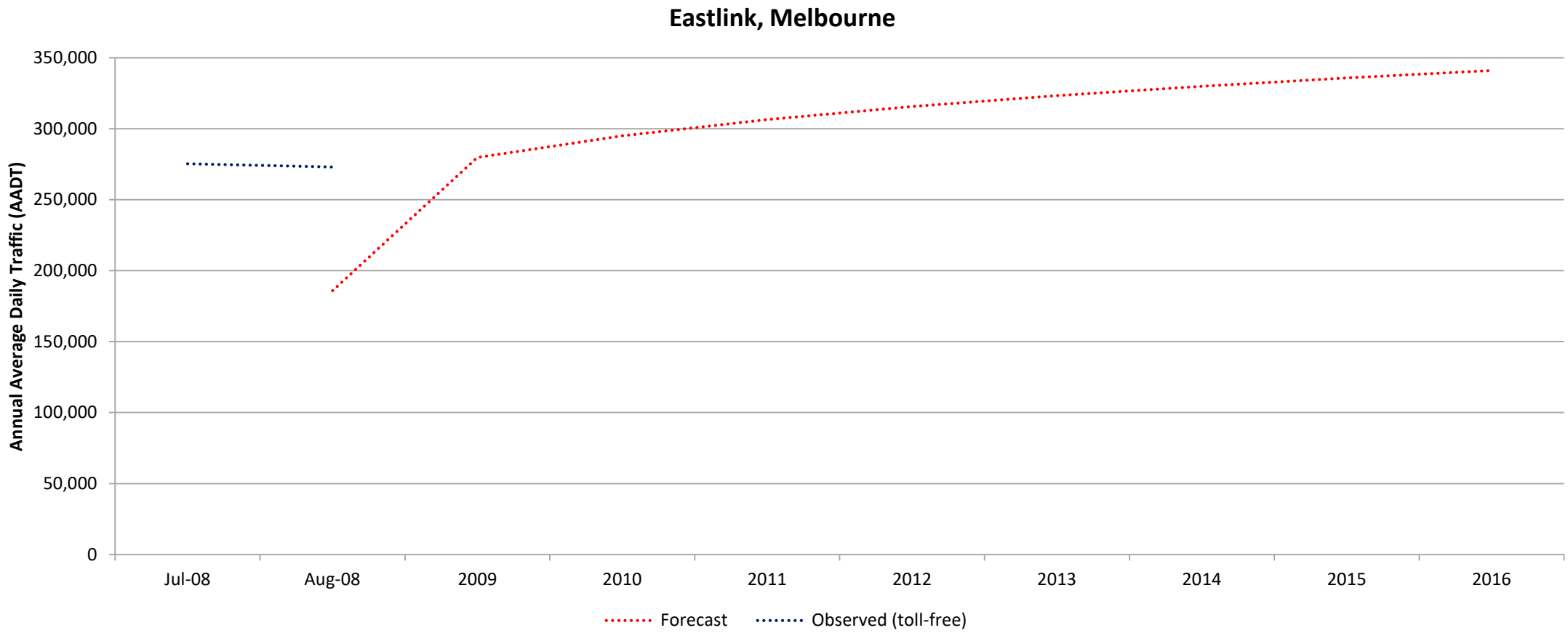

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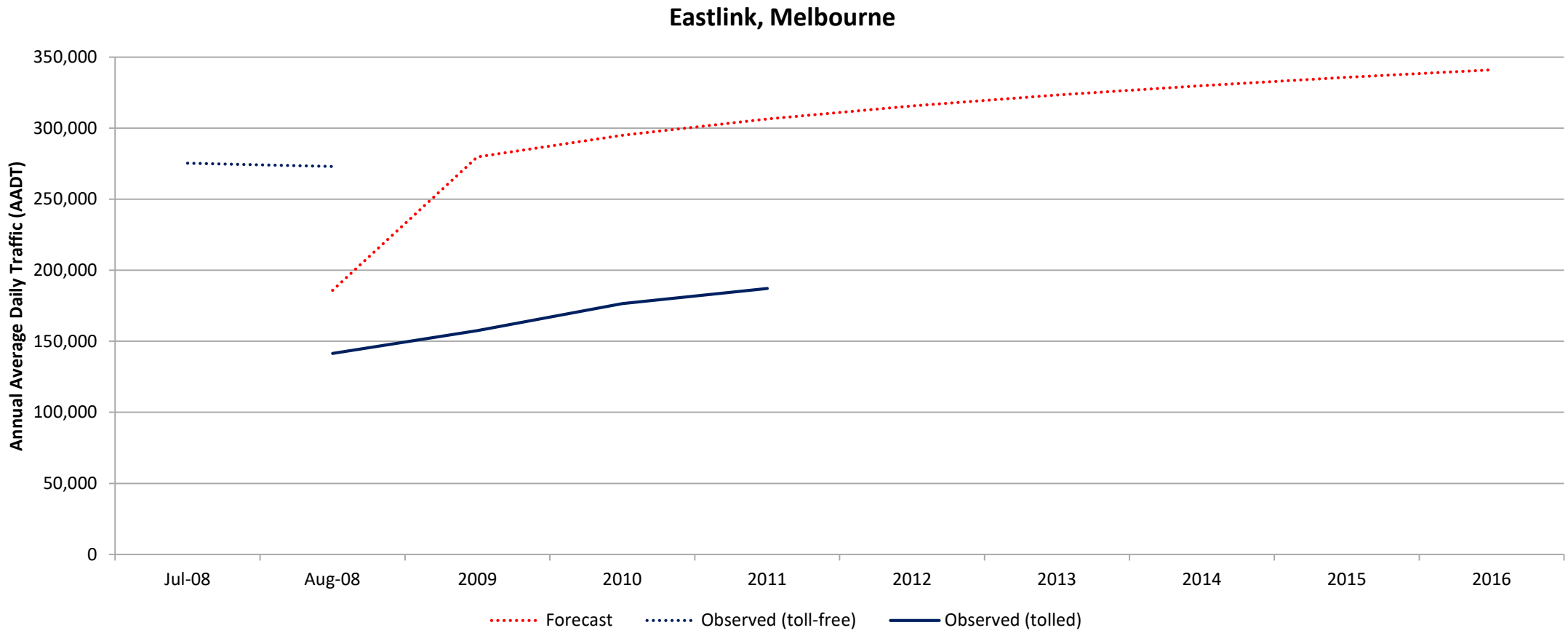

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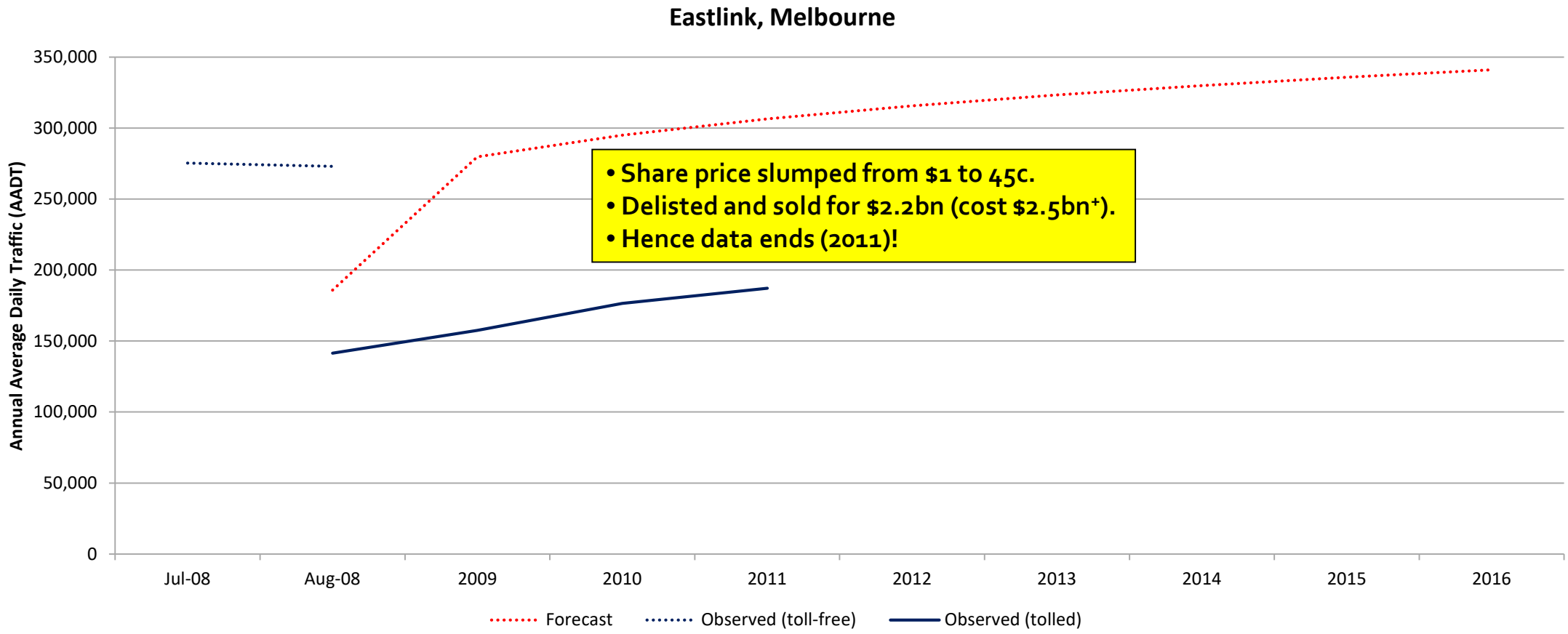

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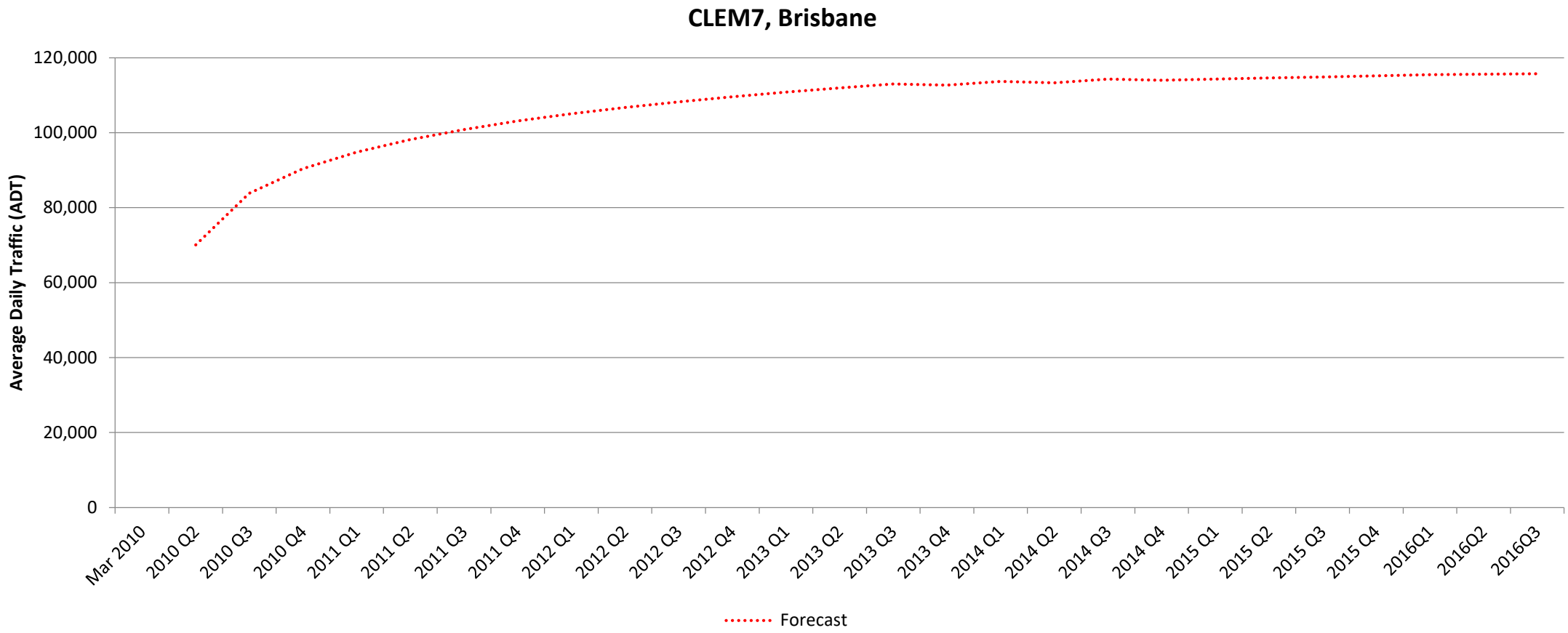

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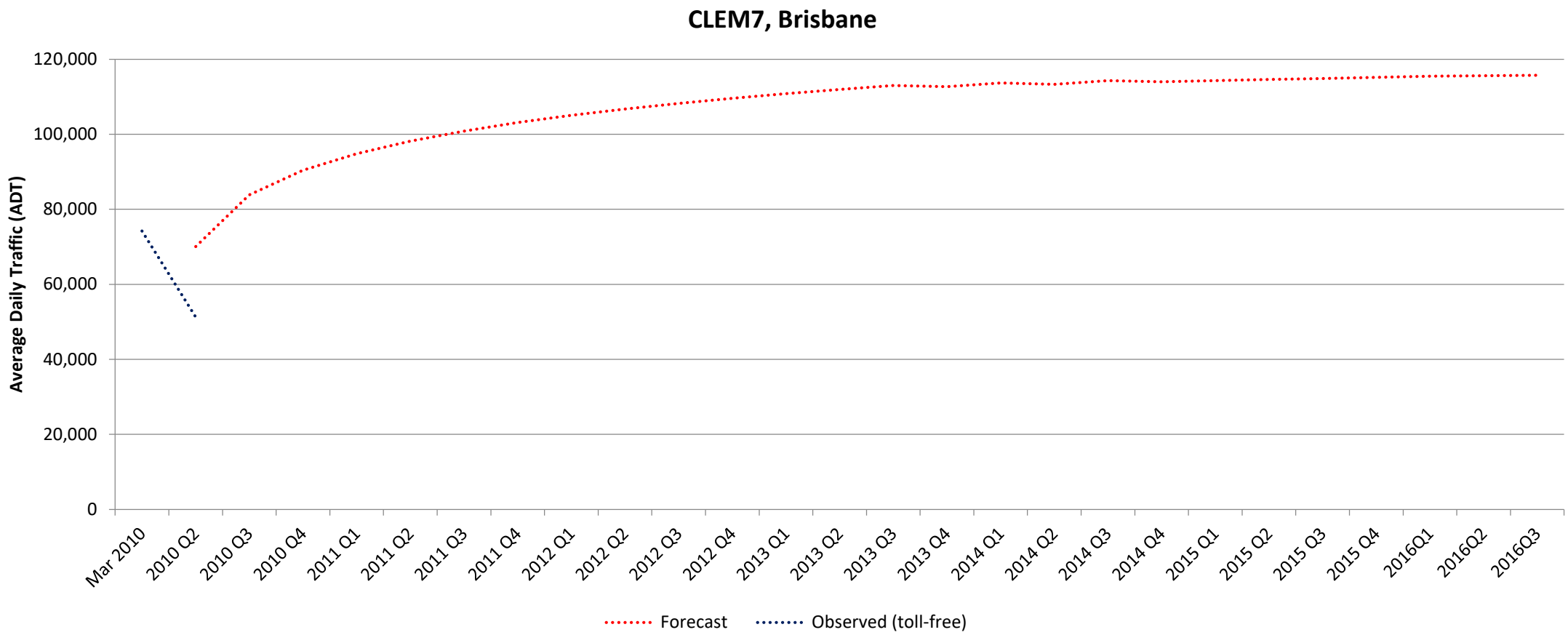

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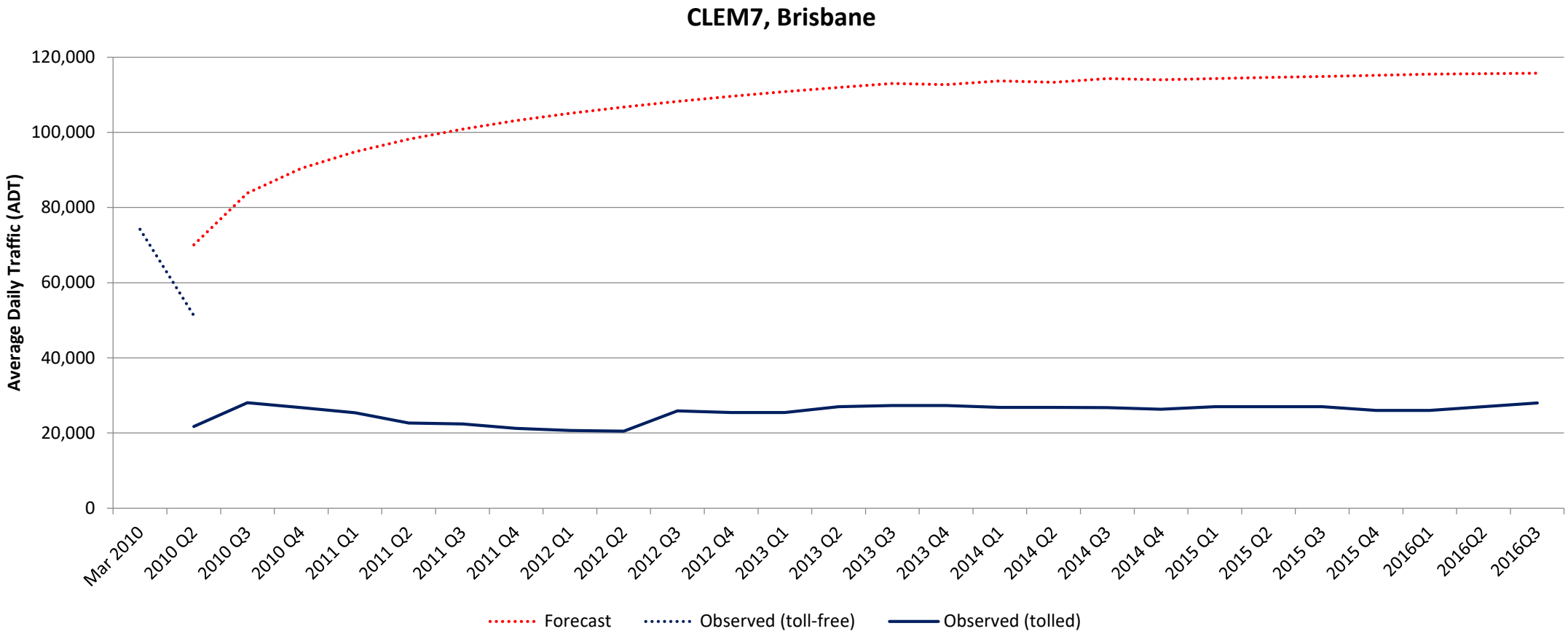

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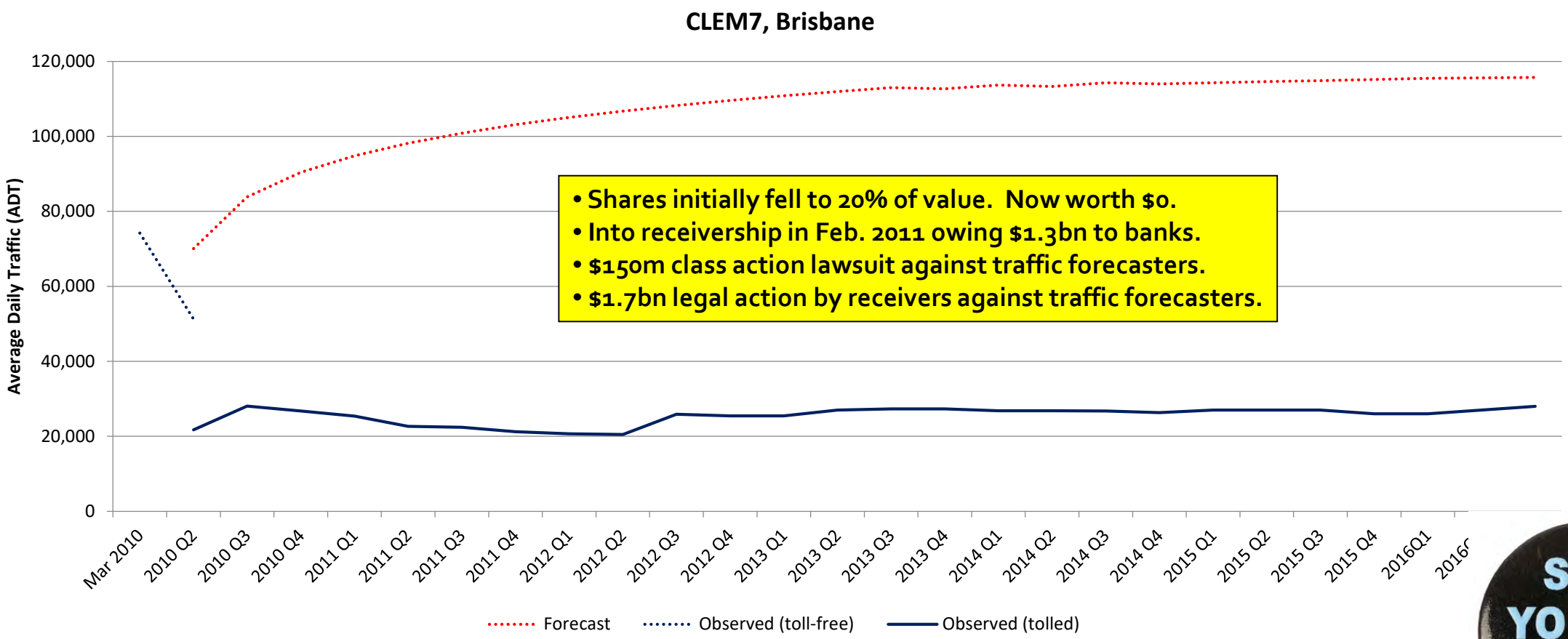

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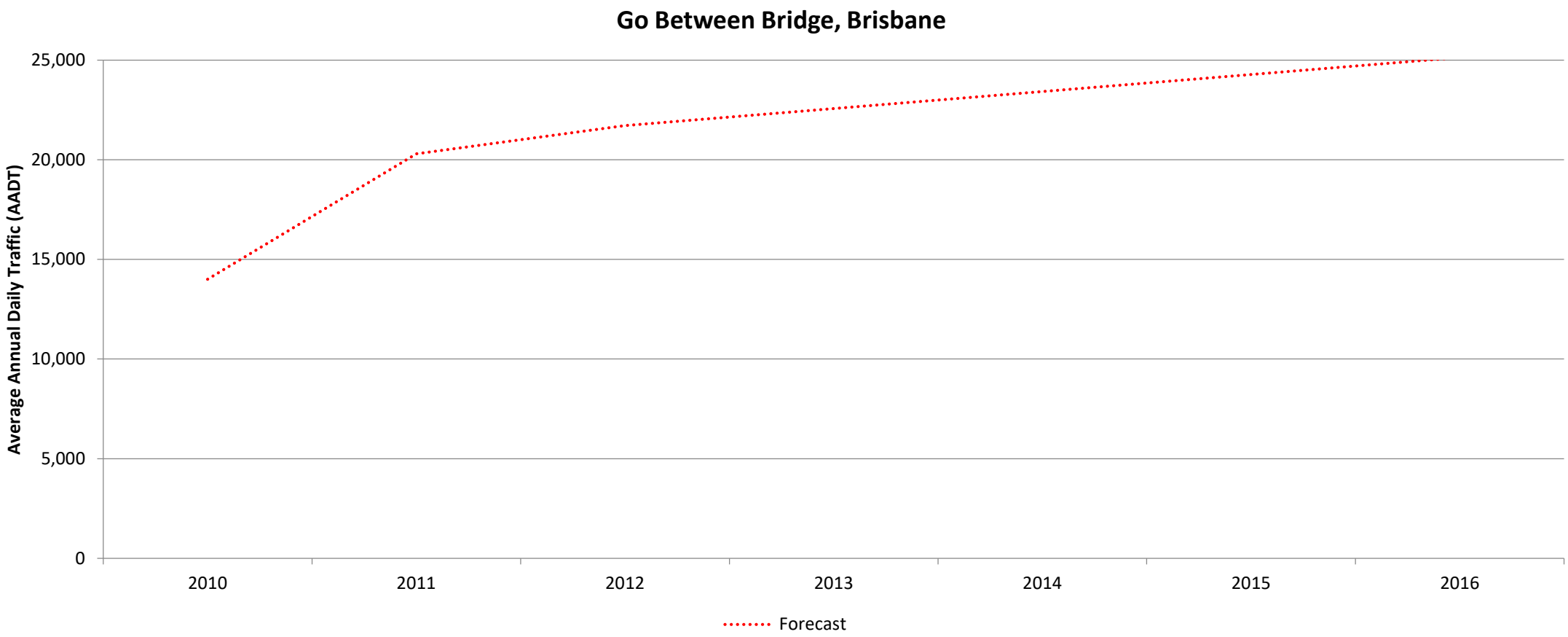

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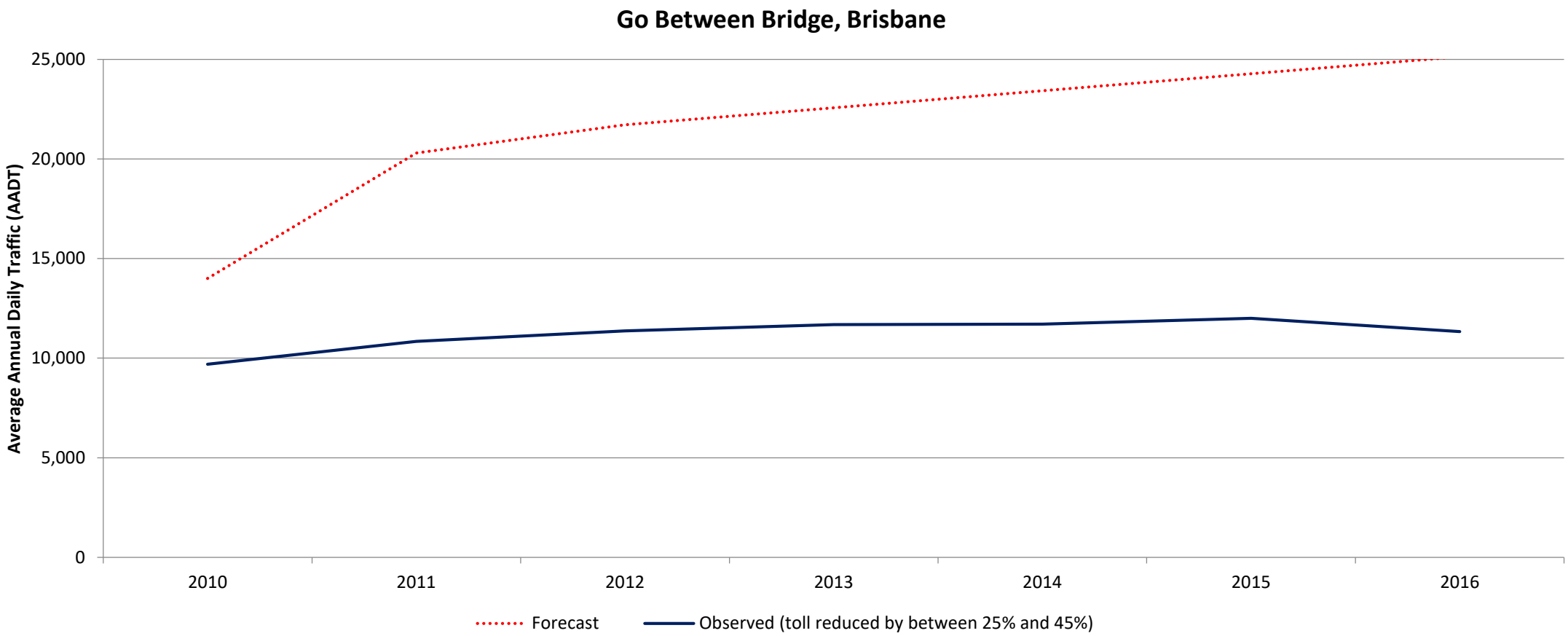

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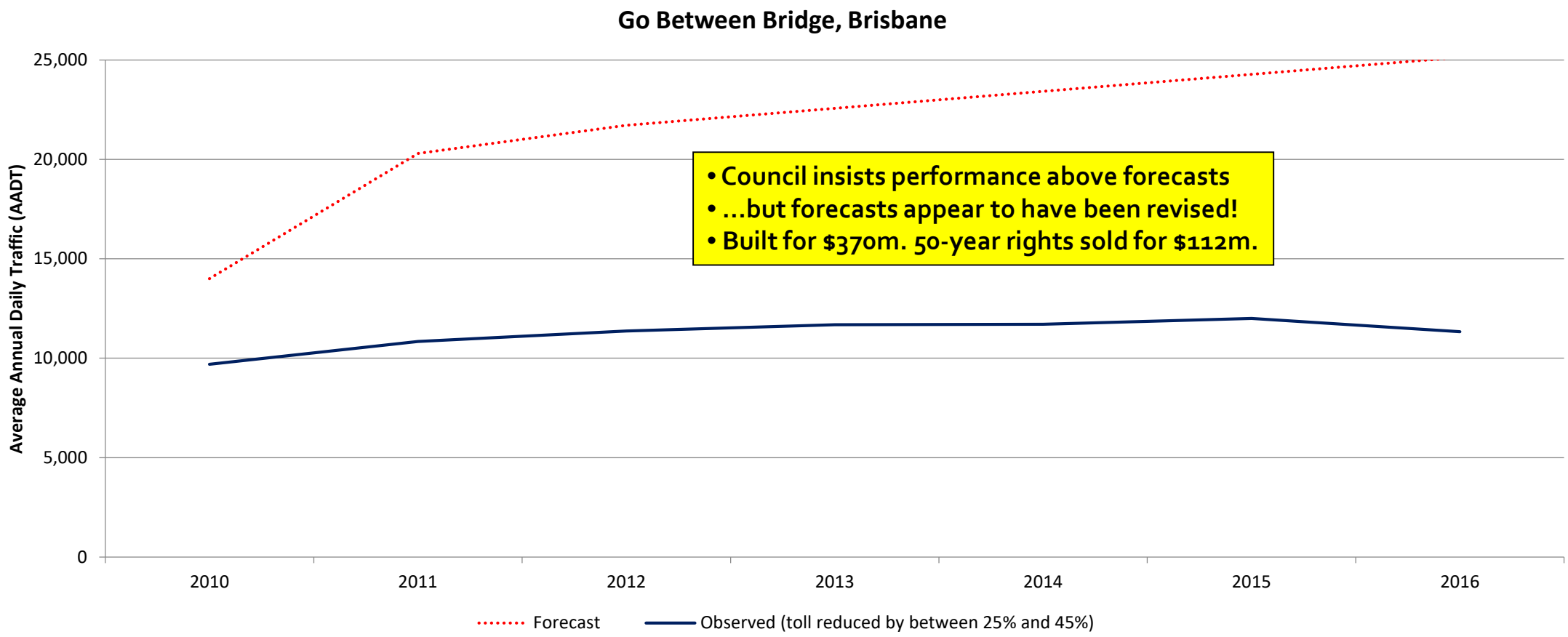

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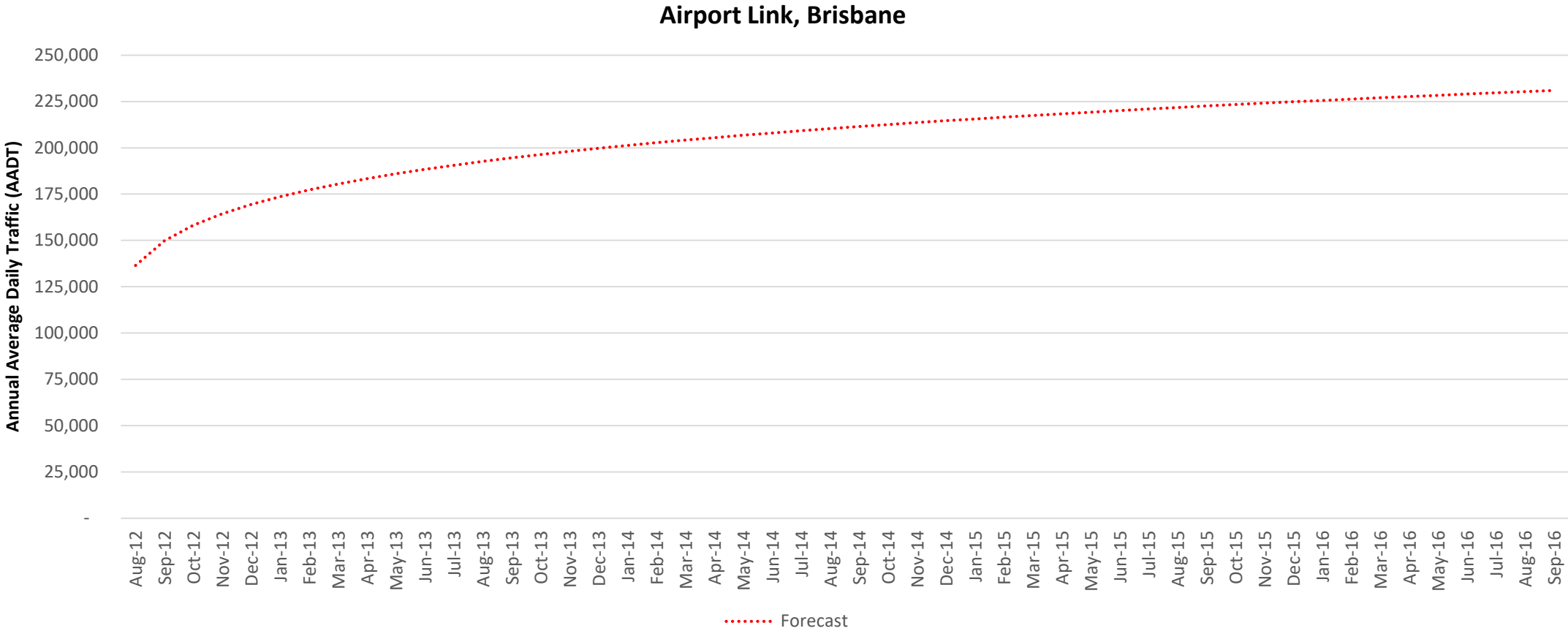

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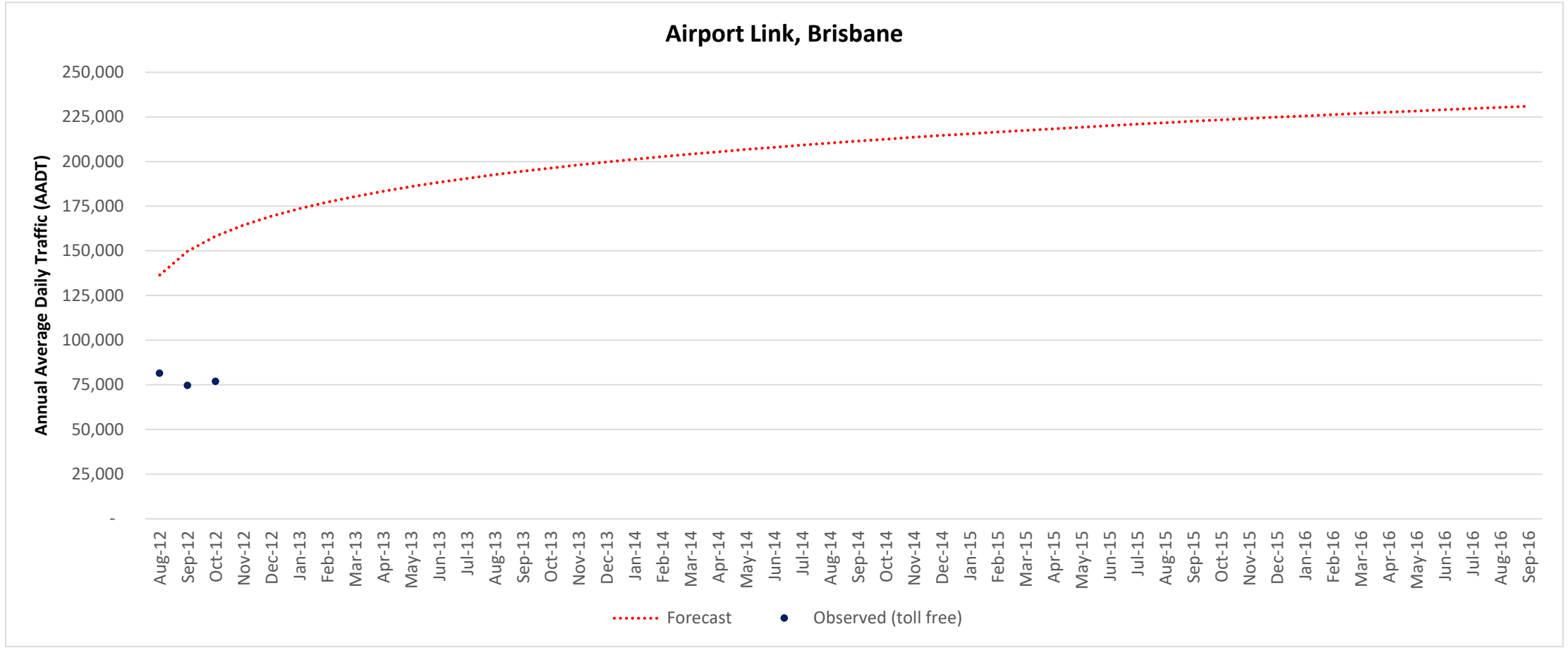

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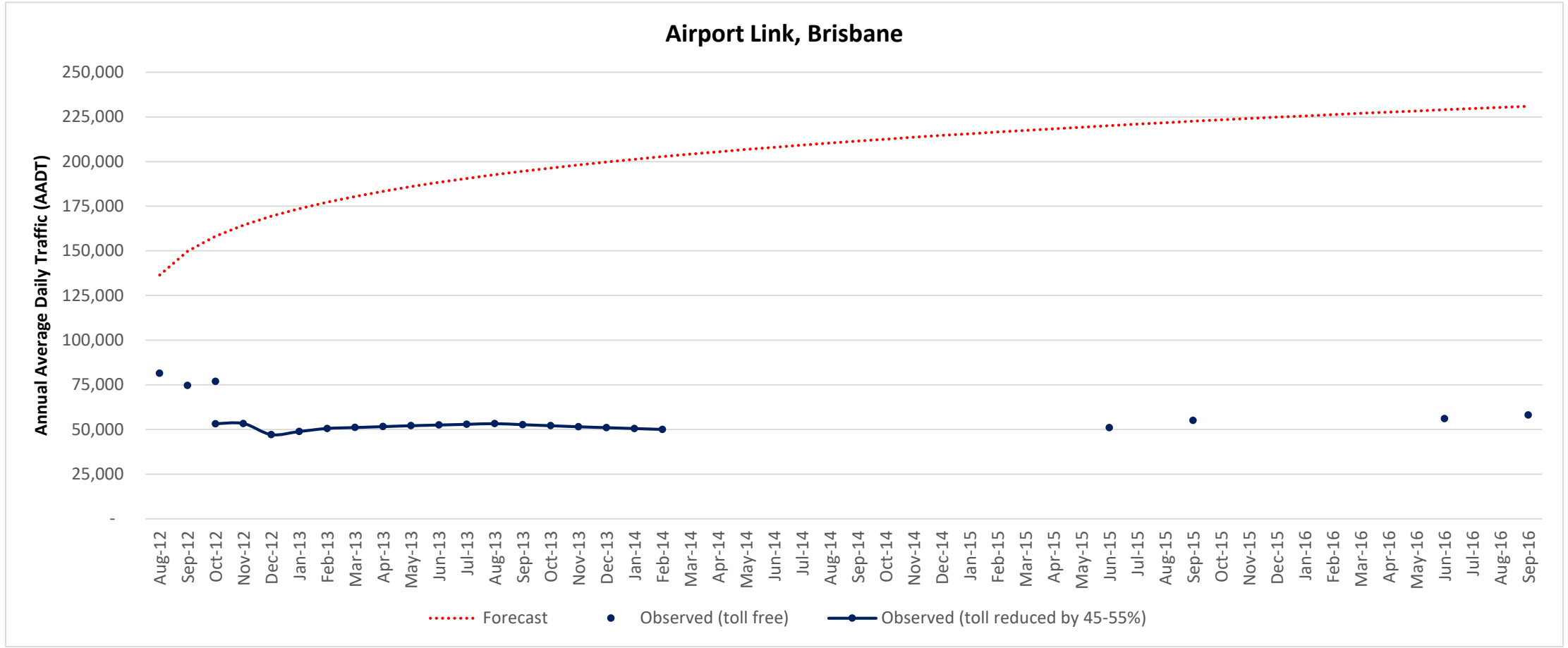

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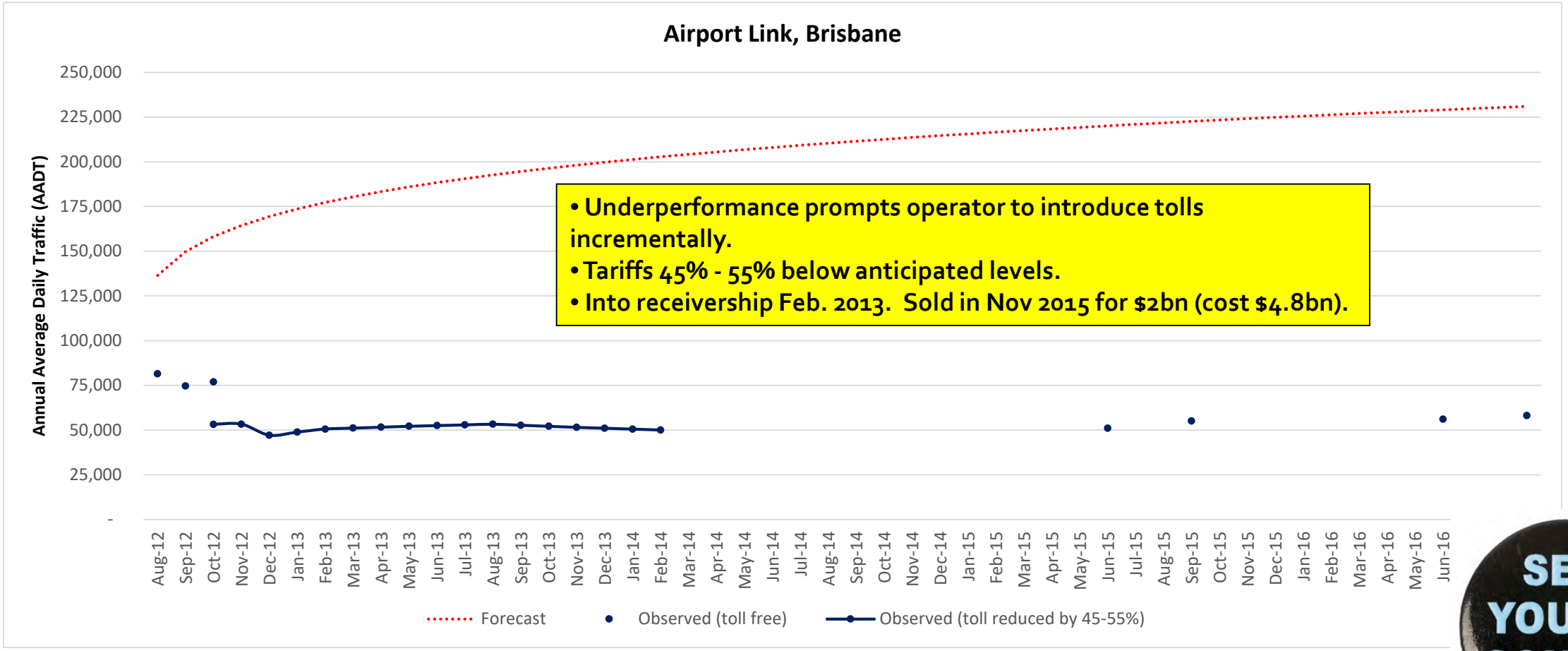

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- Key links (including target) over-capacity from Day 1. Busiest facilities in the world!
- Traffic & revenue auditor dispensed with (or remit considerably reduced)
- Winning bidders way out front (runners-up bunched around half of the winning forecast $s)

Why Bias Before Error?

- Before you can consider/examine/assess error
- …you have adjust for bias

- Why?
  - Answered earlier

- How?

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- How?
  - A **belligerent Scottish** independent reviewer really helps!

Forecasting Error

15 Years of Research in 20 Minutes!

Research Methodology

1. Clearly identify the research subject
   - Quantification of prediction intervals based on empirical evidence

2. Approach the subject from different perspectives using different data/sources
   - 'Triangulation'

3. Pose the research question
   - Are common themes or consistent lessons emerging?

4. Validate research findings using independent data

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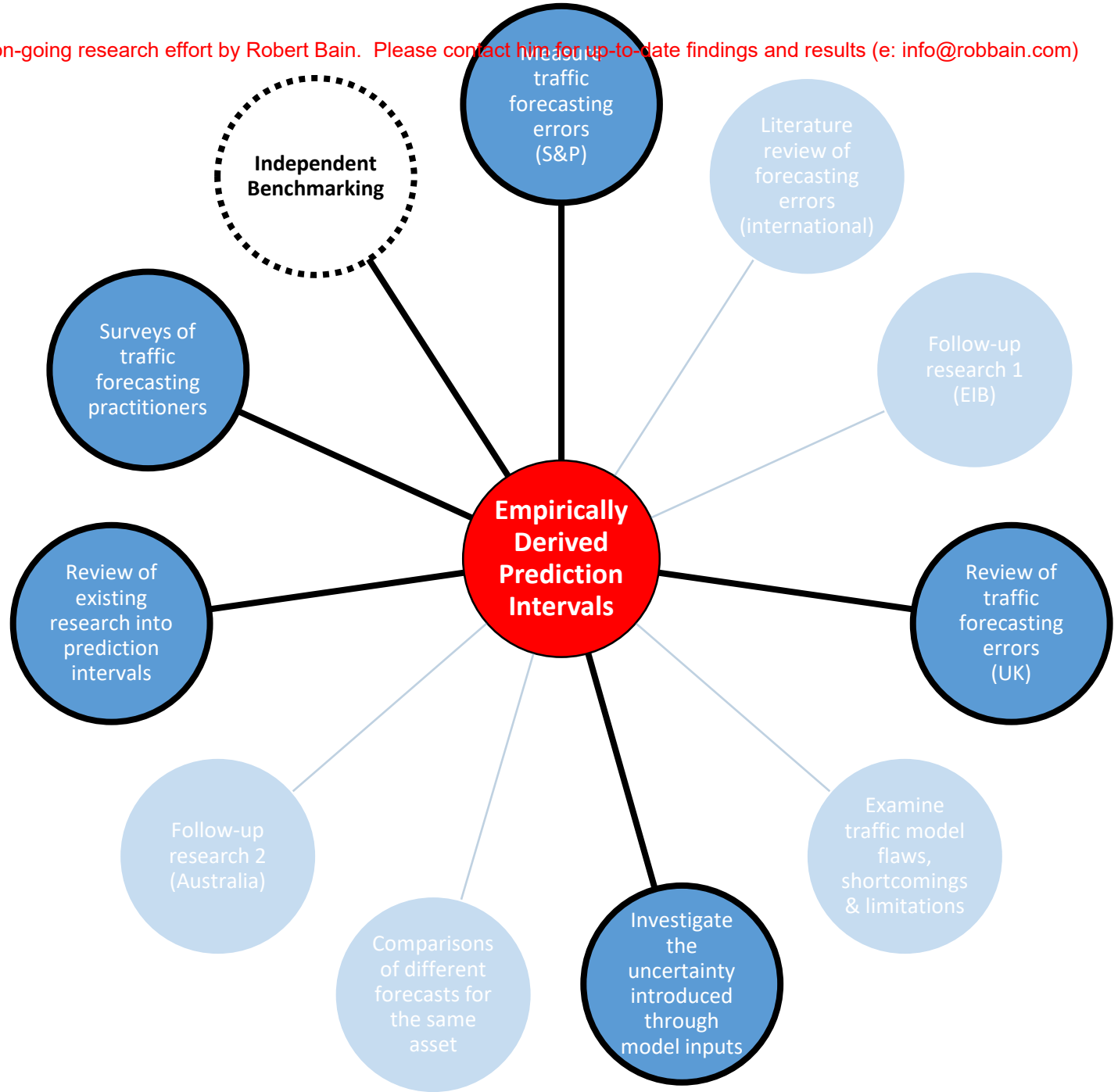
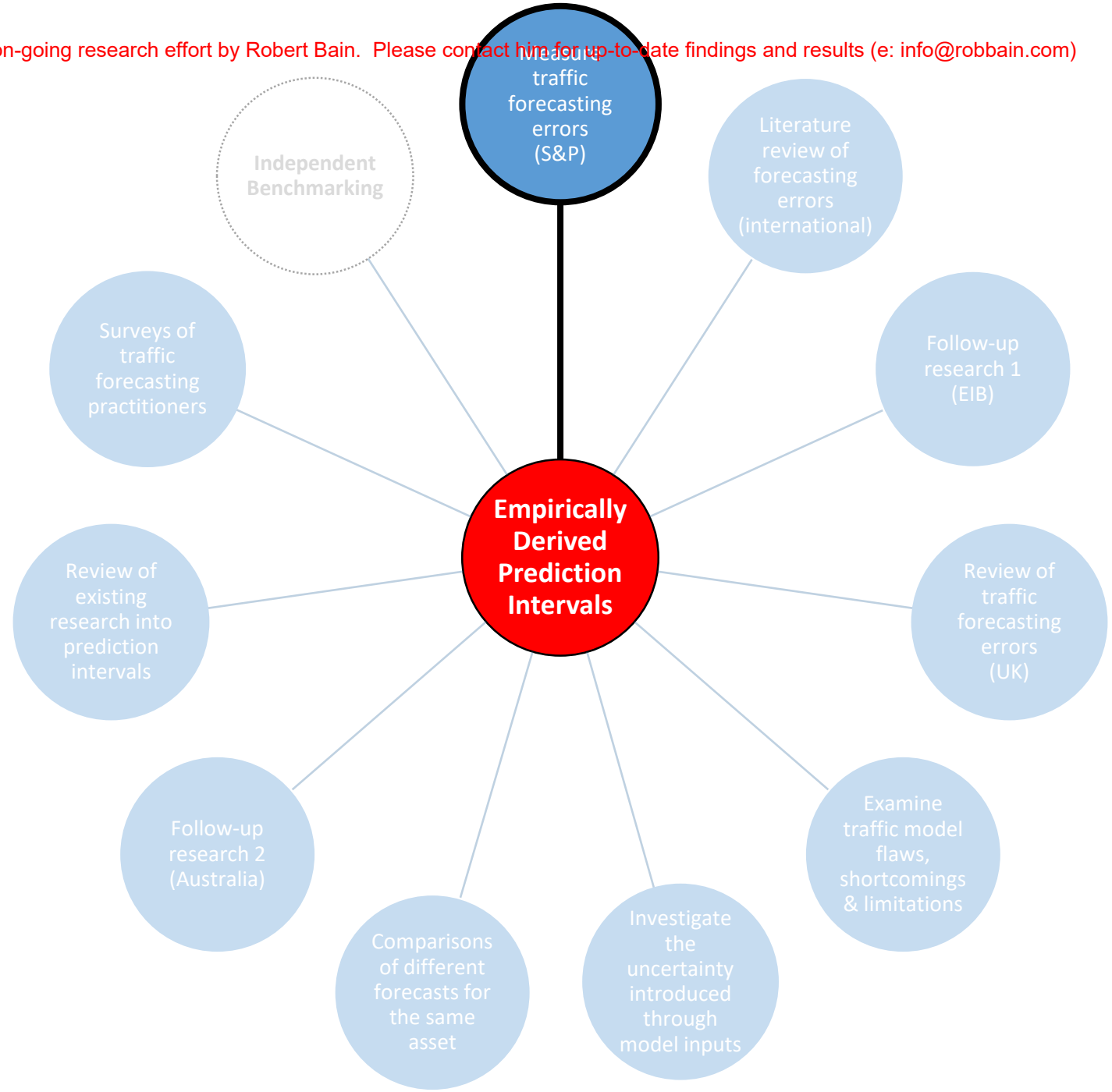
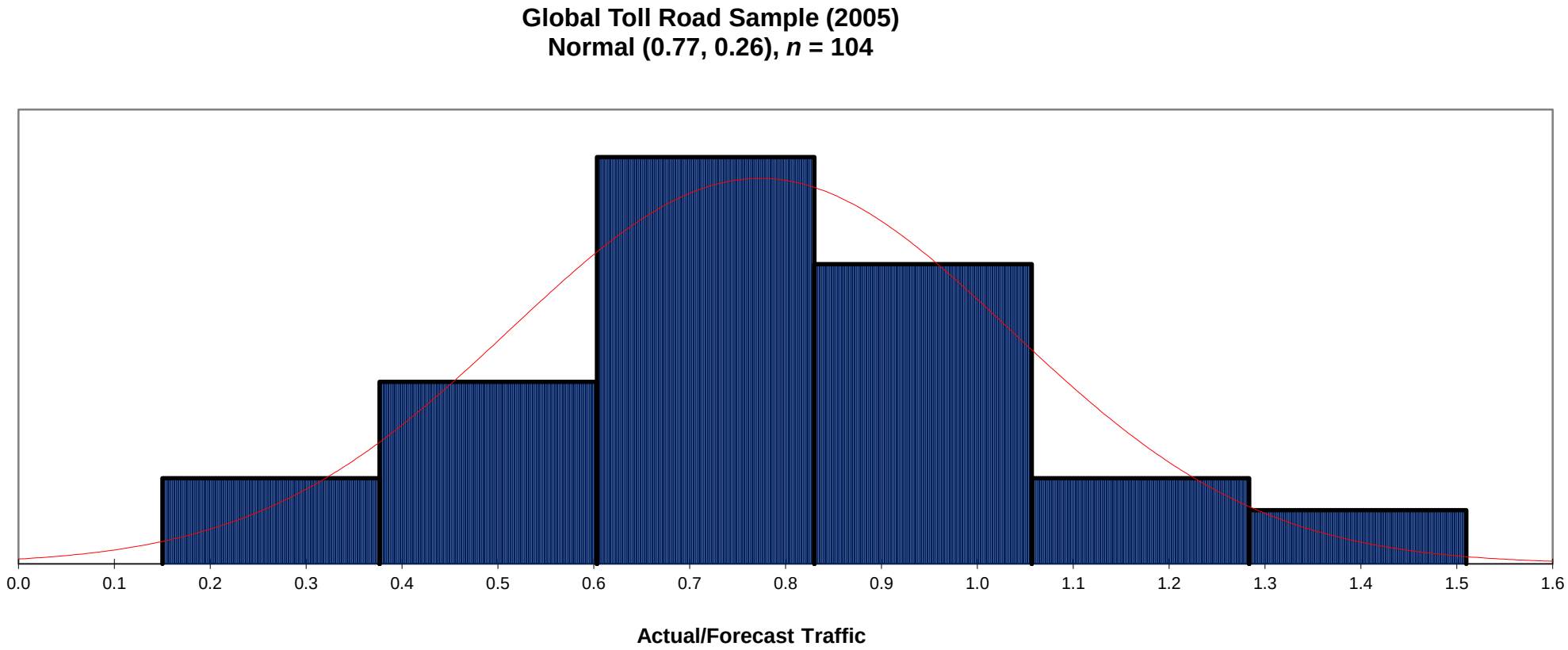
Empirically Derived Prediction Intervals





Research at Standard & Poor's (2002-)

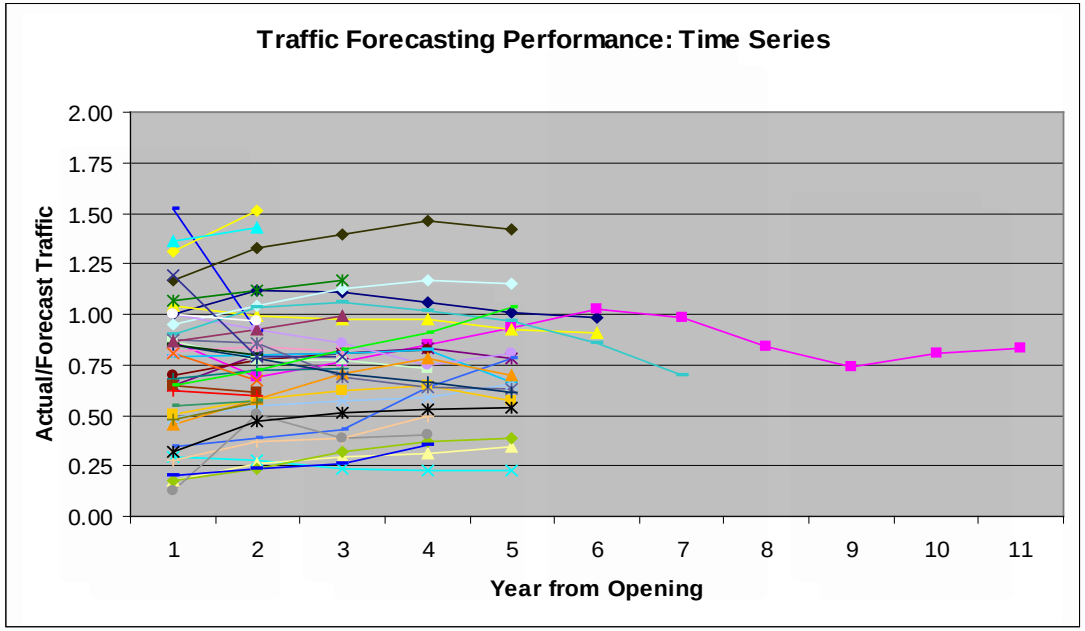


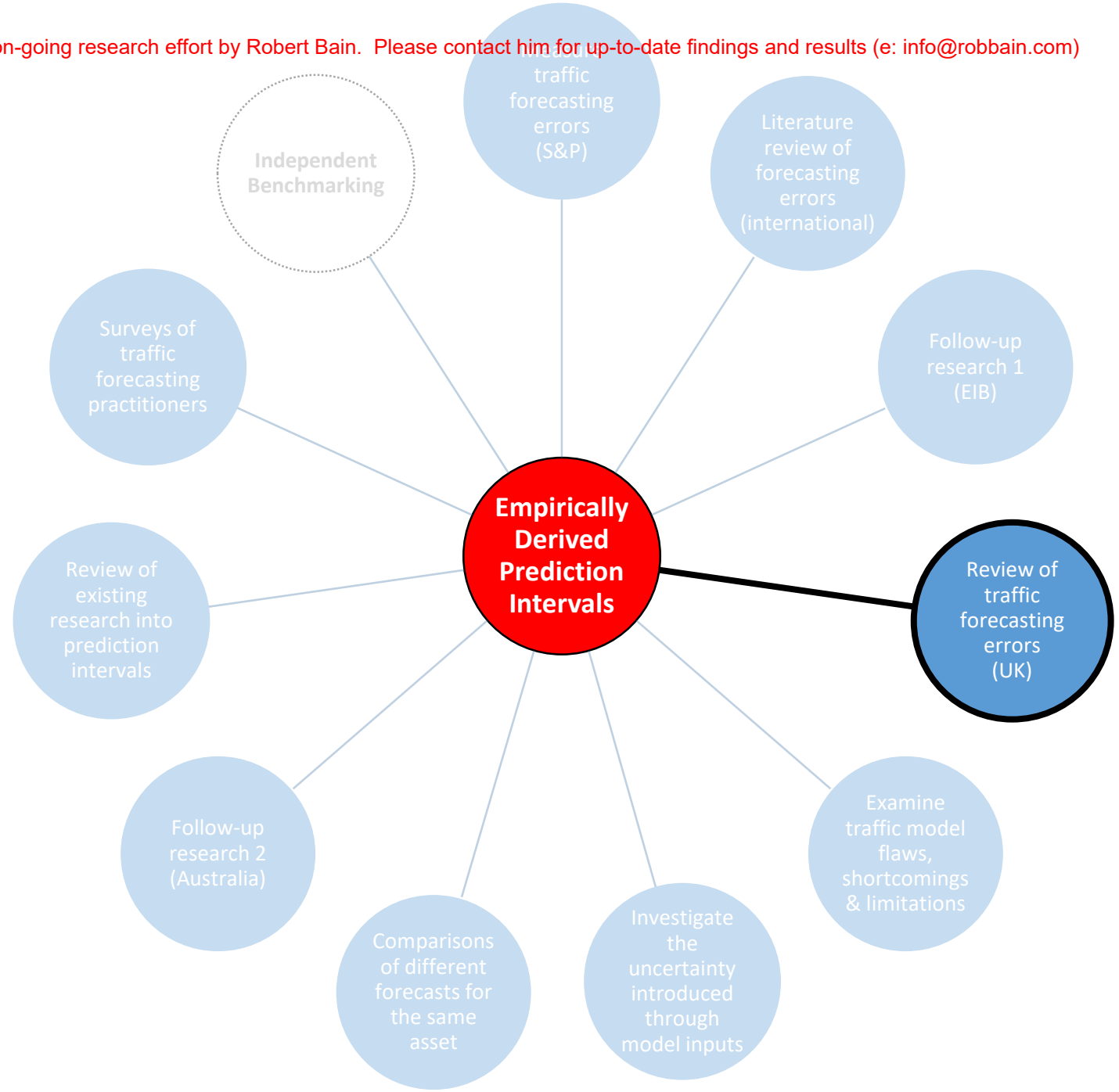
Conclusions

- Toll road forecasting errors…
  - are common
  - are commonly large
  - appear symmetrically distributed (but with a mean < 1)
    - Optimism bias? ✘ Strategic misrepresentation? ✓
- Initial focus was on error (not error propagation through time), but…

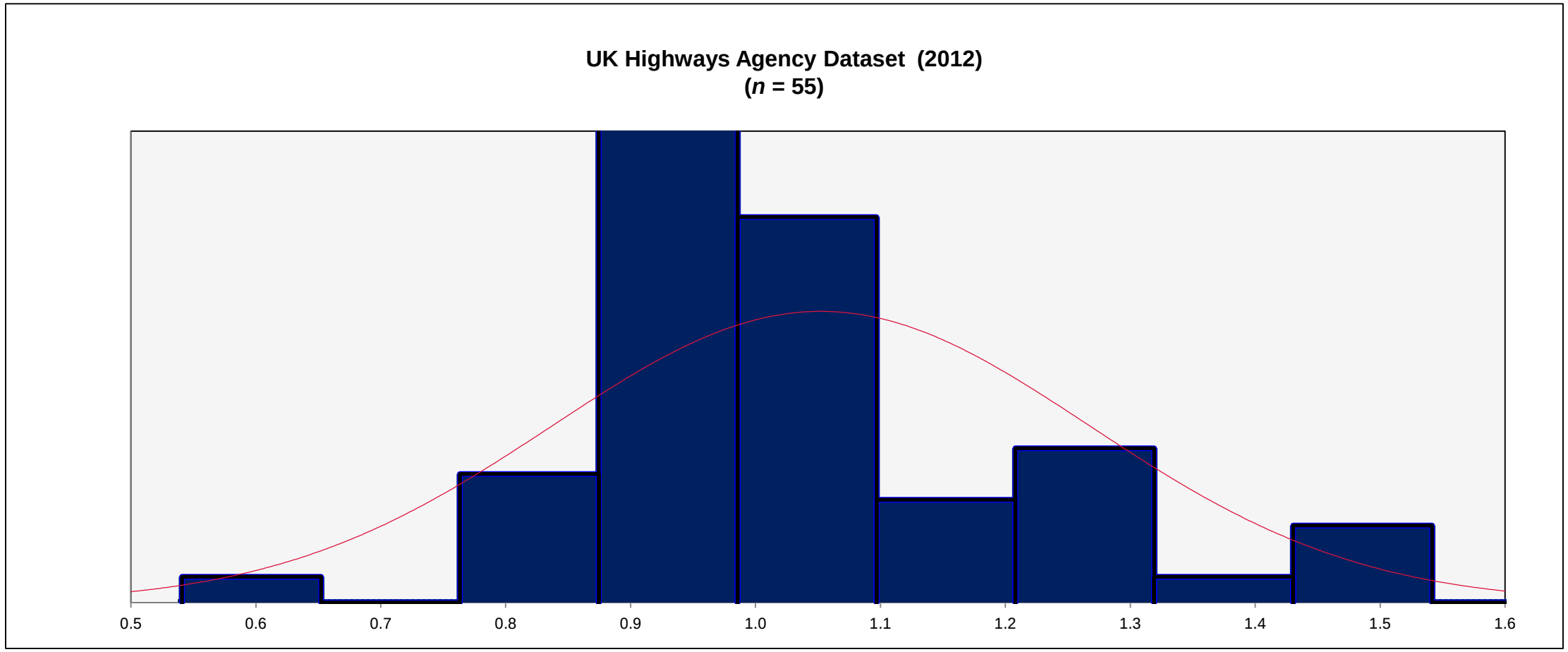
Fall-Out From S&P Research

- Lots!
  - *"Focus on first-year forecasts misses the point. Accuracy always improves after Year 1"*
- In 2003 looked at errors across time
  - Can't say much…
  - But no systematic improvement in accuracy





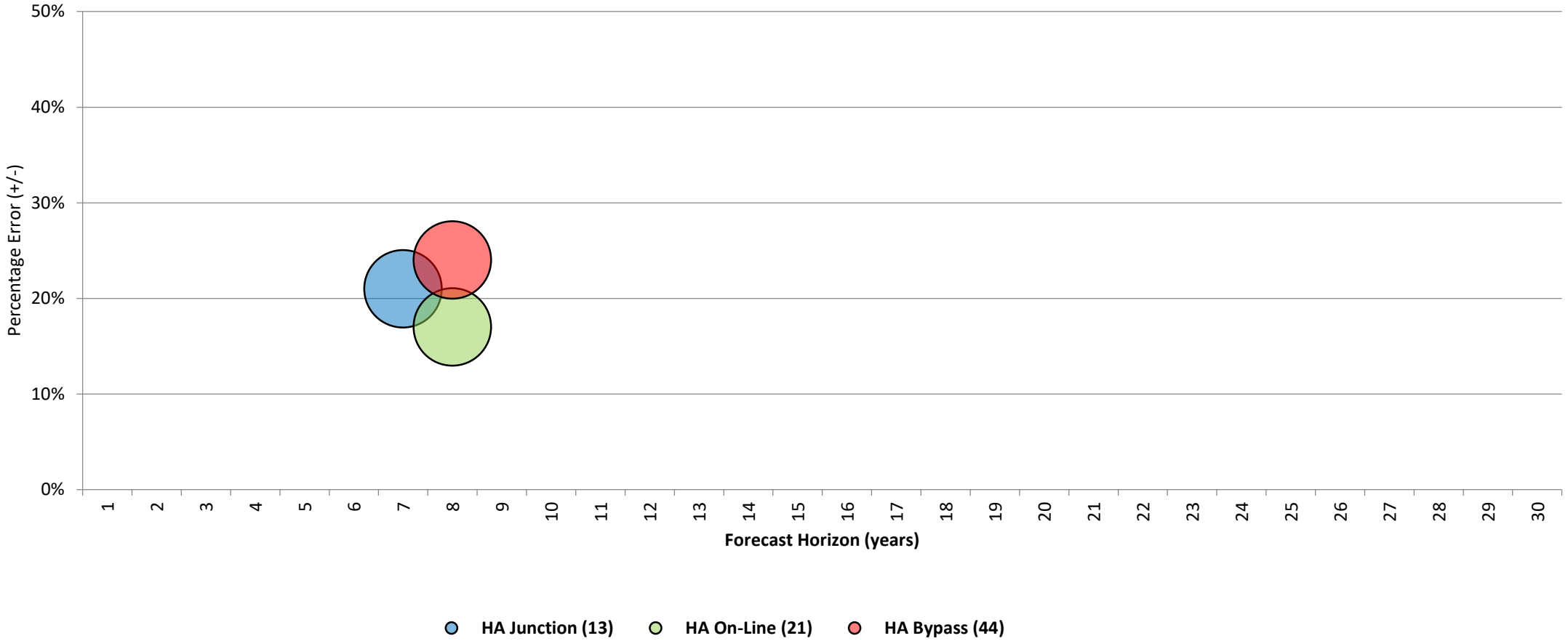
Forecast Accuracy in the UK (toll-free roads)

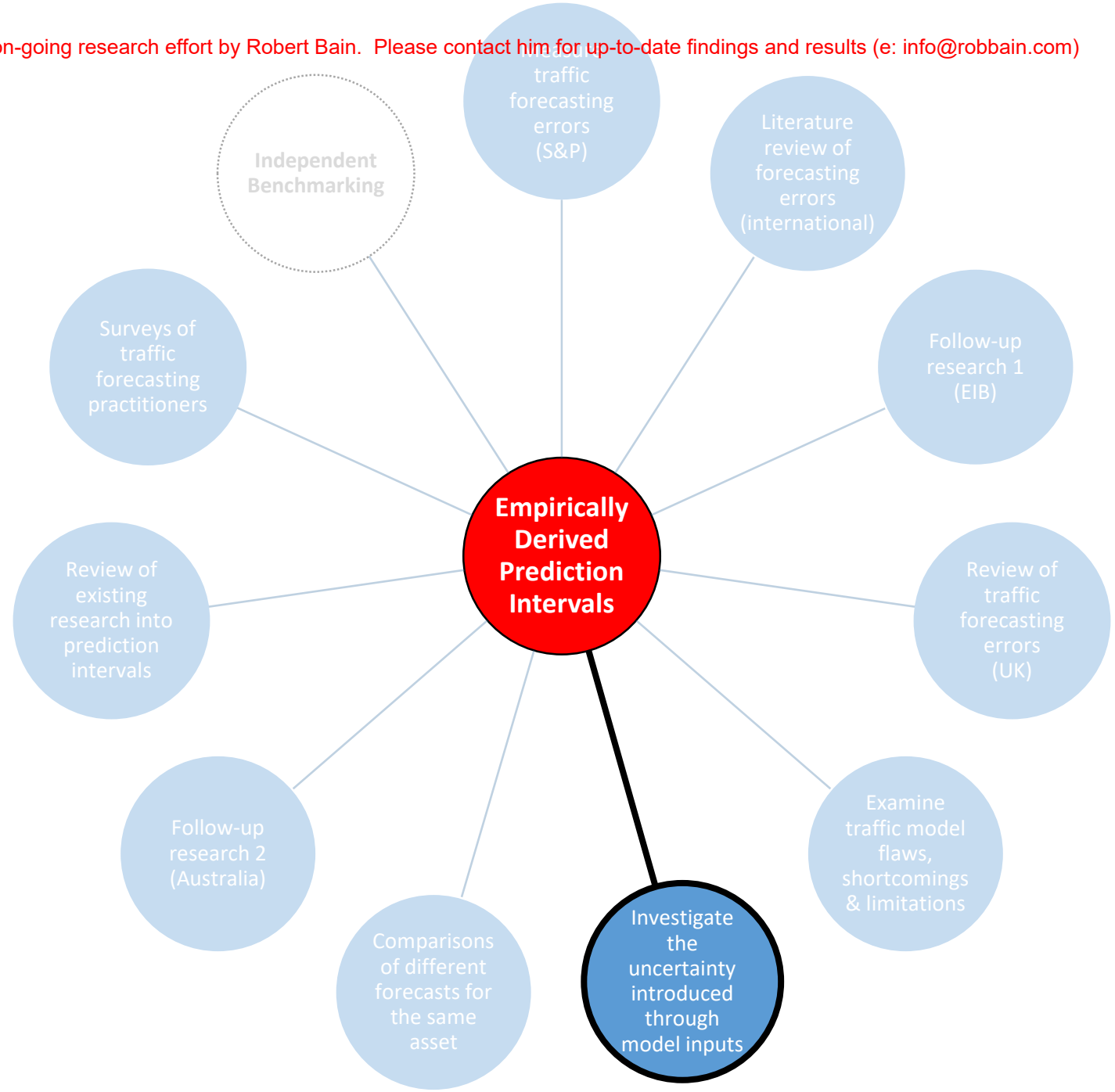


Conclusions

- *"A quarter of forecasts are out by > 15%"*
  - Varied by scheme type
  - From HA raw data I calculated closer to a third!
- In contrast to toll road research findings…
  - Mean is different (≈ 1.0 cf. 0.77)
    - Absence of systematic bias
  - SD is not that different (0.22 cf. 0.26)
    - Still a significant error range
    - Reported errors clustered in the ±15% to ±30% range
- Note of importance (in terms of error propagation)
  - Average age of the forecasts 7-8 years

UK Highways Agency Forecasting Errors





Forecasting Inputs

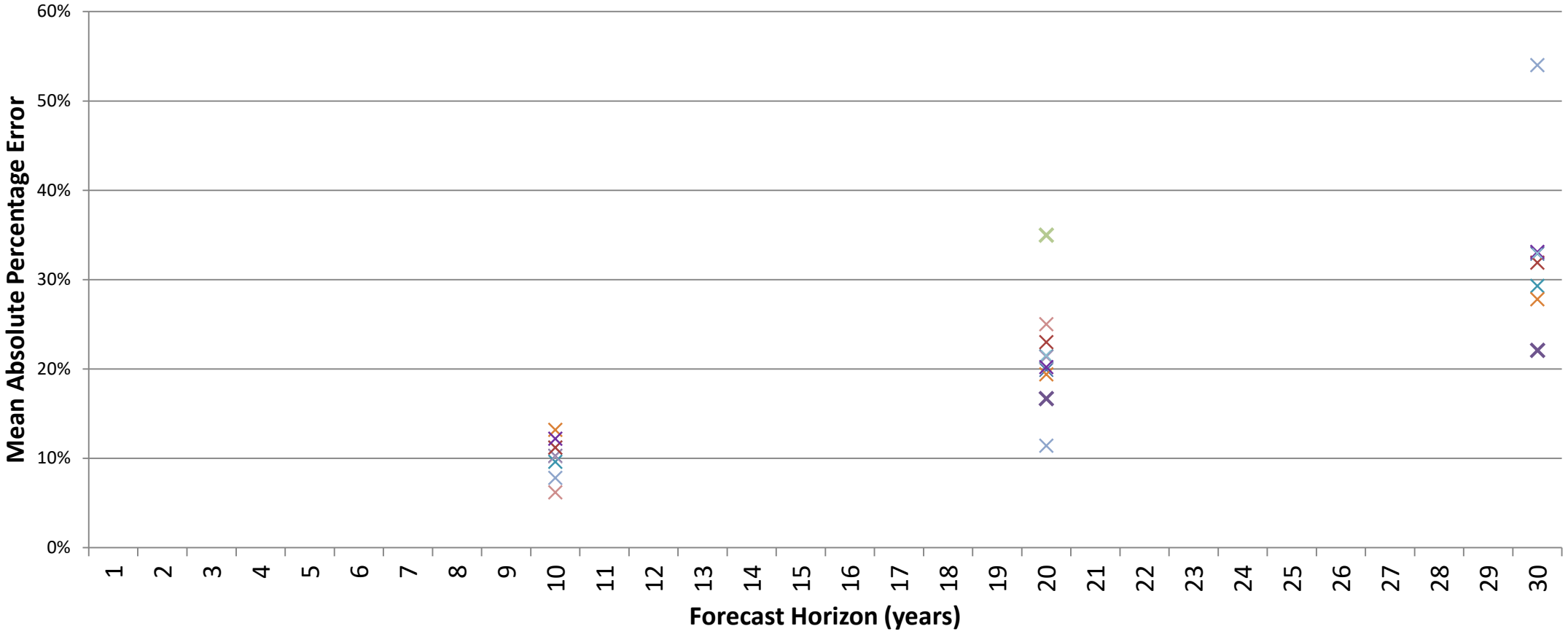
- Population forecasts are a key input for many/most transport demand models

- Population forecasting should be relatively easy

  - We know the population today

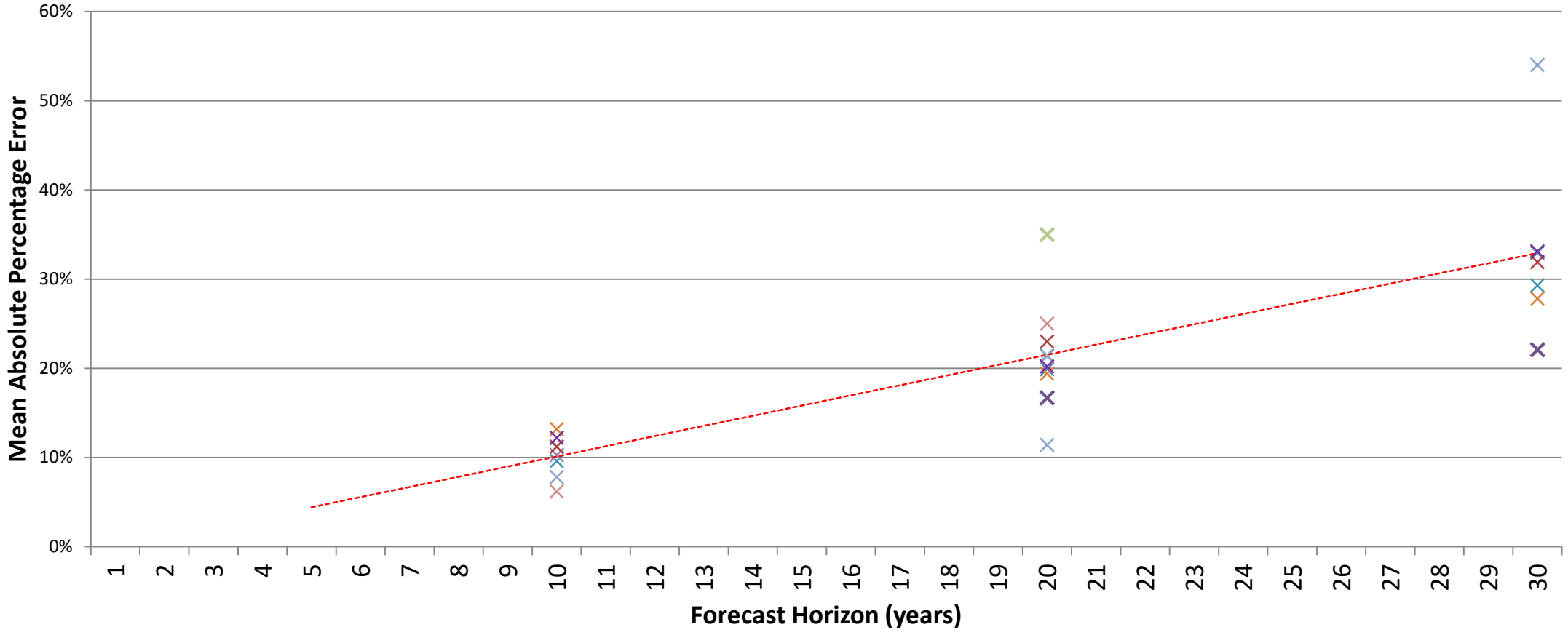
  - There is a limited set of influences
    - Births
    - Deaths
    - Migration

Small-Area Population Forecasts

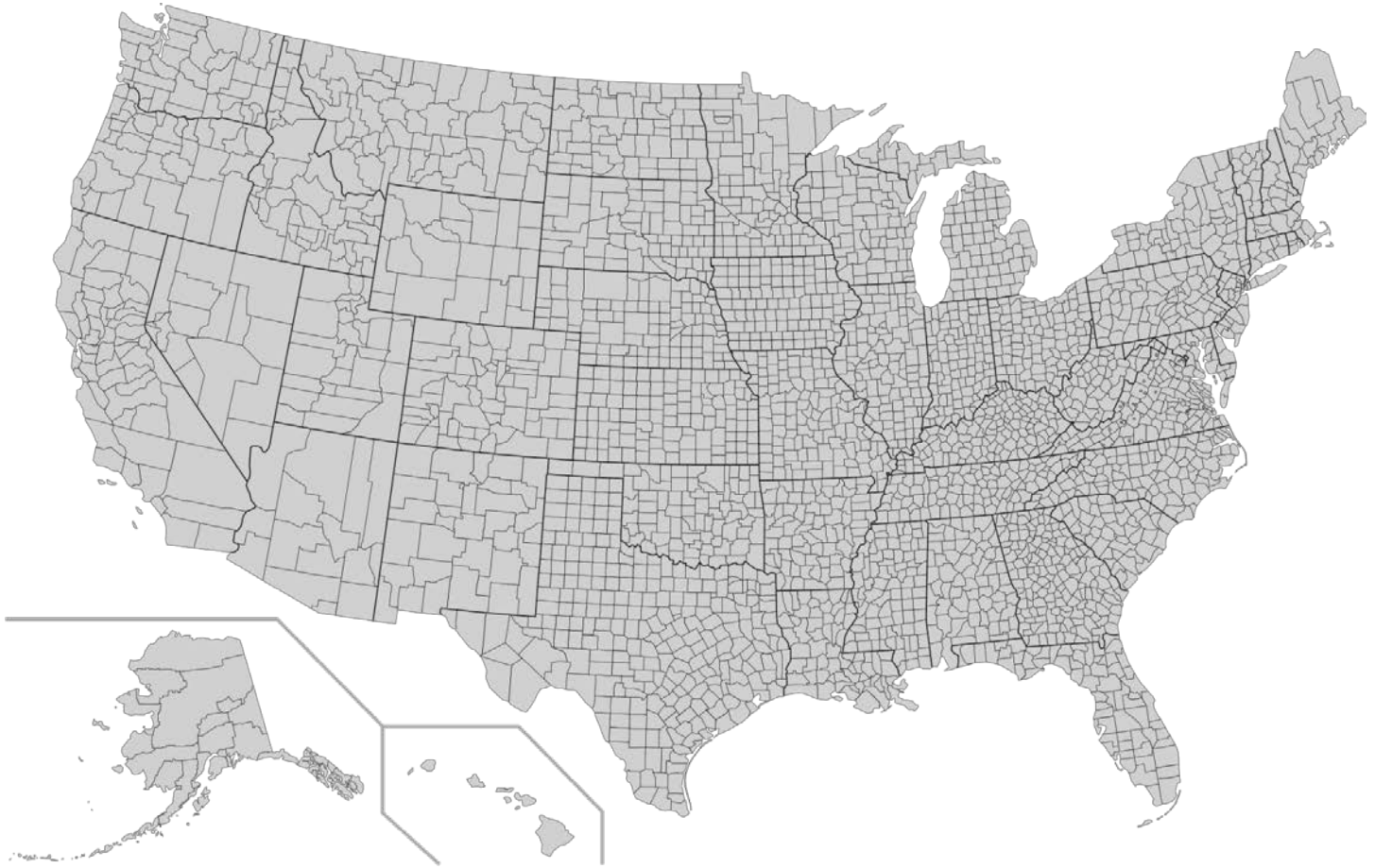


Sources: Smith & Shahidullah (1995), Simpson et al (1997), Smith et al (2001), Shaw (2007) and Rayer et al (2009)

Small-Area Population Forecasts



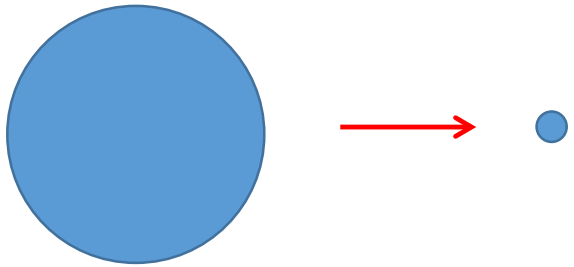
US Small Areas ≈ Counties



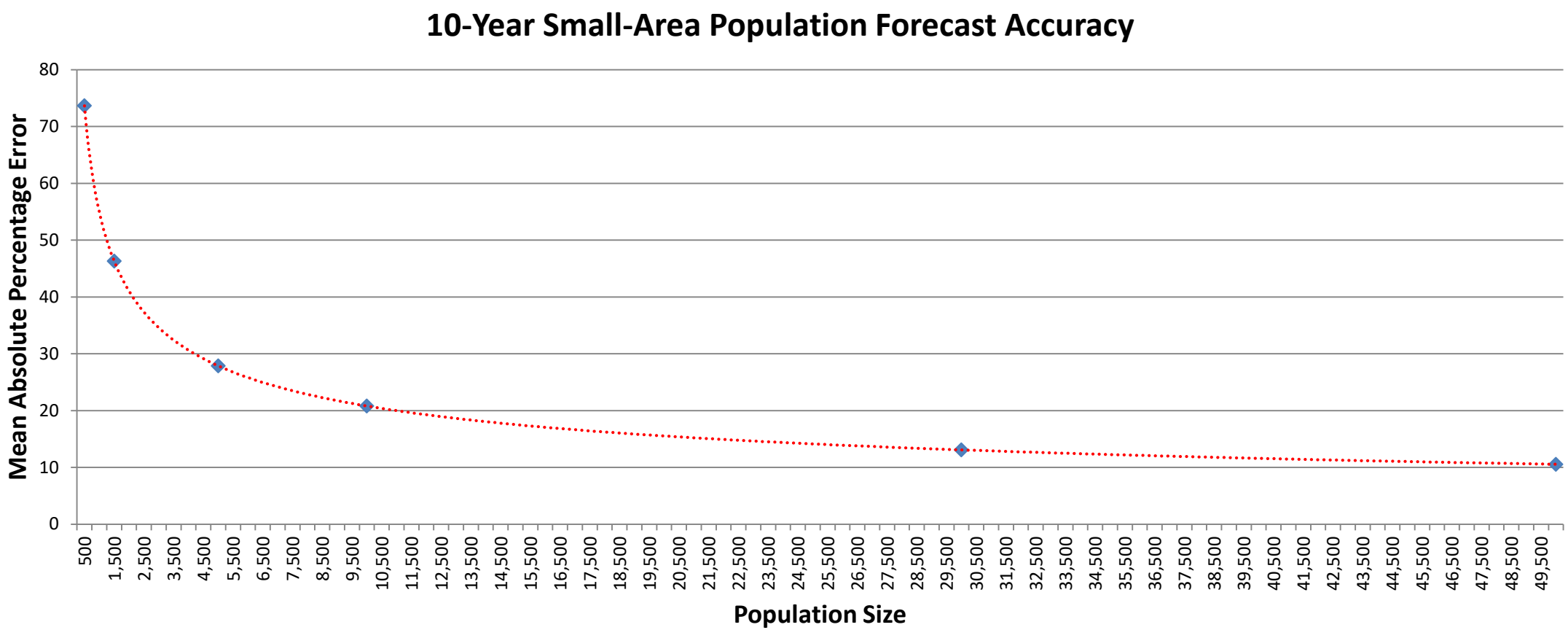
US Counties Are Actually Quite Large

- Average counties/state = 62
- Average population/county = 150,000

- But traffic modelling zones…
  - Populations of around 1,000 - 3,000
  - 70+ times smaller



Predictive Error v Sample Size



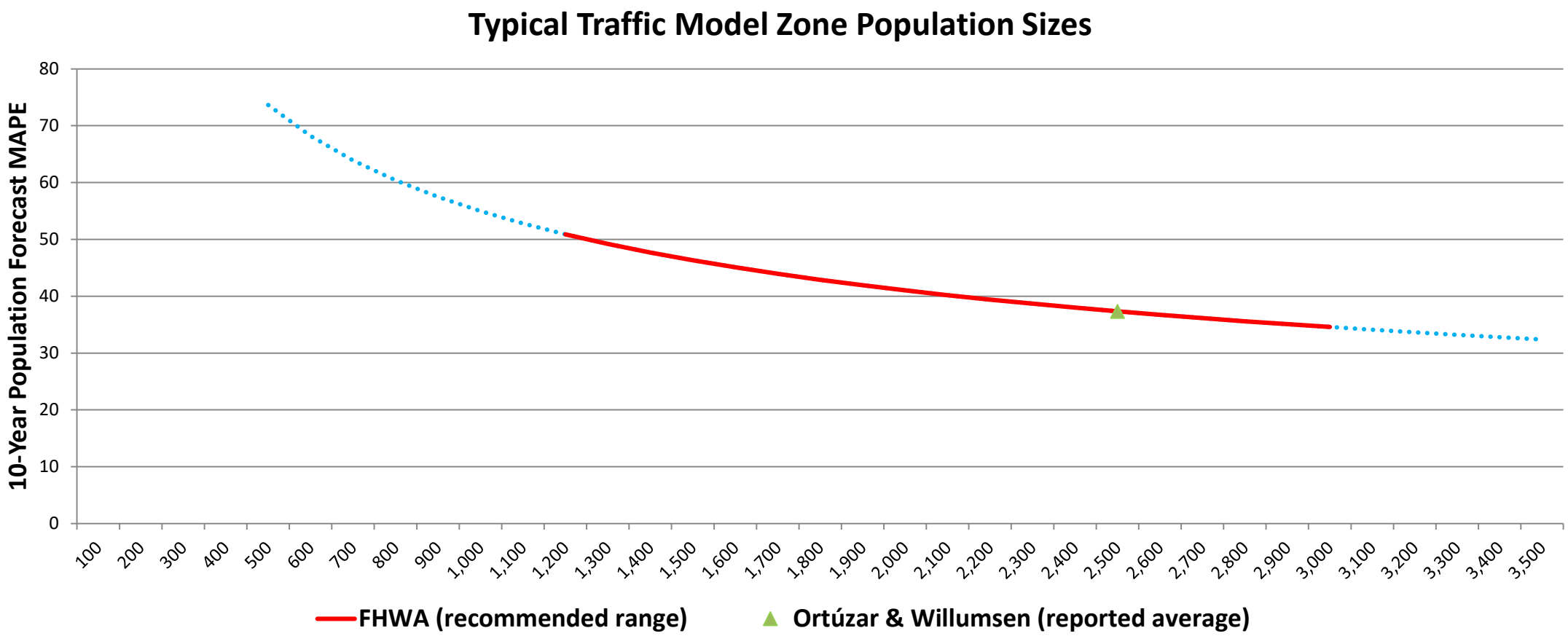
Tayman et al (1998)

Consistent Research Results

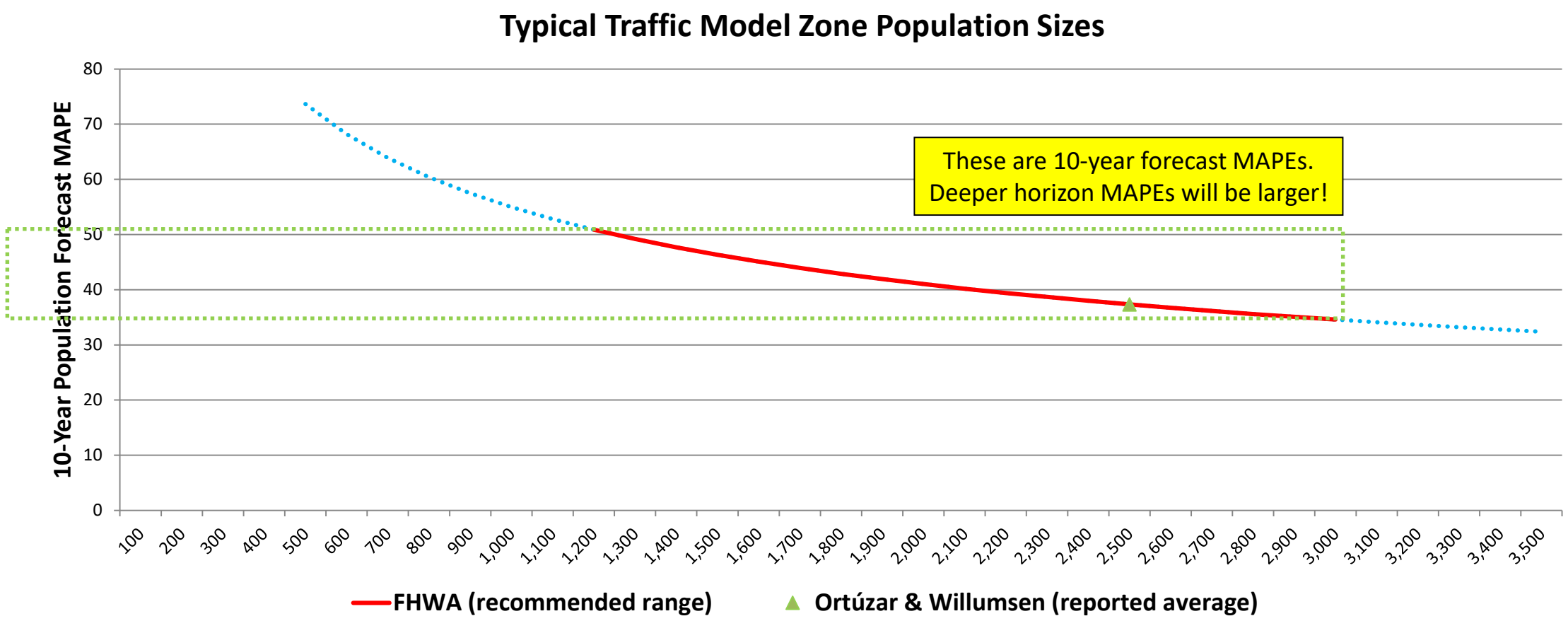
Authors	10-Year MAPEs for Different Population Sizes				
	25,000-100,000	35,000	5,000-7,500	5,000	2,500-5,000
Tayman et al	10.5-12.4	11.5	26.1	27.9	30.6
Others	10.2 [1]	11.0 [2]	19.1 [3]	27.9 [3]	26.8 [2]

1. Isserman (1977)
2. Smith & Shahidullah (1995)
3. Murdock et al (1984)

Our 'Zone' of Interest



Our 'Zone' of Interest



Conclusions 1

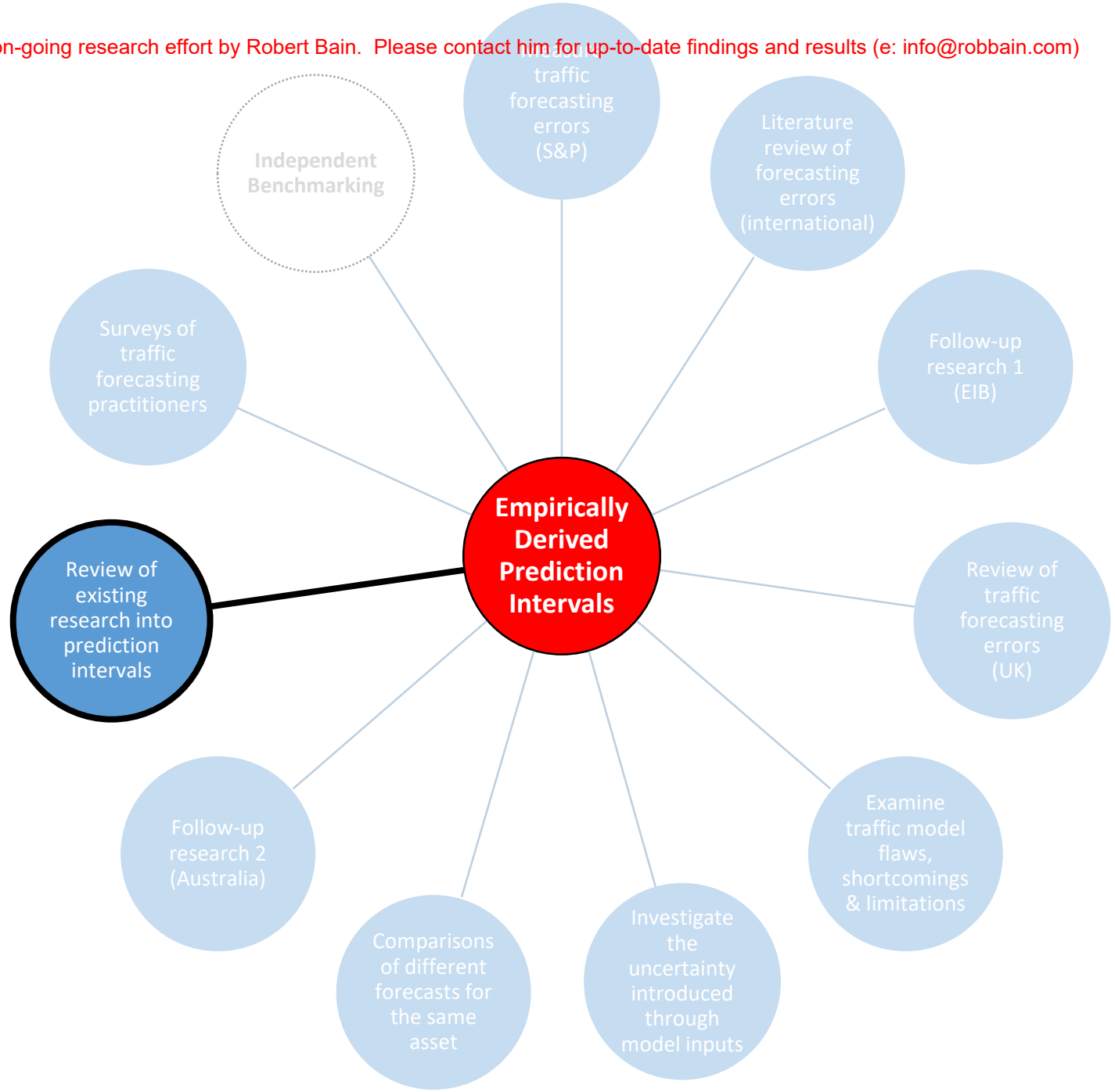
- Population forecasts have sizeable error ranges associated with them
- The error range increases as the forecasting horizon increases
  - Linear relationship?
- The error range increases as the study area decreases
  - Non-linear inverse relationship
- And, as an aside
  - The distributional characteristics of MAPEs appear stable over time (Smith & Sincich, 1988)
  - Therefore, past errors can be used to estimate CIs for current forecasts

Conclusions 2

- Population is one of the more predictable variables commonly used to explain traffic growth
- Try forecasting employment
  - …and allocating that to the correct zones
  - US evidence suggests that employment projections can be twice as inaccurate as population forecasts

Transportation Research Board, 2009

- Try forecasting GDP, income or fuel price!



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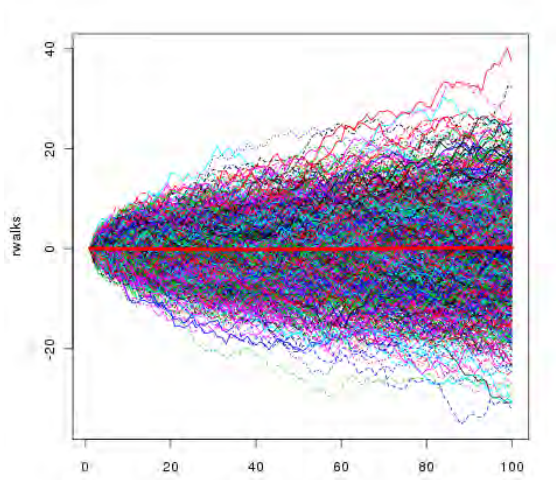
UK Department for Transport Guidance 1

- 'Forecasting and Uncertainty' (TAG Unit M4, November 2014)
  - *"Use a range about the core scenario growth forecast of…"*
    - ±2.5% * √*n* (*n* = number of years ahead)
  - Prediction interval estimated from national traffic forecasting performance

- Functional form is intuitively appealing
  - If error variance increases linearly with time…
  - …SD will vary with the square root of the forecast horizon



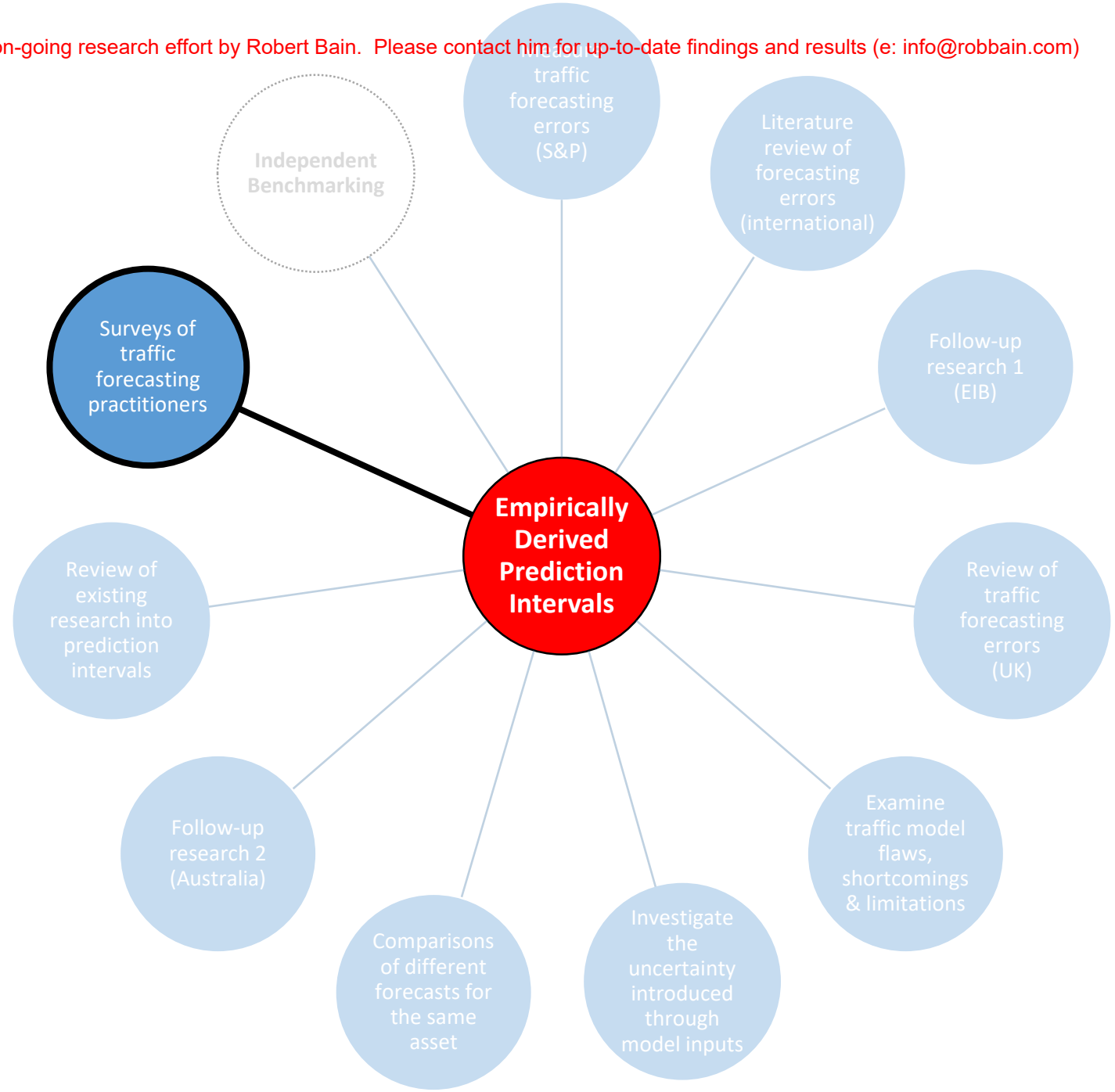
- Note: this is for <u>national</u> traffic forecasting
  - Local forecasts will have a wider (much wider?) range

Department for Transport

UK Department for Transport Guidance 2 and email exchanges

- Turning from national to regional forecasts…
  - *"For total traffic at the GOR level…uncertainty should widen to about ±25% at the 35th year"*
    - 25%/(√35) → 4.2%
    - **e**: *"±25% at GOR level feels narrow compared to ±15% (Year 36) at the national level"*

- So, DfT has estimated the proportionality constants to be:
  - National level: 2.5%
  - Regional level: ≥4.2%
  - Local level: ???
    - **e**: *"The range for individual area types/links will be greater than GOR level* (>> 4.2%)*"*



Practitioner Survey

- Specialist email lists – with international reach
- 46 replies (but high quality responses/respondents)

- Consultants/modelling practitioners
  - President
  - Managing Director
  - Director of Transport Planning

- Government officers
  - Transport Modelling Manager
  - Senior Transport & Economics Advisor
  - Traffic & Toll Modelling Manager

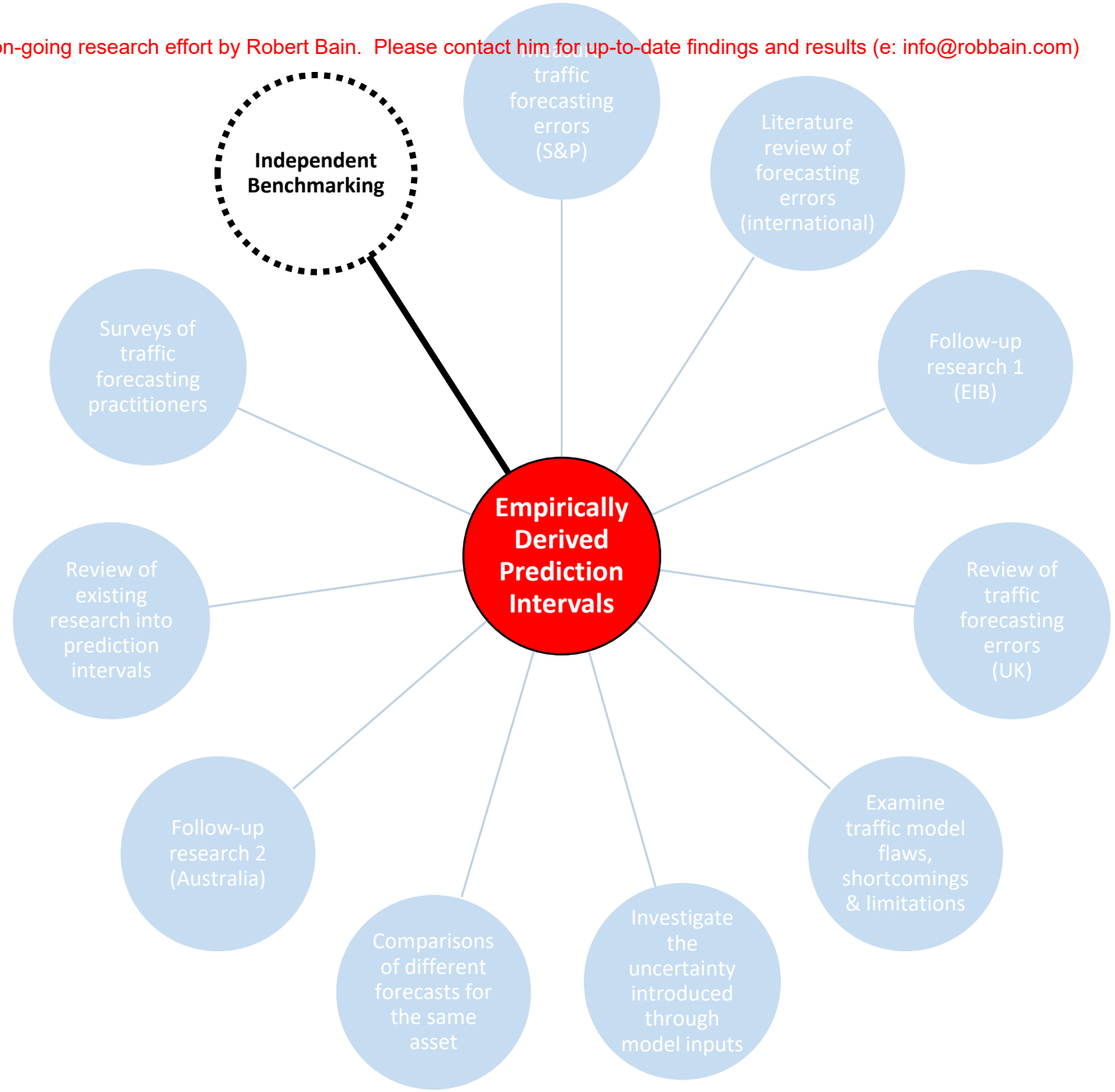
- Academics/researchers
  - 4 professors
    - Including one of the authors of '*Modelling Transport*'
  - Senior lecturers
  - Deputy Director, Centre for Transport Studies

Predictive Performance Survey Results

Forecast Horizon	Traffic Forecasting Accuracy	
	Existing Road	New Road
Next Day		
1 Year		
5 Years		
20 Years		

Predictive Performance Survey Results

Forecast Horizon	Traffic Forecasting Accuracy	
	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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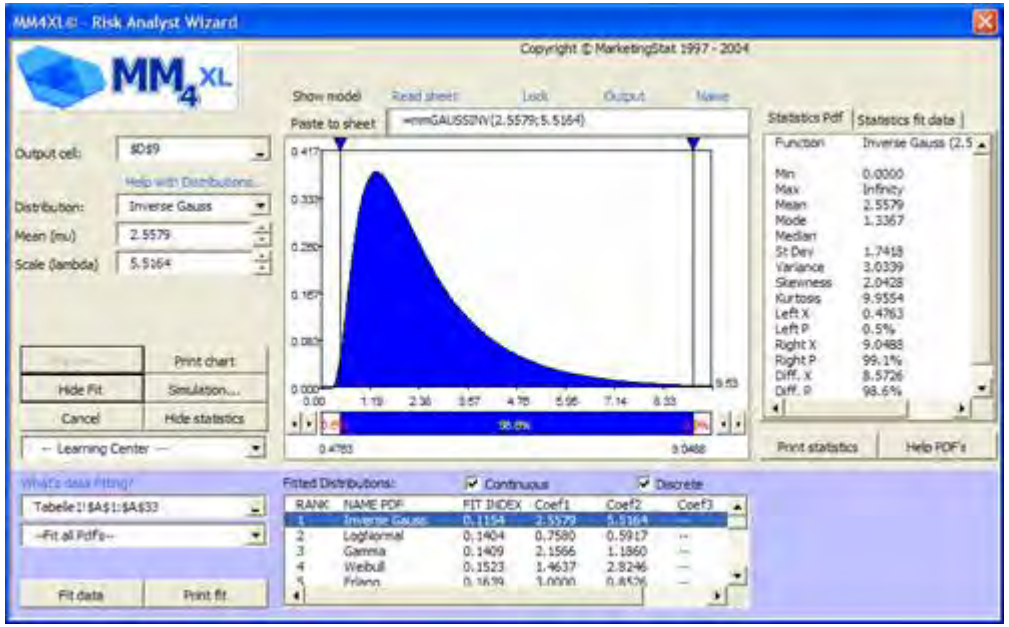
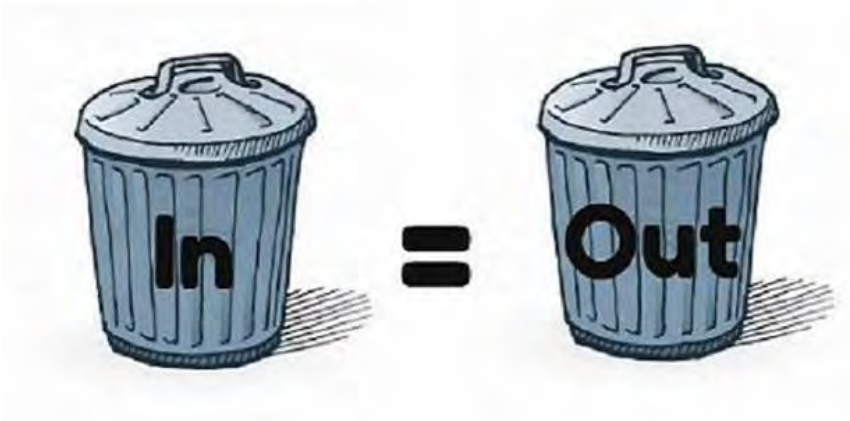
Independent Benchmarking

- Compare my emerging results
  - …with those from demand studies that have explicitly examined future uncertainty
- Most common industry techniques?
  - Scenario analysis
  - Use of Monte Carlo simulation

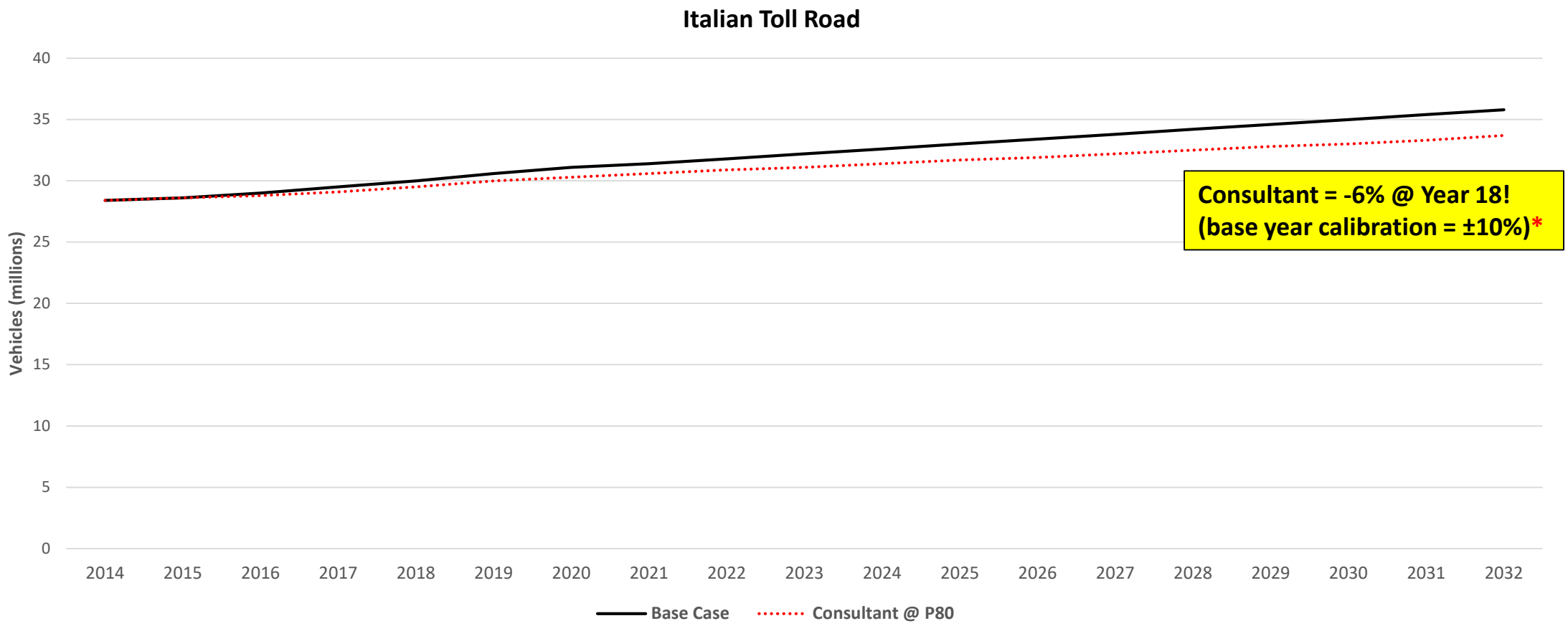


Monte Carlo Simulations: General Caution

- Stochastic results are only as good as the skill, accuracy and discipline of the modeller
- Modelling decisions (distributions, correlations etc.) dictate outputs
  - Or can be 'tailored' to dictate required outputs
- Garbage in, garbage out (ie. nonsense)

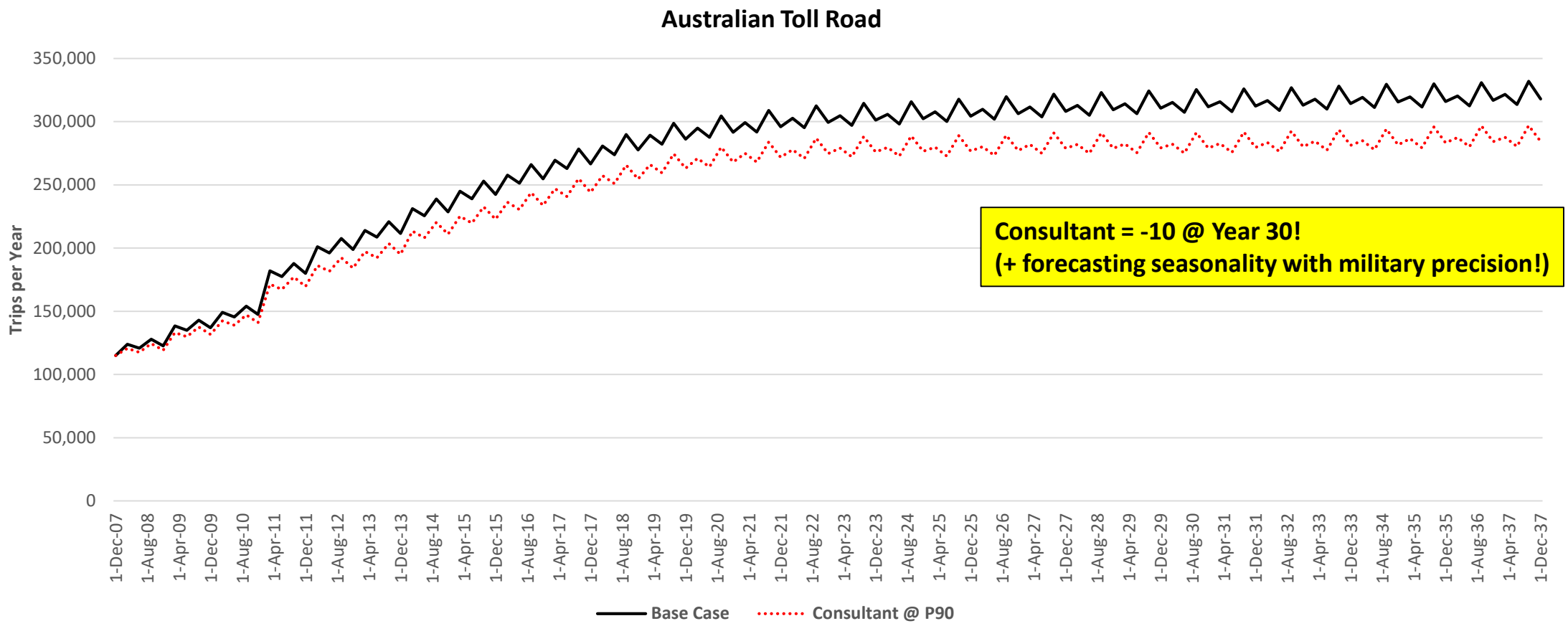


Nonsense!

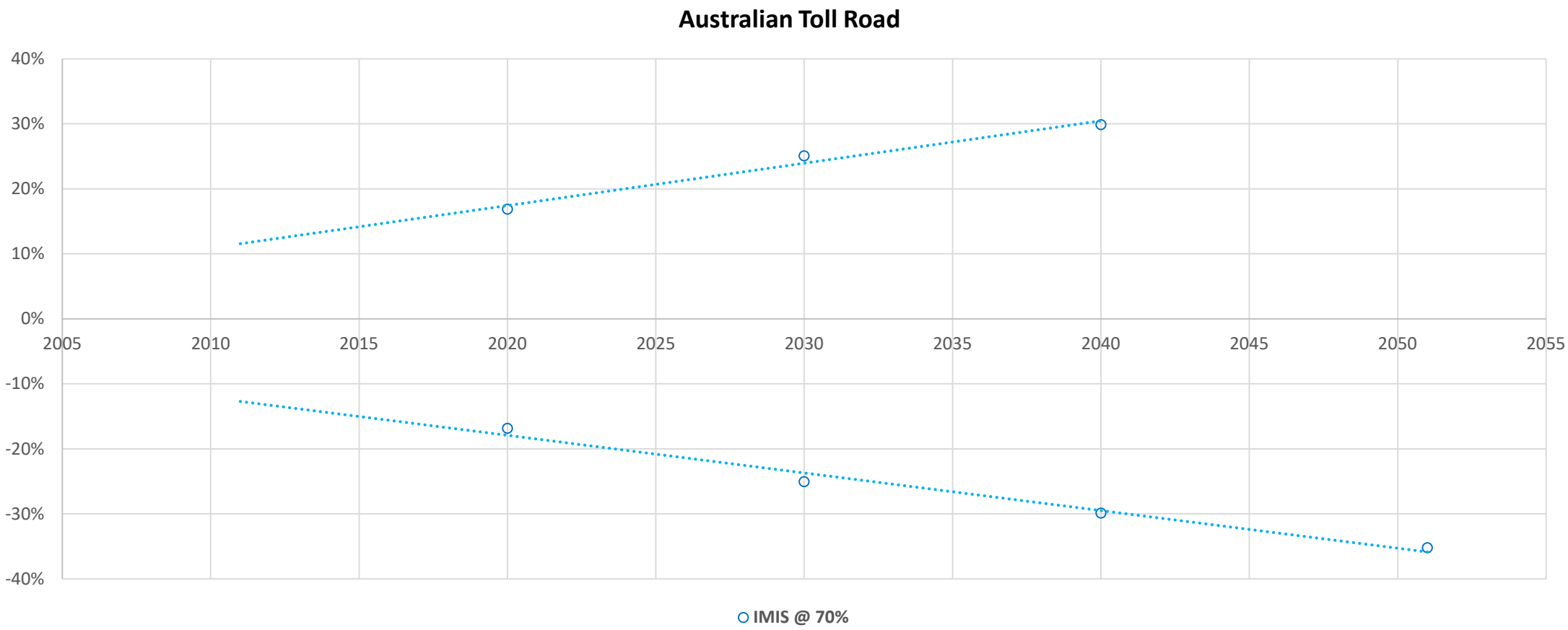


* ±15% for flows of 700-2,700 vph (DfT TAG Unit M3.1, January 2014)

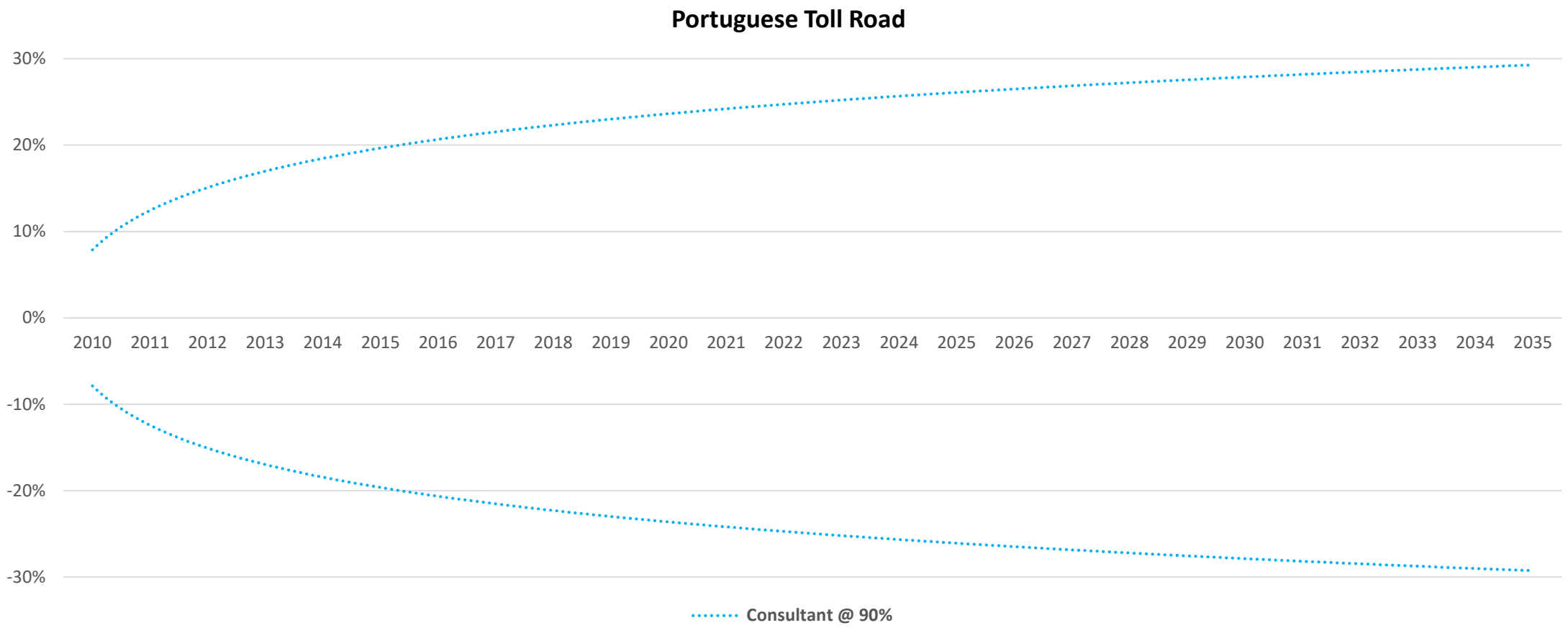
Nonsense!



Monte Carlo Simulation



Monte Carlo Simulation



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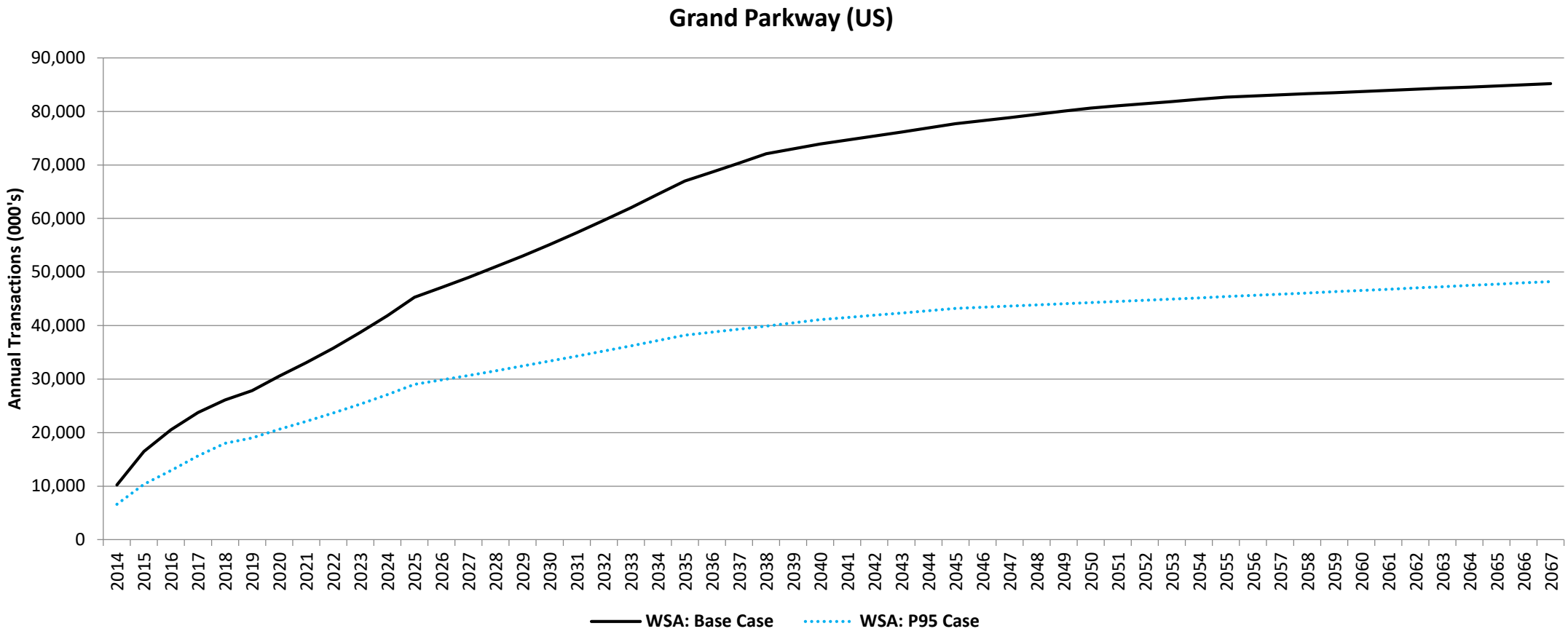

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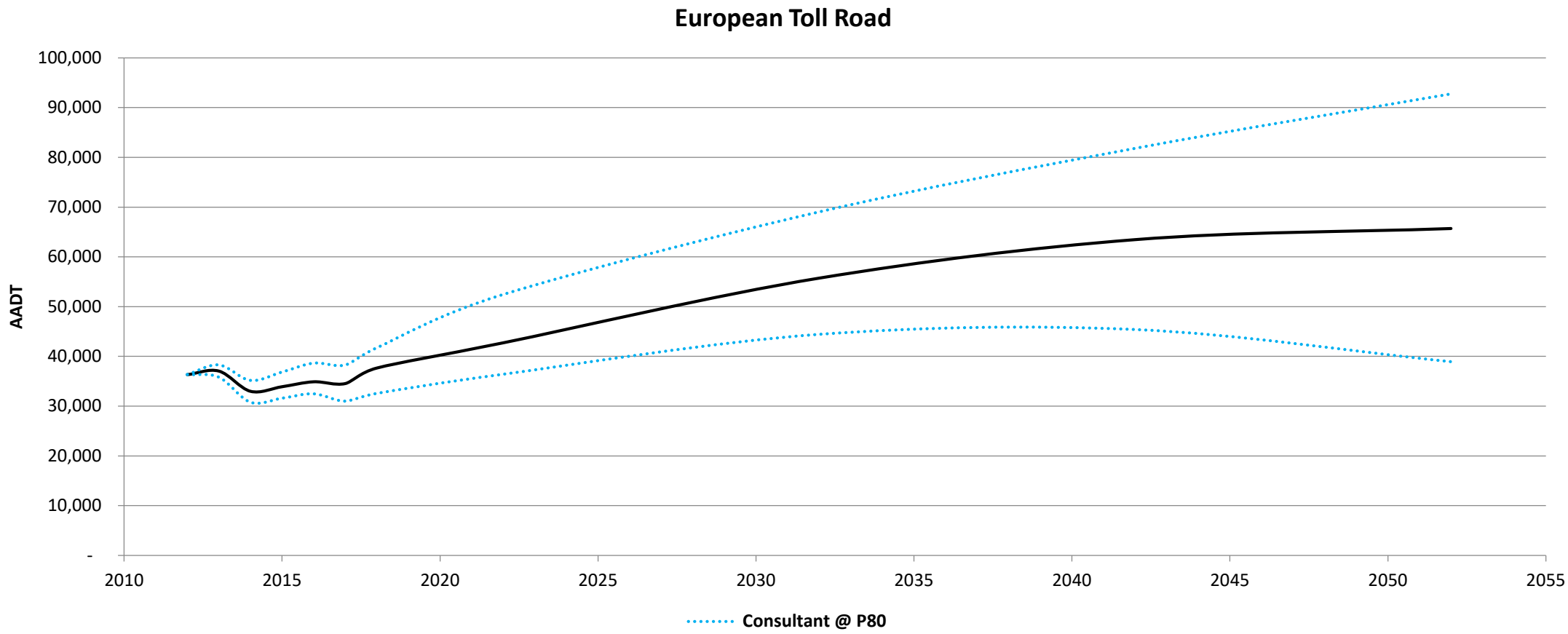

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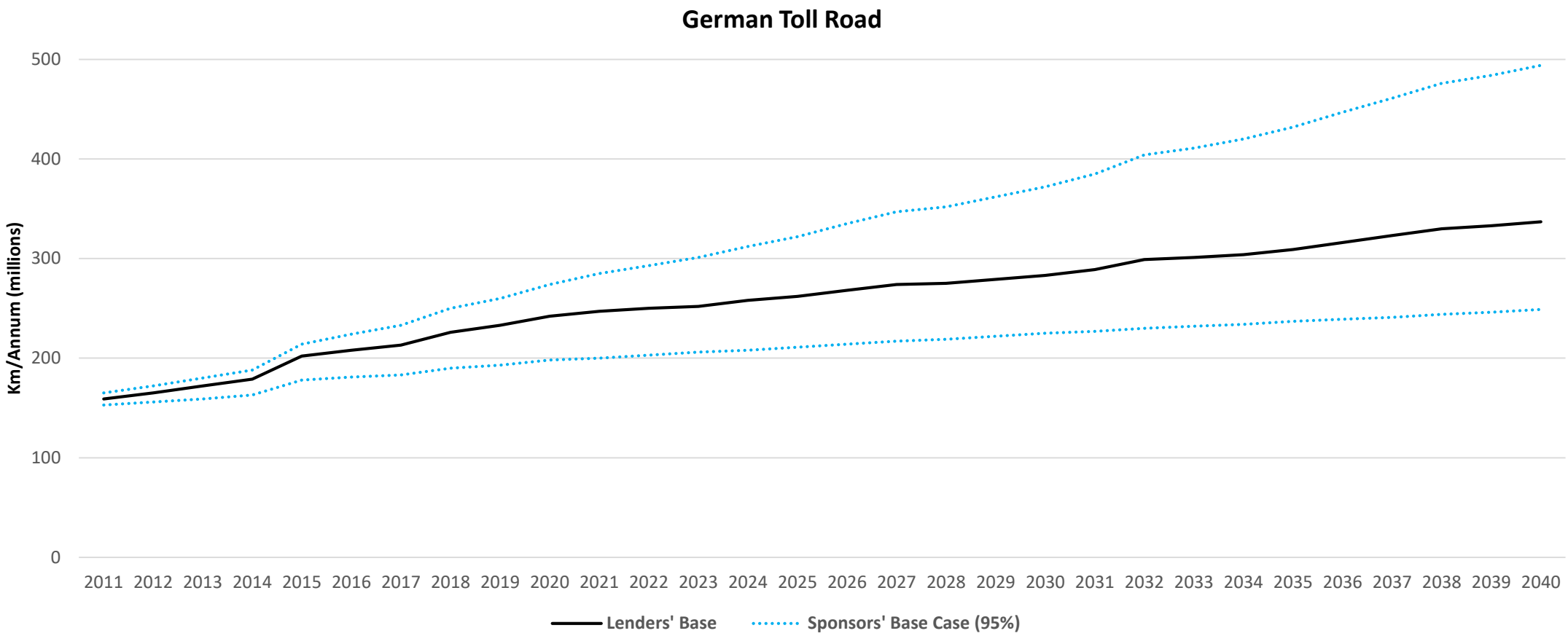

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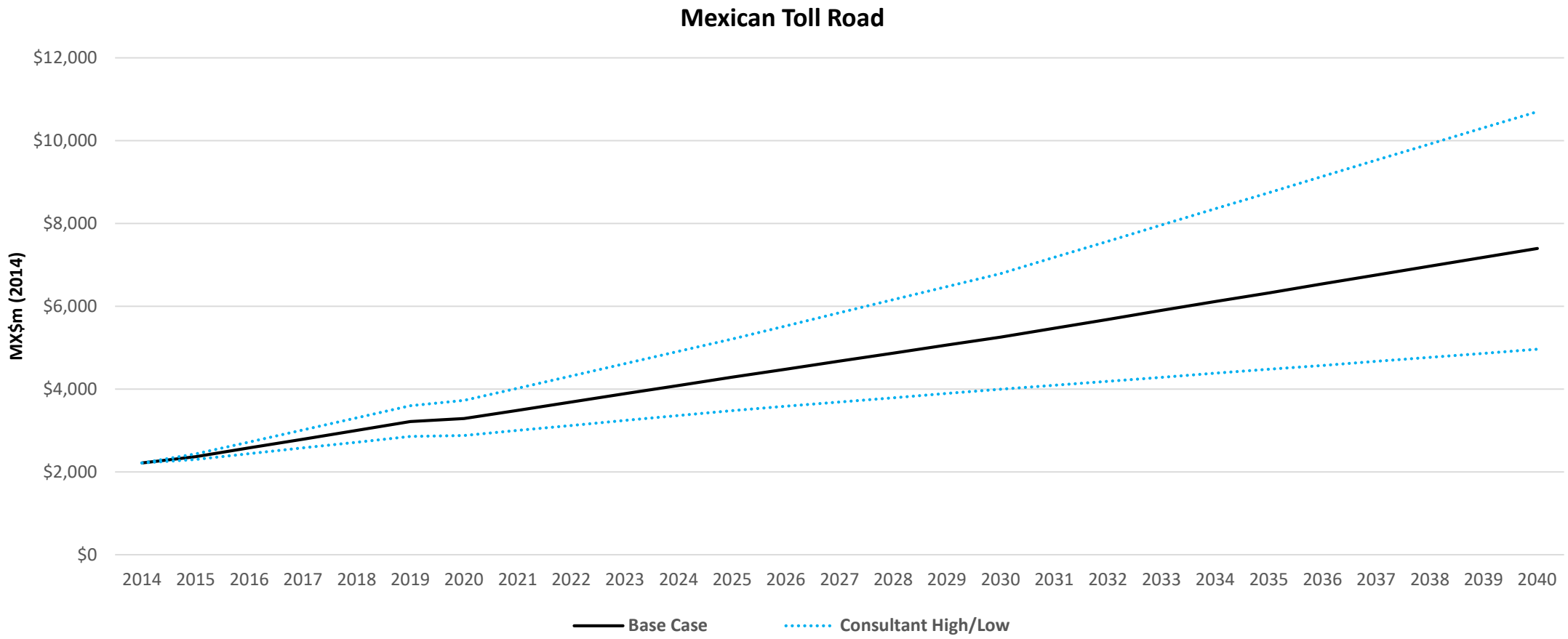
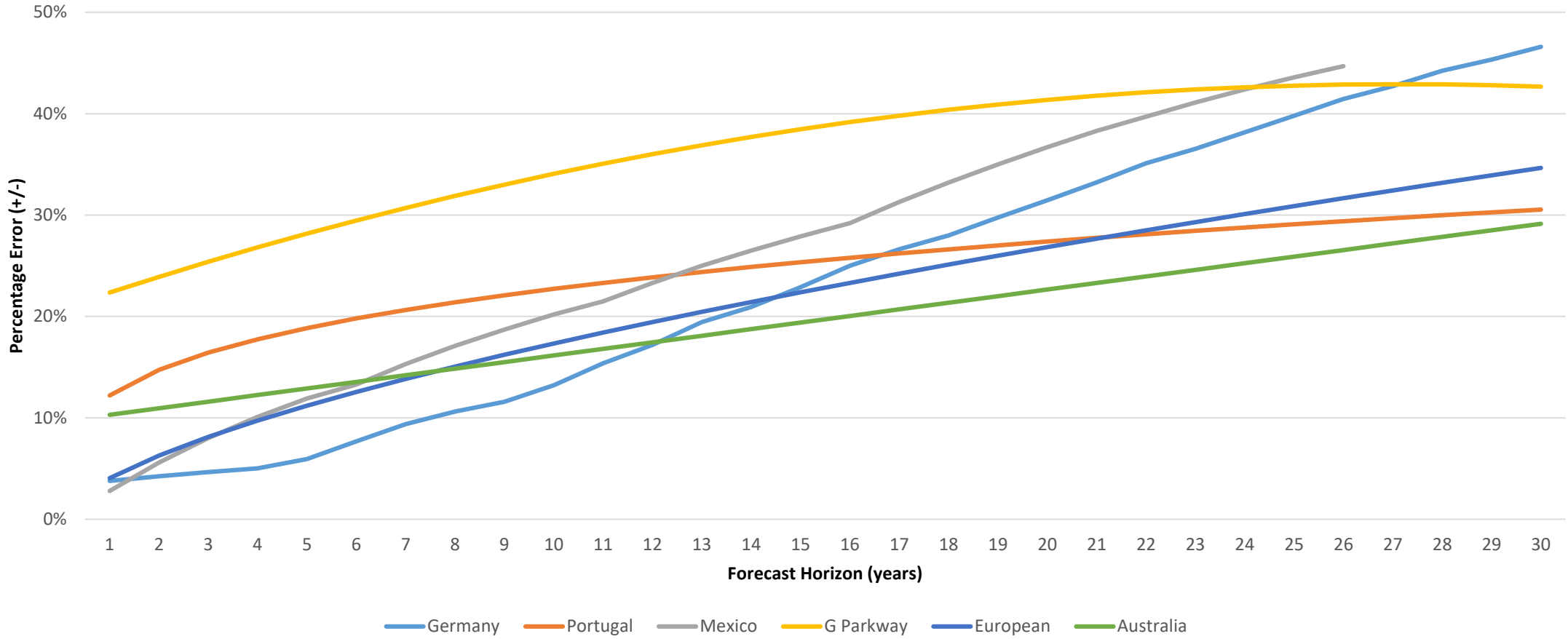


Monte Carlo Simulation: Consolidated



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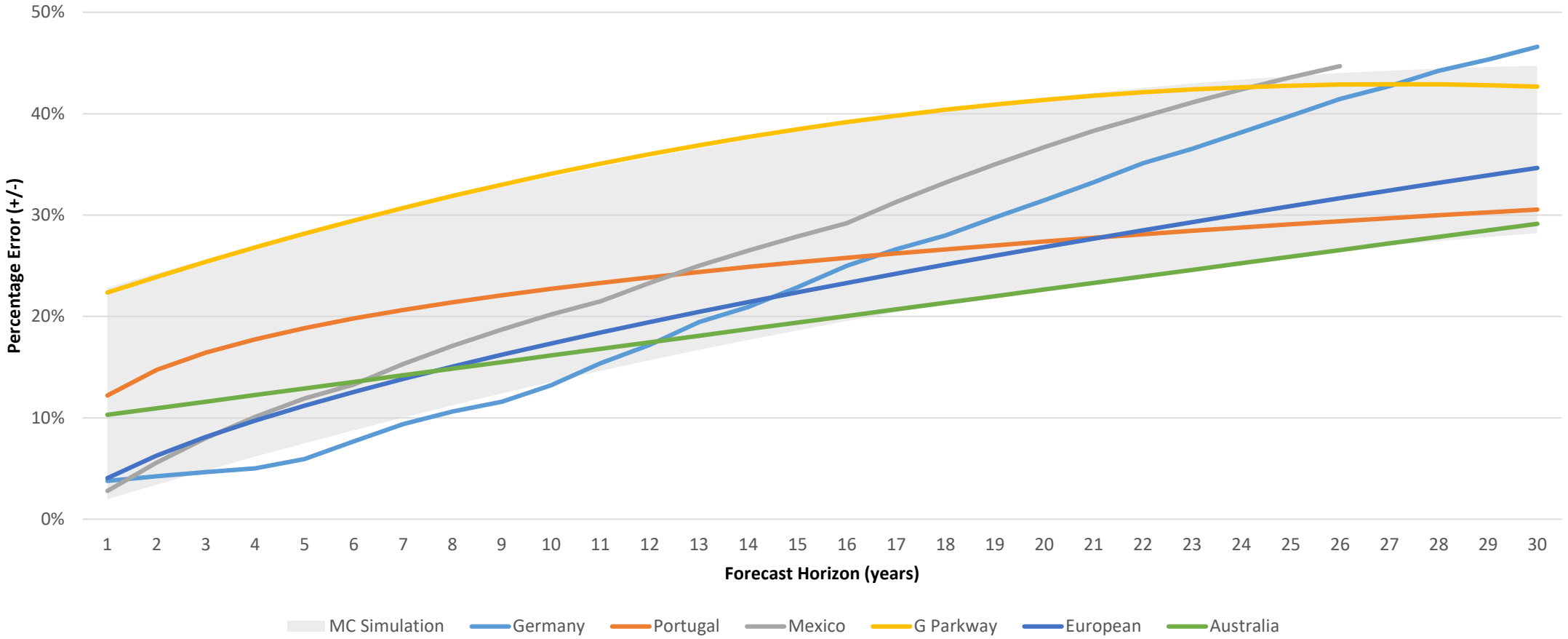

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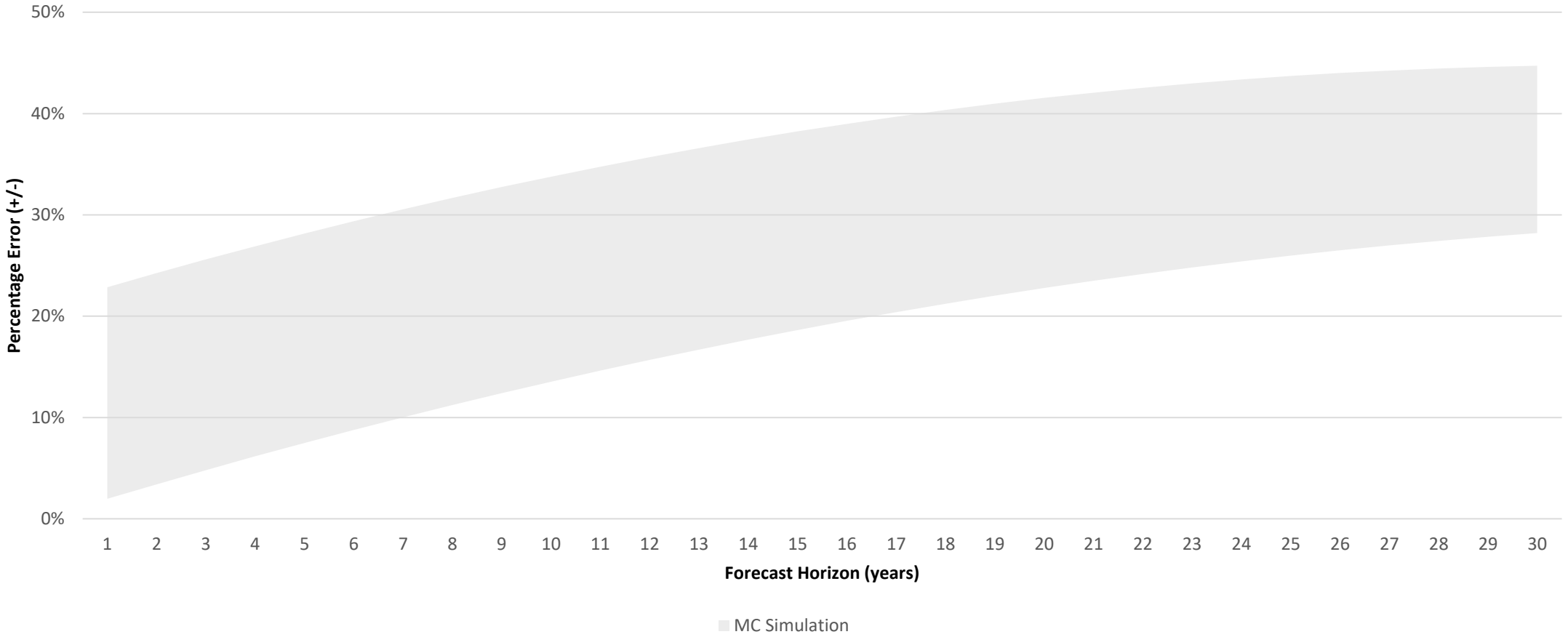

Putting it Altogether

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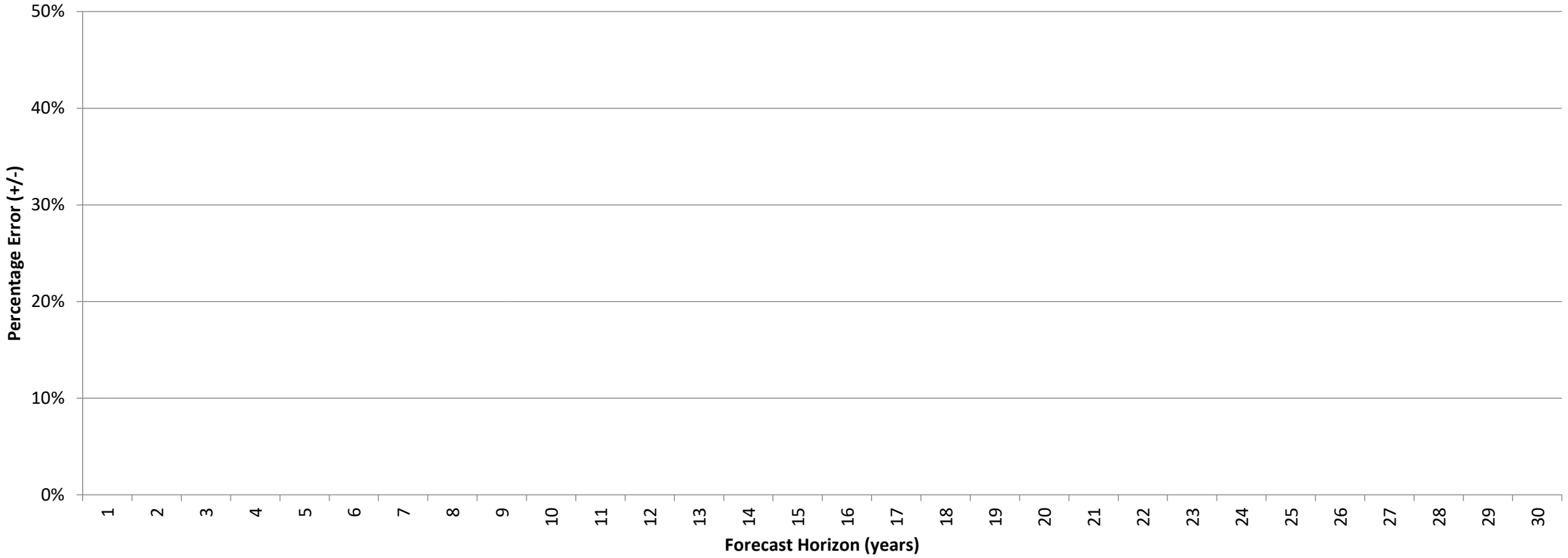

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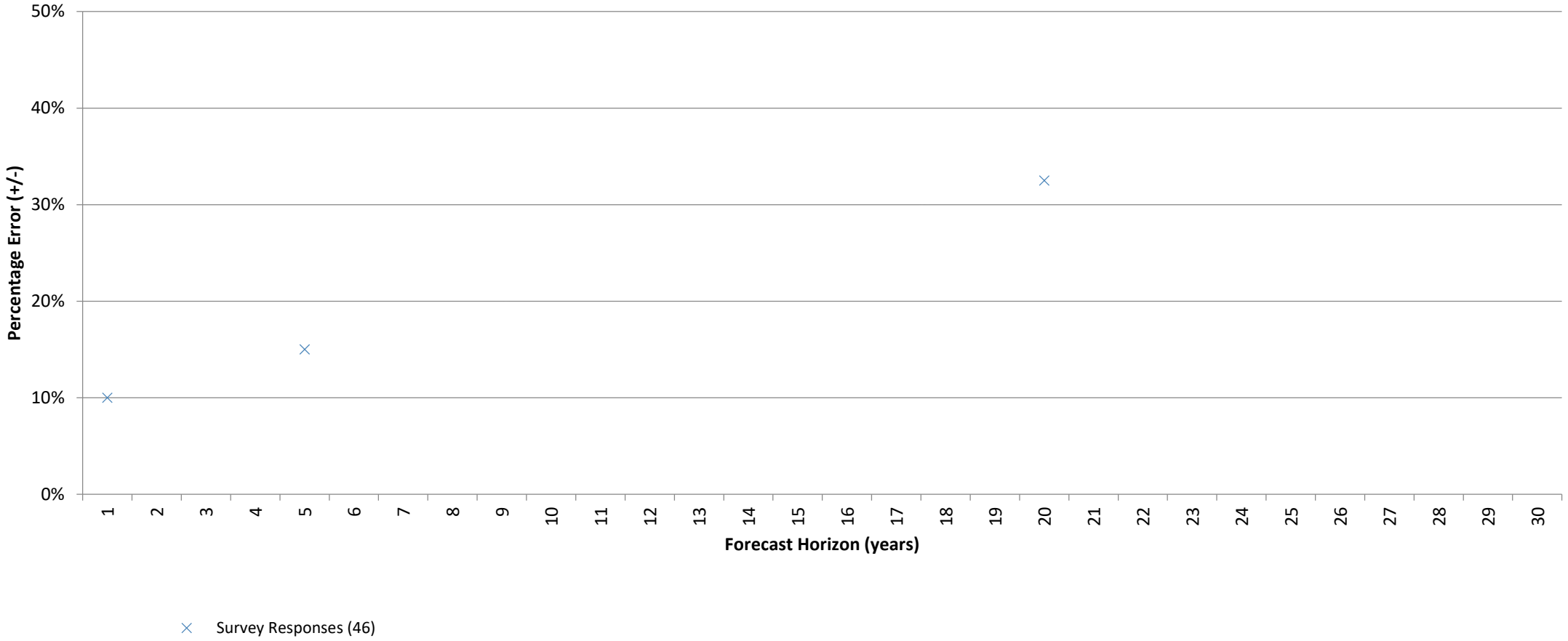

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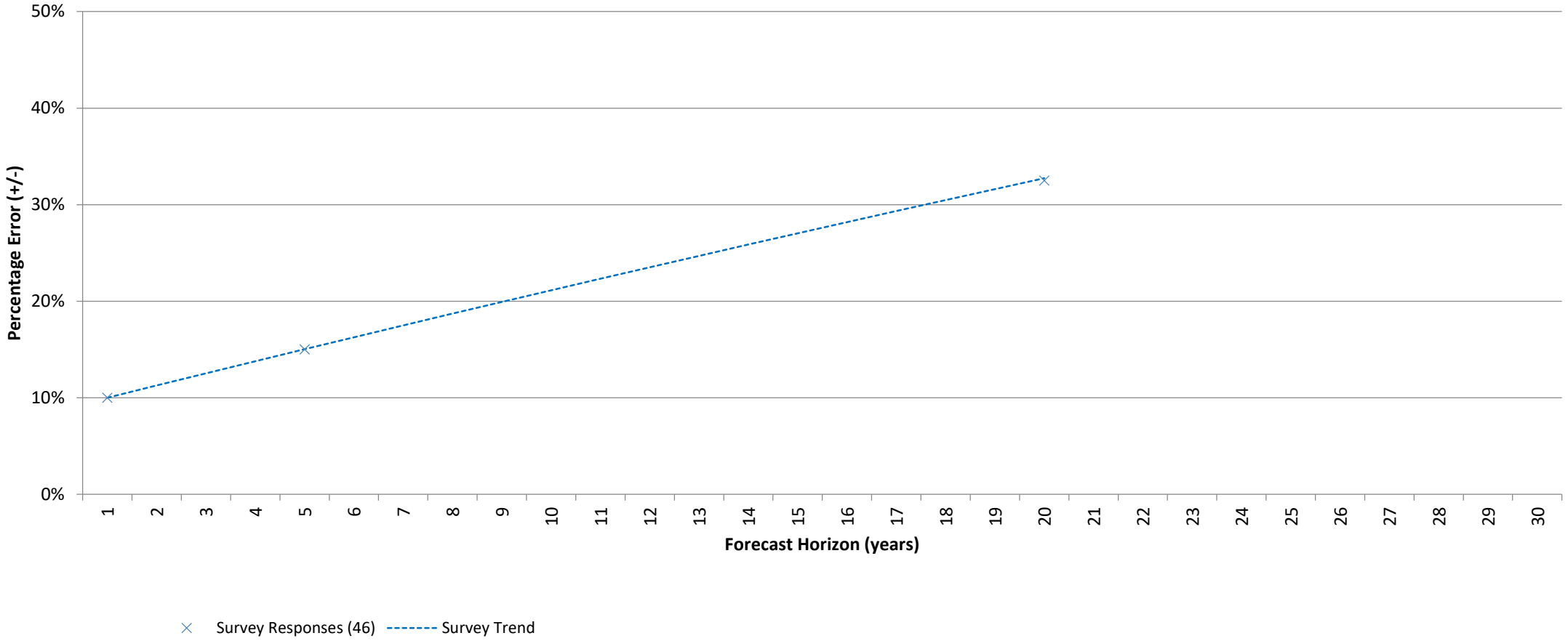

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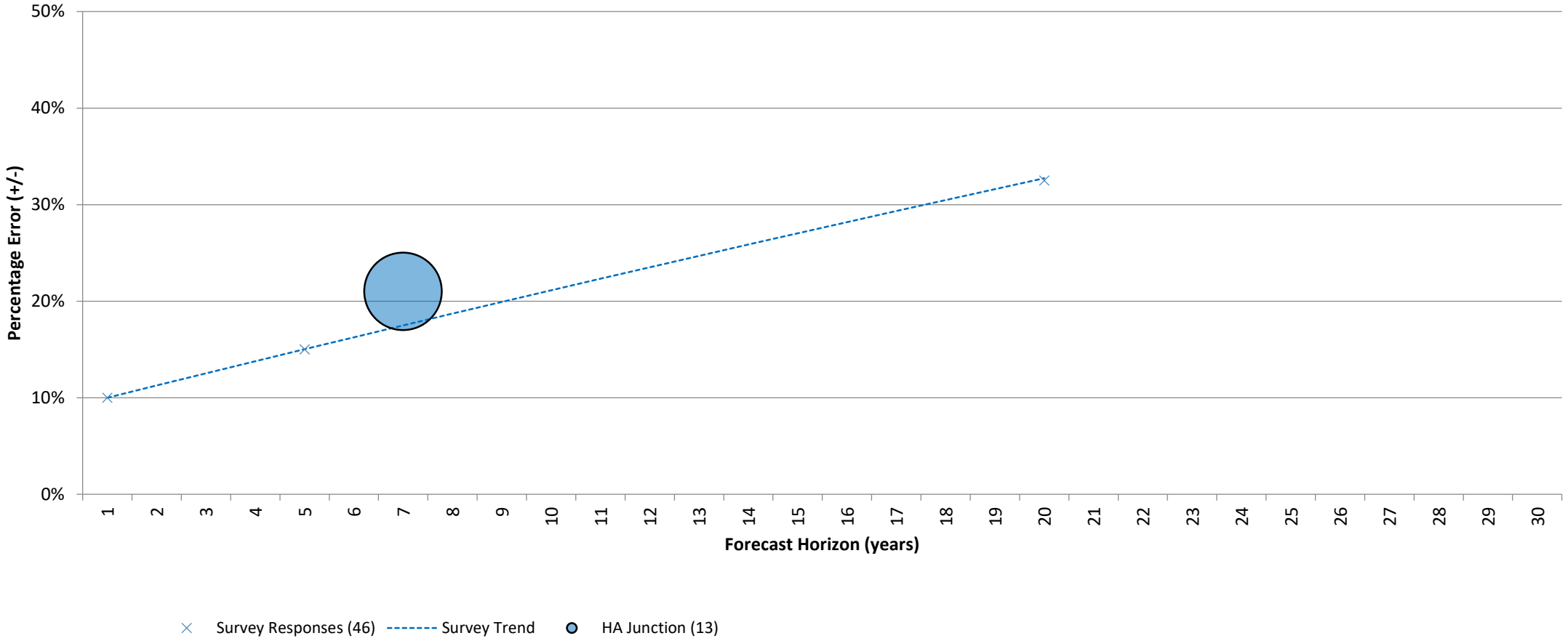

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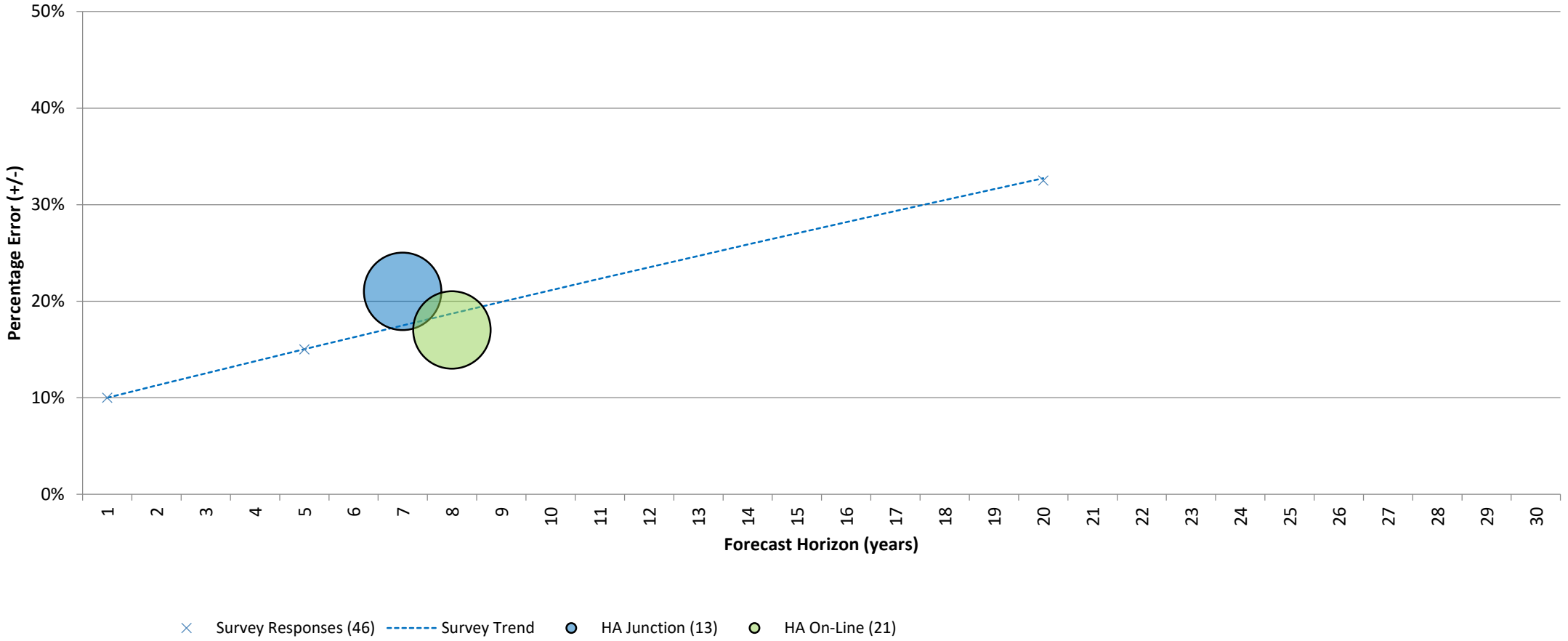

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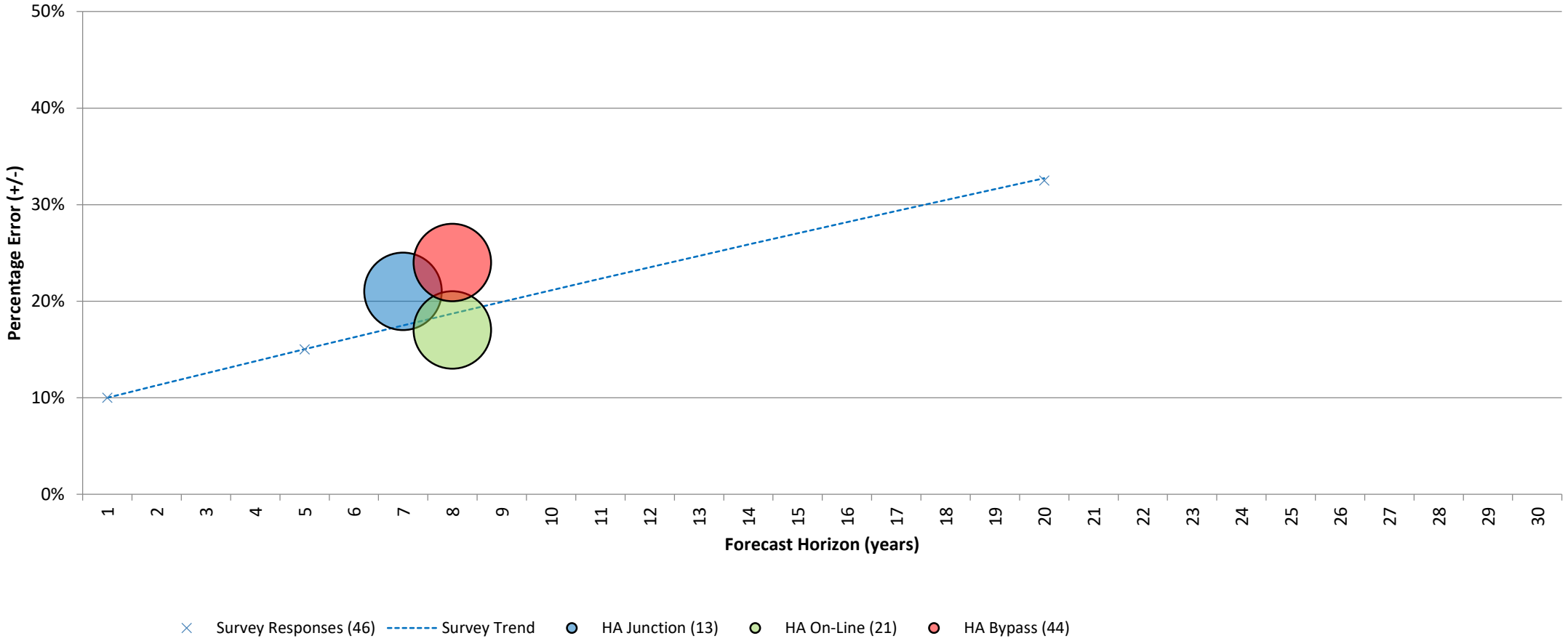

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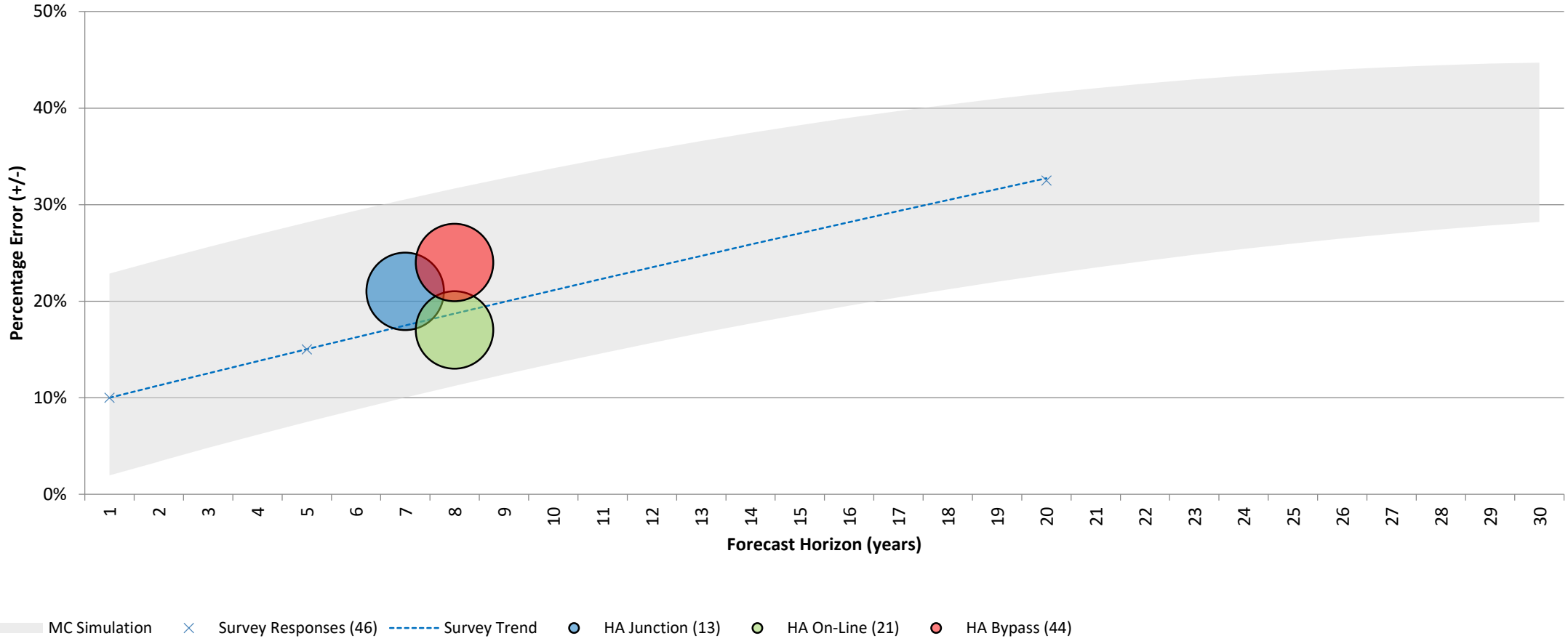

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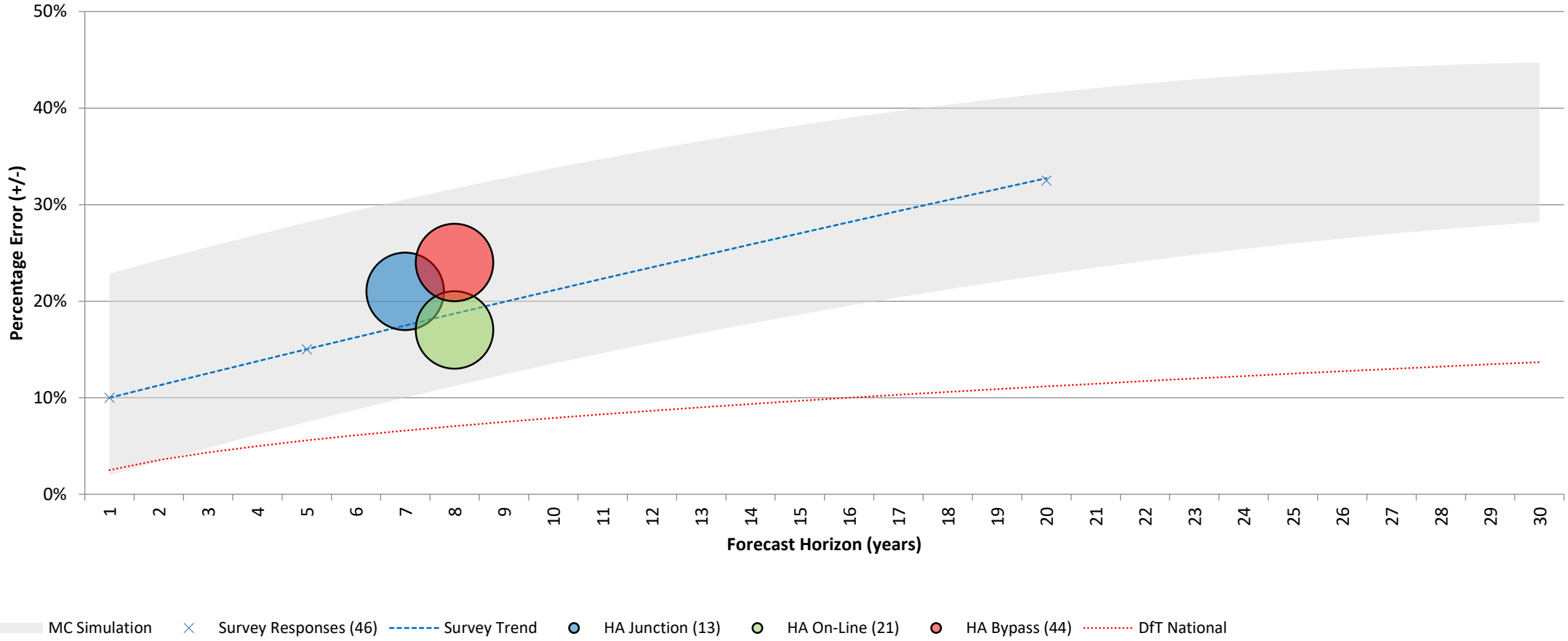

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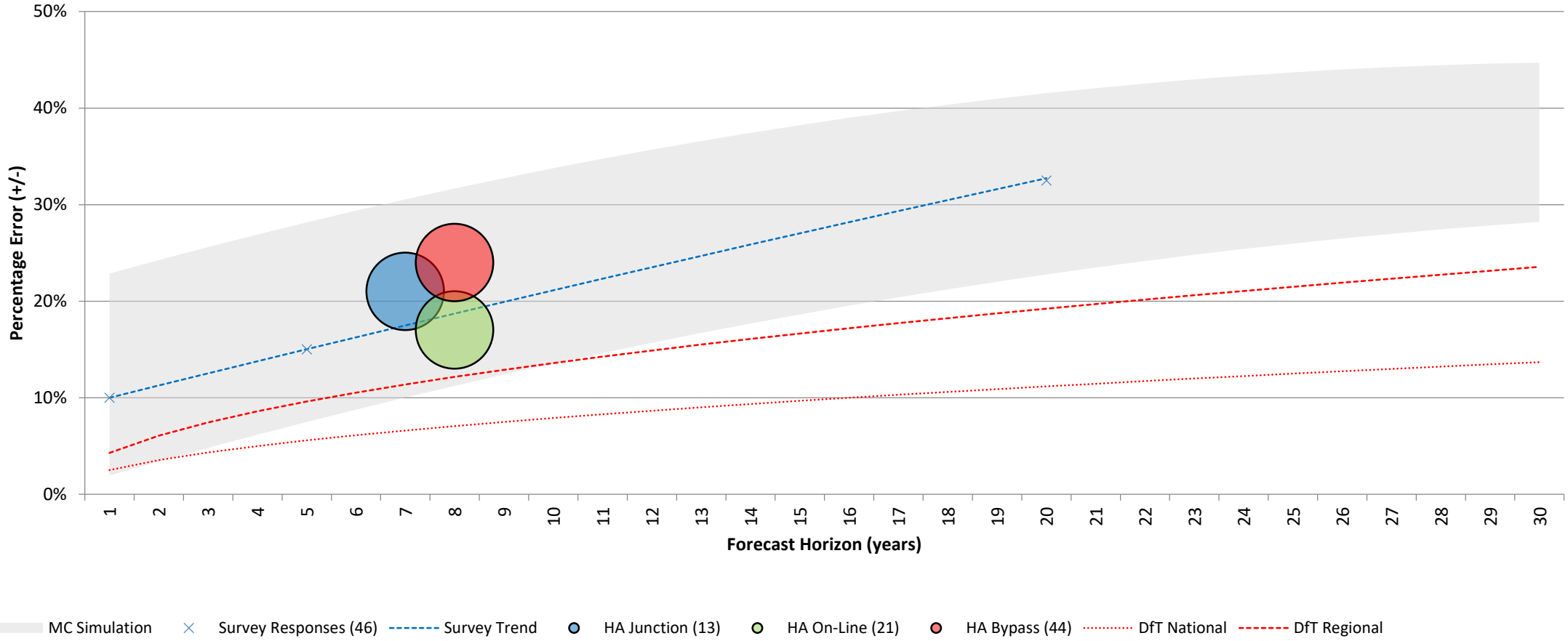

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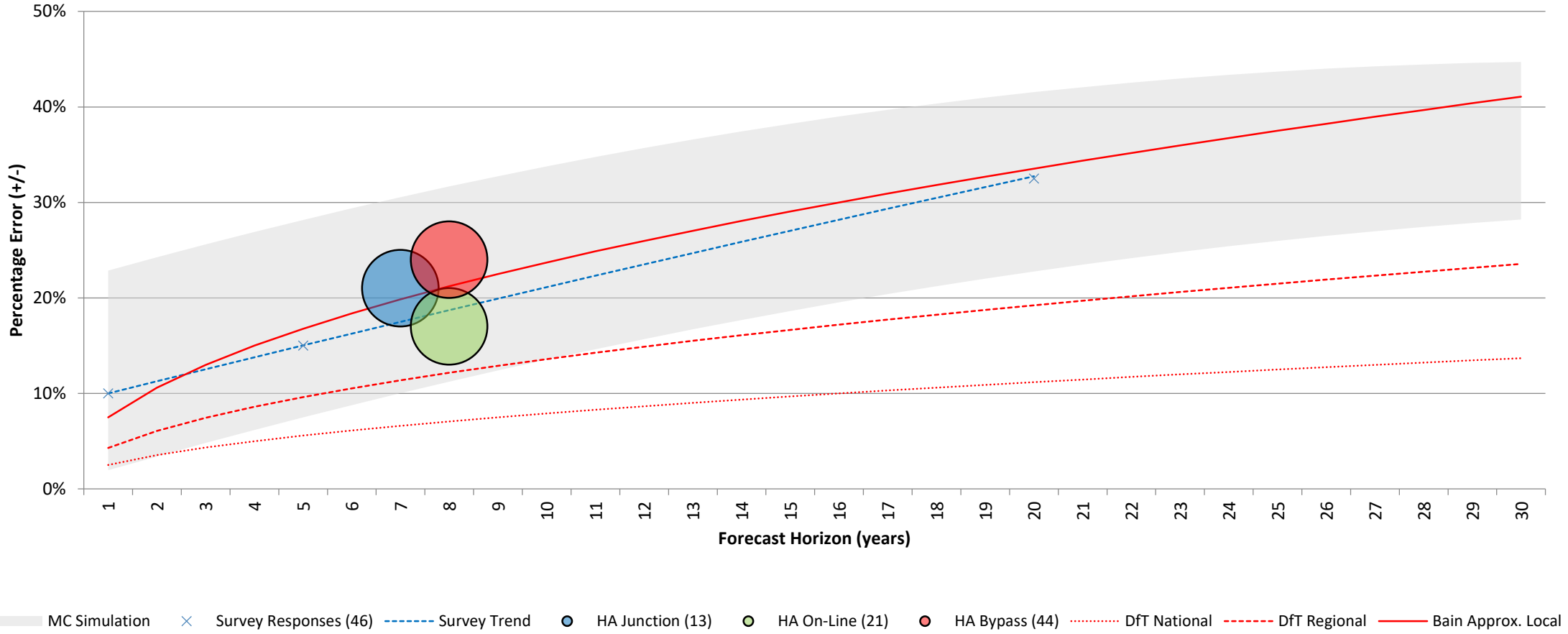

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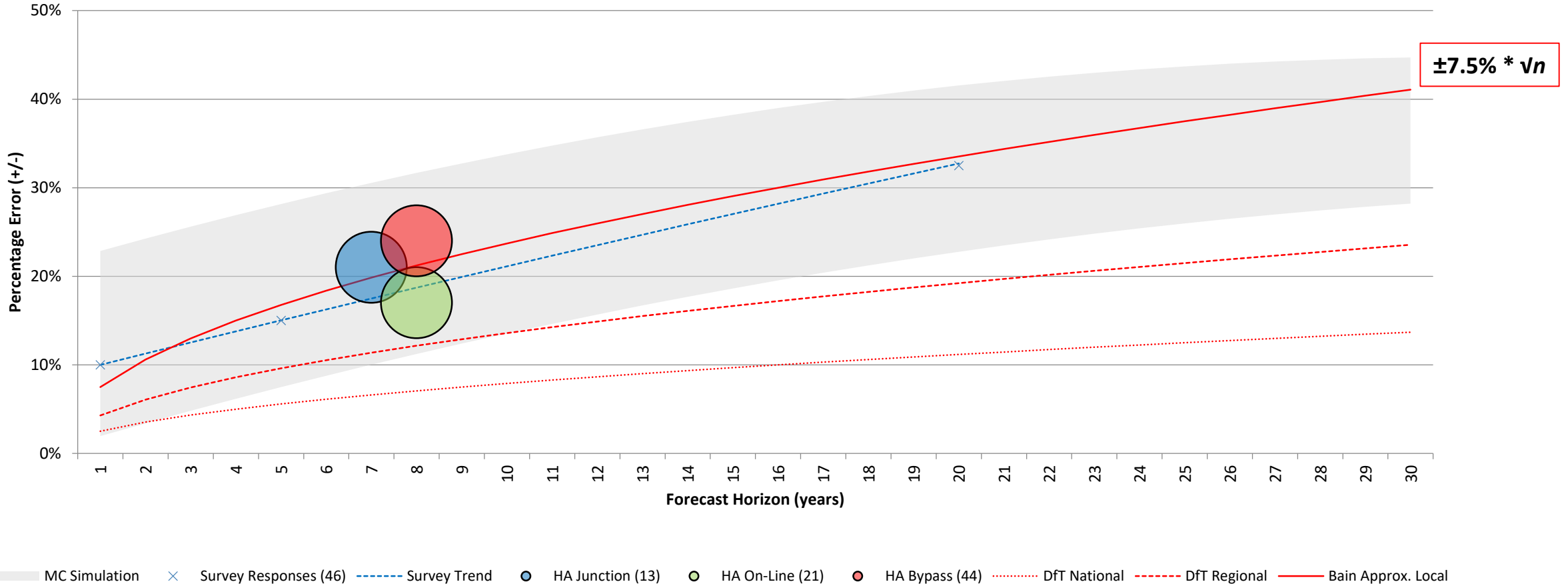


Recap

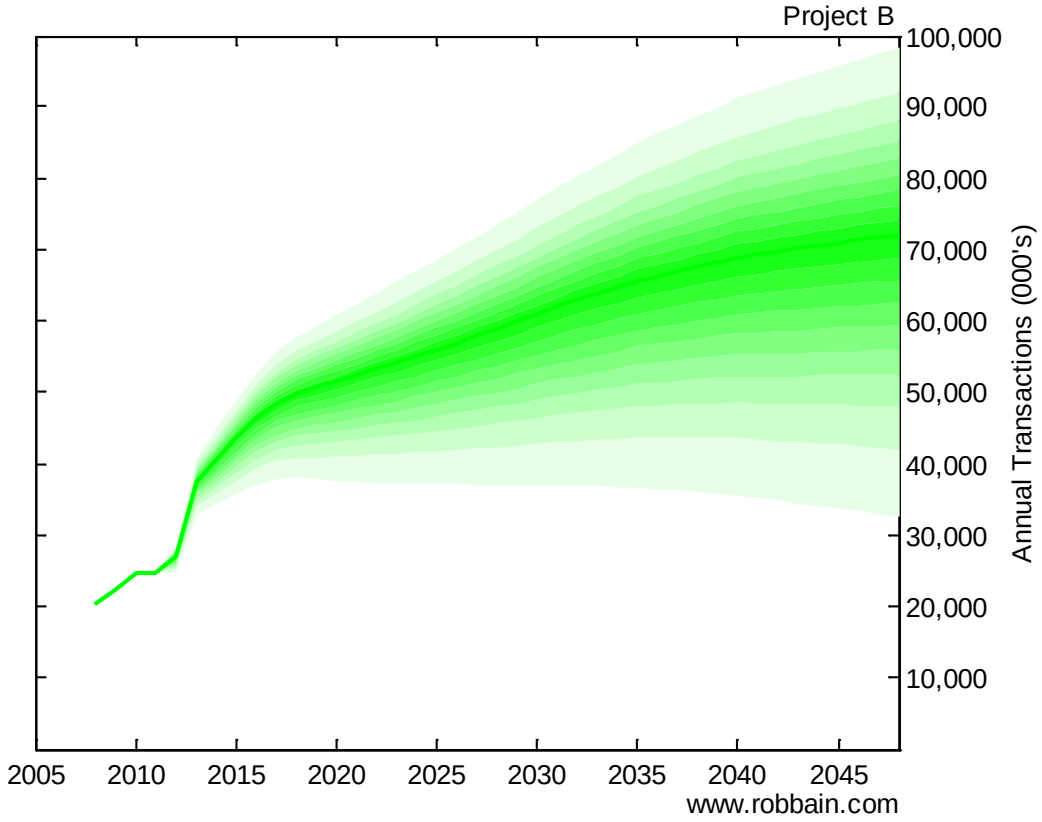
- Predictive reliability (demand forecasting):
  1. We suspect it's poor
     - We're talking about the future, after all!
  2. We know it's poor
     - Bain @ S&P, other international/country studies (US, Spain, Australia), Bain @ EIB, *…
  3. We know why it's poor
     - Models are simplifications of a complex reality
     - Forecasting inputs introduce uncertainties of their own

- So how poor is it (ie. what does 'poor' actually look like)?
  4. DfT provides important insight (at a national level)
     - At the local level it will be even poorer!
     - Nevertheless, a useful and appealing functional form
  5. HA gives local highway scheme data points (±*x*% at Year Y).
  6. Practitioners tell us how poor they actually are!
  7. MC simulation generally supports the emerging shape and form

* In addition, there are many international examples of different consultants coming up with very different forecasts for the same highway project.

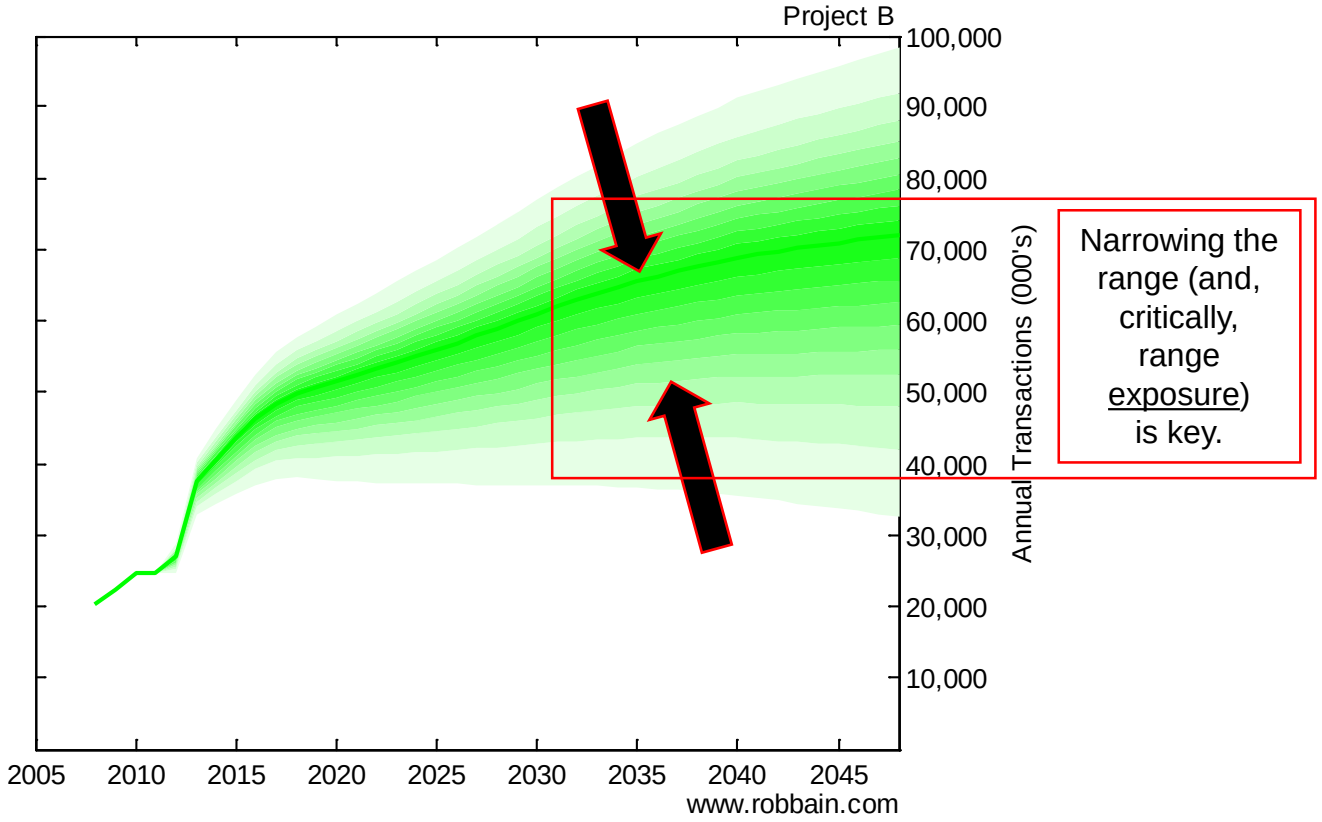
What Traffic Forecasts Should Look Like?

$90\%CI \approx \pm 7.5\% * \sqrt{n}$



Client (ie. Investor) Focus

$90\%CI \approx \pm 7.5\% * \sqrt{n}$



Research Limitations and Shortcomings

- I am the first to acknowledge that
  - Some of my sample sizes are small
  - My approach may *stretch* academic rigor
  - Some of my data is descriptive (rather than quantitative)
  - My 'validation' may suffer from self-serving bias
  - My generalisations may not hold under very different futures
- However, as a practitioner with a focus on applied research
  - I didn't set out to conclude a debate
  - I set out to contribute to one
  - If others can refine or dispute or whatever, bring it on!
    - But please supply evidence in support

Thank You

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