## Accuracy of Traffic and Transit Ridership Forecasts

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How accurate are traffic forecasts?

How accurate are transit ridership forecasts?

Side Bar: What happens when something unexpected shows up?

- US transit ridership declined unexpectedly from 2012-2018. Why?
- Does this trend affect transit ridership forecast accuracy?

How can we quantify uncertainty going forward?













Background on Forecast Accuracy Traffic Forecast Accuracy Transit Ridership Forecast Accuracy

Transit Ridership Decline Estimating Uncertainty

# Background on Forecasts and Their Accuracy

## What makes a forecast "good"?

### Beneficial to the decision-making (Murphy, 1993)

- Sensitive to the policies
- Produce metrics useful to decision making

### Correspondence of the forecasts to the observations?

# Correspondence of forecasts to the observation

Author(s)	Sample	Mean
Mackinder and Evans (1981)	Road: 44	-7%
Pickrell (1990)	Rail: 9	-65%
Flyvbjerg et al. (2006)	Road: 183	+10%
	Rail: 27	-40%
Department for Transportation, UK (2007)	Rail: 19	-37%
Bain (2009)	Toll: 104	-23%
Button et al. (2010)	Rail: 44	-21%
Parthasarathi and Levinson (2010)	Road: 108	+6%
Welde and Odeck (2011)	Toll: 25	-3%
	Road: 25	+19%
Nicolaisen (2012)	Road: 146	+11%
	Rail: 31	-18%
Voulgaris (2019)	Transit: 67	6



Whether the decision would change for a different forecast and would the unselected decision lead to a better outcome. (Voulgaris, 2019)

- Depends on the context
  - Capacity planning
  - Investment planning
- Decision Interval



Source: Anam et al. (2020)



### Metrics:

- Percent Difference from  $Forecast = \frac{Actual Count-Forecast Volume}{Forecast Volume} * 100\%$
- Positive means actual traffic/transit ridership/observation/measurement is higher than forecast
- Negative means observation is lower
- Report Absolute PDF as average deviation

## How accurate are traffic forecasts?





Traffic Forecast Accuracy



2. Transit Ridership Forecast Accuracy 3. Transit Ridership Decline

Estimating Uncertainty



## Contribution to Literature

"The greatest knowledge gap in US travel demand modelling is the unknown accuracy of US urban road traffic forecasts." [Hartgen, 2013]

- 1. Past Studies:
  - Forecasts on toll roads and transit projects are optimistic
  - Not many looked into untolled road traffic forecasts.
  - Small sample sizes for statistically significant analysis
    - Storing forecast information is a proactive exercise
- 2. This study:
  - Employs the largest dataset available
  - Considers forecast accuracy over time
  - Quantifies the effect of the socio-economic variables on forecast performance

References: Pickerell (1990), Flyvbjerg (2007), Odeck and Welde (2017), Nicolaisen (2012), Li and Hensher (2010)



### National Cooperative Highway Research Program (NCHRP) Project 934 Database on Traffic Forecast Accuracy

- Project Information- project type, area, facility type
- Forecast Information- methodology, year forecast produced, forecast horizon, forecast traffic
- Actual Traffic Count- segment and count station information, count itself
- 2600 unique projects, 16000 segments
- 1291 unique projects with 3911 segments have opened and have valid observations





## $~~~\bigcirc~~$ Traffic Forecast Accuracy Over Time



## Traffic Forecast Accuracy Over Time



## Effect of the Great Recession





#### Traffic forecasts are more accurate for:

- Higher volume roads
- Shorter time horizons
- Travel models over traffic count trends
- More recent opening & forecast production years
- Forecast accuracy is affected by macro-economic conditions in the project opening year
  - The Great Recession causing a systemic shift in accuracy
- Forecasts may not capture larger VMT trends

## How accurate are transit ridership forecasts?





Background on Forecast Accuracy 1. Traffic Forecast Accuracy







Transit Ridership Forecast Accuracy 3. Transit Ridership Decline Estimating Uncertainty



## CONTRIBUTION TO Literature

- 1. Past Studies:
  - Transit ridership forecasts are highly optimistic based on projects opening until 2014
  - Most studies had a much smaller sample size
  - Forecasts are observed to be getting better over the years.
- 2. This Study:
  - Has the largest dataset of transit ridership forecasts in the US
  - Has projects that span from 1970s to 2019.
  - Discusses whether the forecast accuracy have been improving through 2019

References: Pickerell (1990), Flyvbjerg (2007), Voulgaris (2019), Schmitt (2016), Button et al. (2003)



Transit Forecasting Accuracy Database (courtesy of Mr. Dave Schmitt, Insight Transportation Consulting, Inc.)

- Project Information- transit mode, opening year, location, fare
- Forecast and observed ridership (average weekday boardings) information
- Model inputs and exogenous forecasts- fuel price, population and employment estimates, roadway congestion estimates
- 164 large-scale transit project, 136 projects with observation within 2 years of opening

## Transit Ridership Forecast Accuracy



### <sup>7</sup> Transit Ridership Forecast Accuracy Over Time

Transit Ridership Forecast





- Optimistically biased, 70% of the projects had ridership lower than forecast
- Forecast performance varies by whether they are produced before 2000 or not\*.
- Better data, preparation and validation of models improved forecast performance since 2000.
- Forecasts for bus rapid transit\*, urban light rail perform better on average than streetcars, commuter and heavy rails\*.
- Projects serving Central Business District (CBD) perform better\*.
- Each year after opening, ridership increases and PDF decreases. So, when we are comparing the forecasts matter.

\* Statistically Significant difference in mean at 90% confidence level



## Side Bar: An Unexpected Journey

# Lessons Learned from Accuracy Assessment

# Determinants of uncertainty in travel demand are multifaceted

- Recession/War
- Auto ownership
- Work from home
- Presence of ride-hailing (Uber/Lyft) and ride-sharing (dockless bike and scooter share)
- Connected and autonomous vehicles

## Transit Ridership Over the Years



#### The decline is:

- Widespread
- During a period of economic growth
- In contrast to most other countries

## Transit Ridership by Mode Over the Years





# Transit Ridership Supply by Mode Over the Years





### Why Public Transit Ridership in the US Has Declined Between 2012 and 2018?







Backgroun d on Forecast Accuracy

Traffic
Forecast
Accuracy

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Transit Ridership Decline

2. Transit Ridership Forecast Accuracy



Estimating Uncertainty Using Quantile Regression





References: (Mahmoud and Pickup 2019; Chakrabarti and Giuliano 2015; Nowak and Savage 2013; Maley and Weinberger 2009;; Brakewood, Macfarlane, and Watkins 2015a; G. D. Erhardt et al. 2021 etc.

# Forecast Performance if Adjusted for the Decline in 2012-2018



# Forecast Performance if Adjusted for the Decline in 2012-2018



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### How can we quantify uncertainty going forward?







Backgroun d on Forecast Accuracy **1**. Traffic Forecast Accuracy

2. Transit Ridership Forecast Accuracy



3. Transit Ridership Decline

#### **Quantifying Uncertainty**





#### Proposed by Bain, 2011

#### Constructed using survey results

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%



## Contribution to Literature

- Existing methods:
  - sensitivity testing (Kriger, Shiu, and Naylor 2006; Briggs et al. 2012),
  - scenario analysis (Davidson 2014; Lyons and Davidson 2016; Lyons and Marsden 2019),
  - Monte Carlo simulation (Lemp and Kockelman 2009; Aldrete et al. 2010; de Jong et al. 2007; Manzo, Nielsen, and Prato 2015a; 2015b)
- This study:
  - Demonstrates a use of Reference Class Forecasting theorized in Ascher (1979), Kahneman and Tversky (1977), Flyvbjerg (2007)
  - Proposes quantile regression methods to quantify uncertainty using past accuracy

## Sensitivity Testing/Scenario Analysis





#### Assumptions about the range of inputs.

## Uncertainty in the input data propagates through the model

Much higher run time on an already time-intensive process.

## Our proposal: Accuracy and Uncertainty



## 

The other option of producing better forecasts is employing what (Ascher, 1979) calls "outsider's approach" and Kahneman and Tversky (1977) calls "reference class forecasts".



Using the base-rate and distribution results from similar situations in the past to adjust forecasts.

# How to Generate Uncertainty Envelopes

## Create uncertainty envelopes around forecasts using empirical evidence of past accuracy

- Considers the spread of the variables inducing bias
  - Traffic forecasts by roadway functional class or project type (new construction, existing roadway)
  - Transit ridership forecasts by locality type (transit or auto oriented, high or low population density) or project type (rail or bus route development) etc.

# Quantile Regression – A method to both measure accuracy and estimate uncertainty envelopes

Draw line through the middle of the cloud: **regression**.

Draw a line along the edge of the cloud: **quantile regression**.

Minimizes the Median Absolute Deviation, so that (1-x)% errors are positive, and x% are negative for x-th quantile



Draw lines so 90% of dots are between the lines



#### Simple Model

- Observation as a function of Forecast
- Detects bias

#### **Inference Model**

- Observation as a function of forecast as well as other statistically significant explanatory variables
- Performance Metric

#### **Forecasting Model**

- Observation as a function of forecast as well as other statistically significant explanatory variables that are known at the time of forecast.
- Uncertainty envelope

### Traffic Forecast Uncertainty Envelope- Example



The project is a new construction project on a Minor Arterial

Forecast is done using a travel demand model.



For a Forecast of 30,000 the 5<sup>th</sup> and 95<sup>th</sup> percentile value of the expected traffic are 19,000 and 41,000 respectively

## Transit Ridership Forecast Uncertainty Envelope

### Light rail project opening in 2021 Light Rail project Forecast produced in 2017 for 2019, i.e. forecast horizon of 2 years

Serves CBD

Observation in 2021, i.e. 2 year ramp up



For a forecast of 15,000 average weekday ridership, the actual ridership can be expected to be between 2,000 to 27,000





**Traffic Forecasting Accuracy** Assessment Research

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## **Questions!**