IS602 – Spreadsheet Modelling for T&O Decisions

Project Report: COE Pricing Model

G1 Group 4 Members:

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1   Problem Statement

To alleviate congestion in Singapore, the government controls the car population using the Certificate of Entitlement ("COE") system. This quota-based license system requires car owners to bid for a COE[1]. The price of the COE (i.e., the price of the bid) depends on: -

- Car's growth rate,
- Supply of COEs, and
- Demand of COEs

While demand is subjected to market forces, vehicle growth rate and supply of COE are largely dependent on government policy. In addition, Singaporeans' desire to own a car for convenience and as a symbol of success and status will continue to fluctuate the COE prices.

So, is it possible to time the market to get a car at low COE price?

In this model, COE quota and demand were used to predict the COE price between 2020 - 2024. The forecasted price was determined by using historical i) COE demand and supply; and ii) deregistration and revalidation data.

The model could assist consumers' decision to purchase a car, by optimizing their financial decisions based on the predicted COE pricings.

2   Data Sources

The data used was extracted from the following government data sources: -

*T*able 1: Data Sources

Data Name	Links
COE Biddings Results	Land Transport Authority: <u>Certificate of Entitlement (COE) Bidding values</u>
COE Premium	Data.gov.sg: <u>Certificate of Entitlement (COE) Bidding Results</u>
Monthly Deregistration	Data.gov.sg: <u>Monthly Deregistered Motor Vehicles under Vehicle Quota System (VQS)</u>
Monthly Vehicle Population	Data.gov.sg: <u>Monthly Motor Vehicle Population by Vehicle Quota Category</u>
Monthly New Registration	Data.gov.sg: <u>Monthly New Registration of Motor Vehicles by Vehicle Quota Categories</u>
Vehicle Growth Rate	Mot.gov.sg: <u>Vehicle Ownership Controls</u>
Monthly Revalidation of COE of Existing Vehicles	Mytrasnsport.sg: <u>Vehicle Registration</u>

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[1] COE bidding is done on the first and third week of the month.

3   Black Box Model and Influence Diagram
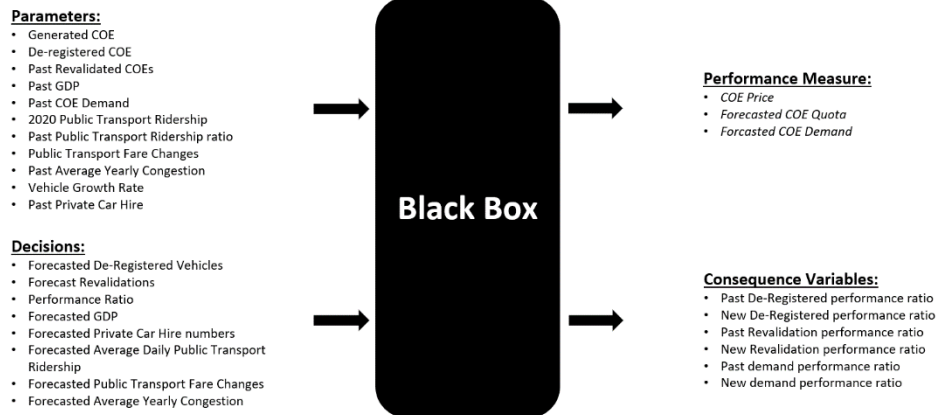
Figure 1: Black Box Model

Parameters:
- Generated COE
- De-registered COE
- Past Revalidated COEs
- Past GDP
- Past COE Demand
- 2020 Public Transport Ridership
- Past Public Transport Ridership ratio
- Public Transport Fare Changes
- Past Average Yearly Congestion
- Vehicle Growth Rate
- Past Private Car Hire

Decisions:
- Forecasted De-Registered Vehicles
- Forecast Revalidations
- Performance Ratio
- Forecasted GDP
- Forecasted Private Car Hire numbers
- Forecasted Average Daily Public Transport Ridership
- Forecasted Public Transport Fare Changes
- Forecasted Average Yearly Congestion

Black Box

Performance Measure:
- *COE Price*
- *Forecasted COE Quota*
- *Forecasted COE Demand*

Consequence Variables:
- Past De-Registered performance ratio
- New De-Registered performance ratio
- Past Revalidation performance ratio
- New Revalidation performance ratio
- Past demand performance ratio
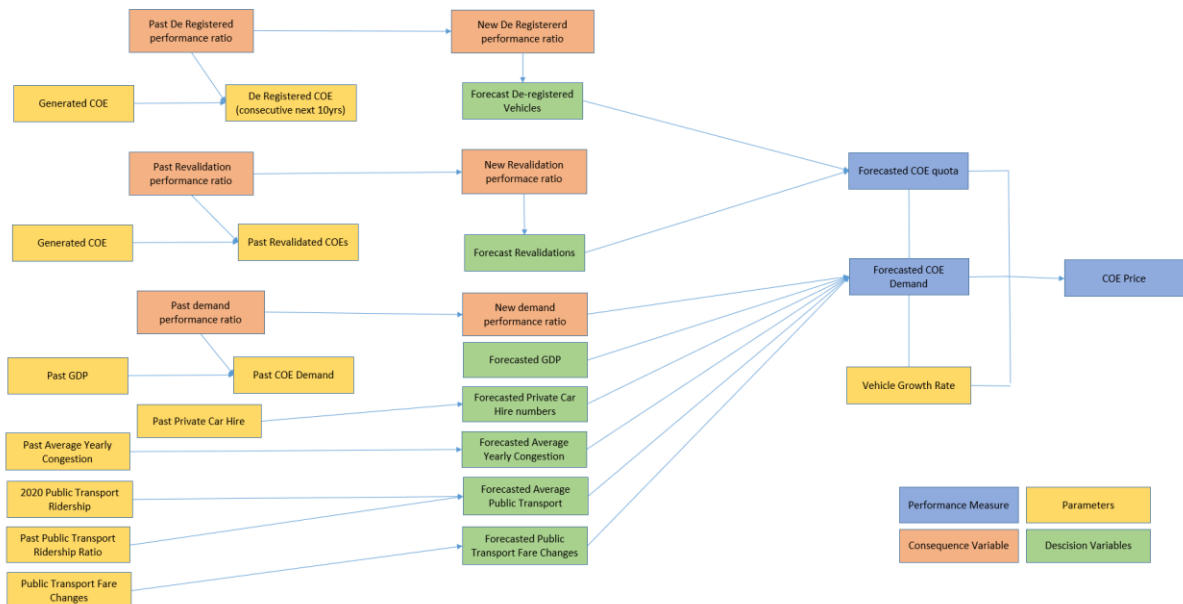- New demand performance ratio

Figure 2: Influence Diagram

4   Model Computation and Analysis

Using historical data, sub models i) Deregistered Motors; ii) Number of Revalidated Vehicles; and iii) COE Demand were created, to forecast the respective values using appropriate methods like the trend function and forecast formulae. Based on these forecasted values, the relationship between the number of COE allotted, demand and price were determined to forecast COE prices and quota.

In the final query function, users will be able to choose their preferred bidding month/year and input the government's assigned annual growth rate. The model returns the respective COE price and COE quota.

4.1 Analytical approach and techniques

4.1.1 Deregistered Vehicles

COEs are valid for 10-years[2], and vehicle owners de-register their vehicles and obtain a new COE. To understand the trend of deregistering vehicles, a performance ratio was calculated by dividing i) COEs generated in the preceding 10years, over, ii) the number of deregistered motors at the end of a 10-year window. This was used to first forecast the performance ratio for 3Q20 to 4Q24 by using the trend function. Thereafter, the predicted deregistered motors for 3Q20 to 4Q24 were calculated by dividing the COEs generated during the preceding 10 years of 3Q20 to 4Q24 with their respective performance ratios.

Historical figures noted that the lowest number of de-registrations occurred during Circuit Breaker in April 2020 – July 2020. Future trends suggest that suggest that Cat A de-registrations would fluctuate more than Cat B. A smaller range of fluctuations could reduce the likelihood of feast or famine COE prices.

Figure 3: Prediction of Deregistration of COE for both CAT-A & CAT-B till 2024
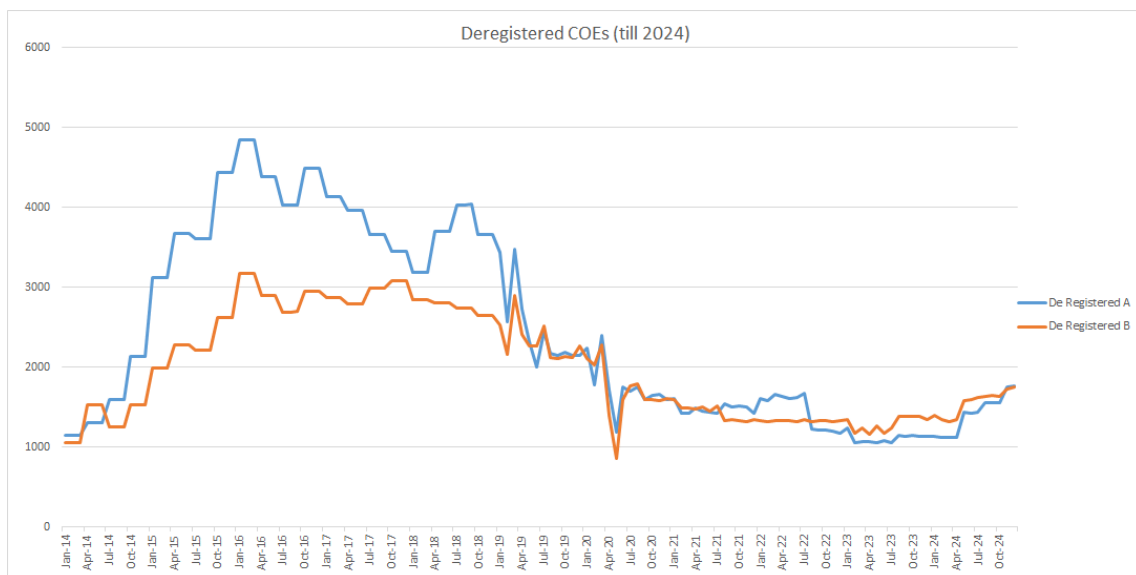
4.1.2 Number of Revalidated Vehicles

The same analysis method was used for Deregistered Motors and Revalidations. As opposed to new COEs, vehicle owners do not need to bid to revalidate COEs. This absorbs some COE quota, decreasing the number of new COEs in the market. To understand the trend, a performance ratio was derived by dividing i) COEs generated in year 2004-2009, over, ii) revalidations in year 2015-2020. The future performance ratio was predicted using the trend function. The forecasted performance ratios were used to predict the COE Revalidations.

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[2] New COEs are valid for 10-years. Expiring COEs can be extended.
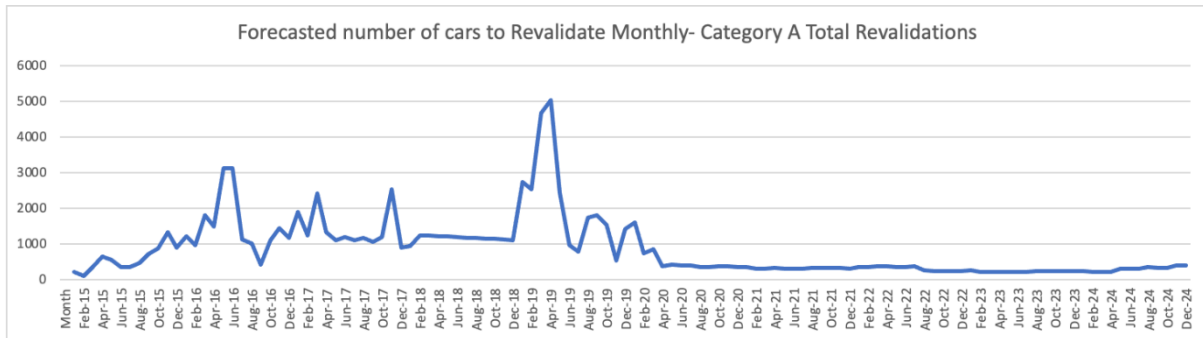
Figure 4: Prediction of Revalidation of COE

Forecasted number of cars to Revalidate Monthly- Category A Total Revalidations

Figure 5: Prediction of Revalidation of COE

Forecasted Total Revalidations - Category B

The model suggests a sharp decline in Revalidated COEs between January 2020 to April 2020. This could add to new COE demand and increase COE prices. The sharp decline could be credited to the economic uncertainty that arose from Covid -19[3].

Other factors that may impact owners' decision to revalidate their COEs, such as, cost of car maintenance, were not considered in this model.

4.1.3 COE Demand

The forecasted COE Demand was calculated taking the following factors into consideration.

a. GDP/Capita
b. Performance ratio: (Bids Received)/ (GDP per Capita)
c. Private car hire numbers
d. Average daily public transport ridership
e. Public transport fare change
f. Yearly average congestion

Most of the data were sourced via open-source government databases and sources. In addition, performance ratio was calculated by dividing Bids Received by the GDP per Capita. Forecasted GDP/Capita data was sourced online and the rest of the factors were forecasted based on their past trend while excluding 2020 data due to its anomalous nature.

Figures 6 and 7 below show the model and demand chart for Category A vehicles while Figure 8 shows the demand chart for Category B vehicles, which is derived from a similar model with different bids received. "Bids Received" were forecasted from November 2020 onwards for both categories.

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[3] Ref: <u>Anticipating the Covid impact on COE Prices</u>

The forecasted demand was obtained by multiplying the forecasted data to their respective coefficients taken from the regression analysis run on past data and adding the intercept coefficient. The formula is seen at the top of Figure 6 in the red box.

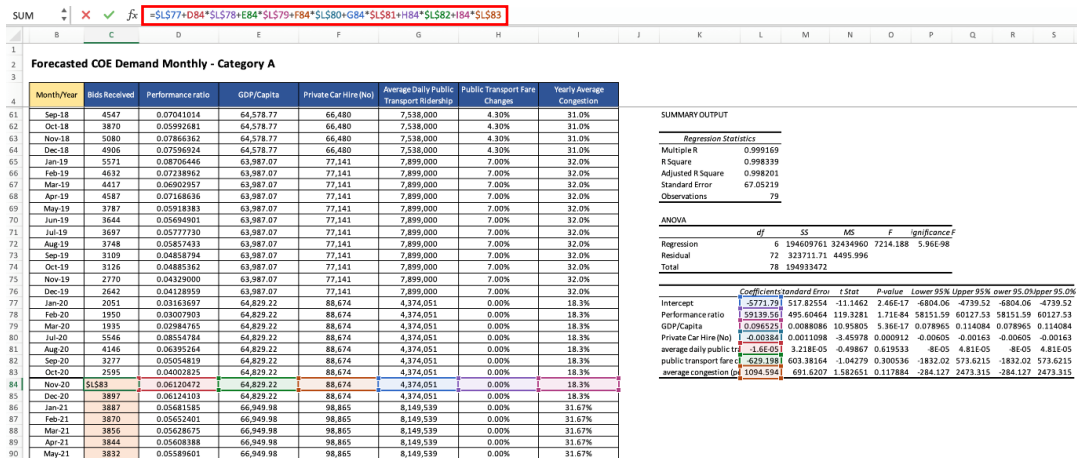*Figure 6: COE Demand Forecast Model for Category A Vehicles*

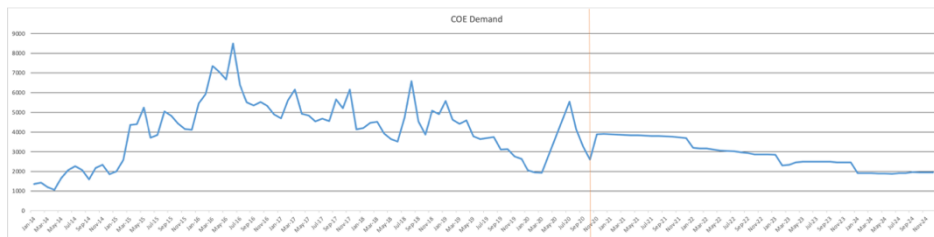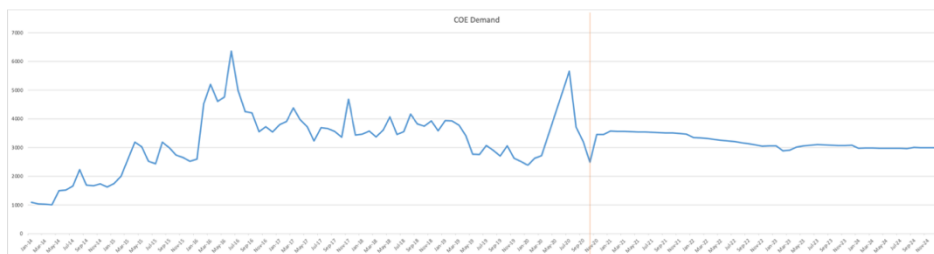*Figure 7: COE Demand for Category A chart*

Figure 8: COE Demand for Category B chart

4.1.4 Final Model

The quota was calculated by taking the difference between the forecasted deregistered vehicles and forecasted revalidations and adding the annual growth rate. The model offers an option for users to enter the growth rate. A similar statistical approach was also used for the prediction of Category-B COE quota and COE price

Figure 9: Predicted COE Quota

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To predict the final COE price, regression model was employed. Taking the Quota (Supply) and Demand as independent variables, the relative coefficients are calculated. Therefore, using the forecasted valued of these two variables, the future COE prices are predicted.

Figure 10: Regression Model

	COE Quota A	Demand	Price
Jan-15	1409	2008	66010
Feb-15	1980	2589	62002
Mar-15	1974	4371	61410
Apr-15	1975	4395	67749
May-15	2878	5242	68589
Jun-15	2861	3709	66000
Jul-15	2901	3857	58700
Aug-15	3444	5043	56209
Sep-15	3375	4829	57089
Oct-15	3377	4439	56001
Nov-15	3326	4149	56001
Dec-15	3367	4110	56989
Jan-16	3318	5450	45002
Feb-16	4087	5937	46651
Mar-16	4086	7354	45000
Apr-16	4167	7046	46009
May-16	4435	6673	47889
Jun-16	4470	8502	53694
Jul-16	4494	6389	52301
Aug-16	4052	5515	52503

SUMMARY OUTPUT

Regression Statistics

Multiple R	0.223810821
R Square	0.050091283
Adjusted R Squ	0.01842766
Standard Error	11963.51714
Observations	63

ANOVA

	df	SS	MS	F	Significance F
Regression	2	452844700.5	226422350.3	1.581982014	0.2140209
Residual	60	8587544547	143125742.4		
Total	62	9040389247			

	Coefficients	Standard Error	t Stat	P-value	Lower 95%	Upper 95%	Lower 95.0%	Upper 95.0%
Intercept	39130.71953	6758.205421	5.790105078	2.74619E-07	25612.29594	52649.14311	25612.29594	52649.14311
X Variable 1	-3.436308393	3.669294316	-0.936503888	0.352768109	-10.77598982	3.903373035	-10.77598982	3.903373035
X Variable 2	3.390176478	2.097952282	1.615945466	0.111352679	-0.806352902	7.586705858	-0.806352902	7.586705858

Figure 11: Predicted COE Price for CAT-A

4.2 Results

A general decline of the forecasted numbers was noted. This was mirrored in the three models: Deregistered Motors, Revalidated Vehicles and COE Demand. This could be due to: -

- For all three models:
    - The current unpredictable market trend due to the impact of Covid -19[4].
- For deregistered motors:
    - The model showed a decline in the number of deregistered motors for both Cat-A and Cat-B till Q2 2024. After which, there was an increase till Q3 2026 and continues to remain constant until Q1 2030. However, due to the data constrains of other models, only data up till Q4 20204 was considered.
- For revalidated vehicles:
    - There was a severe decline in Cat A generated and Cat B generated during the period of past years.
    - The revalidation number has other factors affecting it and the change is affected largely due the type of car taken into consideration.
- For COE Demand:
    - There was a general decline in the past 4 years and the model does not accurately account for the unpredictable spikes in the demand over the years.
    - Unexpected events at that point could have accounted for the spikes, and this could not be simulated in this model.

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[4] Ref. Anticipating the Covid impact on Coe Prices

5 Sensitivity Analysis and Trade Off analysis

5.1 Sensitivity Analysis: Deregistered Motors

The sensitivity of COE's generated with changing performance ratios was analyzed between 2Q20 to 1Q30. As described in the model analysis, the performance ratio was calculated by using number of COE's generated and deregistered COE's. The analysis was modeled by varying the performance ratio through a range of (-2.5% to 2.5%). The results of the model show that there will be significant change when the performance ratio is high i.e., 2.5% (small numbers of deregistered COEs). However, when the performance ratio is low i.e., -2.5% (a high number of deregistered COEs) the model depicts steady number of COE's generated.

Figure 12: Sensitivity Analysis of Category A
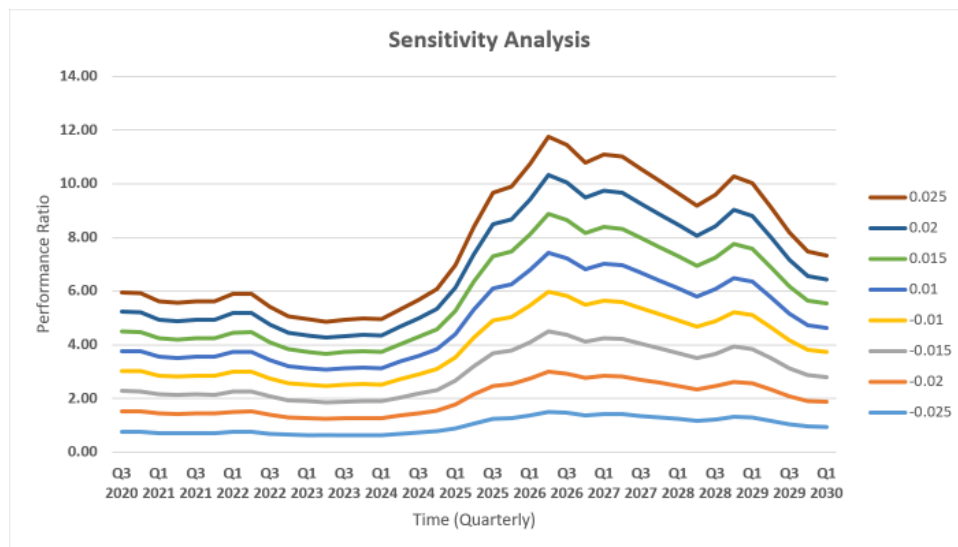
5.2 Trade off analysis

To perform trade-off analysis, the model was assessed from a) prospective buyer's; and b) government policy lens.

a. Prospective Buyer
Prospective buyers would be interested in forecasted COE prices, and their decision to purchase a Cat A or Cat B car would depend on i) urgency; and ii) budget. The buyer makes a trade-off between time, money and category.

The buyer may weigh his options by prioritizing price:

Figure 13: Trade off used to find future COE price for Cat A & Cat B

Lowest Cat A COE in 2021	Lowest Cat B COE in 2021
Nov-21	Jan-21
Lowest Cat A COE between 2021 - 2024	Lowest Cat B COE in 2021 between 2021 - 2024
Dec-24	Dec-24

Figure 14: Trade off used to find future COE price for Cat A & Cat B
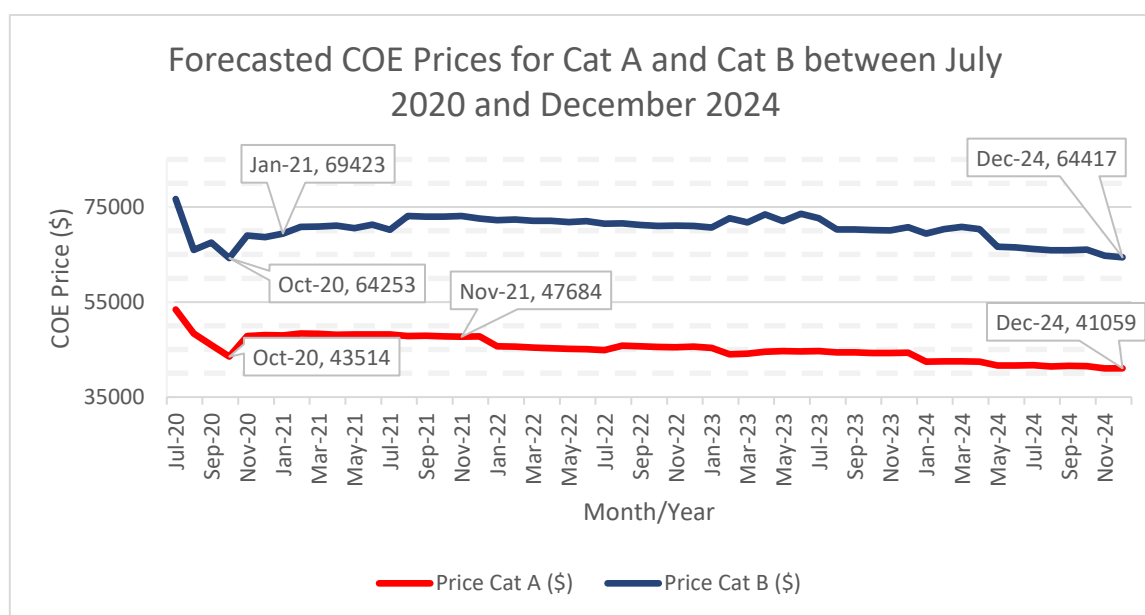
b. Government Policy

Crafting policy requires inputs from multiple agencies, each with its own mandate to a) reduce car ownership; b) sustainably increase public transport fares; and c) cap congestion, whilst national GDP grows.

The following variables were traded-off to understand the demand outcome for Cat A vehicles. This could form the basis for future COE price models and flesh out the difference between forecasted and ideal COE demand.
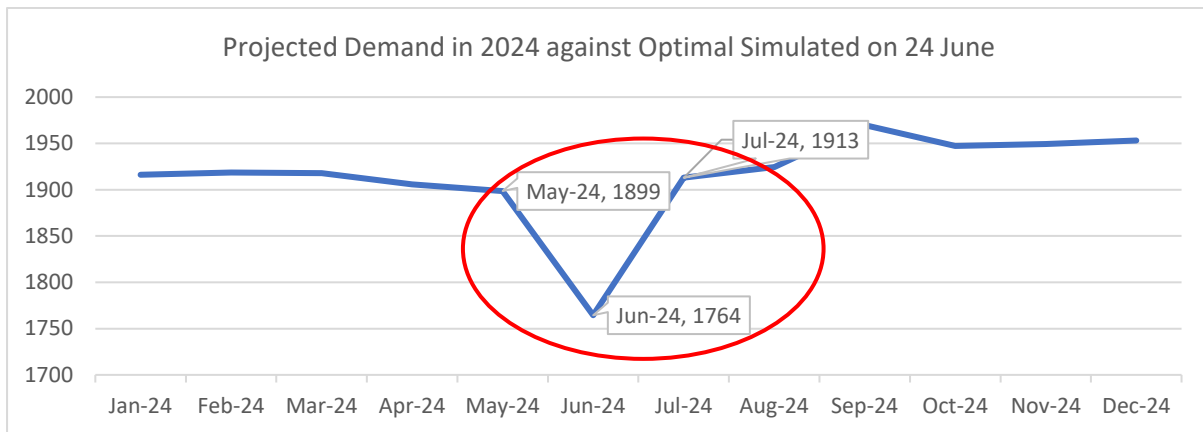
Table 2: Variable List with its Considerations & Constraints

Variable	Constraints	Considerations
GDP/Capita	$57,564<= GDP/Capita <= $75,631	Barring any major global phenomena, GDP/Capita should be on course to hit its forecasted $75,631 in 2024 and shall not go below the GDP/capita in the past 5 years.
Private Car Hires	100, 000 <= Public Car Hires <= 130,000	Private car hires (including car sharing) will continue to increase given the lower upfront and maintenance cost vis-à-vis owning a car. Constraints are placed based on forecasted values.
Average Daily Public Transport Ridership ("ADPTR")	7,899,000 <= ADPTR <= 9,000,000	The development of a Covid-19 vaccine as early as 1H21[5] could increase daily public ridership. In addition, taking a 3-year view, it is expected that foreigner arrivals would increase. On that note, ADPTR is taken between January 2019 and January 2024's forecasted.
Public Transport Fare Changes ("PTFC")	10% <= PTFC <=A min. increase of 5% to supplement growing costs and a max of 25%[6] is considered.	With a growing train network, the cost of building and maintenance will increase, and commuters would have to bear the some of the burden.
Average Congestion (per year)	28% <= Average Congestion <= 33%	Average congestion is capped at 33% (allowing a 2% increase) and targets a 5% decrease.

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[5] https://www.straitstimes.com/singapore/health/singapore-could-have-a-covid-19-vaccine-by-early-2021-close-to-300m-commitment-from

[6] Can be tranched over years.

Figure 15: Projected Demand in 2024 against Optimal Simulated on 24 June

As policy takes a long- term view, optimizing the bid in 2024 based on the inputs above, provides an overview of how the other bids compare against the optimal bid. Comparing optimal (1764) and average bids (1925) in 2024, policy makers have a further 161 bids to reduce despite optimizing their model. They should assess other factors that could bring demand down further[7].

6   Model Limitations

a.   Data missing for certain years
Revalidation data for 2018 was missing from Land Transport Authority's available data sheets. This revalidation data was required to calculate the performance ratio and predict future COE prices. Too patch the date, the trend function was used on historical values. There was a need to aggregate data as there are a total of two bidding rounds per month.

Lastly, the model forecasts monthly values, but monthly revalidation data was not available[8]. Thus, there was a need to segregate the data to provide monthly revalidation values.

b.   Forecasted GDP was available only till 2024
As forecasted GDP was sourced externally, the model was limited to the data available i.e., 2024. Thus, with the availability of further GDP numbers, the model can be extended to predict subsequent COE values.

c.   Impact of Covid 19:
Due to the recent events and closure of the bidding for three months (April 2020 –June 2020), the trend of the model for revalidation and the final model were deeply impacted. The revalidations numbers seem to be much lower than the previous years due to the extension provided to vehicle in this period. In addition, in the final model, the supply was taken as zero for the above-mentioned months.

d.   Unconsidered factors:
In the revalidation of vehicles, factors such as maintenance cost and insurance rates were not considered due to the lack of available data.

e.   High p-value

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[7] Such as i) encouraging car-sharing business models; ii) increasing public transport frequency and speeds; iii) introduction new express bus routes.
[8] Only quarterly data was available.

7   References

1	2005 - 2014 public transport ridership	https://www.lta.gov.sg/content/dam/ltagov/who_we_are/
2	2015 - 2018 public transport ridership	https://public.tableau.com/profile/
3	2019 public transport ridership	https://www.tnp.sg/news/singapore/public-transport-ridership-hits-new-high-except-taxi-trips
4	2020 public transport ridership (trend extrapolation)	https://www.sbstransit.com.sg/ridership
5	2014-2018 public transport fare changes	https://www.channelnewsasia.com/news/singapore/
6	2019 public transport fare increase (Tentative source/data)	https://blog.seedly.sg/bus-train-fare-review-exercise/
7	2020 no public transport fare increase	https://www.straitstimes.com/singapore/transport/.
8	2017-2019 congestion levels sg	https://www.tomtom.com/en_gb/traffic-index/singapore-traffic/
9	2015-2016 congestion level (tentative source)	https://www.carbuyer.com.sg/tomtom-traffic-index-2017-singapore/
10	2014-2015 congestion level	https://www.straitstimes.com/singapore/transport/singapores-road-congestion-improves-index
11	2020 congestion levels (average of week 1-41 = 9.4%)	https://www.tomtom.com/en_gb/traffic-index/singapore-traffic/
12	2021 public transport fare increase	https://www.todayonline.com/singapore/
13	2015-2018 vehicle population	https://data.gov.sg/dataset/monthly-motor-vehicle-population-by-vehicle-quota-category?view_id=46b41a34-4213-4f88-be92-4c9cb8c7c25b&resource_id=31b9aa99-c8ff-4e5c-9568-bdf3c6863bef
14	2019-2020 vehicle population	https://www.lta.gov.sg/content/dam/ltagov/who_we_are/statistics_and_publications/statistics/pdf/M01-MVP_By_Quota.pdf
15	Decline in Revalidations and Quota	https://www.sgcarmart.com/news/events_features.php?AID=3852