Multi-tiered ridesourcing services in the e-hailing market

Guipeng Jiao
Andres Fielbaum
Mohsen Ramezani

TransportLab, School of Civil Engineering, University of Sydney

Background

What is the e-hailing market?

- E.g. Uber & Didi
- Point-to-point: A service that takes passengers from A to B
- Two sided: A digital platform is used to connect drivers and passengers

What are the ridesourcing services?

- One passenger (group), one driver
- On-demand: trip orders occur in real time

Objective

To improve the operational efficiency for a platform

- Lower vehicle deadheading
- Fewer passenger cancellations
- Higher platform profitability

} improving overall social welfare

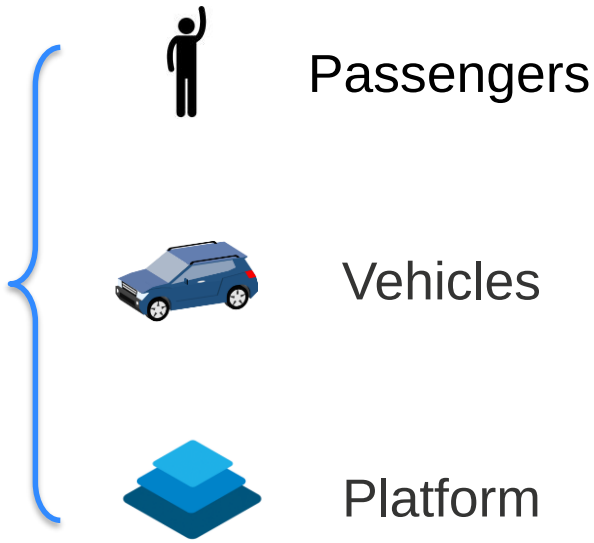
Our idea: multi-tiered ridesourcing services

- Premium service: higher prices, shorter waiting time
- Economy service: lower prices, longer waiting time

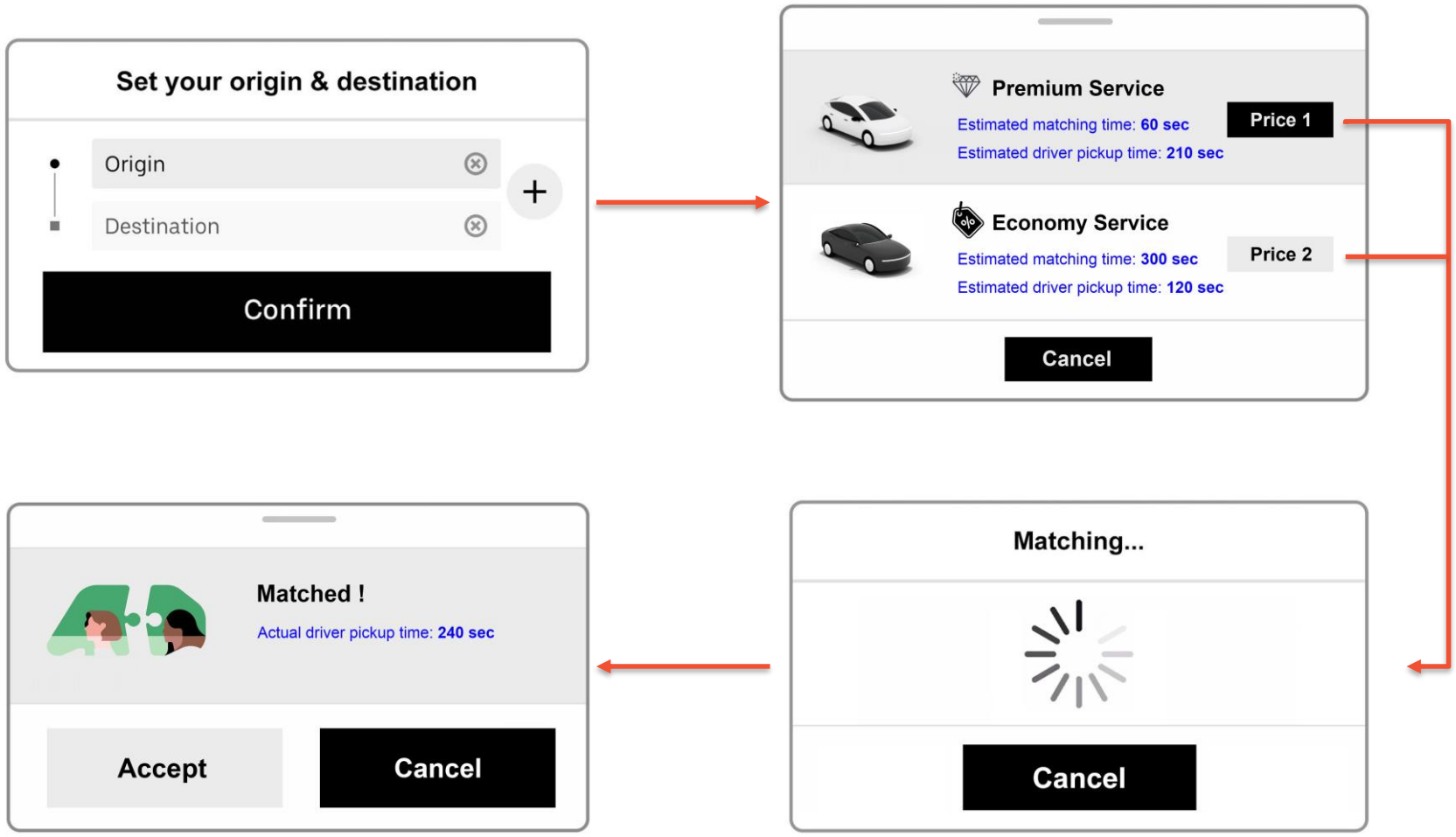
How does multi-tiering improve overall efficiency

- People with lower VOT opt for economy service
- The platform hold them in the system for longer until a really good match

Framework



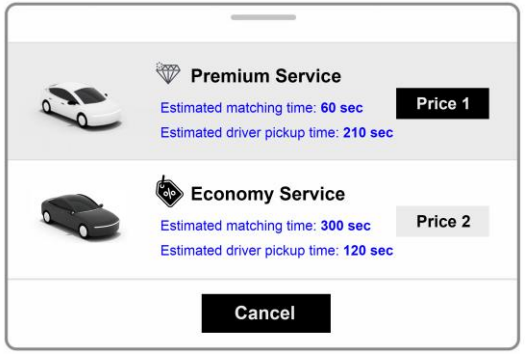
Passenger's Perspective



Problem description

- **Determining the following for each option for each passenger i:**
  - Estimated matching time, $\hat{t}_{\mathrm{m}}^{i}$
  - Estimated pickup time, $\hat{t}_{\mathrm{p}}^{i}$
  - Price, f^{i}
- **And how to match passengers (after selecting the options) to idle vehicles**
- **With the goal of:**
  - Maximizing total profit and/or
  - Maximizing social welfare
- **Assuming:**
  - Platform knows population mean characteristics of passengers
  - Fixed fleet size, and vehicles comply with the platform's directions

Passenger Choice Modelling



Premium vs Economy vs Other modes

- The utilities of the options for passenger i:

$$U^i_{\text{prem}} = \text{A}_{\text{ridesourcing}}\left(\text{trip length}^i\right) - \text{VOT}^i \times \left(\hat{t}^i_{\text{m,prem}} + \hat{t}^i_{\text{p,prem}}\right) - f^i_{\text{prem}}$$

$$U^i_{\text{eco}} = \text{A}_{\text{ridesourcing}}\left(\text{trip length}^i\right) - \text{VOT}^i \times \left(\hat{t}^i_{\text{m,eco}} + \hat{t}^i_{\text{p,eco}}\right) - f^i_{\text{eco}}$$

$$U^i_{\text{public}} = \text{A}_{\text{public}}\left(\text{trip length}^i\right) - \text{VOT}^i \times \left(\text{additional travel time}^i\right) - f^i_{\text{public}}$$

- The probabilities of choosing each option:

$$P(\text{premium}) = \frac{e^{\beta U^i_{\text{prem}}}}{e^{\beta U^i_{\text{prem}}} + e^{\beta U^i_{\text{eco}}} + e^{\beta U^i_{\text{public}}}}$$

Passenger Choice Modelling

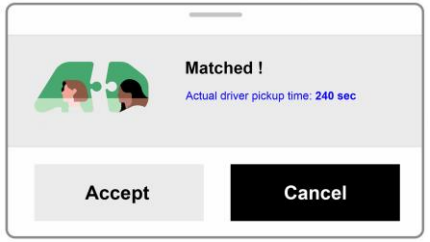
Matching impatience & Service quality sensitivity

- Passenger cancels during matching if matching patience exceeded:

$$\text{Matching threshold}^i = \hat{t}_{\text{m}}^i + \$0.5/\text{VOT}^i$$

- Passenger cancels after being matched if the pickup time too long:

$$\text{Pickup threshold}^i = \hat{t}_{\text{p}}^i + \$2/\text{VOT}^i$$



Note: VOT for each passenger is drawn from truncated normal distributions with mean of $24/hour, and $12/hour and $36/hour bounds

Platform Operation: Price and Wage

- **Price of trips**

$$f_{\text{prem}}^{i} = \alpha_{1,\text{prem}} + \alpha_{2,\text{prem}} \times \text{trip length}^{i}$$

$$f_{\text{eco}}^{i} = \alpha_{1,\text{eco}} + \alpha_{2,\text{eco}} \times \text{trip length}^{i}$$

- **Wages**

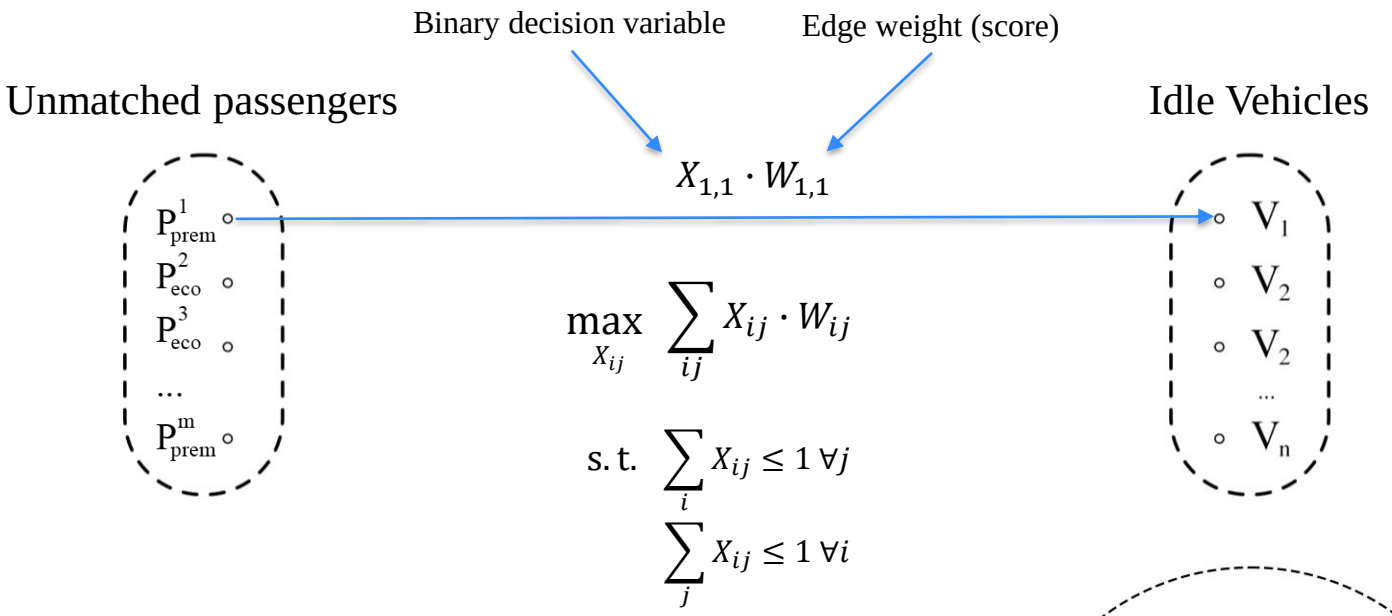
$$\text{Salary} = \alpha_3 \times \text{price}$$

$$\alpha_3 = 80\%$$

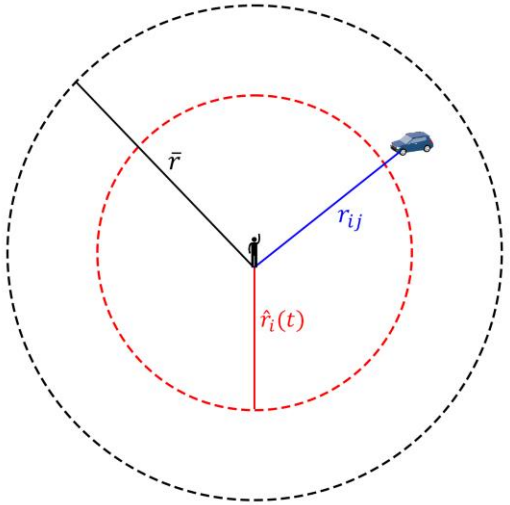
Platform Operation: 3 Stages

- **Stage 1: Estimating matching time and pickup times for the options**
  - Help passengers make an informed decisions based on accurate estimates
  - May need to be forward looking
  - The values are not misrepresented to skew passenger choice
- **Stage 2: Pricing the options**
  - Dynamically price the options
  - Aim to maximize profit by skewing passenger choices and improving efficiency
- **Stage 3: Matching algorithm**
  - An efficient algorithm with known passenger choices

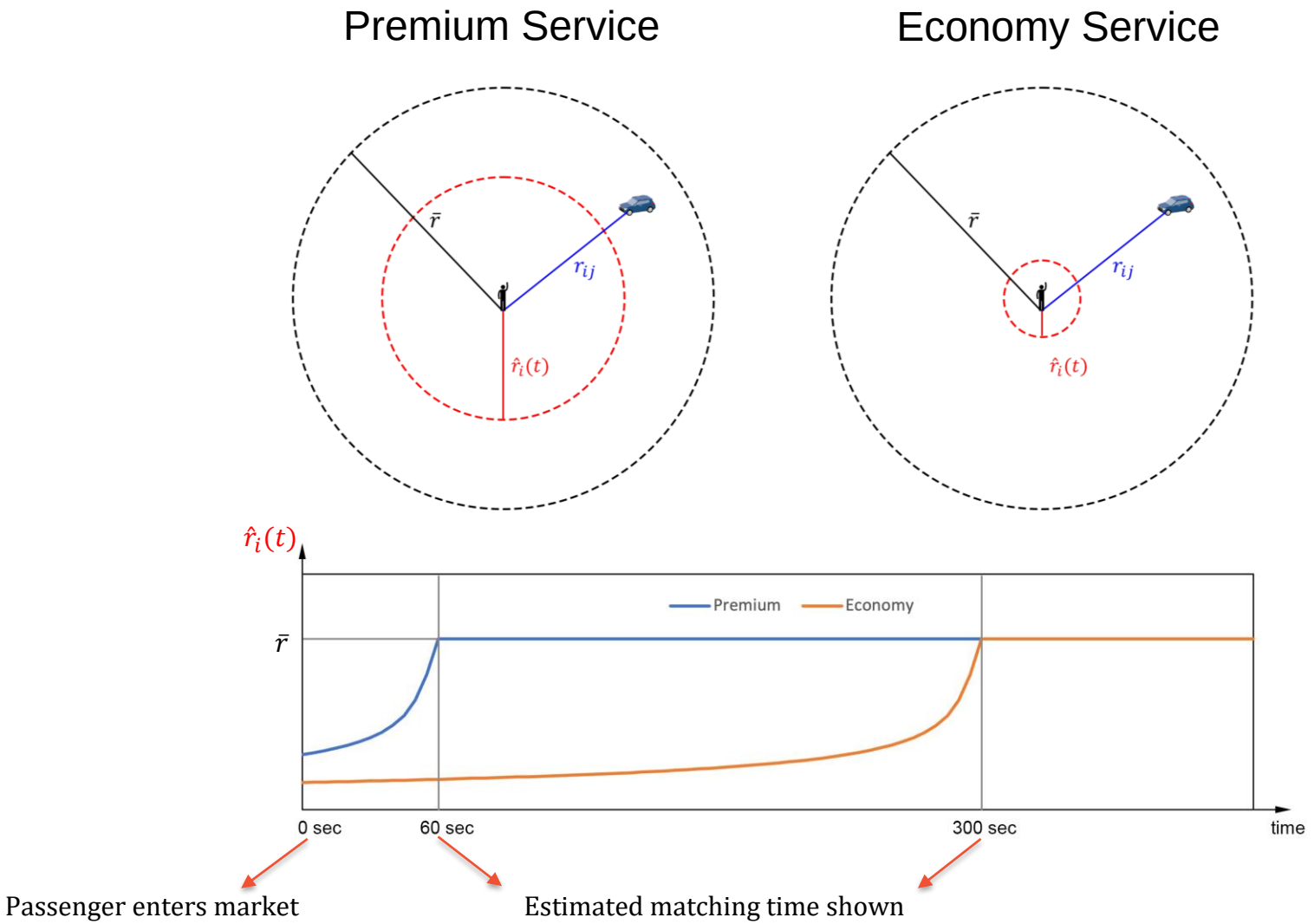
Matching algorithm



Where: $W_{ij} = \begin{cases} -1 & \text{if } r_{ij} > \hat{r}_i(t) \\ \bar{r} - r_{ij} & \text{otherwise} \end{cases}$



Dynamic Search radius



Preliminary experiments

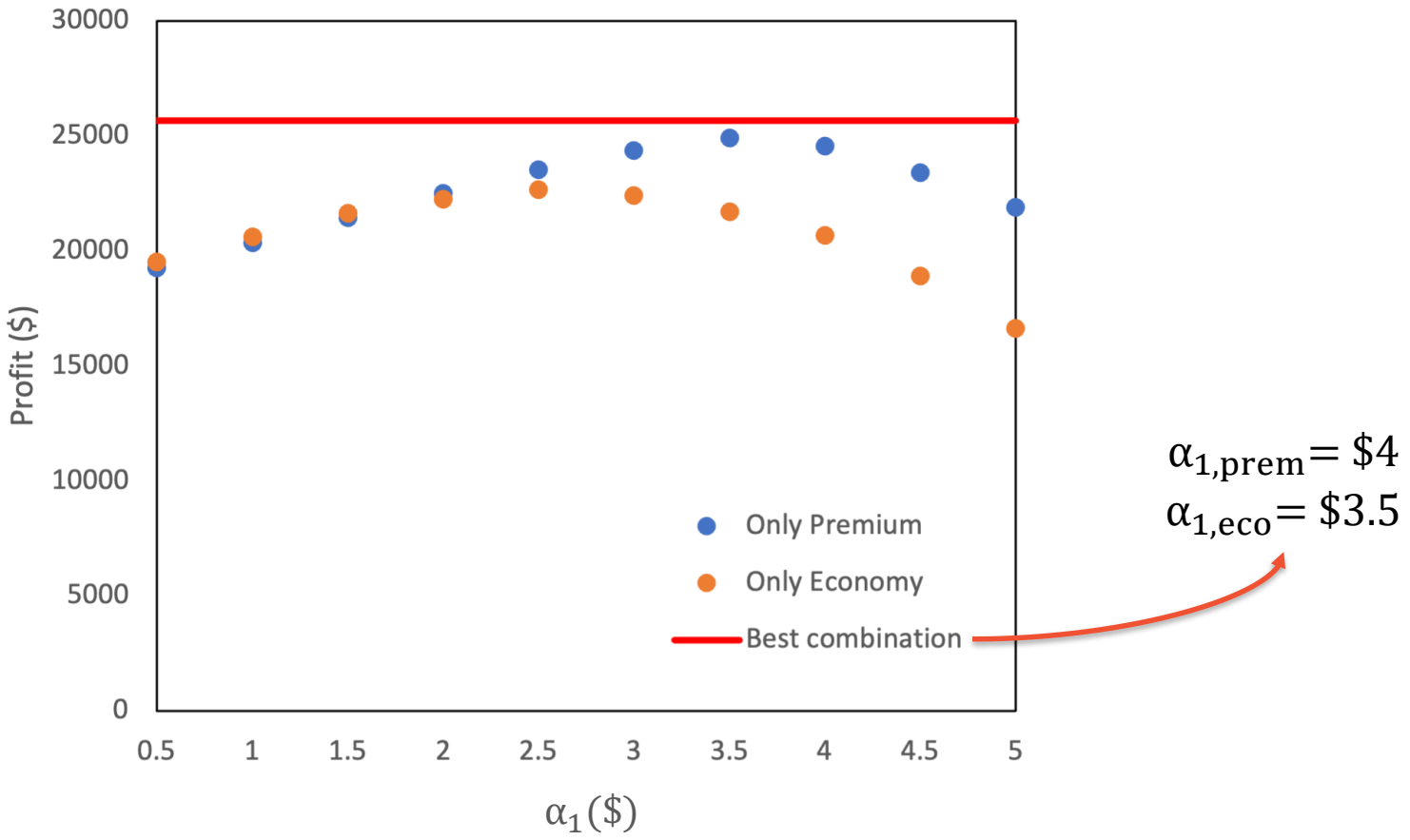
	Economy	Premium
Matching time	300 s	60 s
Pickup time	120 s	210 s
α_1	Variable	Variable
α_2	\$0.6 per min	\$0.6 per min

- Total of 3000 vehicles (4 new vehicles per second for the first 750 seconds generated at random locations)
- Passengers appears within the system according to real world demand (3/2/2015 Monday)
- 2-hour simulations, with 1 hour warmup (18864 potential demand in the final 1 hour)

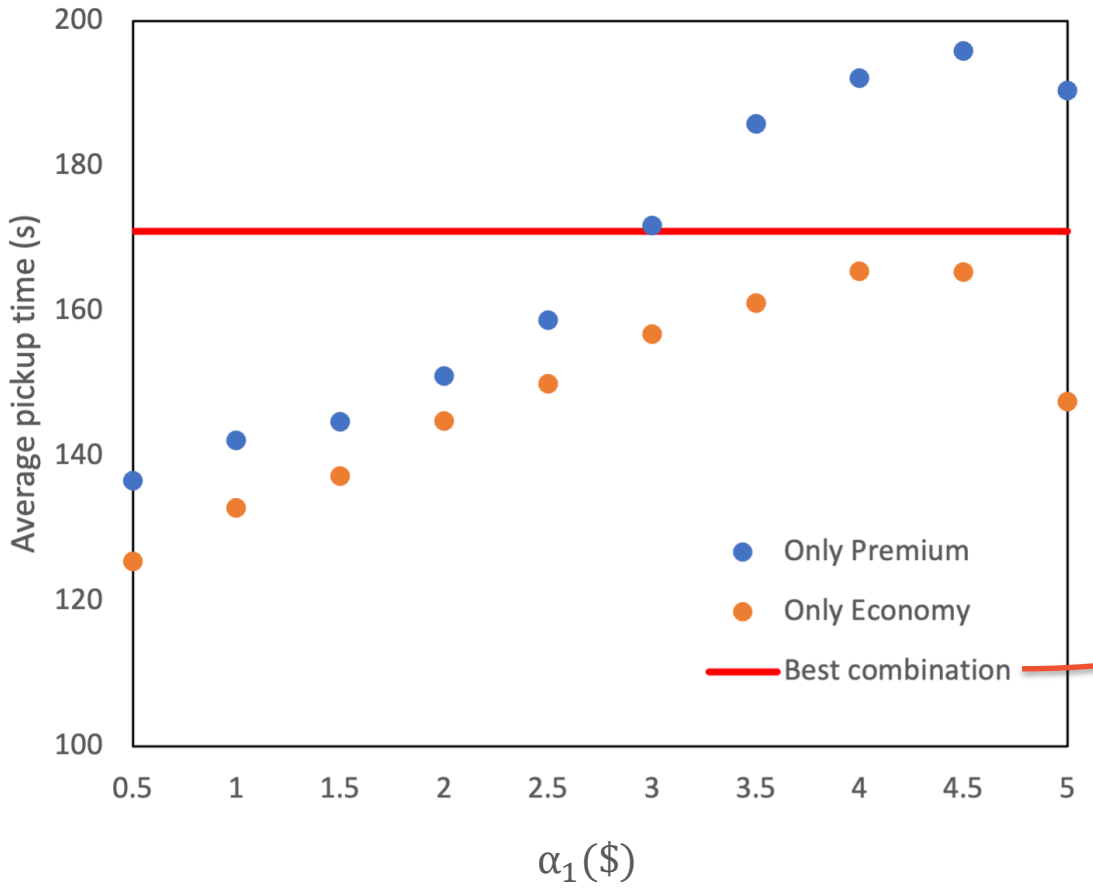
Test cases

Service offered	Price parameter ($)
Only Premium	$\alpha_{1,\text{prem}} = 0.5{:}0.5{:}5$
Only Economy	$\alpha_{1,\text{eco}} = 0.5{:}0.5{:}5$
Both	$\alpha_{1,\text{prem}} = 0.5{:}0.5{:}5$ $\alpha_{1,\text{eco}} = 0{:}0.5{:}\alpha_{1,\text{prem}}$

Total Profit



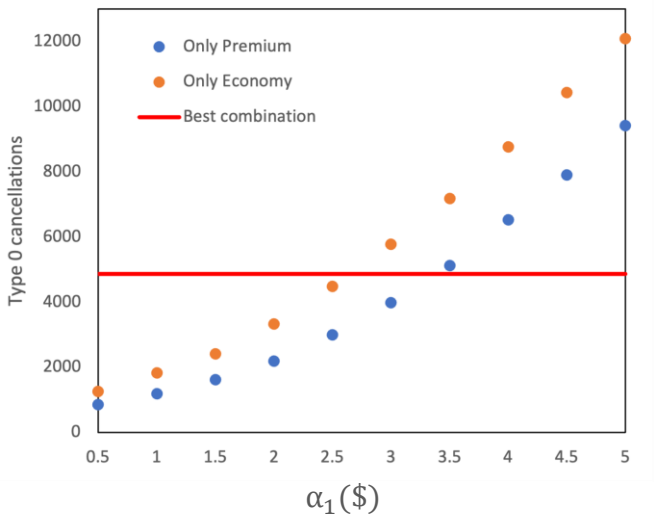
Average Pickup Times (deadheading)

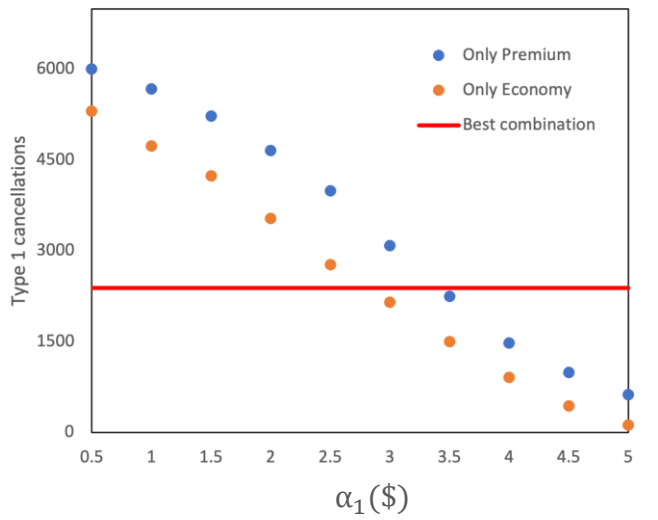


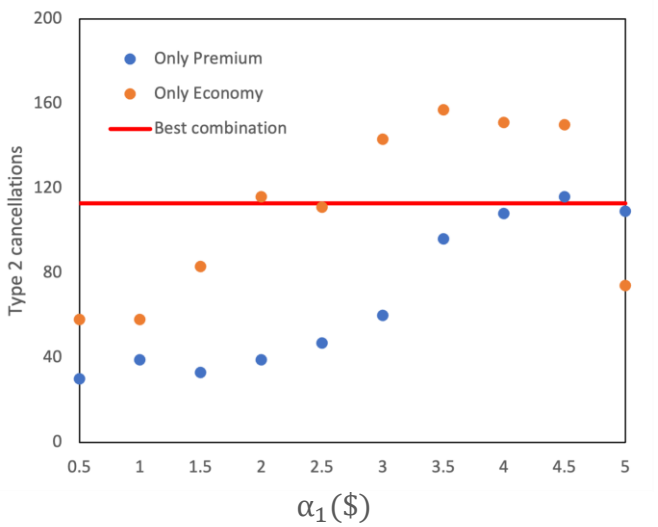
$\alpha_{1,\text{prem}} = \$4$

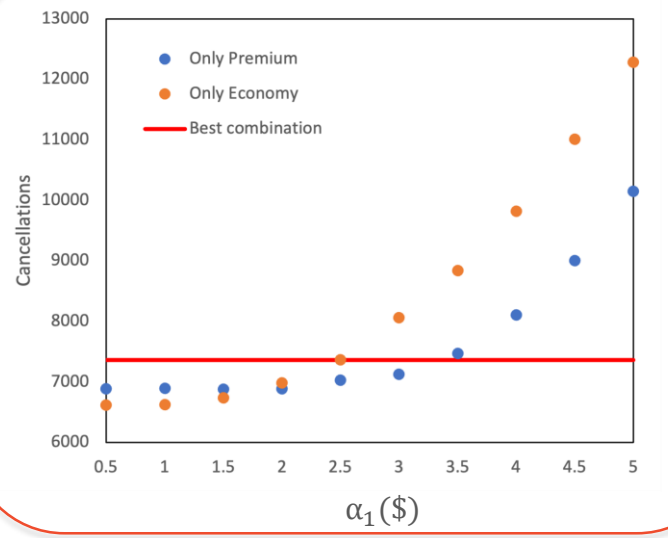
$\alpha_{1,\text{eco}} = \$3.5$

Total Cancellations









Thank You

THE UNIVERSITY OF
SYDNEY