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A Model of Dynamic Offer Generation for Bundling Flights and Ancillaries

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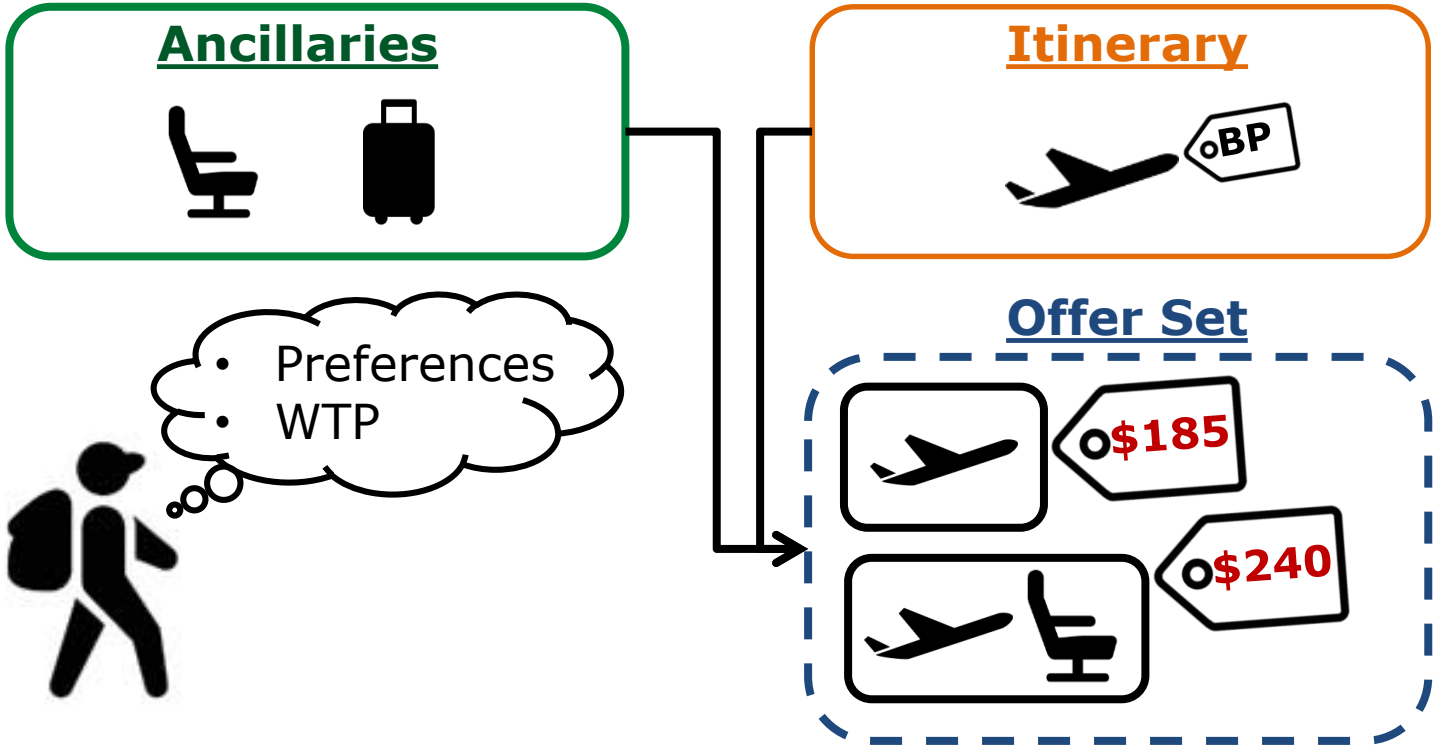
What Is Dynamic Offer Generation?

- Dynamic Offer Generation (DOG) aims to generate and optimize a dynamically priced set of flight and ancillary offers in real-time
- It combines two current trends in airline pricing and revenue management: Continuous Pricing and Ancillary-aware Revenue Management



Select and price a set of offer(s) that maximizes expected revenue from each booking request

The Dynamic Offer Generation Problem with One Ancillary Service

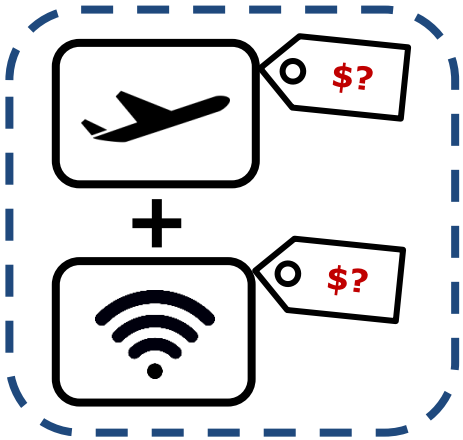
- Suppose an airline offers one flight and one ancillary service:

Flight
Bid Price: BP

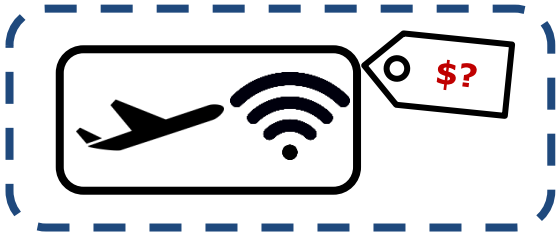
Ancillary
Cost of Provision: c_a

- **Dynamic Offer Generation** (DOG) solves these two problems simultaneously:
  - Which **offer set** should we present to customers?

A La Carte

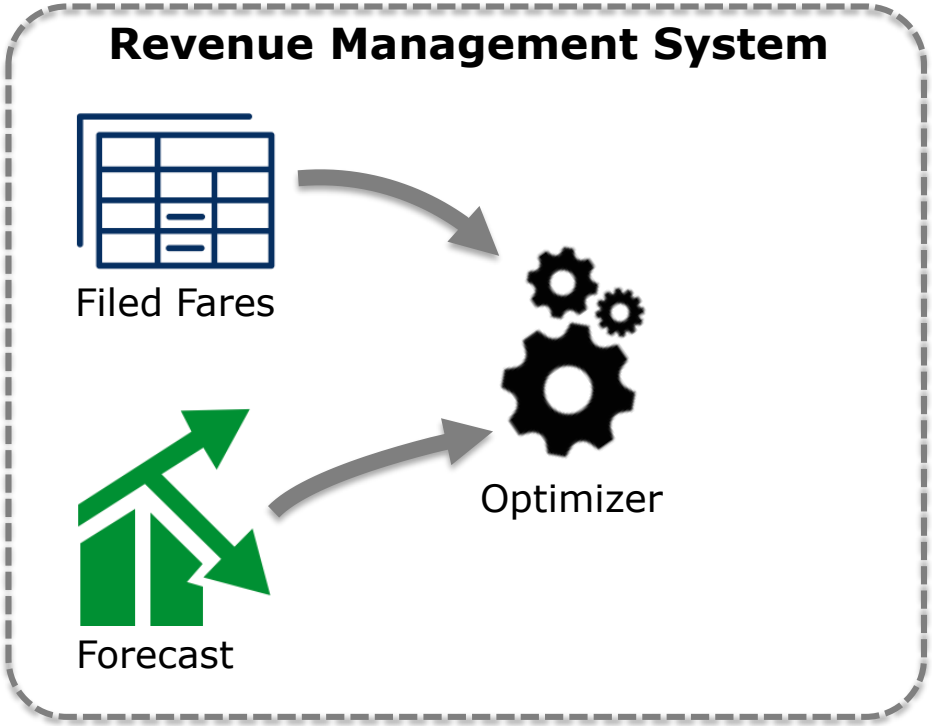


Bundle



  - What **prices** should we charge to maximize expected revenue?

Schematic Overview of DOG



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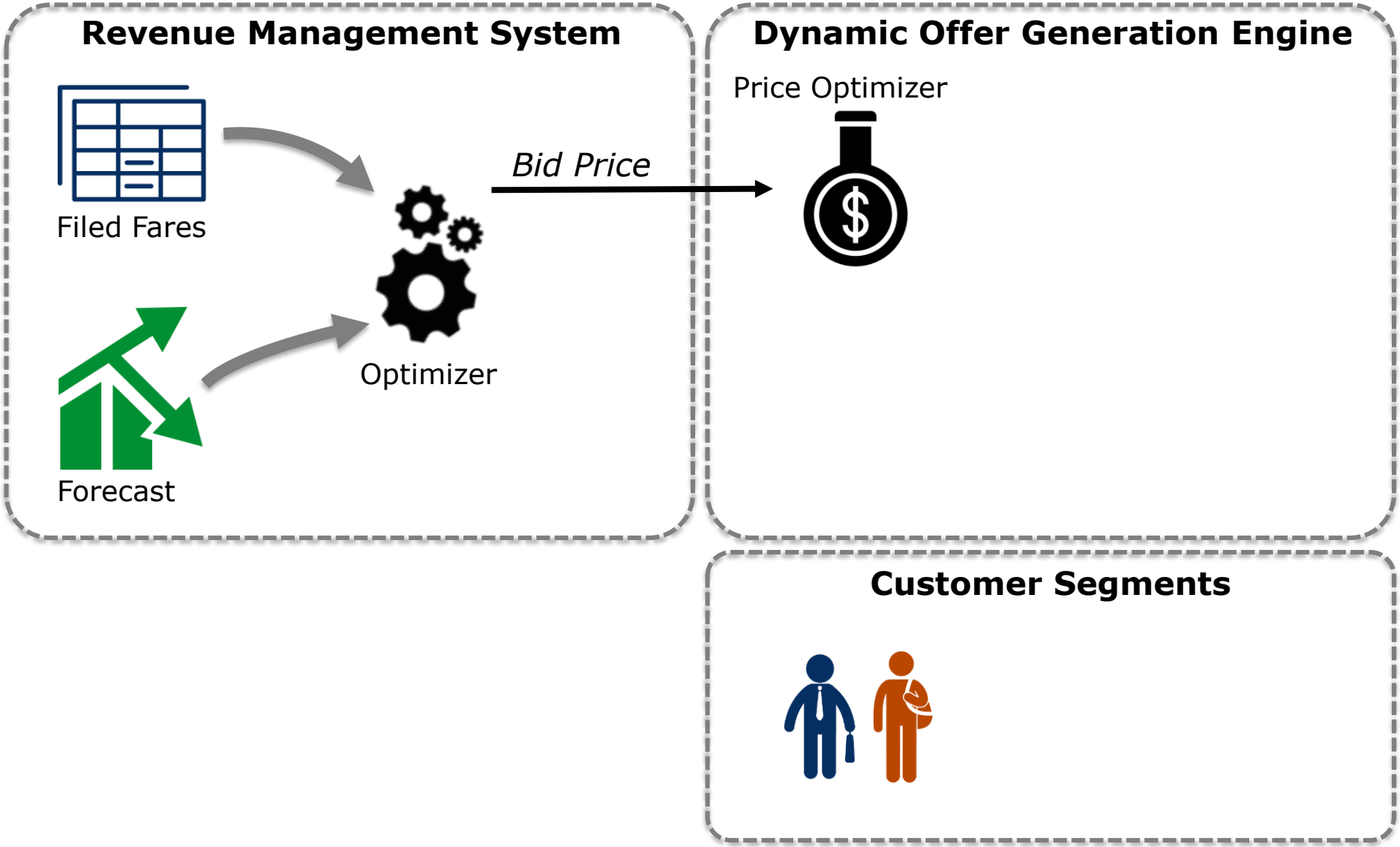

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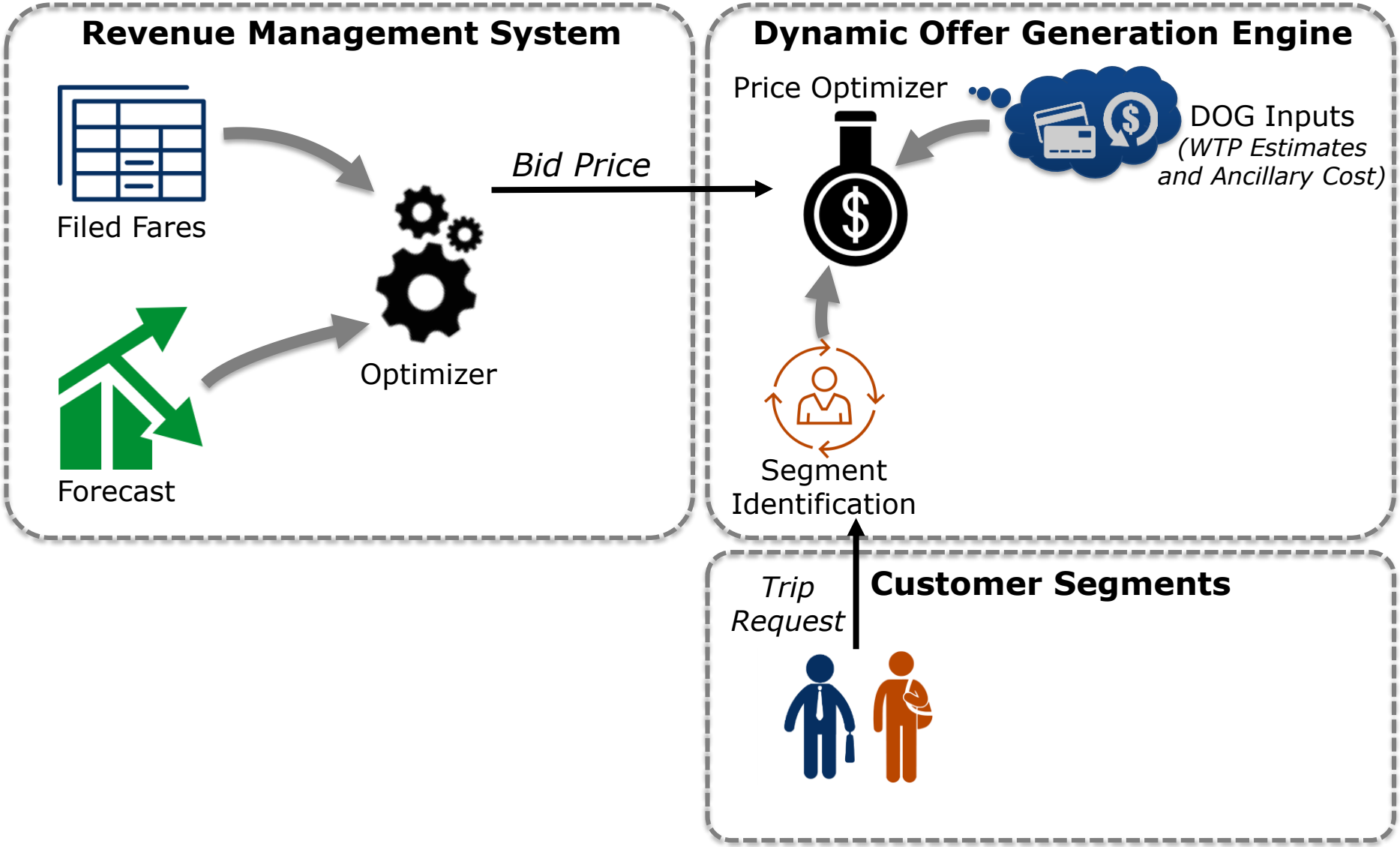

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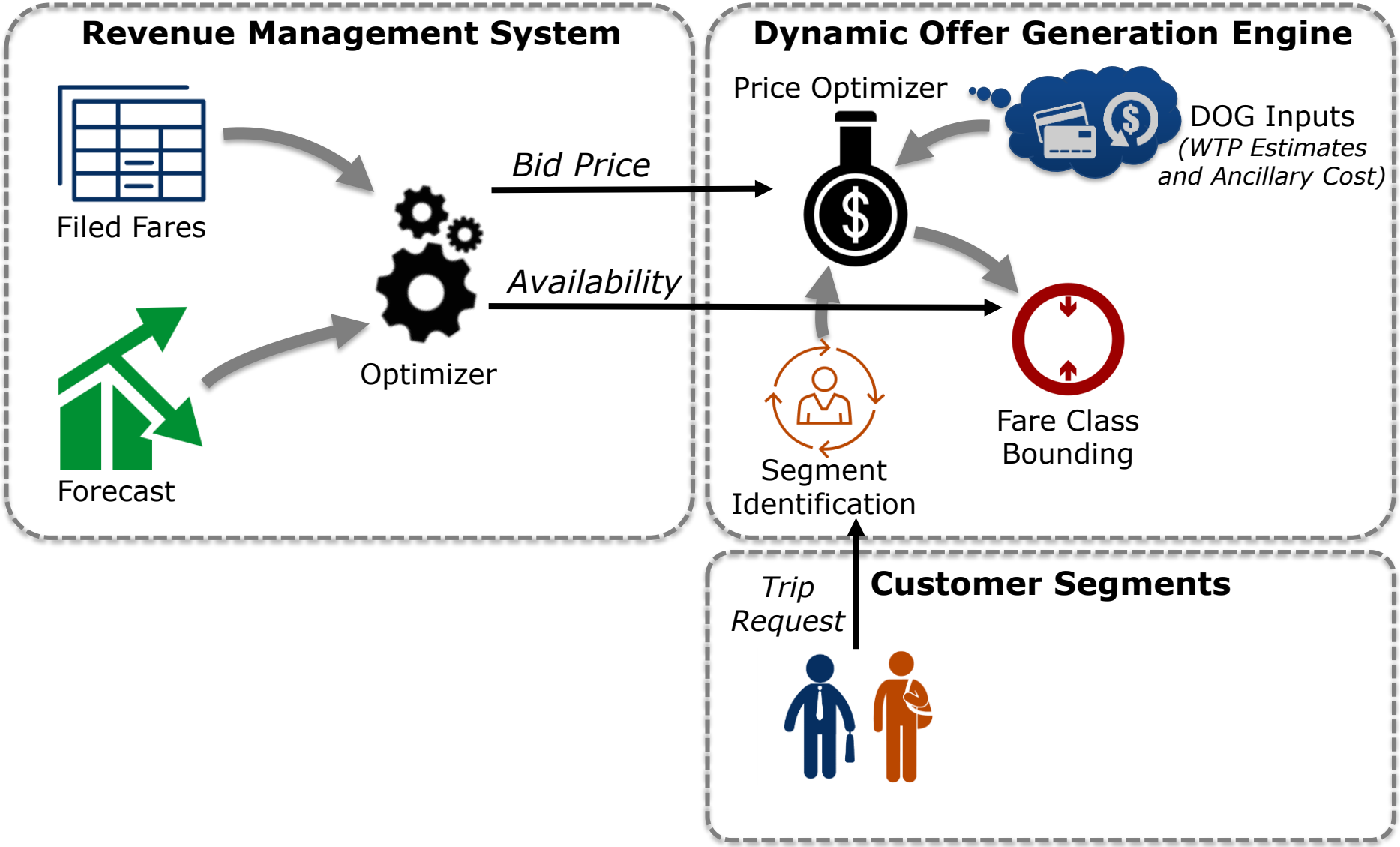

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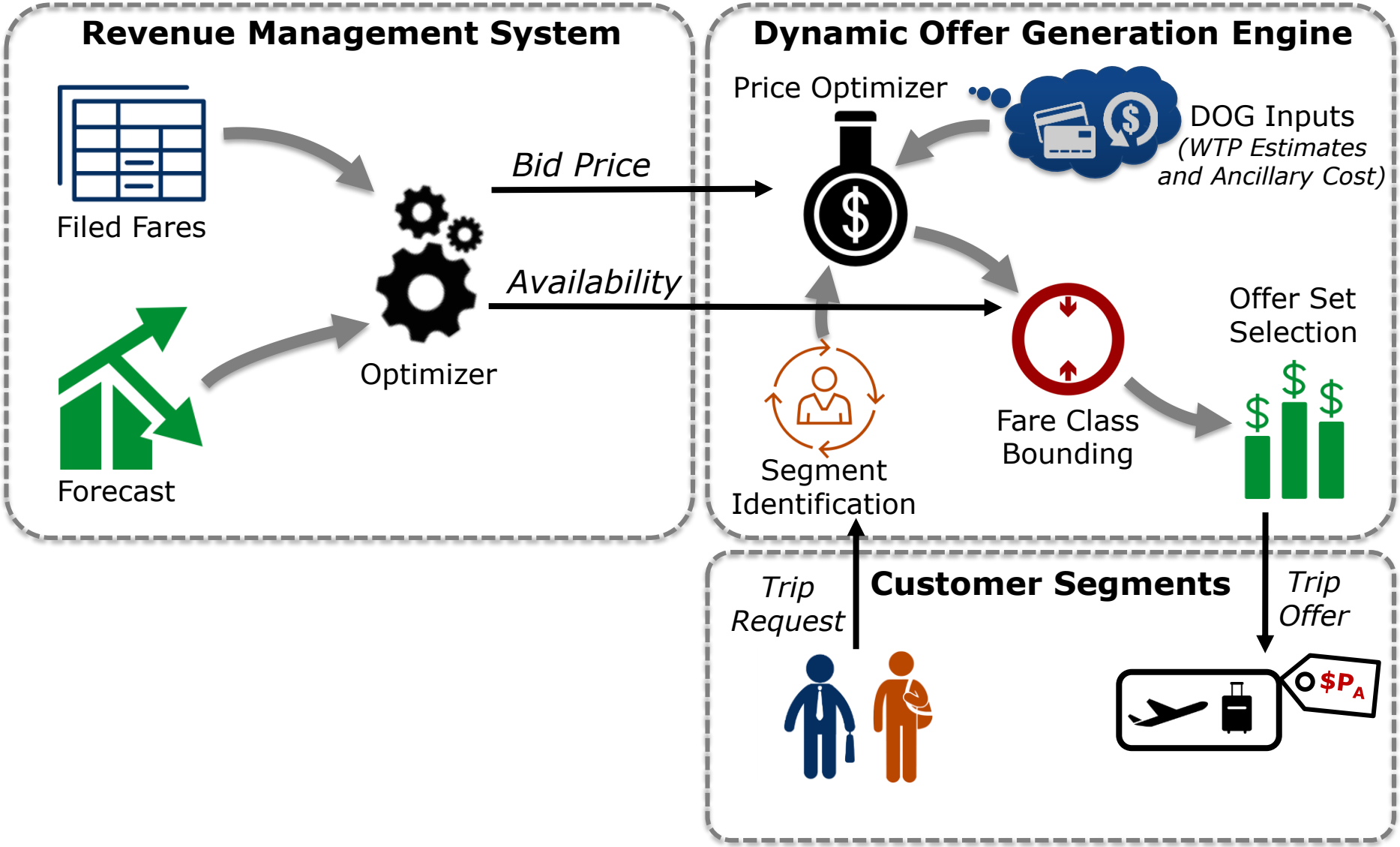

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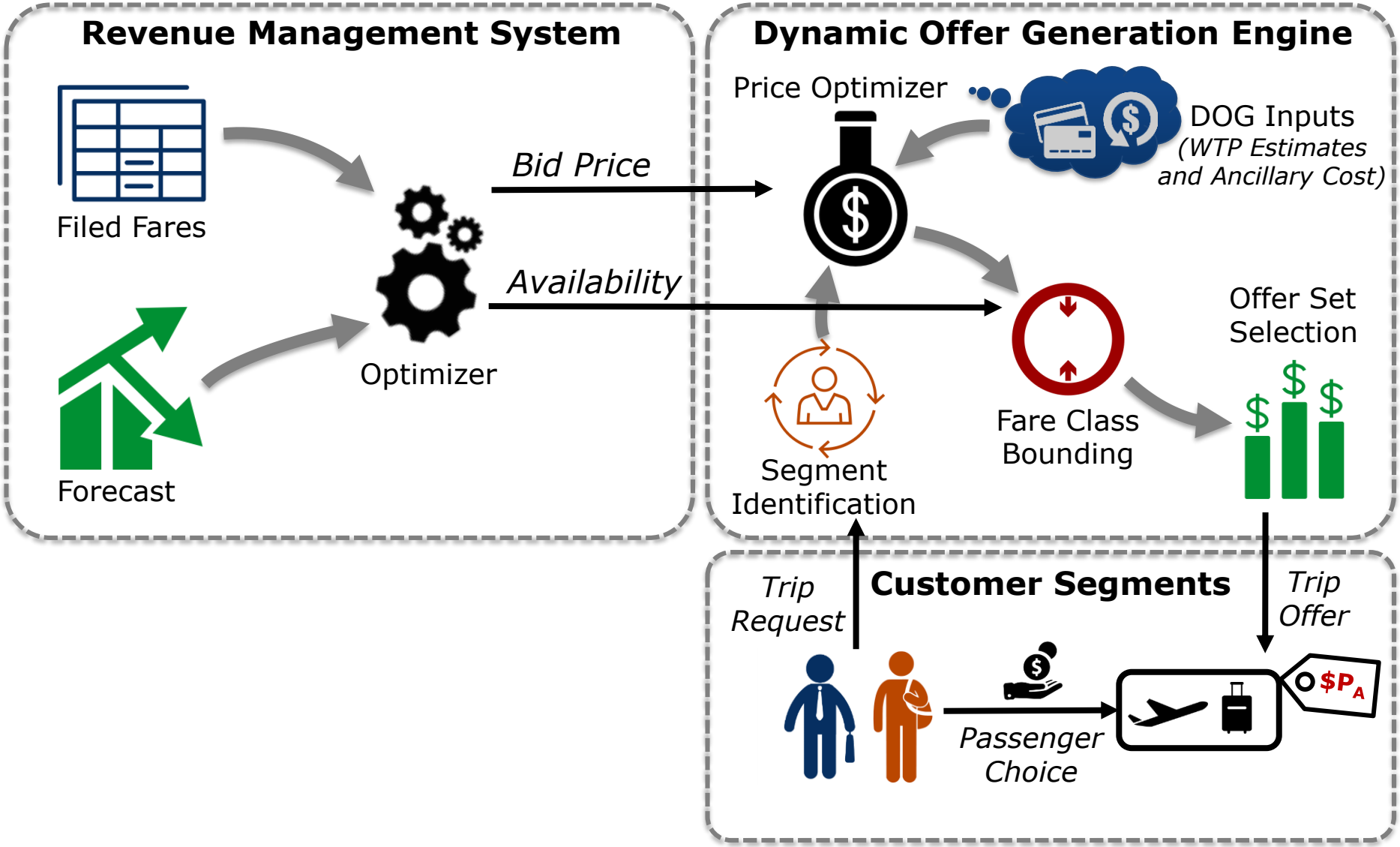

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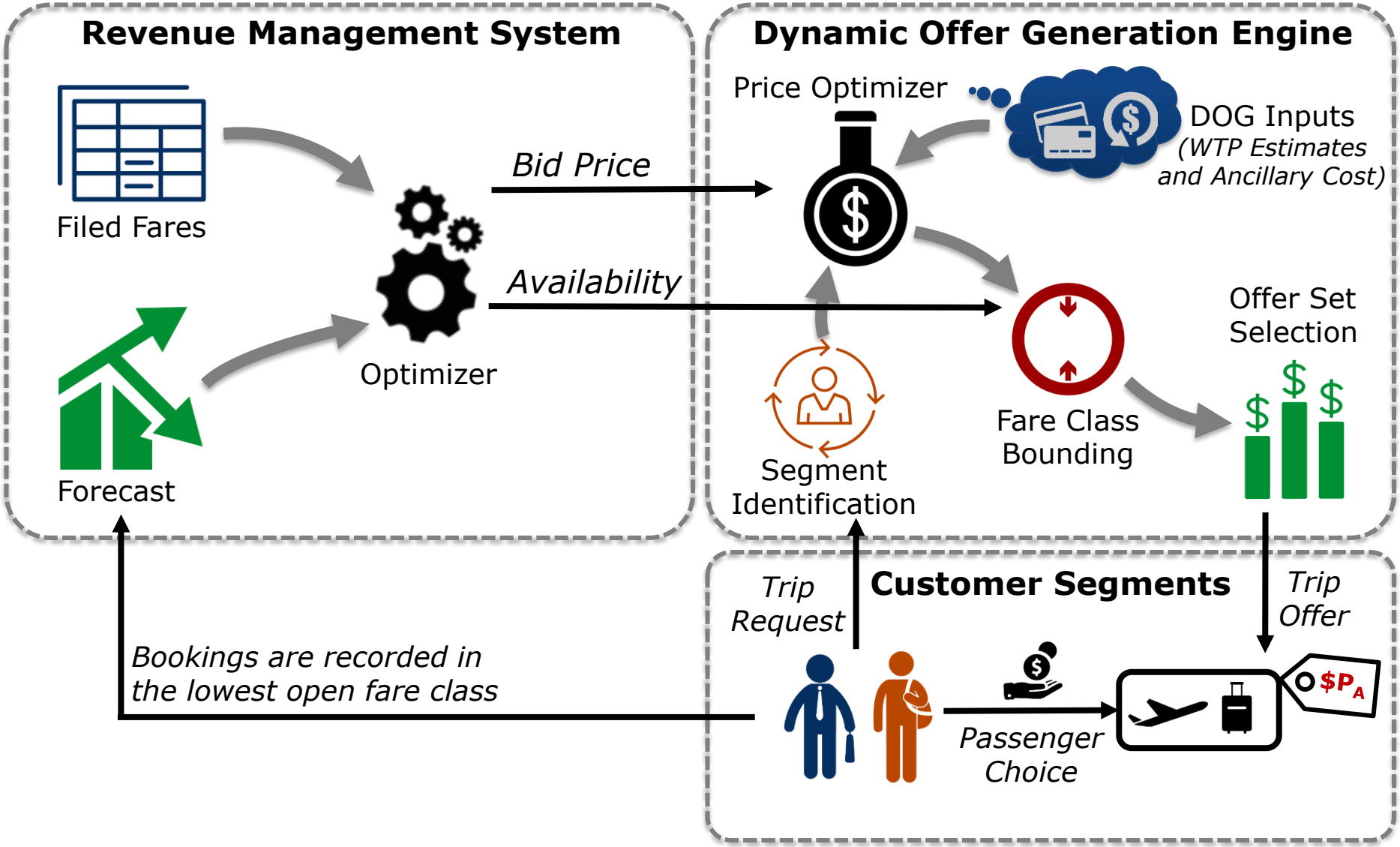
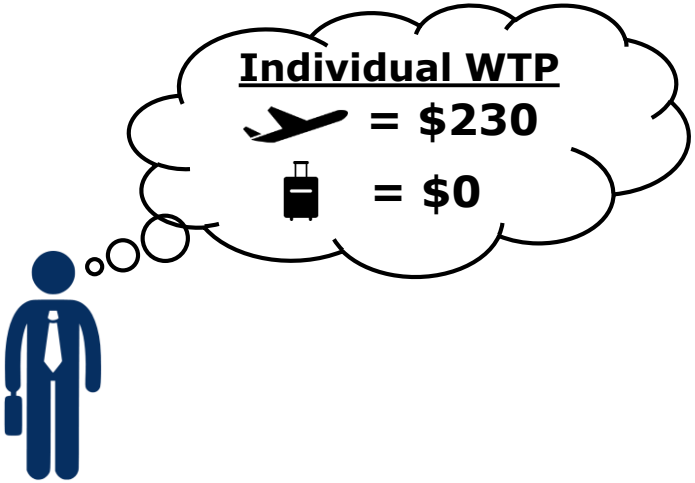
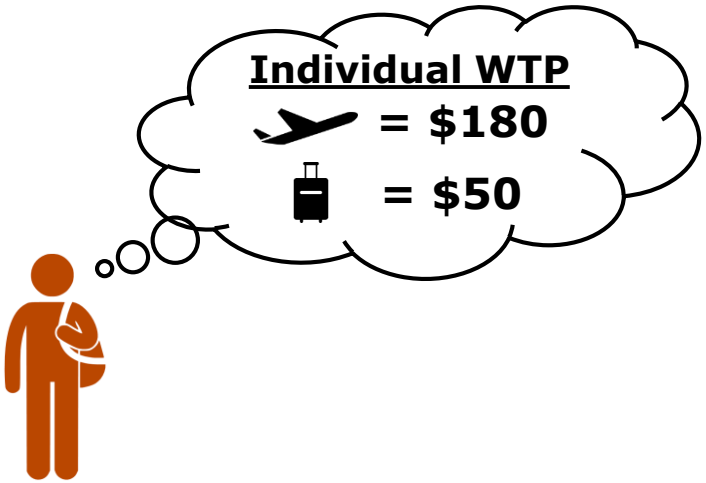


What Would Each Passenger Purchase?





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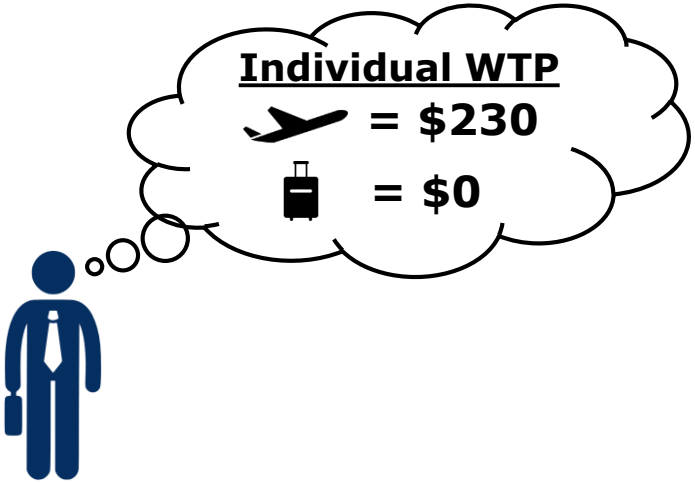
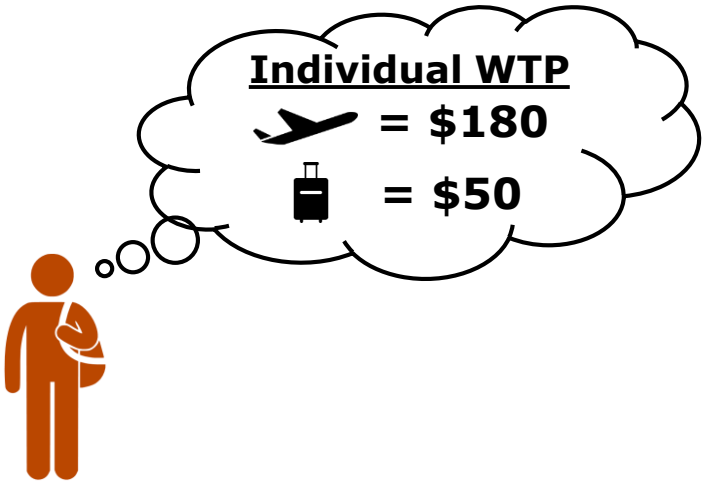
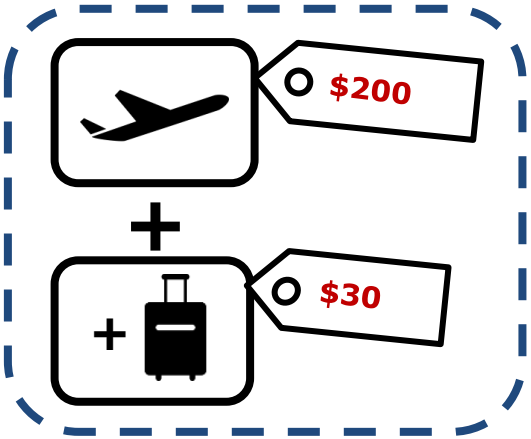




A La Carte



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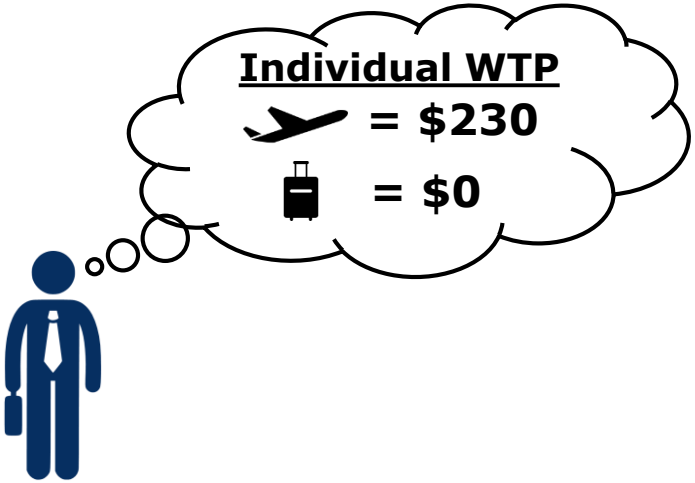
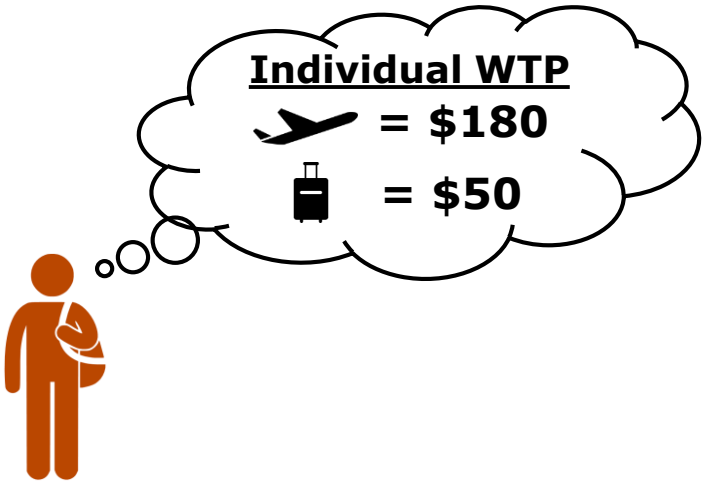
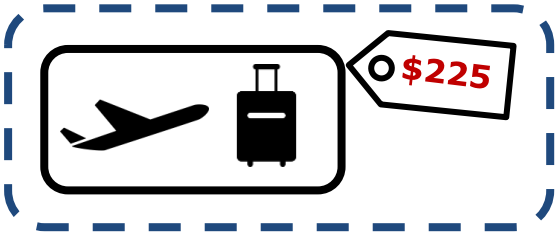




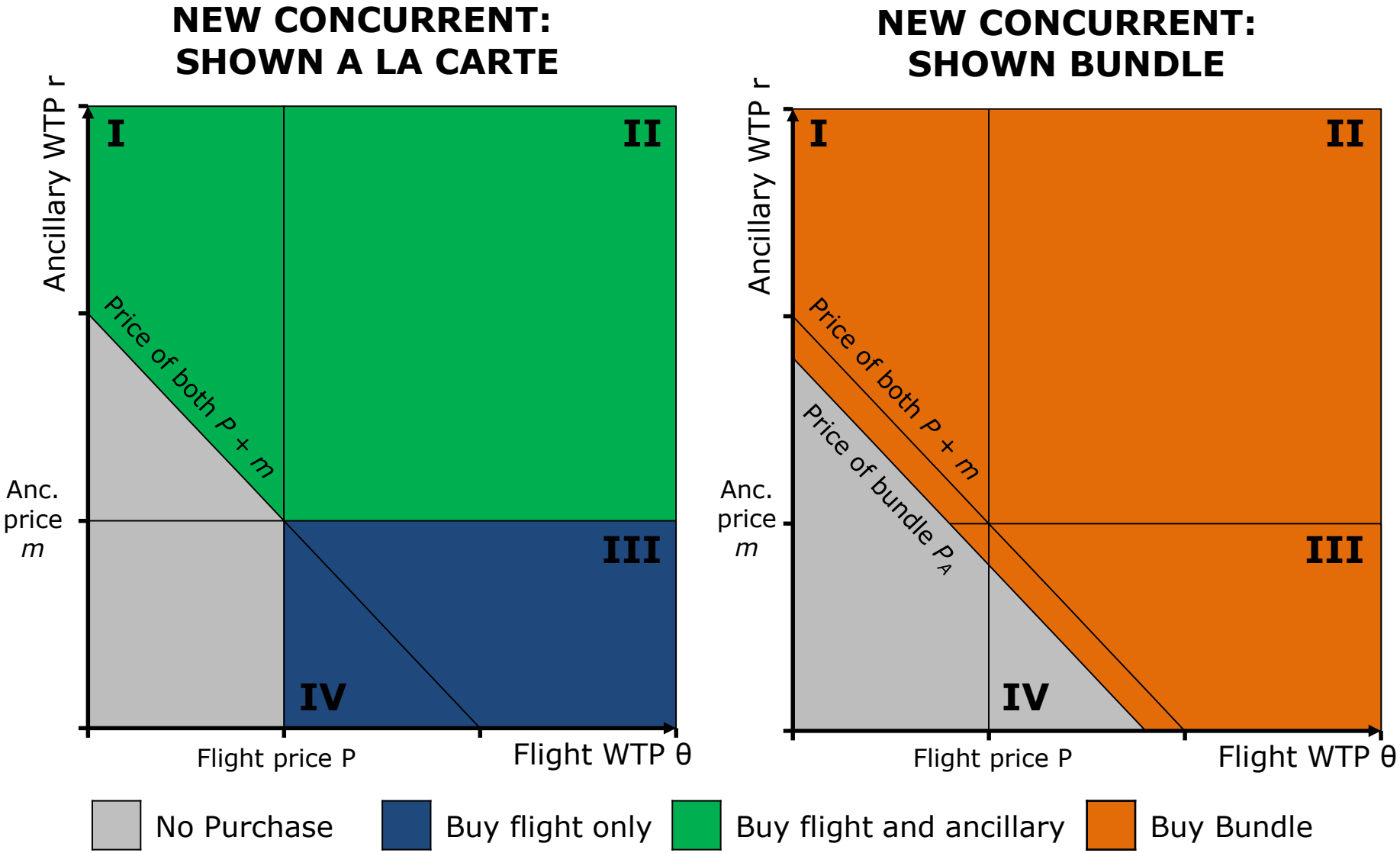
Bundle



How Do We Model Passenger Choice?

- We developed a concurrent passenger choice model for DOG, which gives each passenger two separate budgets:
  - The flight willingness to pay $\boldsymbol{\theta}$
  - The ancillary disutility/WTP $\boldsymbol{r}$
- When passengers evaluate the A La Carte offer set:
  - They purchase the flight if their flight WTP exceeds the flight price
  - They purchase the optional ancillary only if their ancillary disutility exceeds the add-on purchase price
  - They can **cross-subsidize** a shortfall in flight WTP with excess ancillary WTP (sum of both WTP > price of both flight and ancillary)
- When passengers evaluate the Bundle:
  - They purchase the bundle if the sum of their two budgets $\boldsymbol{\theta + r}$ exceeds the price of the bundle

DOG Assumes Concurrent Passenger Choice



The DOG Price Optimizer

In our formulation, the dynamic price optimization depends on four input variables:

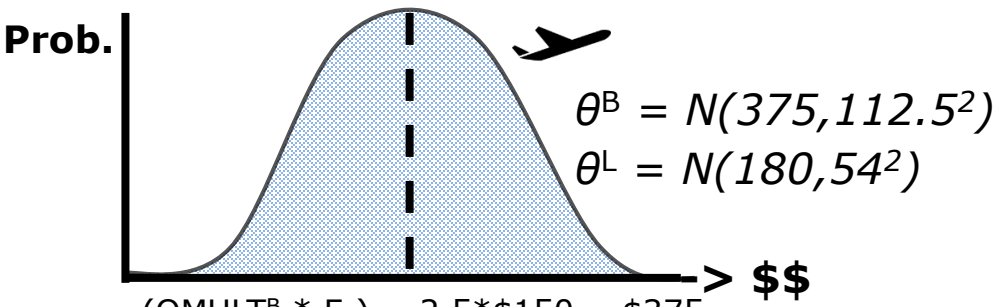
Flight-related inputs
(Bid Price ***BP*** and estimated Flight WTP distribution $\boldsymbol{\theta}$)

Ancillary-related inputs
(Ancillary Cost $\boldsymbol{c_a}$ and est. Ancillary WTP distribution $\boldsymbol{r}$)

Airline Estimates WTP for Flight and Ancillary

- In the DOG model, the airline assumes that passenger flight WTP θ and ancillary disutility r are normally distributed
- Each passenger segment's mean flight WTP is described by a Q multiplier on the lowest published fare F_n in each OD market
- In this example, F_n = \$150 and Q=2.5 for business/Q=1.2 for leisure
- A coefficient of variation (CV) is used to set the standard deviation at 30% of the mean

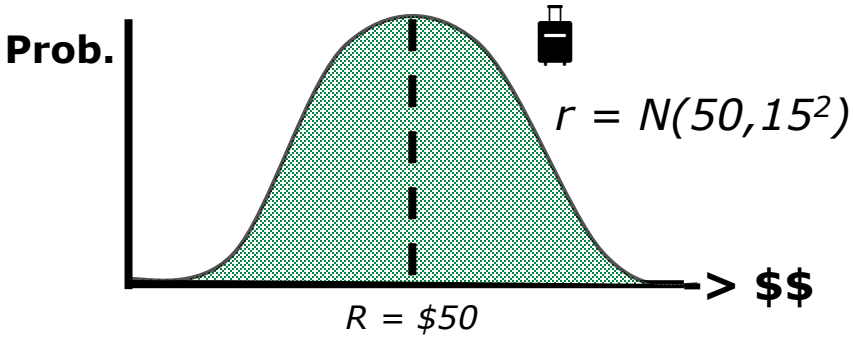
Estimated Flight WTP θ is normally distributed with mean (QMULT * f_n) and CV k_θ where F_n is the lowest filed fare



$(QMULT^B * F_n)$ = 2.5*\$150 = \$375

$(QMULT^L * F_n)$ = 1.2*\$150 = \$180

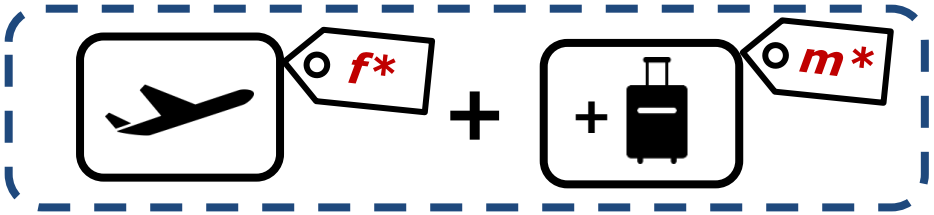
Estimated Ancillary WTP r is normally distributed with mean R and CV k_r

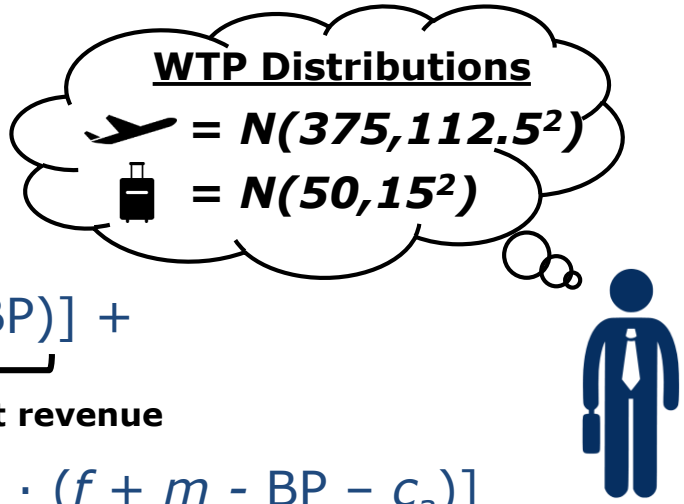


Pricing the Offer Sets: A La Carte

- Find a la carte prices f^* and m^* that maximize expected revenues:

A La Carte





$$E_1(f,m) = \underbrace{[\text{Prob}(r < m \textbf{ and } \theta > f)}_{\textbf{Prob(Flight only purchased)}} \cdot \underbrace{(f - \text{BP})}_{\textbf{Net flight revenue}}] +$$

$$\underbrace{[\text{Prob}(r > m \textbf{ and } \theta + r > f + m)}_{\textbf{Prob(Flight and add-on purchased)}} \cdot \underbrace{(f + m - \text{BP} - c_a)}_{\textbf{Net flight and add-on revenue}}]$$

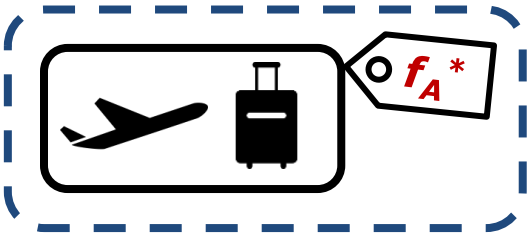
- We approximate this optimization in a sequential process:
  - First, the ancillary price $m^* = \arg\max [\text{Prob}(r > m) \cdot (m - c_a)] =$ **\$54.81**
  - Then, the business price $f^{B*} = \arg\max E_1(f,m^*) =$ **\$302.24**
  - Equally, the leisure price $f^{L*} = \arg\max E_1(f,m^*) =$ **\$151.84**

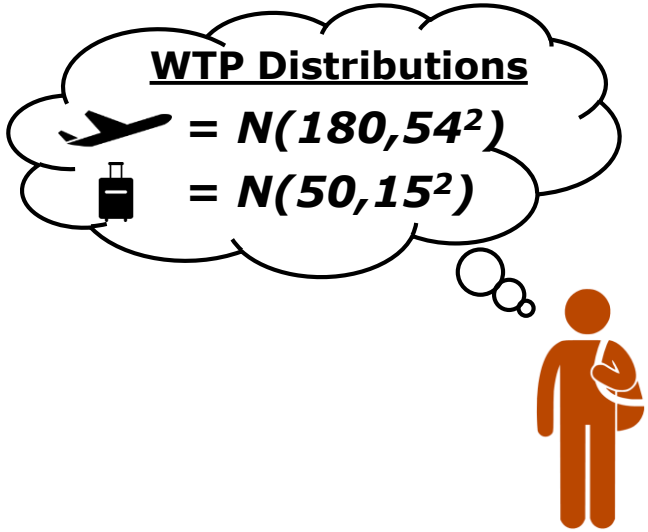
Note: Calculations use BP = c_a = \$40

Pricing the Offer Sets: Bundle

- Next, find the bundle price f_A^* that maximizes expected revenue:

Bundle



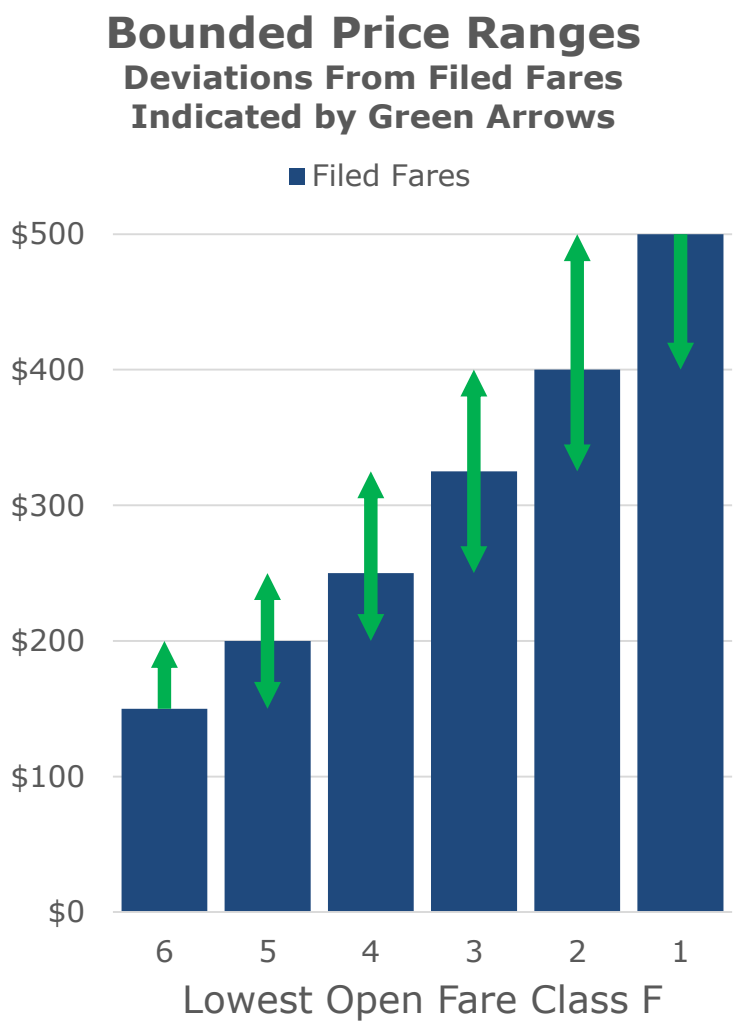


$$E_2(f_A) = \underbrace{\text{Prob}(\theta + r > f_A)}_{\text{Prob(Bundle purchased)}} \cdot \underbrace{[f_A - BP - c_a]}_{\text{Net bundle revenue}}$$

- The equivalent bundle prices for the business and leisure pax are:
  - f_A^{B*} = arg max $E_2(f_A)$ = **$348.29**
  - f_A^{L*} = arg max $E_2(f_A)$ = **$198.12**

Note: Calculations use BP = c_a = $40

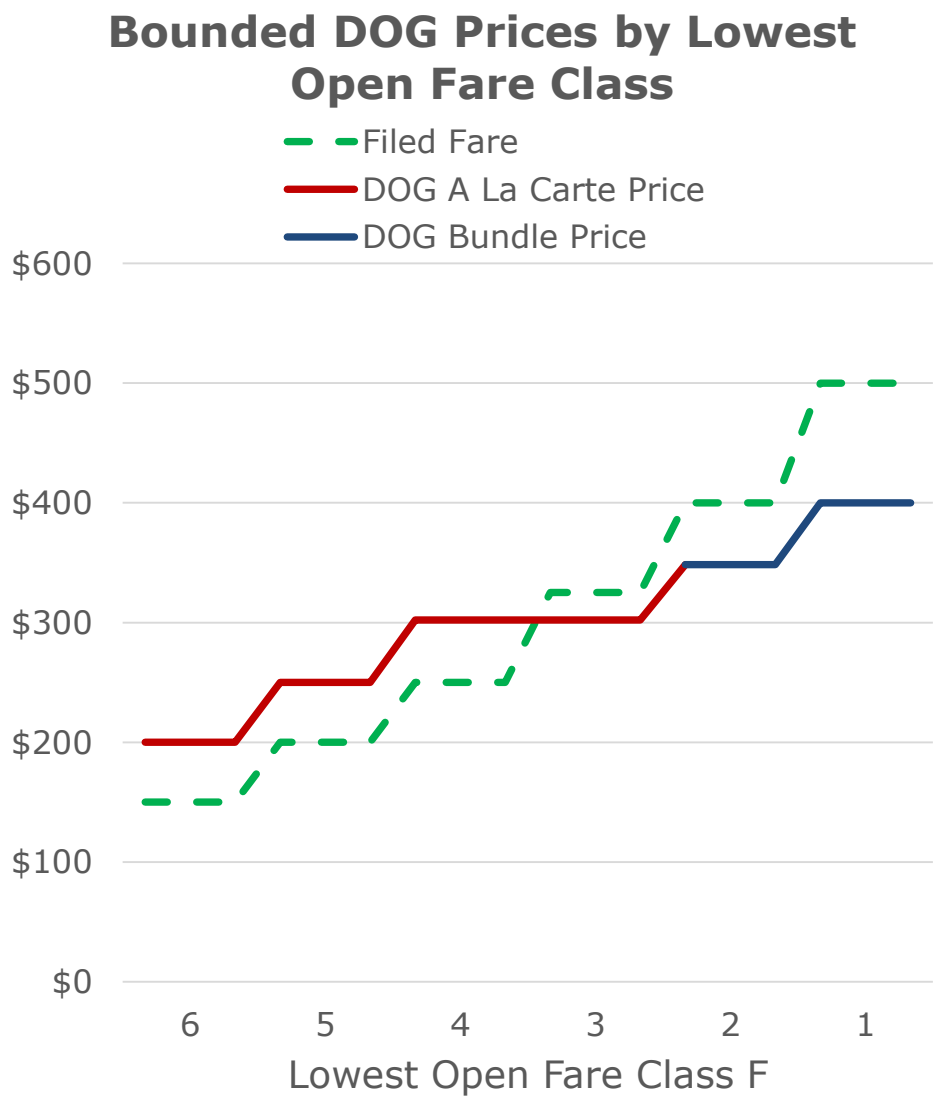
Fare Class Bounding



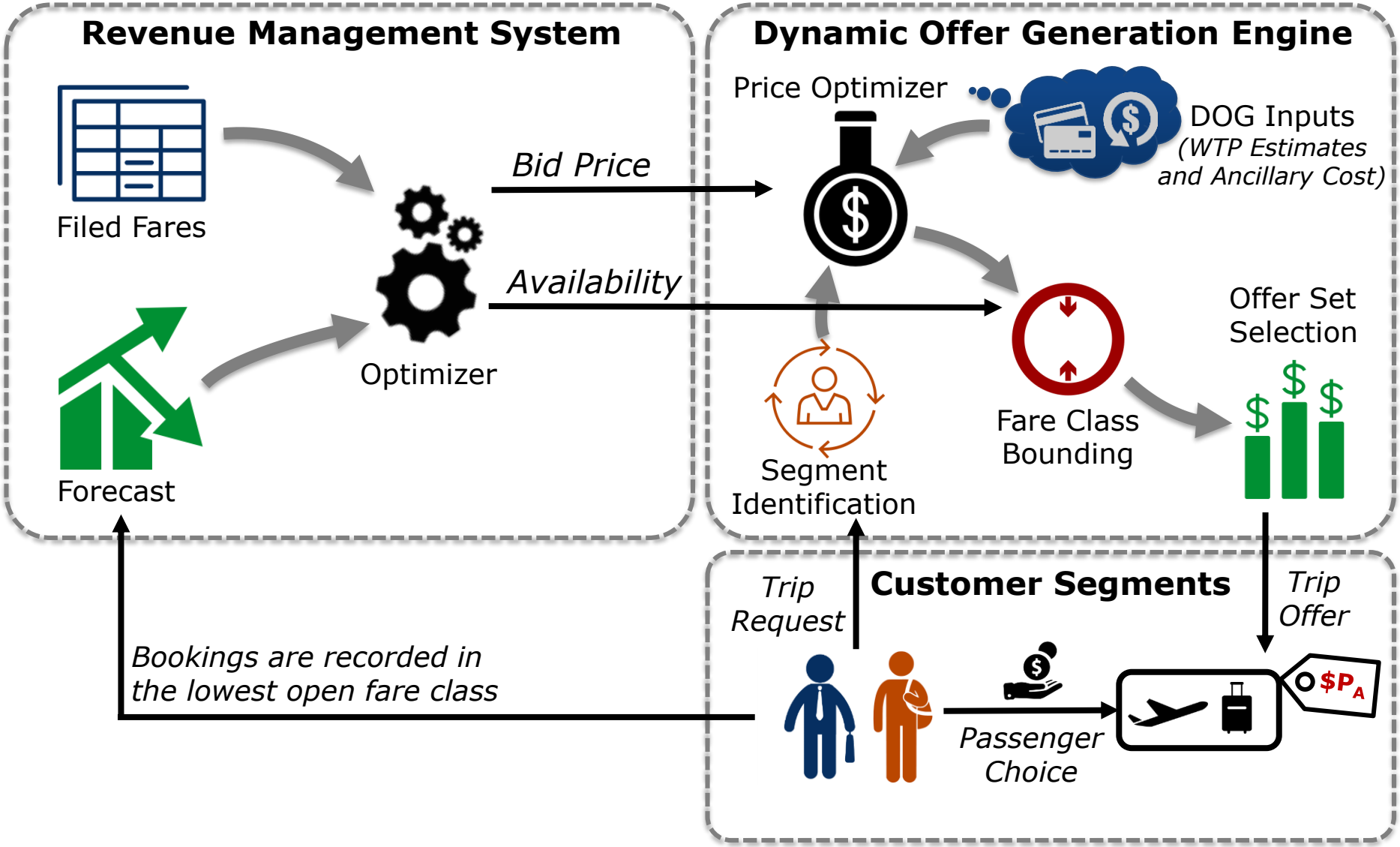
- The DOG price optimizer returns continuous prices, which we realign with class-based RM and filed fares through fare class bounding
- Our current bounding rules are:
  - Absolute bounds to the lowest and highest filed fares: $F_n \leq \{P_i^*, P_{A,i}^*\} \leq F_1$
  - Relative bounds to the next adjacent filed fares: $F_{i+1} \leq \{P_i^*, P_{A,i}^*\} \leq F_{i-1}$
  - Both f_A^* and f^* are subject to the same bounds
- After bounding, we recompute the expected revenues for each offer set and show the passenger the most profitable offer set

DOG Prices vs Filed Fares

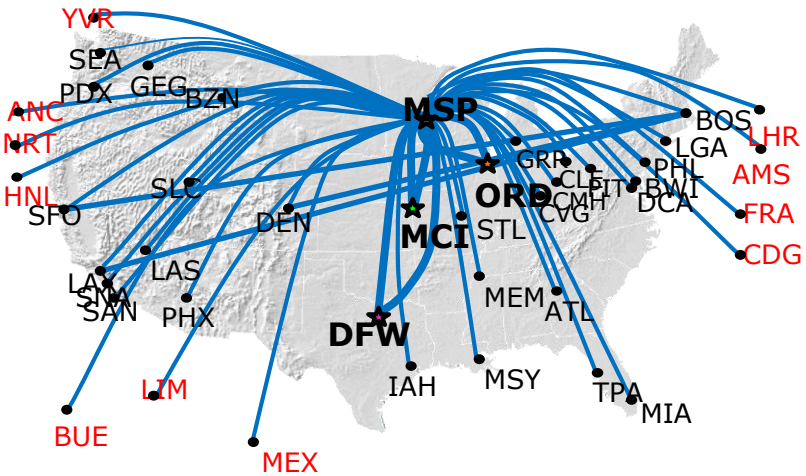
- Plot shows a typical profile of bounded DOG prices compared against the original filed fares
- In the lower fare classes, DOG prices tend to be higher than the filed fare and no bundles are offered (A La Carte)
- In the higher fare classes, DOG discounts the filed fare and bundles ancillaries to increase the likelihood of purchase
- This difference between DOG and filed fares explains the effects observed when a DOG airline competes against an airline with filed fares in PODS



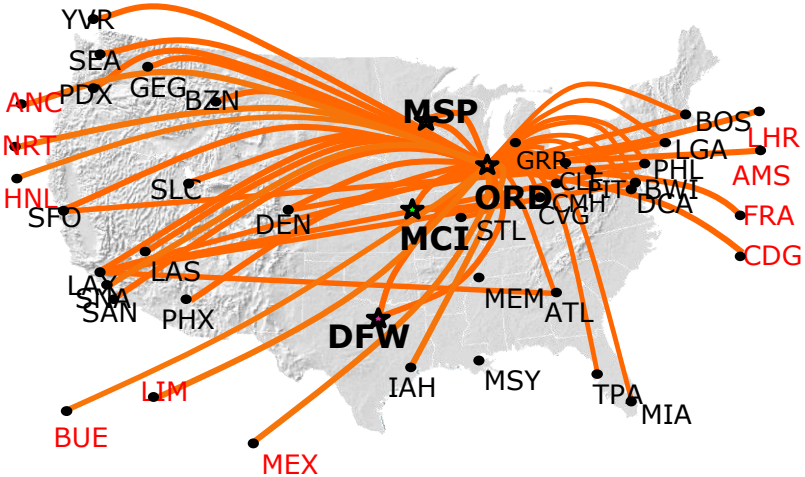
Recap: Overview of DOG



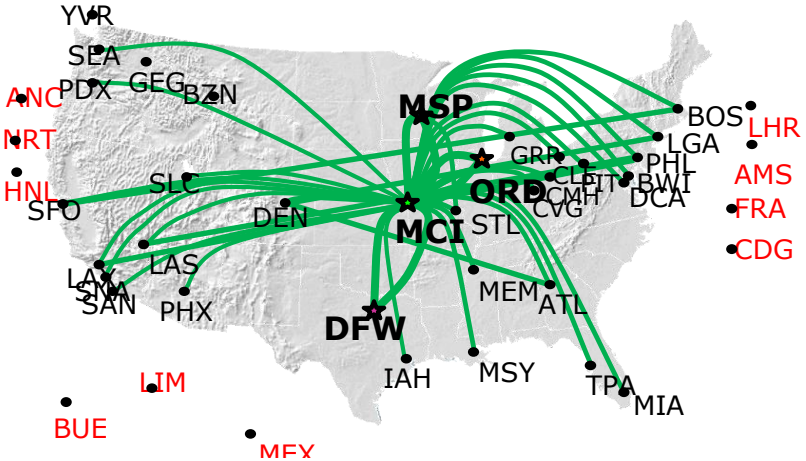
We Present Results From PODS Simulations Performed in Unrestricted Network U10



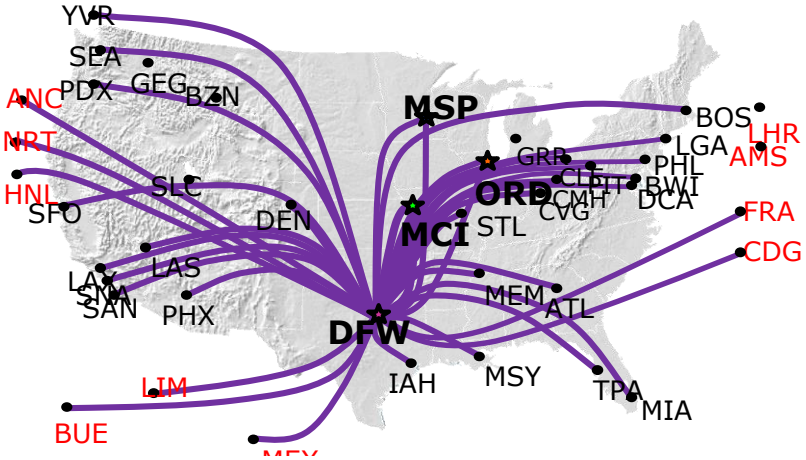
AL1 MSP Network (DAVN)



AL2 ORD Network (DAVN)



AL3 MCI Domestic Network (DAVN*)



AL4 DFW Network (DAVN)

**unless otherwise noted*

Unrestricted Network U10 Has No Restrictions or APs in Any Fare Class or Fare Product

Product 1: Domestic

FC	AP	MIN3	CXL	SAT
1	0	0	0	0
2	0	0	0	0
3	0	0	0	0
4	0	0	0	0
5	0	0	0	0
6	0	0	0	0
7	0	0	0	0
8	0	0	0	0
9	0	0	0	0
10	0	0	0	0

Product 2: Domestic

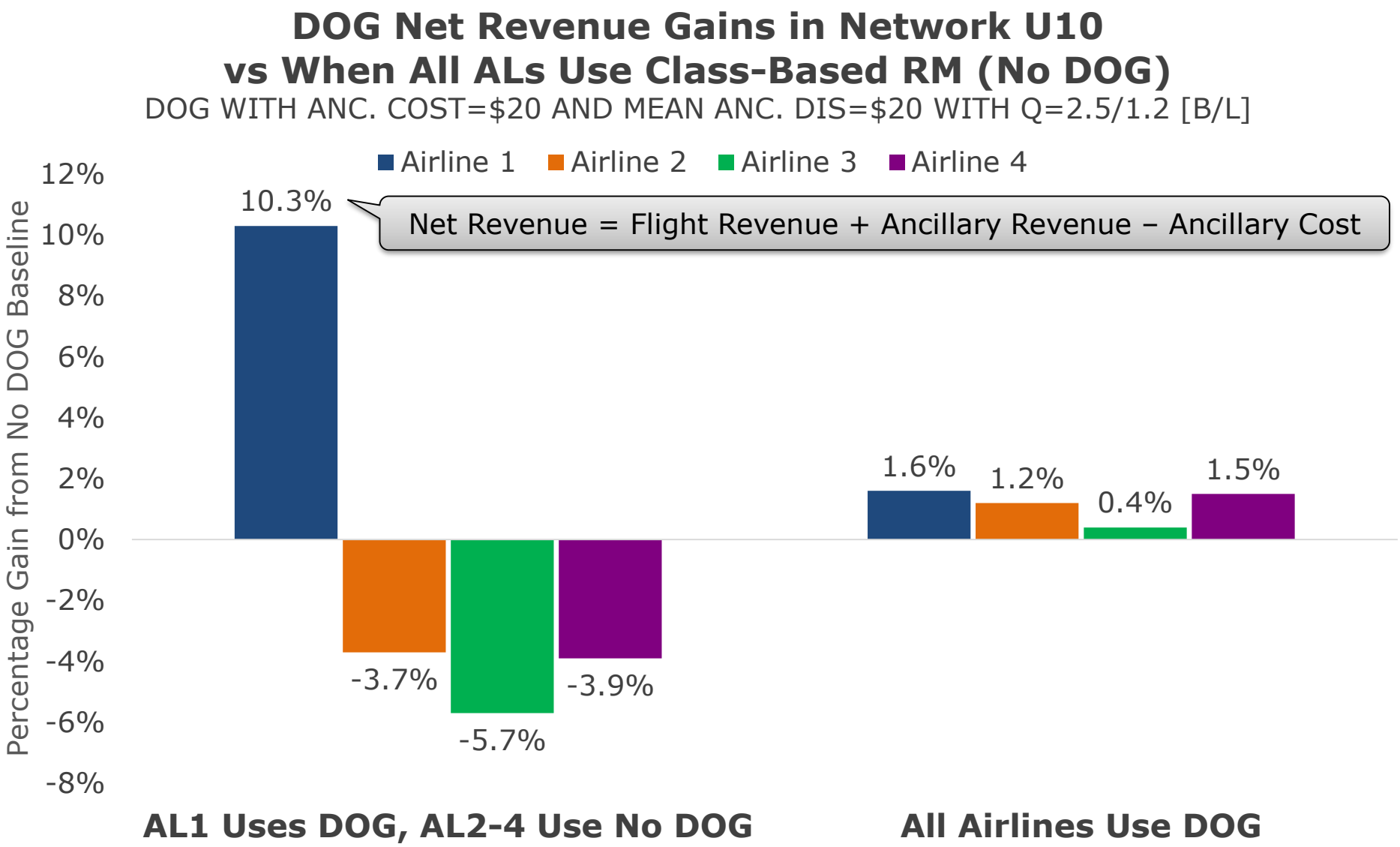
FC	AP	MIN3	CXL	SAT
1	0	0	0	0
2	0	0	0	0
3	0	0	0	0
4	0	0	0	0
5	0	0	0	0
6	0	0	0	0
7	0	0	0	0
8	0	0	0	0
9	0	0	0	0
10	0	0	0	0

Product 3: International

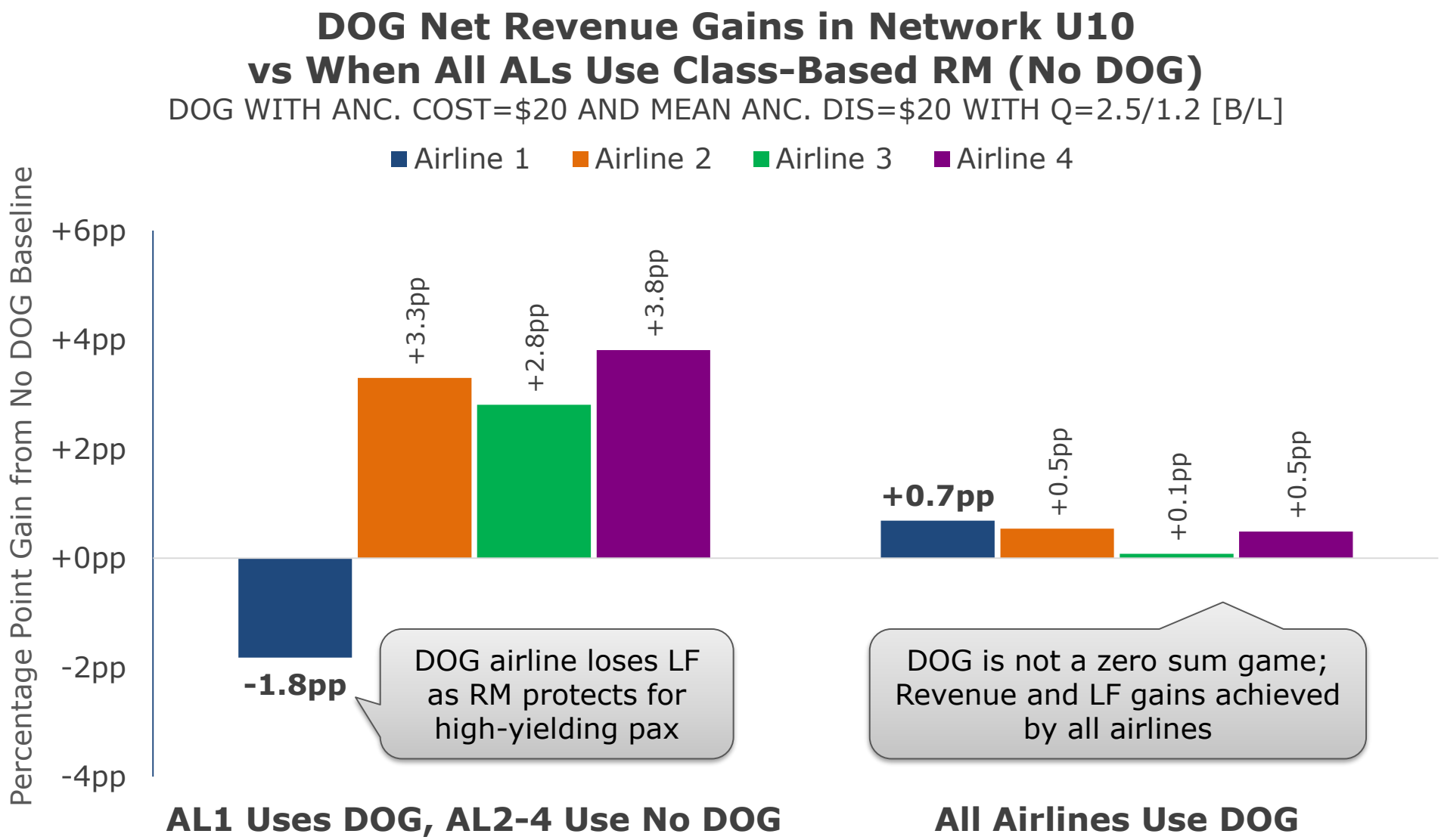
FC	AP	MIN3	CX	SAT
1	0	0	0	0
2	0	0	0	0
3	0	0	0	0
4	0	0	0	0
5	0	0	0	0
6	0	0	0	0
7	0	0	0	0
8	0	0	0	0
9	0	0	0	0
10	0	0	0	0

Current DOG model is built for unrestricted fares (Passengers can only choose one flight offer per flight)

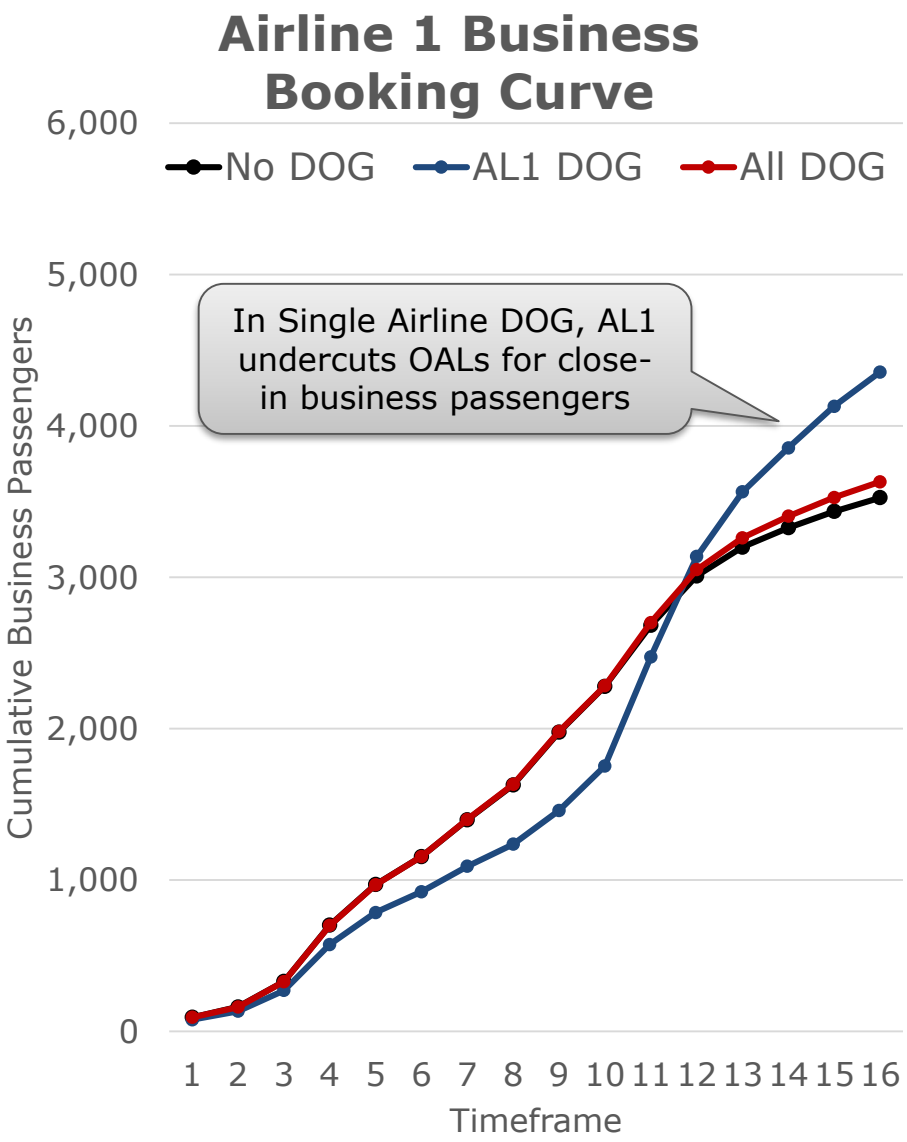
DOG Can Lead to Revenue Increases

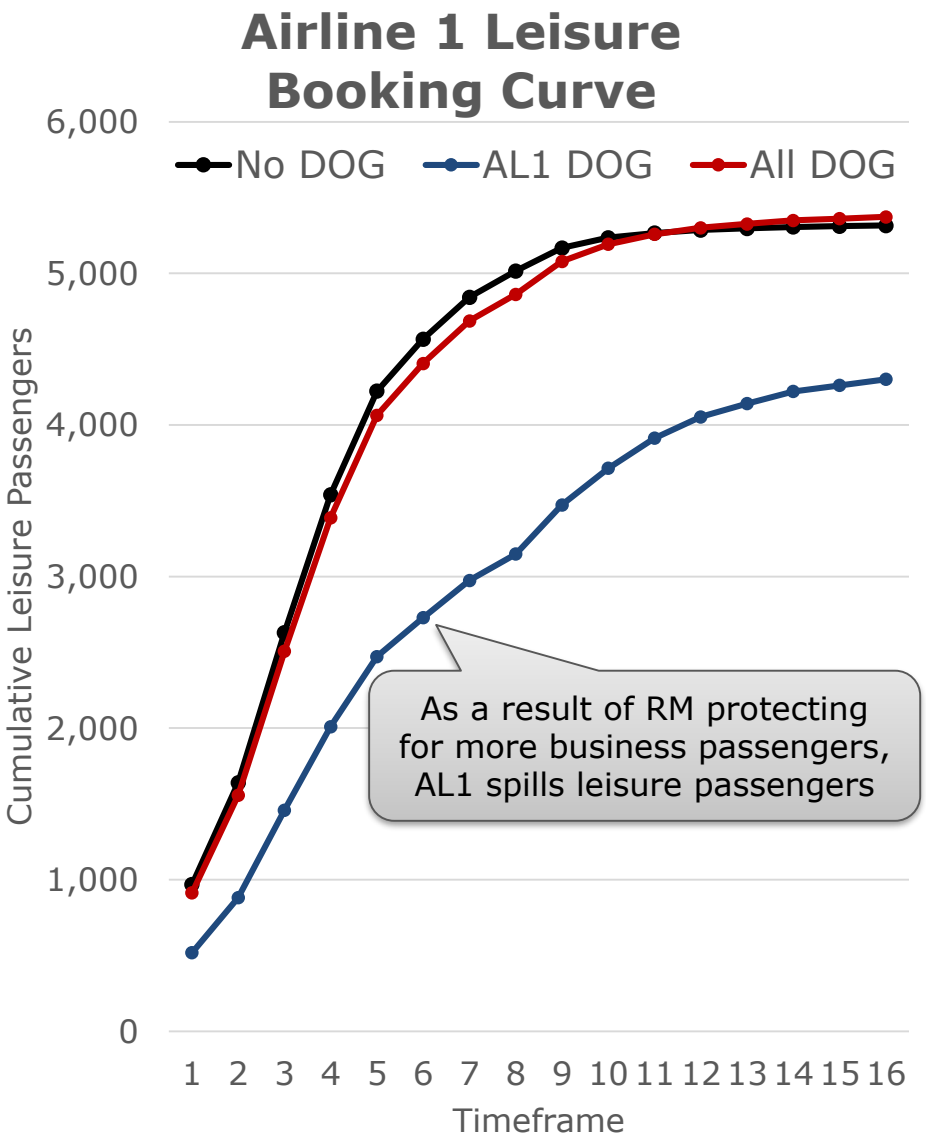


DOG Effect on Load Factors

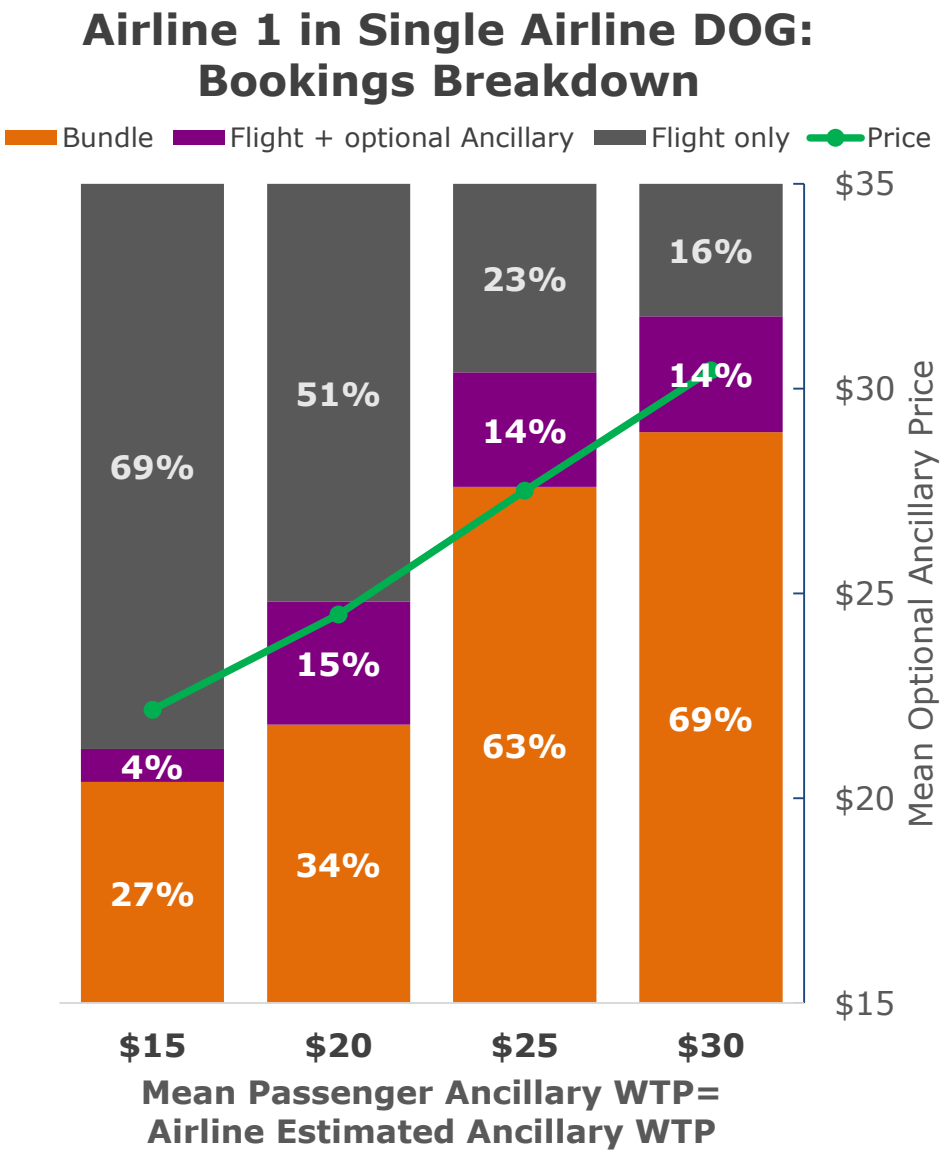


Large Competitive Feedback Effects Distort Booking Curves in Single Airline DOG



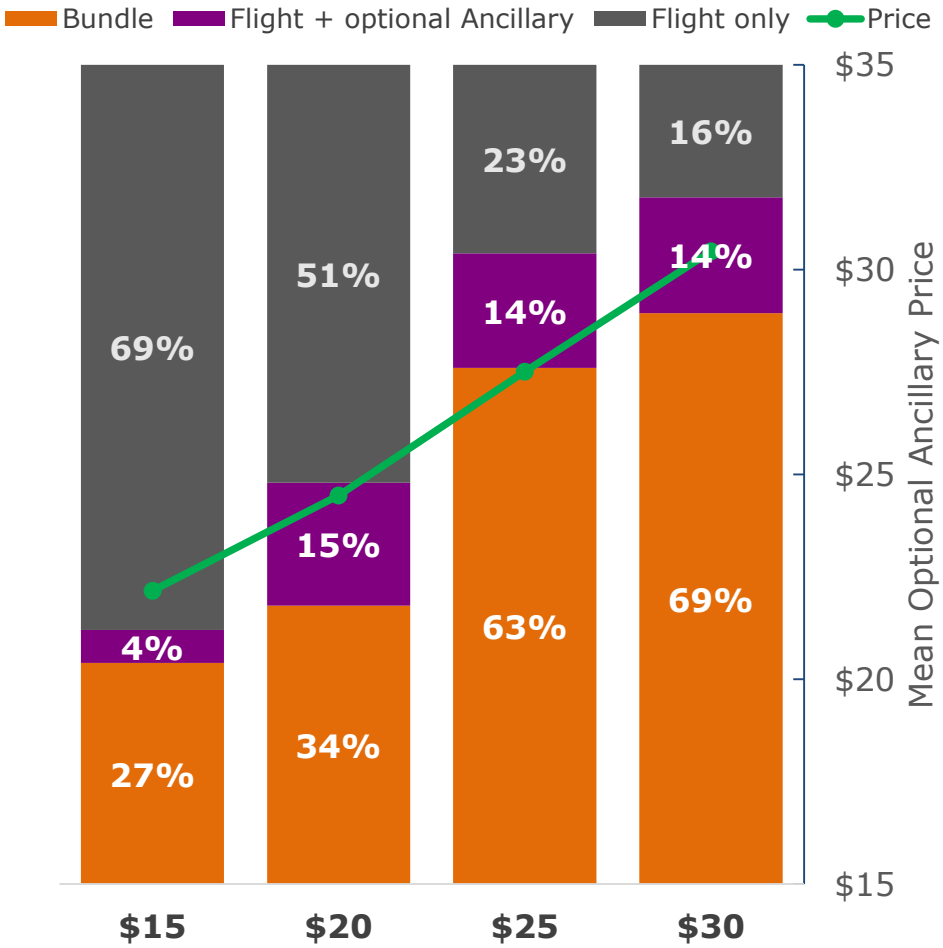


More Bundles and Ancillaries Are Sold as Ancillary WTP Increases

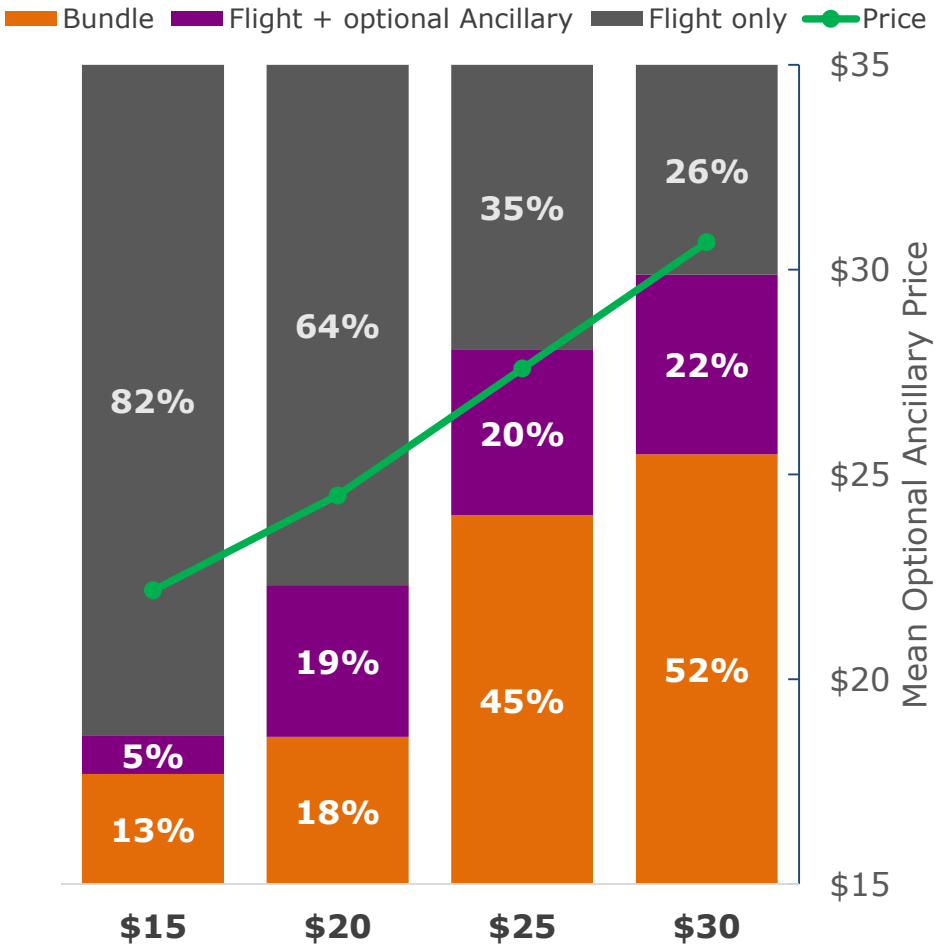


More Bundles and Ancillaries Are Sold as Ancillary WTP Increases

Airline 1 in Single Airline DOG: Bookings Breakdown

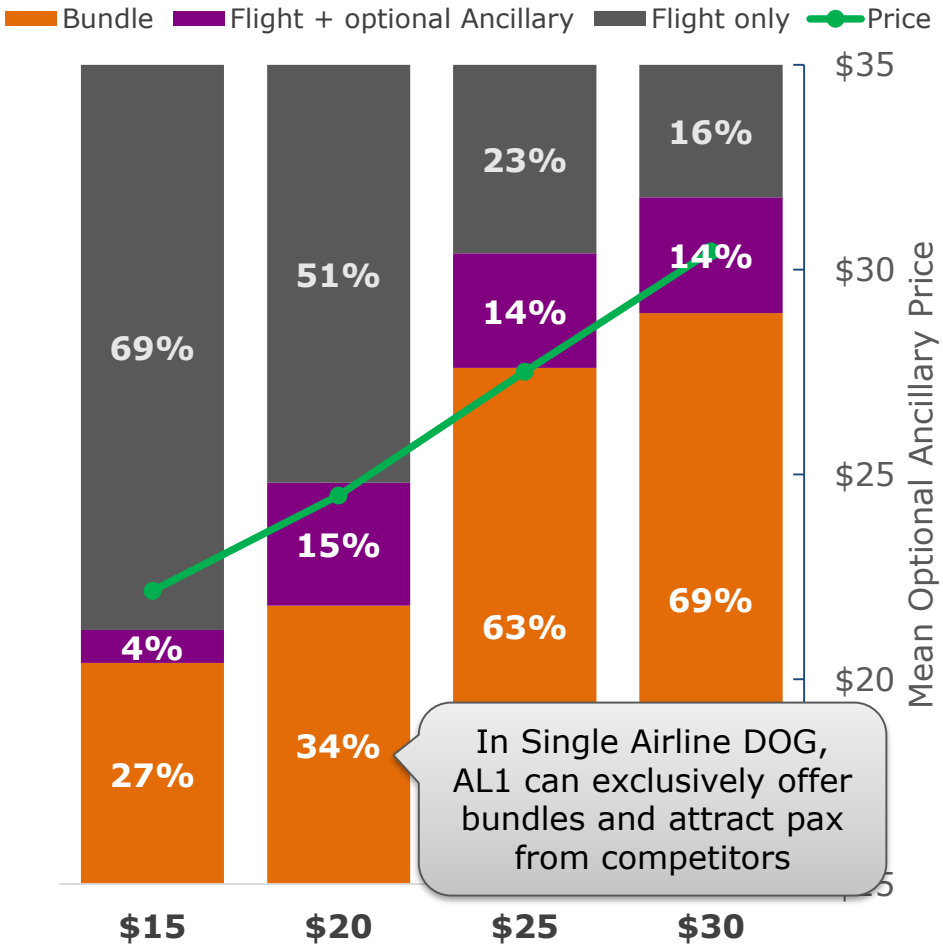


Airline 1 in All Airline DOG: Bookings Breakdown



More Bundles and Ancillaries Are Sold as Ancillary WTP Increases

Airline 1 in Single Airline DOG: Bookings Breakdown



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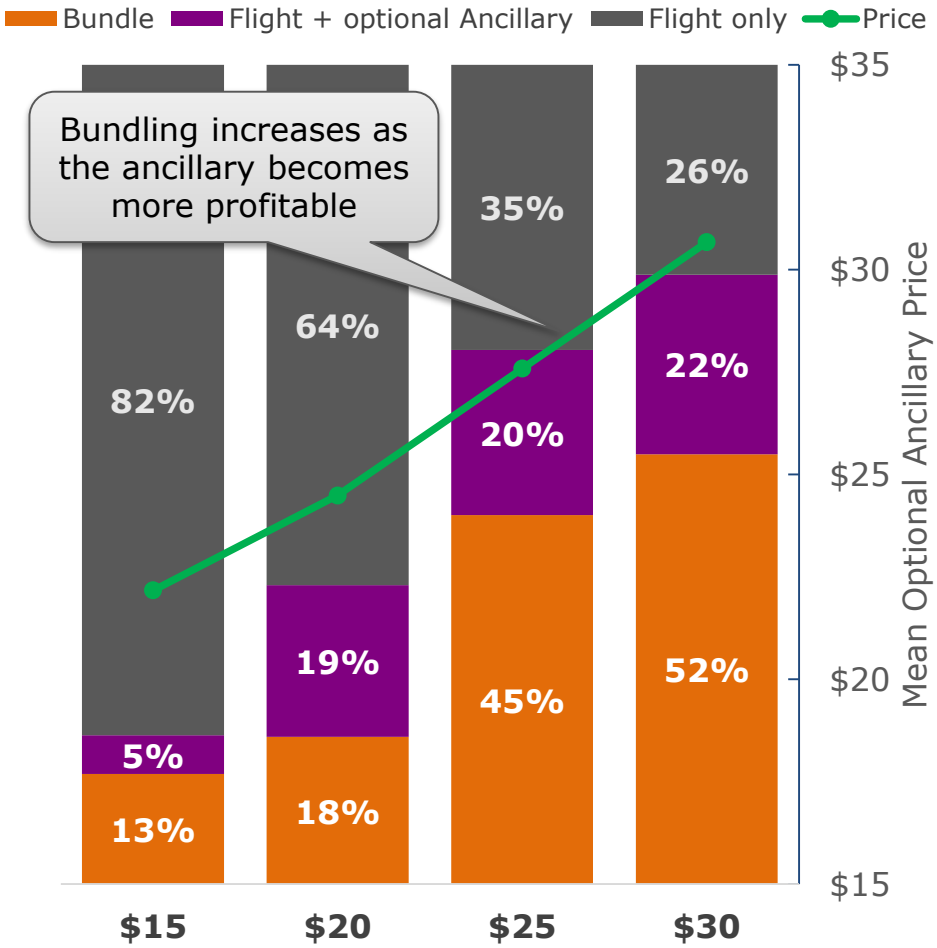
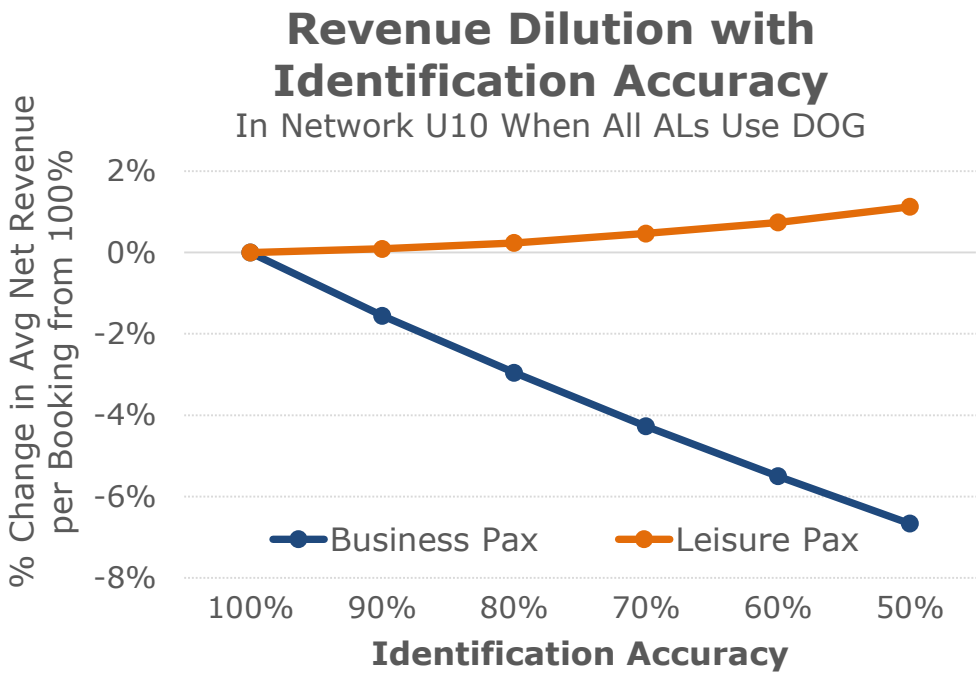


Passenger Type Identification Accuracy

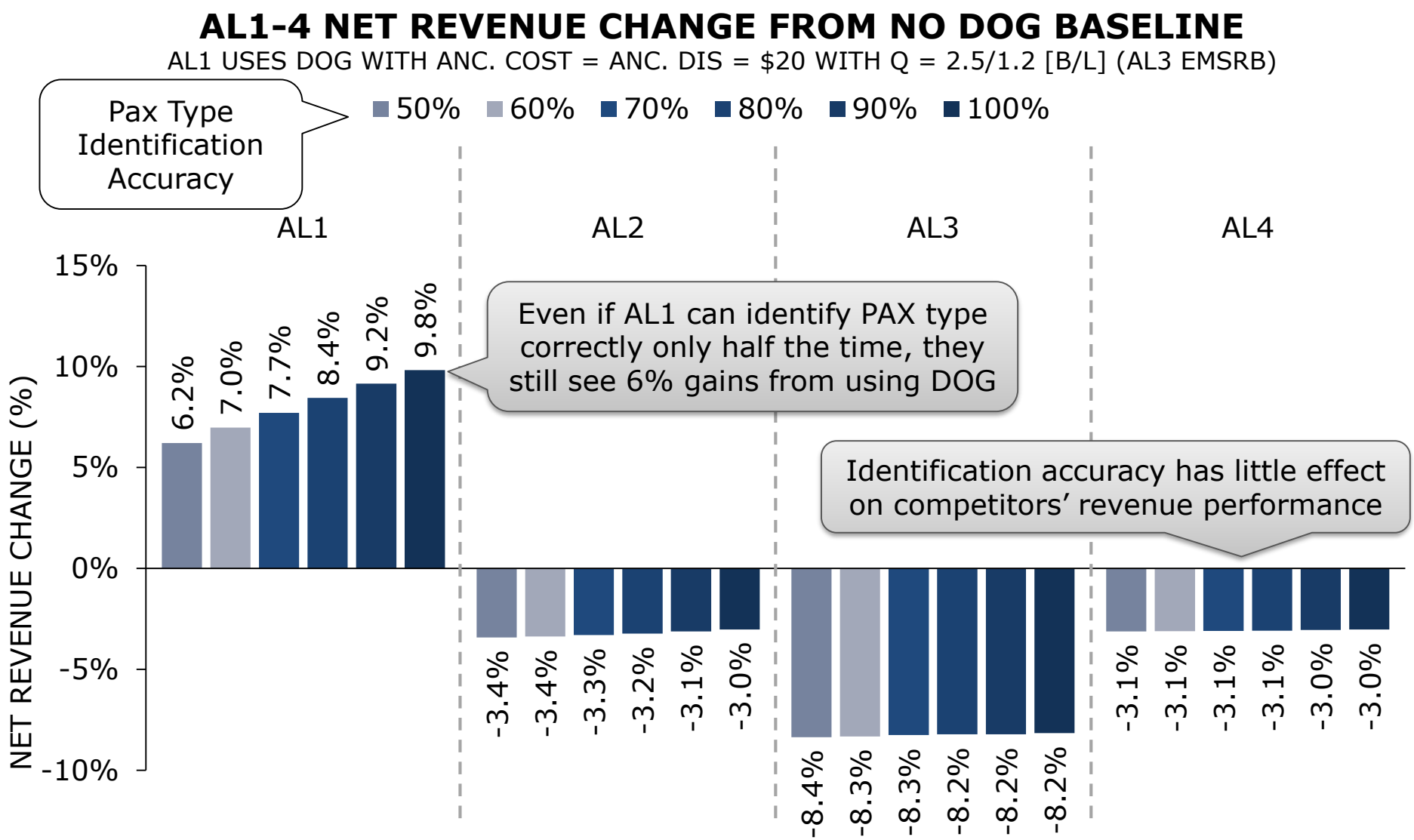
- Identification accuracy is an important driver of segmented DOG performance, as it determines which offer is presented to each passenger
- Most leisure passengers cannot afford the business offers if misidentified, but business passengers would buy down to the cheaper leisure offers

Choice Matrix	Business Passenger	Leisure Passenger
Business Offer	Buy	No Go
Leisure Offer	Pay Less	Buy



- This is a general trend in segmented DOG: lower accuracy leads to revenue losses as business pax buy down and leisure pax book away

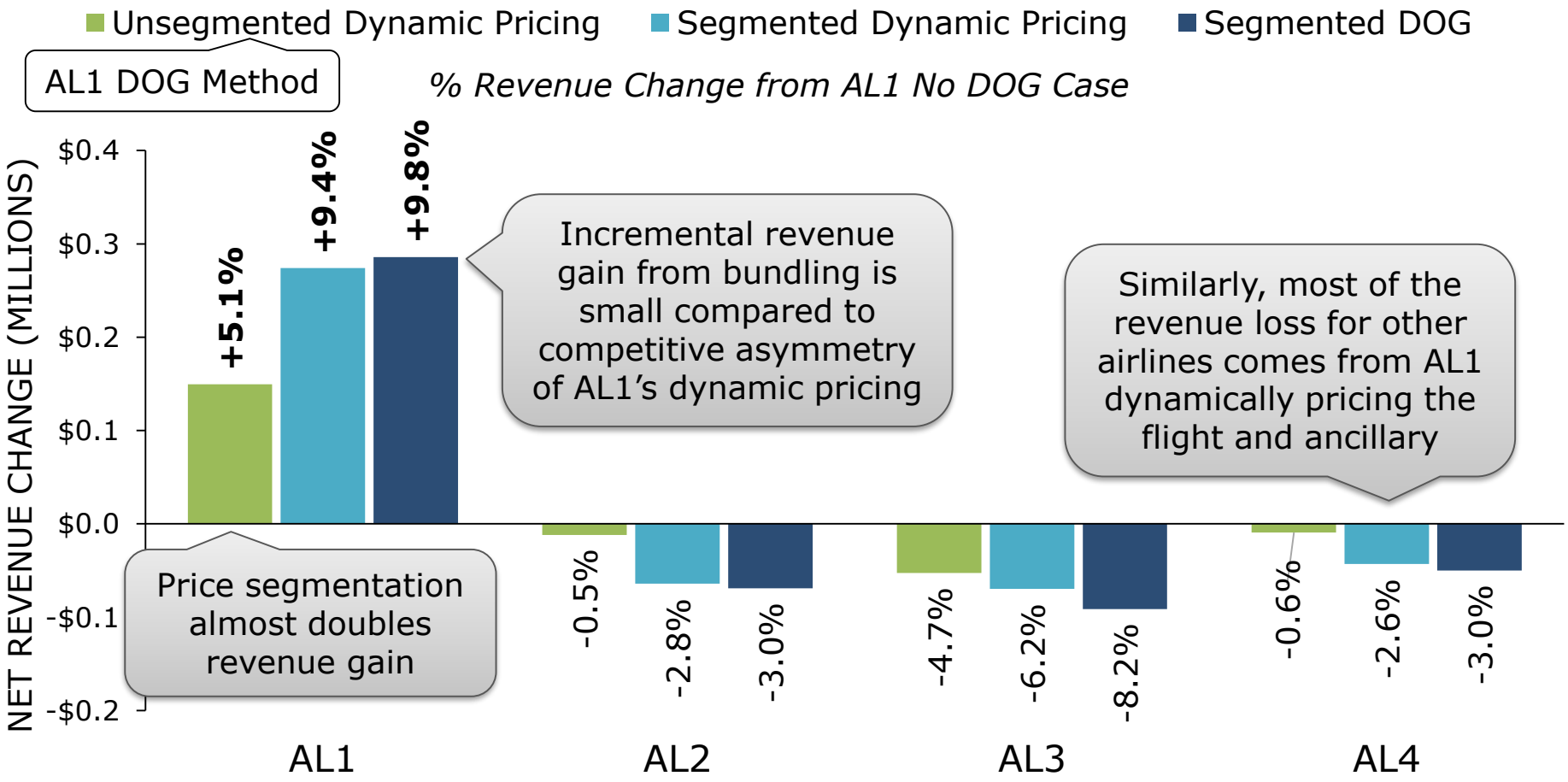
As AL1 Makes More PAX Type Identification Mistakes, the Revenue Gain from Using DOG Reduces



Most of Single Airline DOG's Revenue Gain Comes from the Dynamic Pricing of A La Carte Offers, Not Bundling

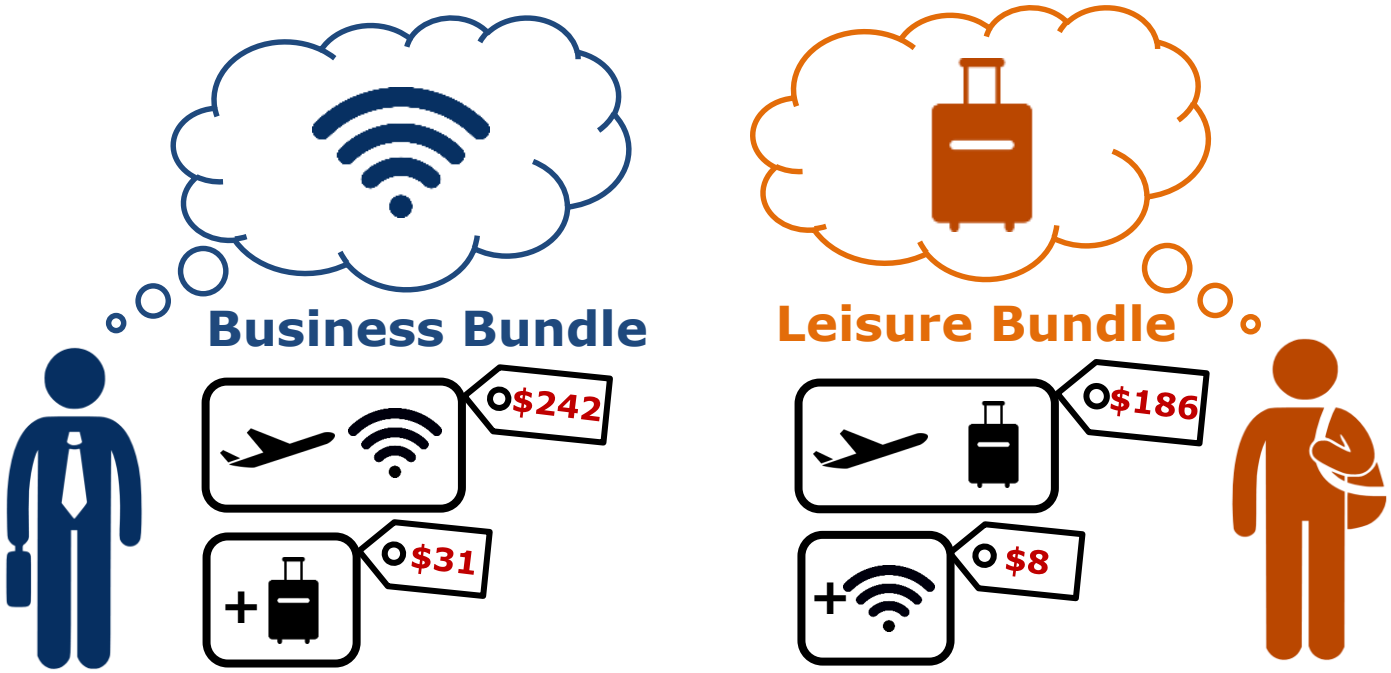
REVENUE CHANGE FROM NO DOG BASELINE

AL1 ONLY DOG USES ANC. COST AND DISUTILITY = $20 (AL3 EMSRB)
SEGMENTED CASES USE Q-MULT = 2.5/1.2 [B/L]



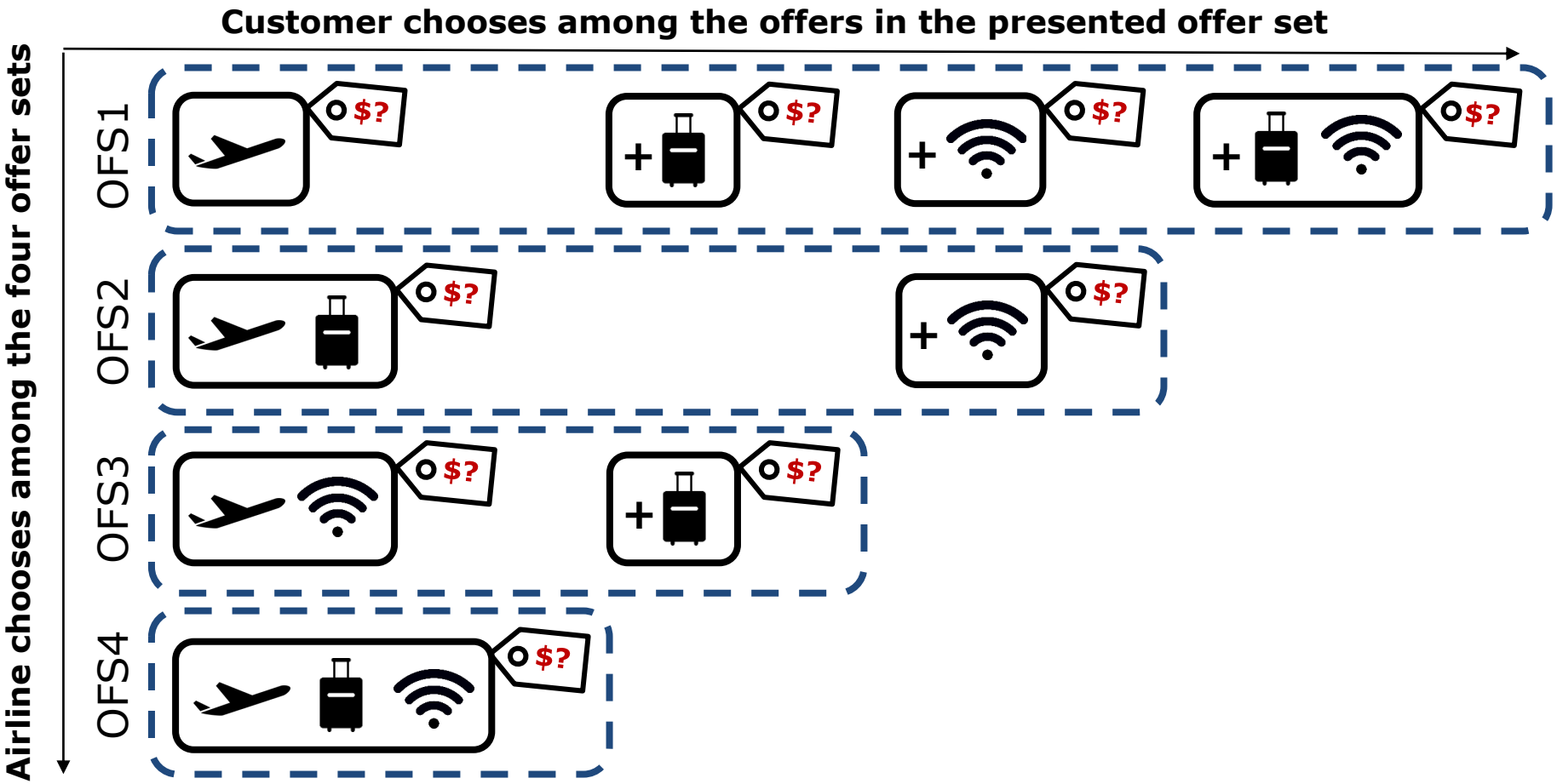
Extending the Model to Two-Ancillary DOG

- DOG with two ancillary services enables new scenarios with segmented and differentiated ancillary offers
- Idea: Passengers value different travel services differently, can we make our travel offers more customized and differentiated?
- Initial results from DOG experiments where business and leisure passengers value two ancillaries differently indicate that DOG is an effective tool for ancillary price segmentation



Two Ancillary DOG Has Triple the Number of Potential Offers

- With two ancillaries, the complexity increases and the airline now chooses to present one of four potential offer sets. We have also extended the concurrent passenger choice model to account for the increased options.



Future Work

- In the PODS Consortium, we are currently developing new concepts for the Dynamic Offer Generation model:
- **Mixed Bundling**
  Offering both an a la carte option and a discounted bundle simultaneously
- **Passenger Choice Model**
  Testing DOG with combinations of different passenger choice behaviors
- **Forecasting and RM Feedback**
  Improving feedback of DOG bookings into forecasts;
  by revising fare class bounding and examining the reporting of revenue

References and Acknowledgements

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