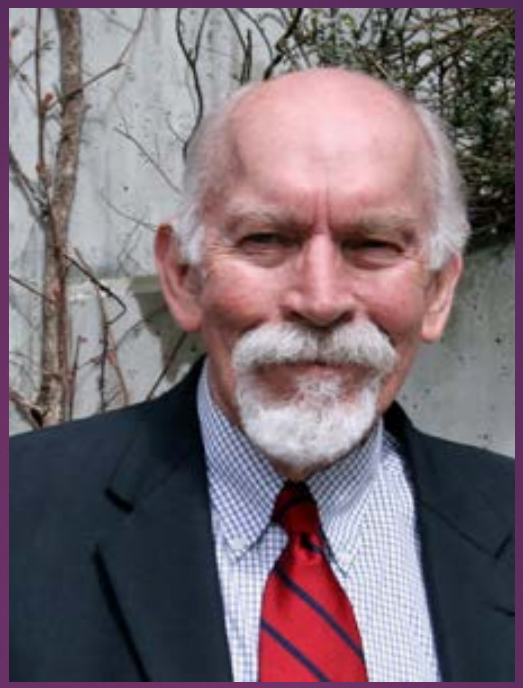
IN MEMORIAM



AGIFORS Fellow

Craig A. Hopperstad

1937-2019

MIT International Center for Air Transportation

PODS

Continuous Pricing: RM Algorithms and Competitive Impacts

Peter Belobaba

AGIFOR RM Study Group Meeting

Panama

May 2019

Six Next-Generation Pricing Mechanisms Are Currently Under Development in the Airline Industry

Least Complex

1. More Frequent Updating of Fare Structures
2. Dynamic Availability of Fare Products
3. Advanced RBD Capabilities
4. Dynamic Pricing Engines
5. Continuous Pricing
6. Dynamic Offer Generation

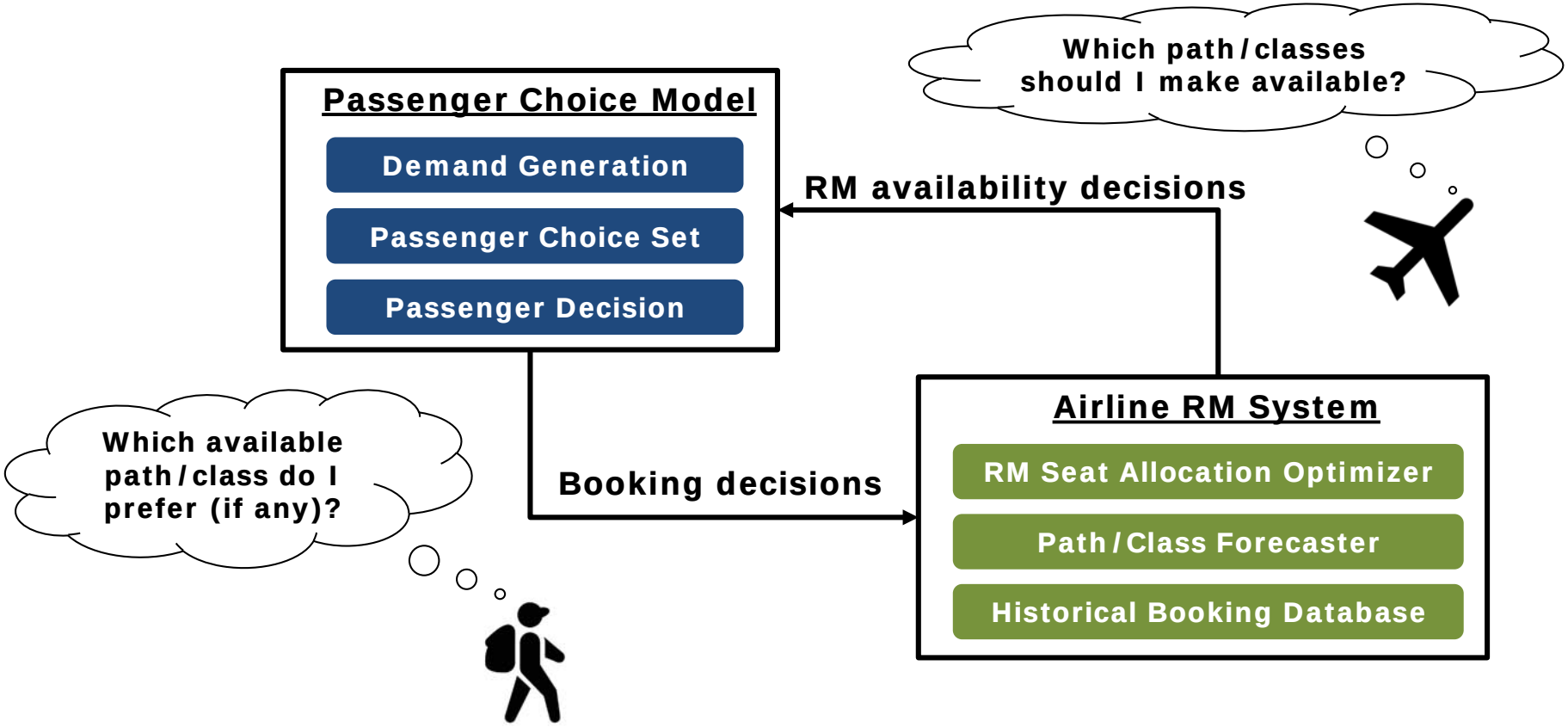
Most Complex

PODS CONSORTIUM RESEARCH

Source: Belobaba, Brunger and Wittman, "Advances in Airline Pricing, RM and Distribution", for ATPCO (2017)

These Mechanisms Are Being Tested in the MIT PODS Revenue Management Consortium

- The **Passenger Origin-Destination Simulator** (PODS) models interactions between passenger choice and airline revenue management systems:



Mechanism 5: Continuous Pricing

- Continuous pricing does not rely on a set of pre-determined price points for fare quotes:
  - Airline generates a single “optimal” price to quote at a given time
- Two possible options for distribution:
  - **File a separate fare basis** for each possible price point, then use continuous pricing to select which price to display.
  - **Use the New Distribution Capability** to distribute continuously chosen prices without reference to pre-determined price points.
- Either approach requires new WTP-based RM forecasting and optimization processes.
  - But, could be based on existing class-based RM or new classless RM databases and algorithms

Classless RM and Continuous Pricing Framework

		Forecasting and Optimization	
Pricing / Distribution		Class-Based	Classless
	Fixed Price Points	Traditional Class-Based RM	Classless for Fixed Prices RM
	Continuous Price Points	Class-Based RM for Continuous Pricing	Classless RM for Continuous Pricing

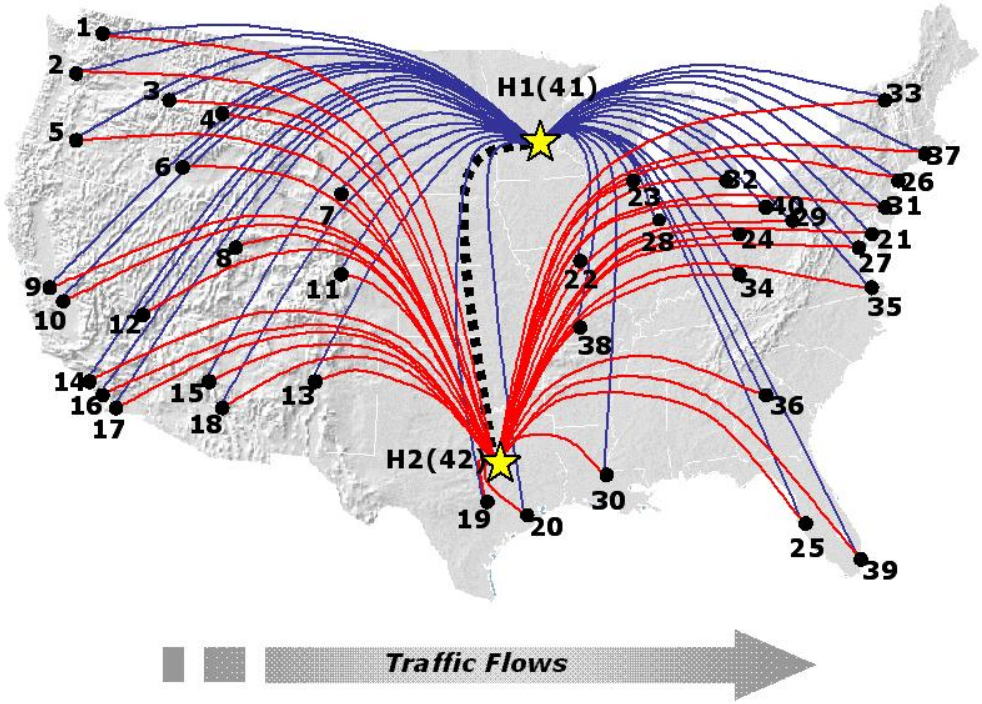
RM Schemes: Implementation Details

RM Type	Traditional Class-Based RM	Class-Based RM Continuous	Classless RM Continuous
Number of Fare Classes	6, 11, 16, 21	6, 11, 16, 21	N/A
Forecasting	Q (WTP) by Path/Fare Class	Q (WTP) by Path/Fare Class	Q (WTP) by Path/TF
Fare Adjustment	Marginal Revenue Transformation	Marginal Revenue Transformation	N/A
Optimization	Class-Based ProBP/UDP	Class-Based ProBP/UDP	Classless ProBP/UDP
Price Points	Fixed	Continuous	Continuous
Fare Quote Rule	Filed Fare Class Open if (Price ≥ Bidprice + MR)	Fare Quote = Bidprice + MR	Fare Quote = argmax[P(WTP > Fare)*(Fare−Bidprice)]

Unrestricted Fare Structure – Network D6

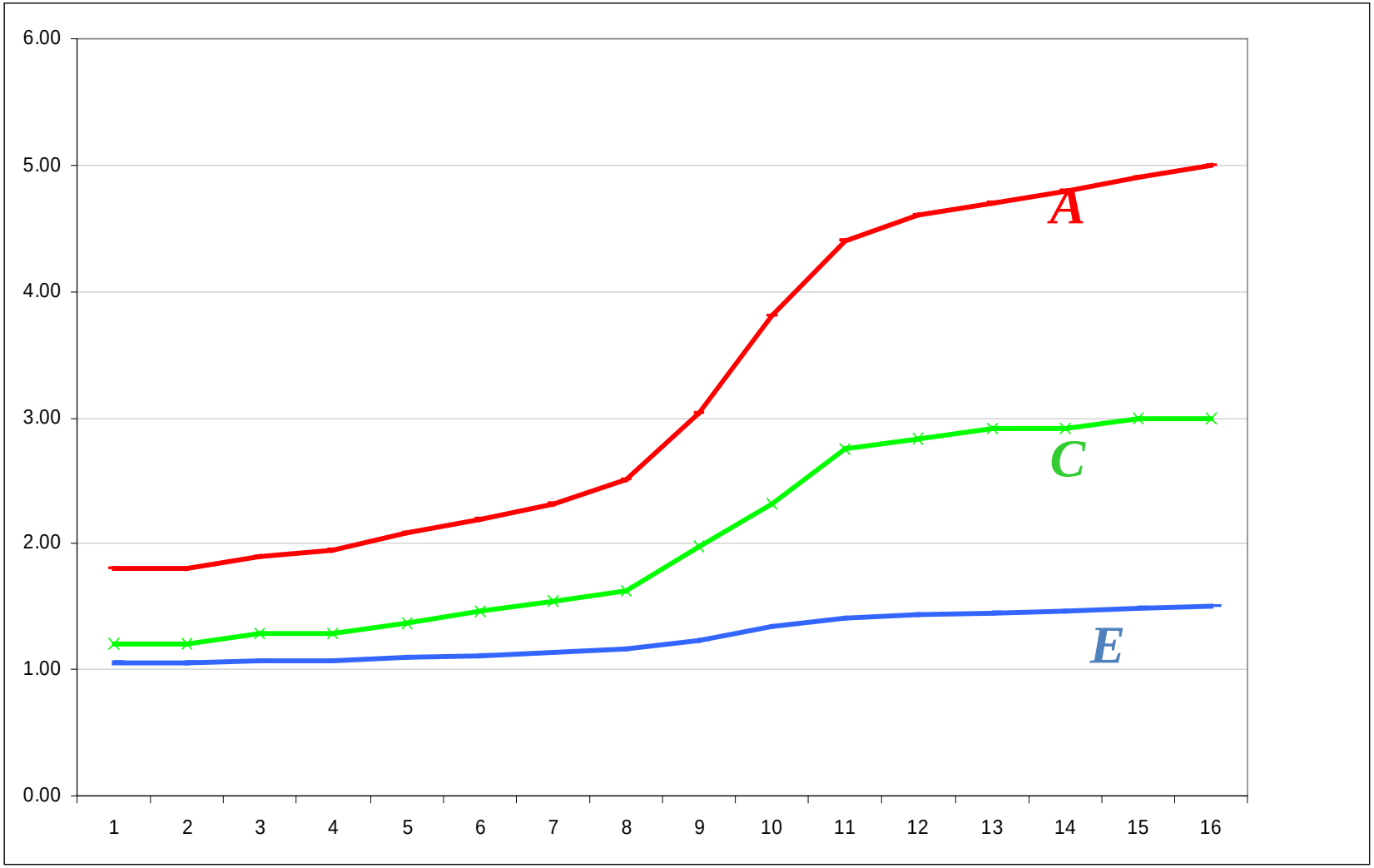
- 2 airlines
- 40 Spoke Cities
- 252 legs
- 482 OD markets
- 6 fare classes

Class	AP	R1	R2	R3
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



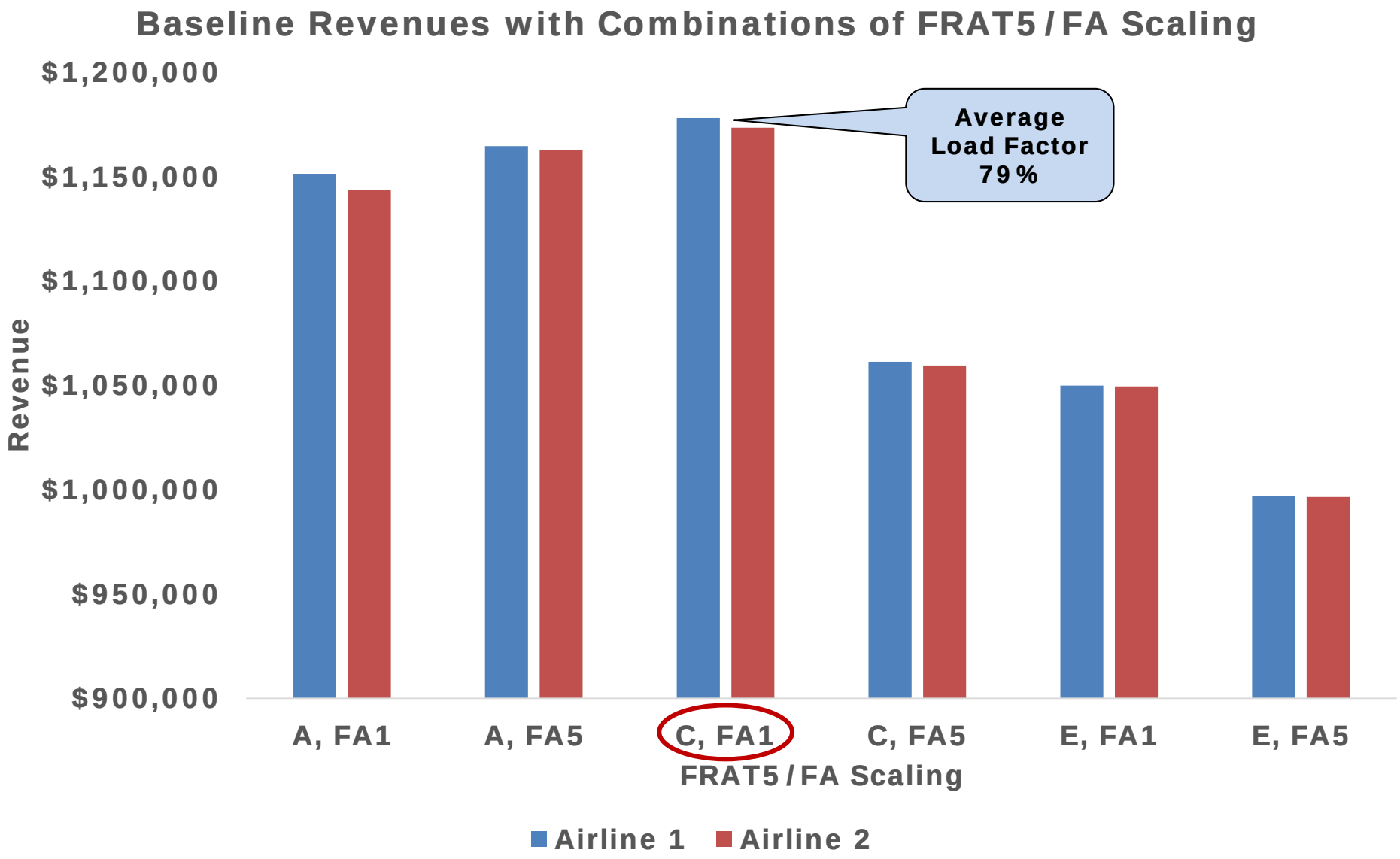
Class	1	2	3	4	5	6
Average Fare	$412.85	$293.34	$179.01	$153.03	$127.05	$101.06
Minimum Fare	$188.33	$136.83	$87.58	$76.39	$65.19	$54.00
Maximum Fare	$742.52	$514.82	$297.02	$247.52	$198.02	$153.00

Standard FRAT5 Input Curves in PODS

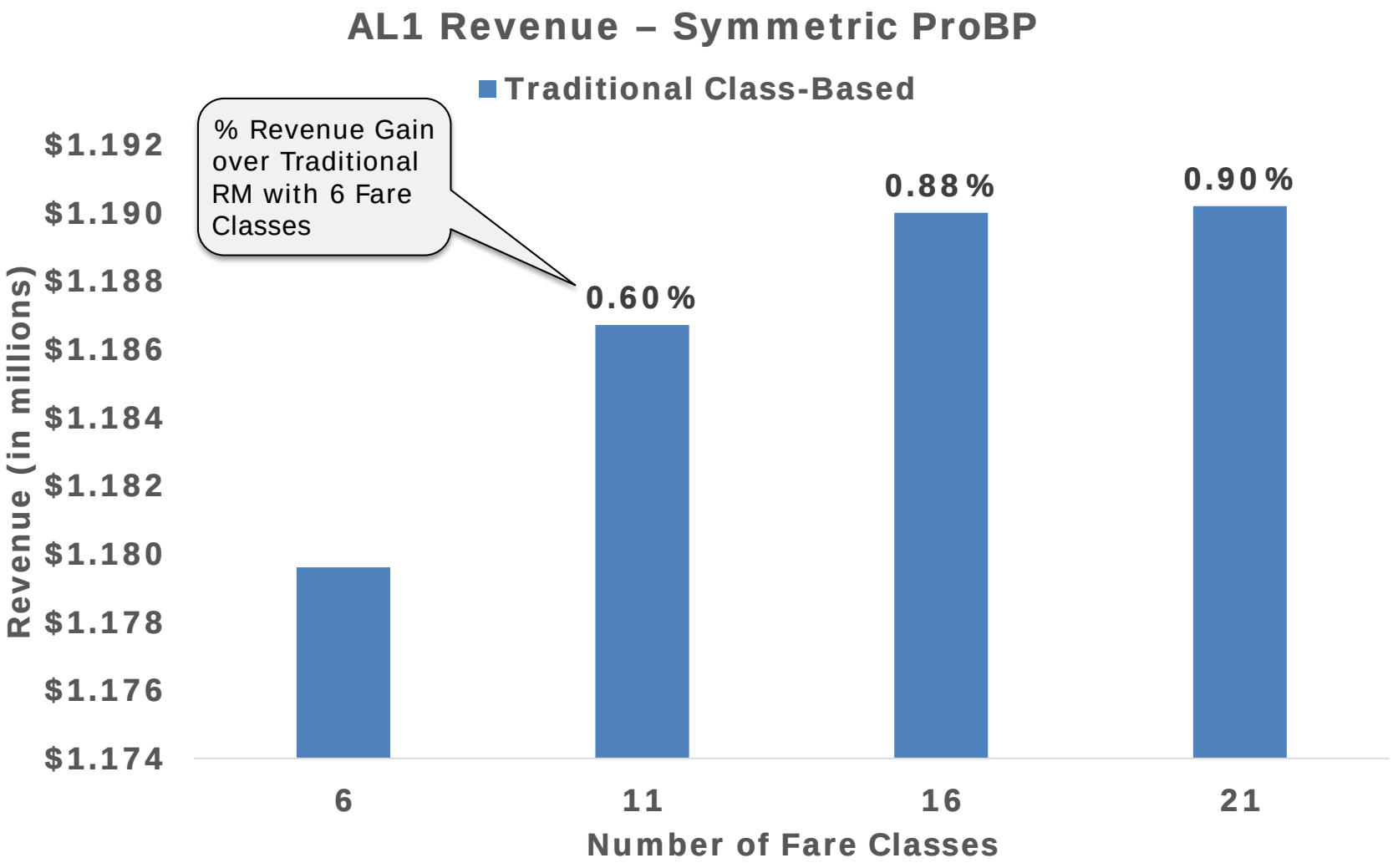


BOOKING PERIODS (DCPs)

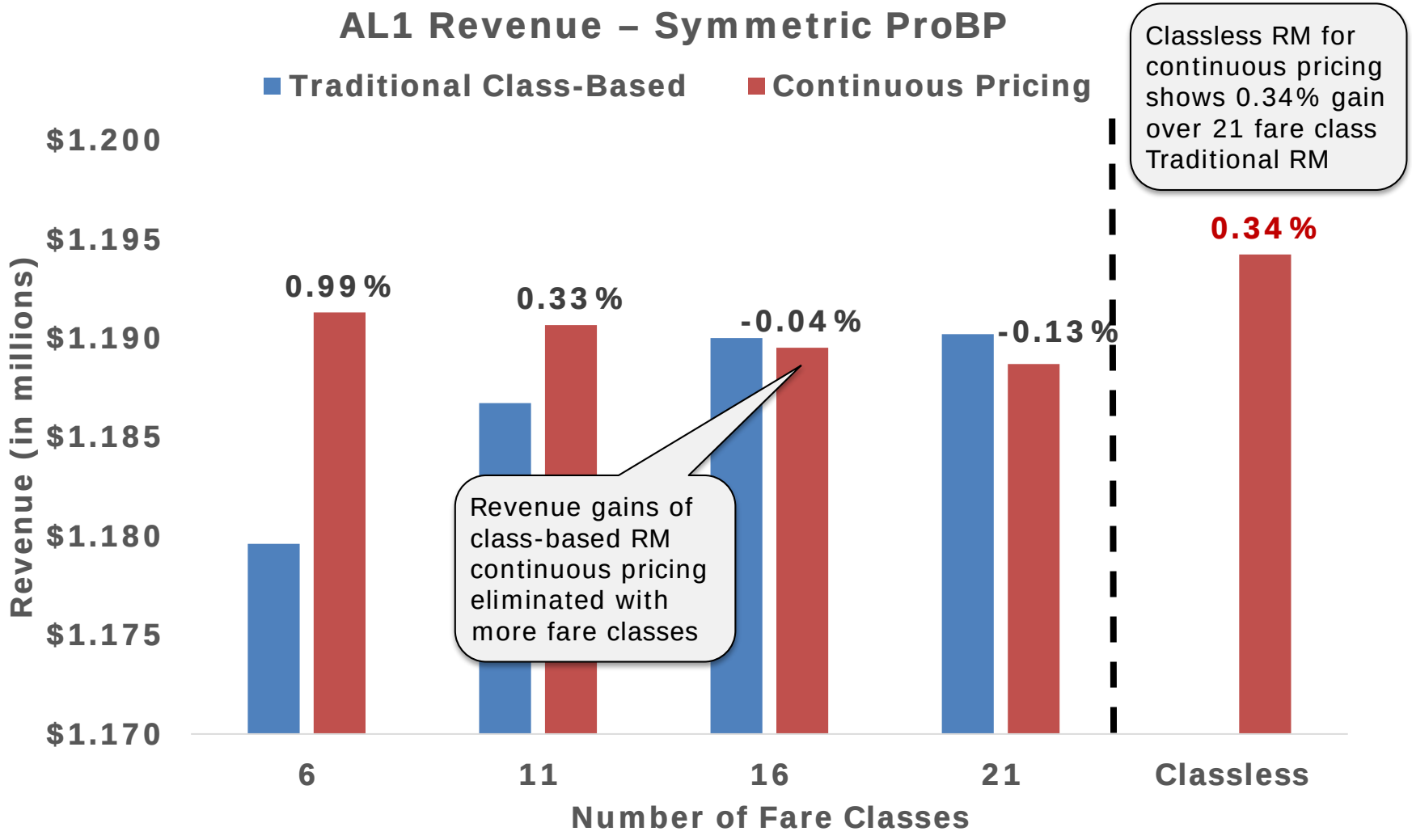
Class-Based RM: FRAT5 C with 1.0 Fare Adjustment Produces Highest Revenue in Unrestricted Network D6



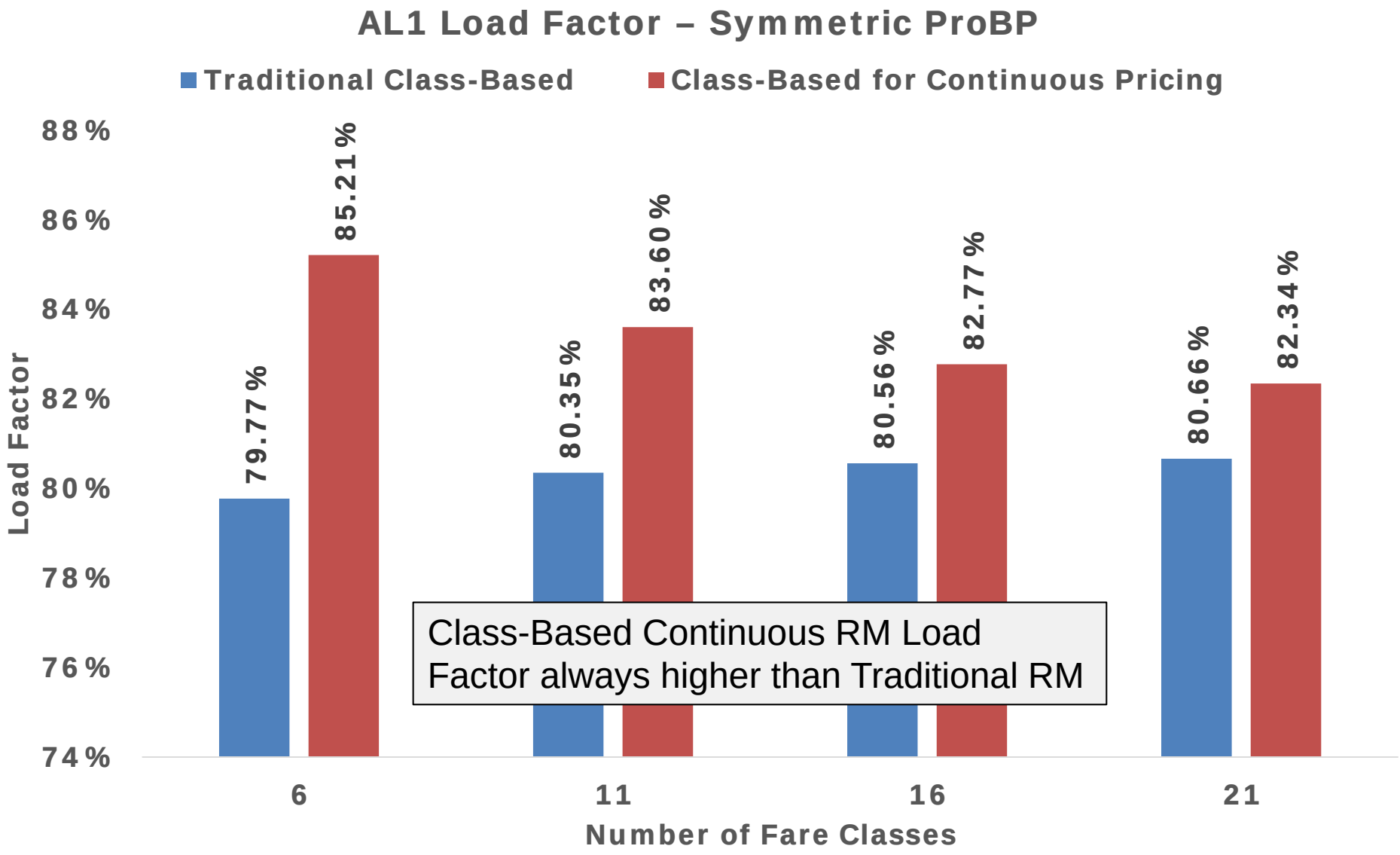
Traditional Class-based RM Revenues Increase with Number of Fare Classes



Continuous Pricing vs Traditional RM: Revenue Gains Depend on Number of Fare Classes

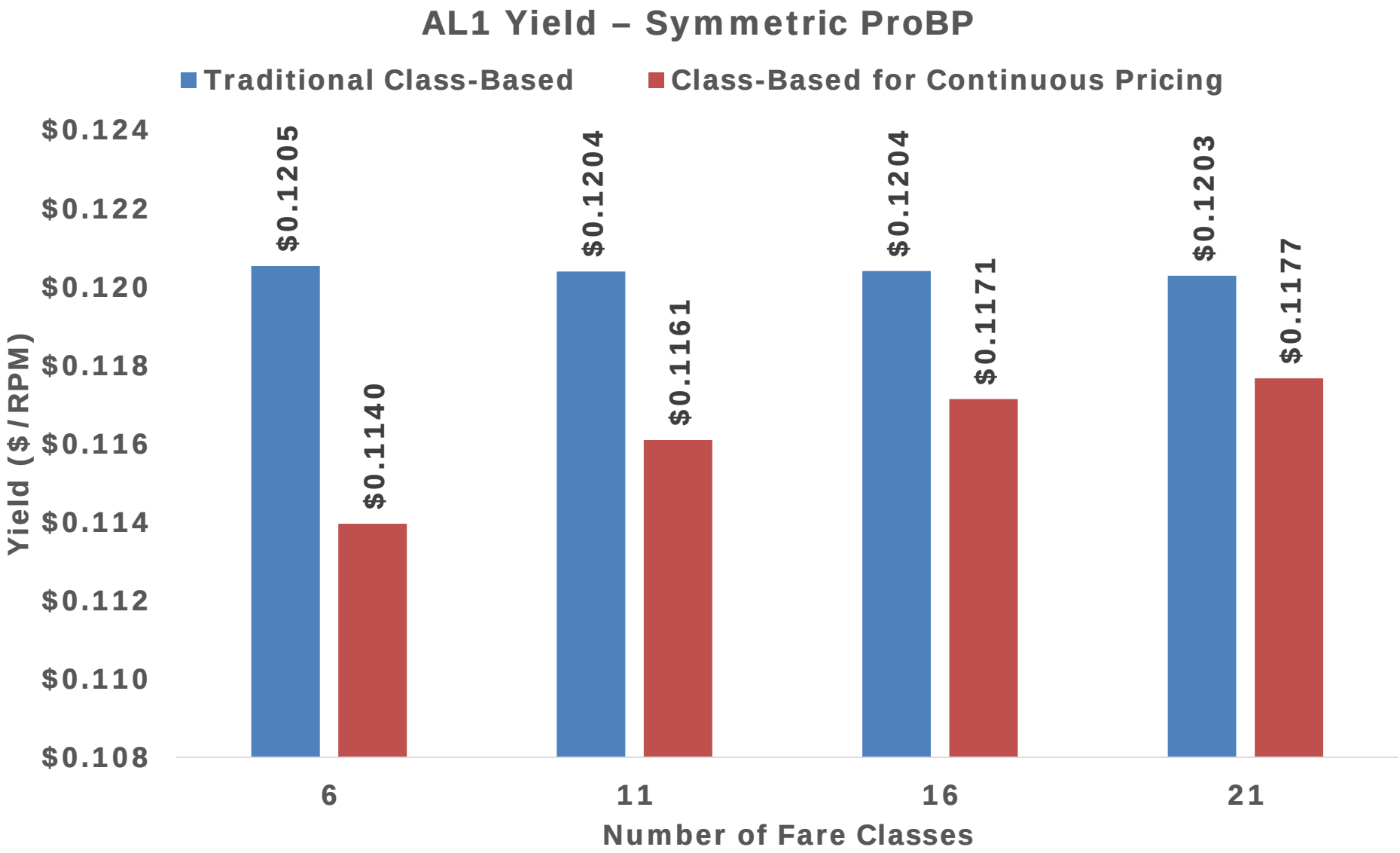


Adding Fare Classes Increases LF for Traditional ProBP, Decreases for Class-Based Continuous

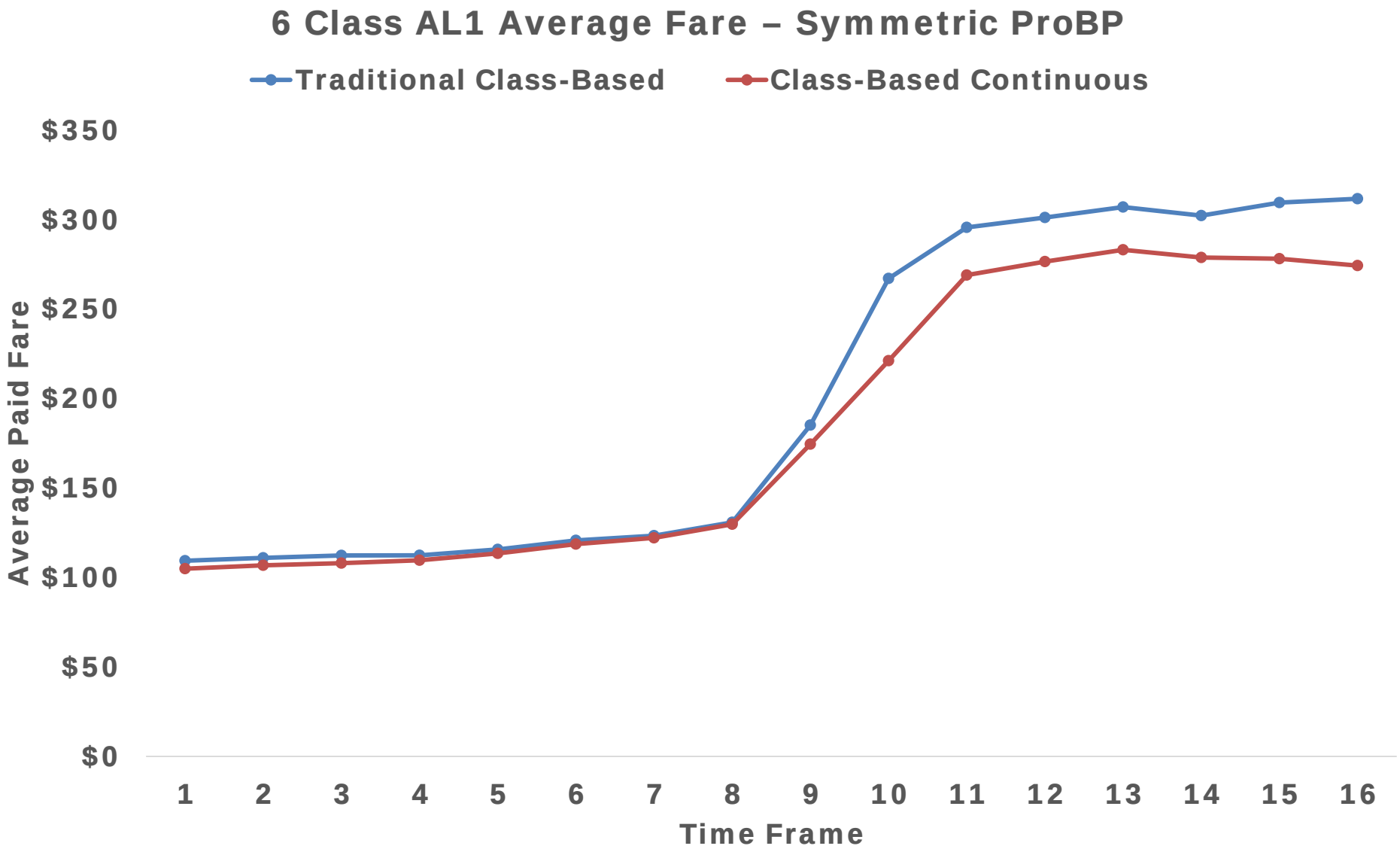


Class-Based Continuous RM Load Factor always higher than Traditional RM

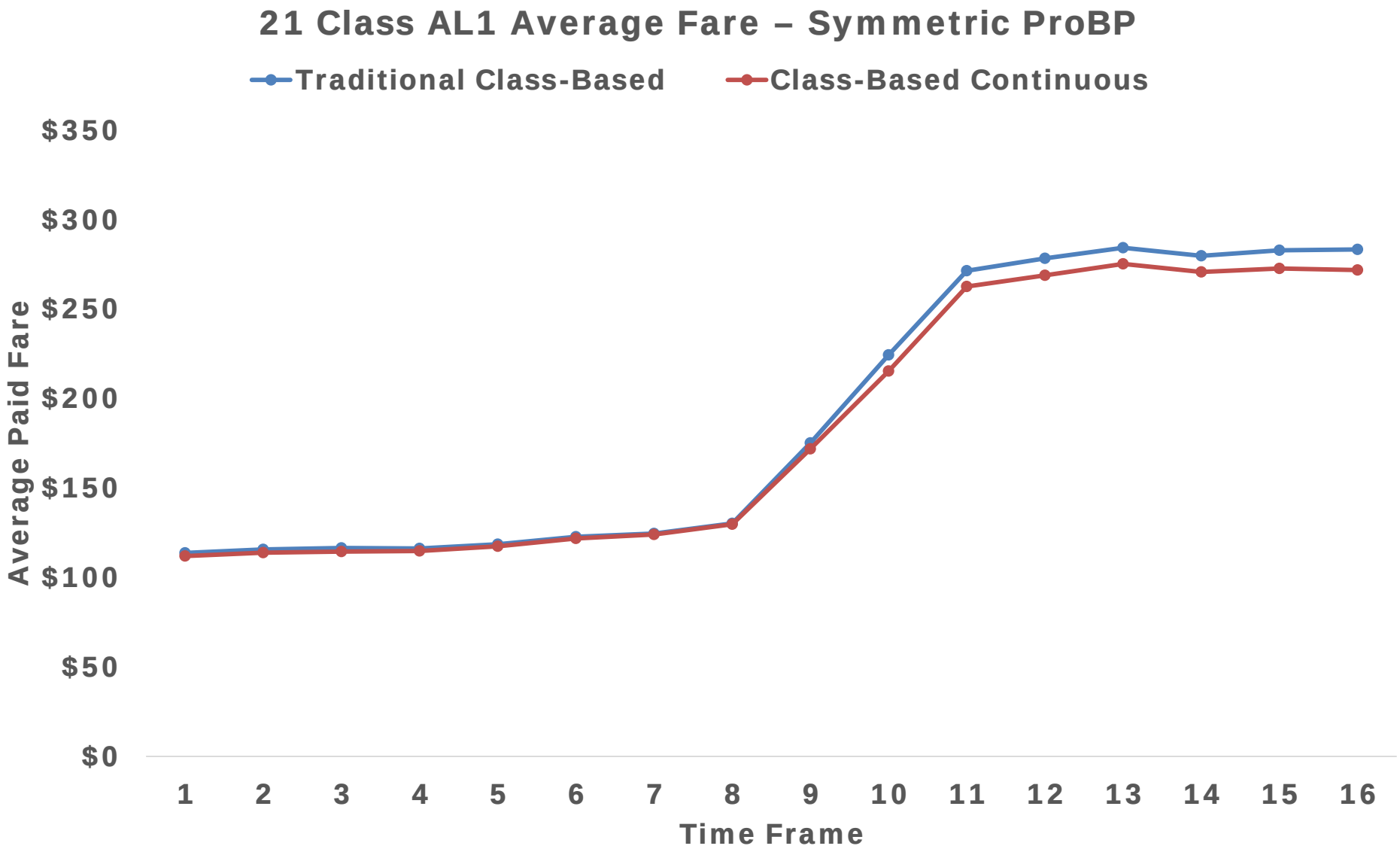
Class-Based Continuous ProBP Yields Consistently Lower than Traditional RM



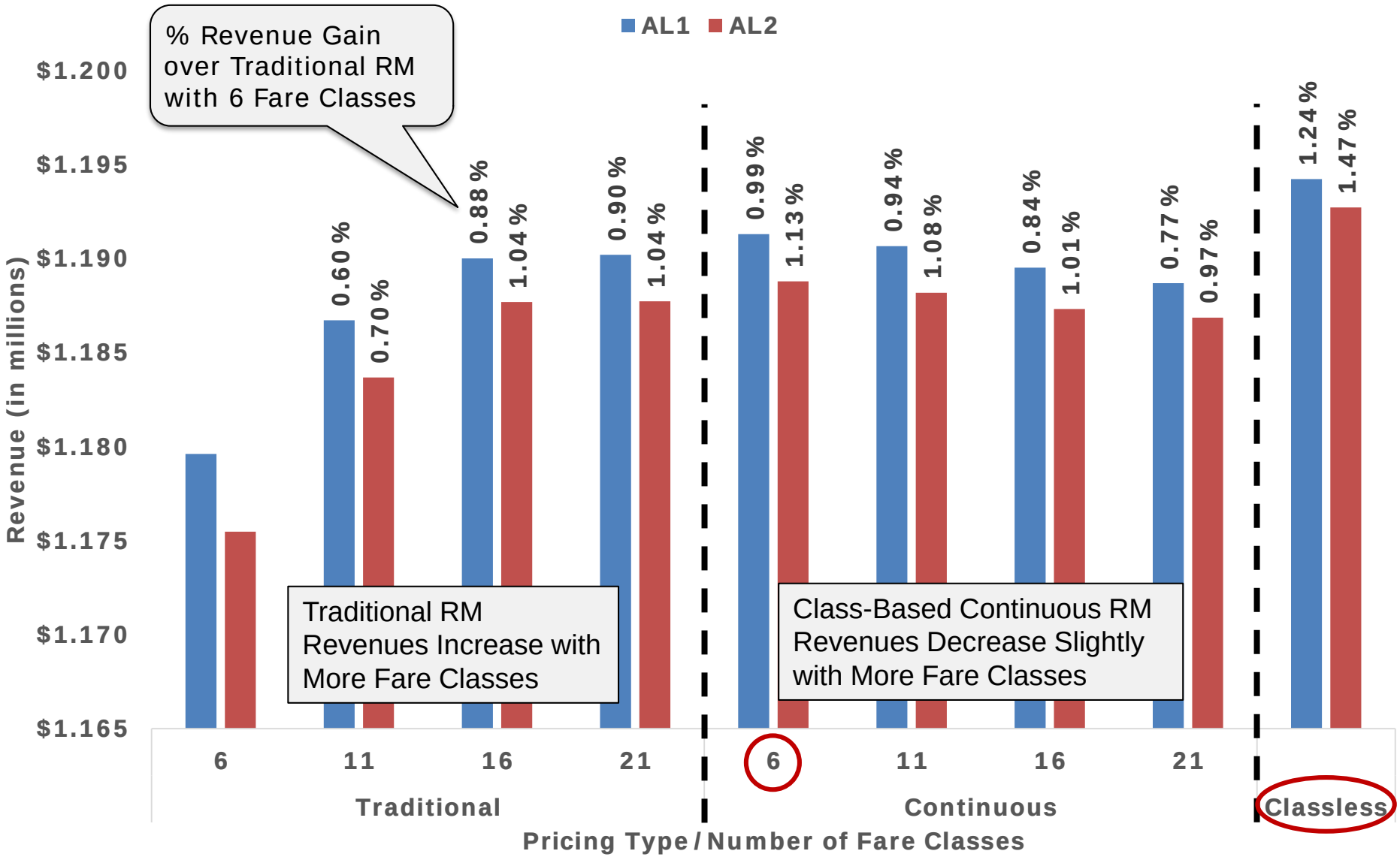
With 6 Fare Classes, Class-Based Continuous Fares are Lower than Traditional RM Fares in Later TFs



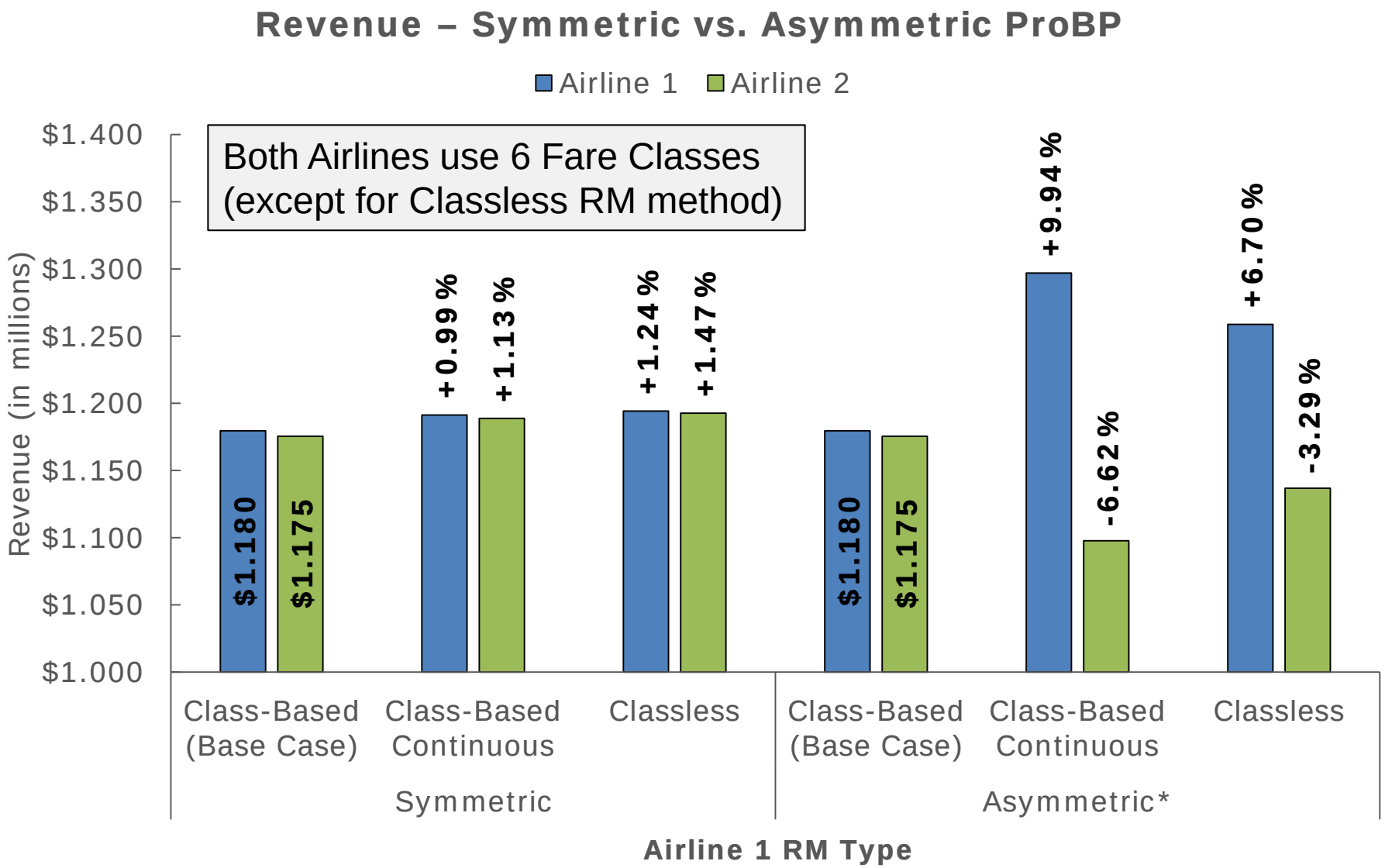
Gap Between Traditional and Class-Based Continuous Fares Narrows with 21 Fare Classes



Summary of Revenue Gains with ProBP Methods
Symmetric Tests: Both Airlines Use Same RM Scheme

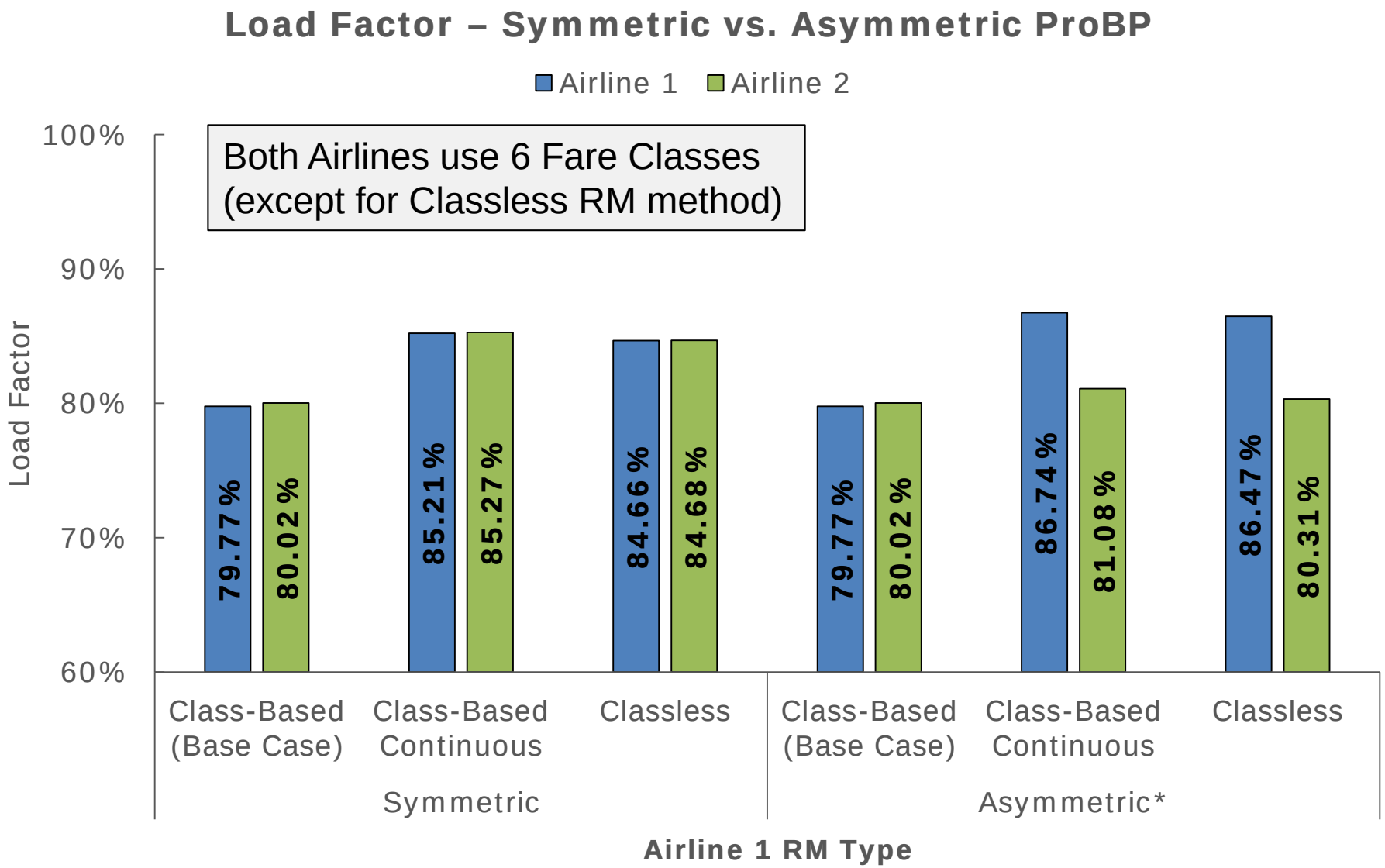


Small Revenue Gains When Both Airlines Implement, Large Gains When 1 Airline Uses Continuous Pricing



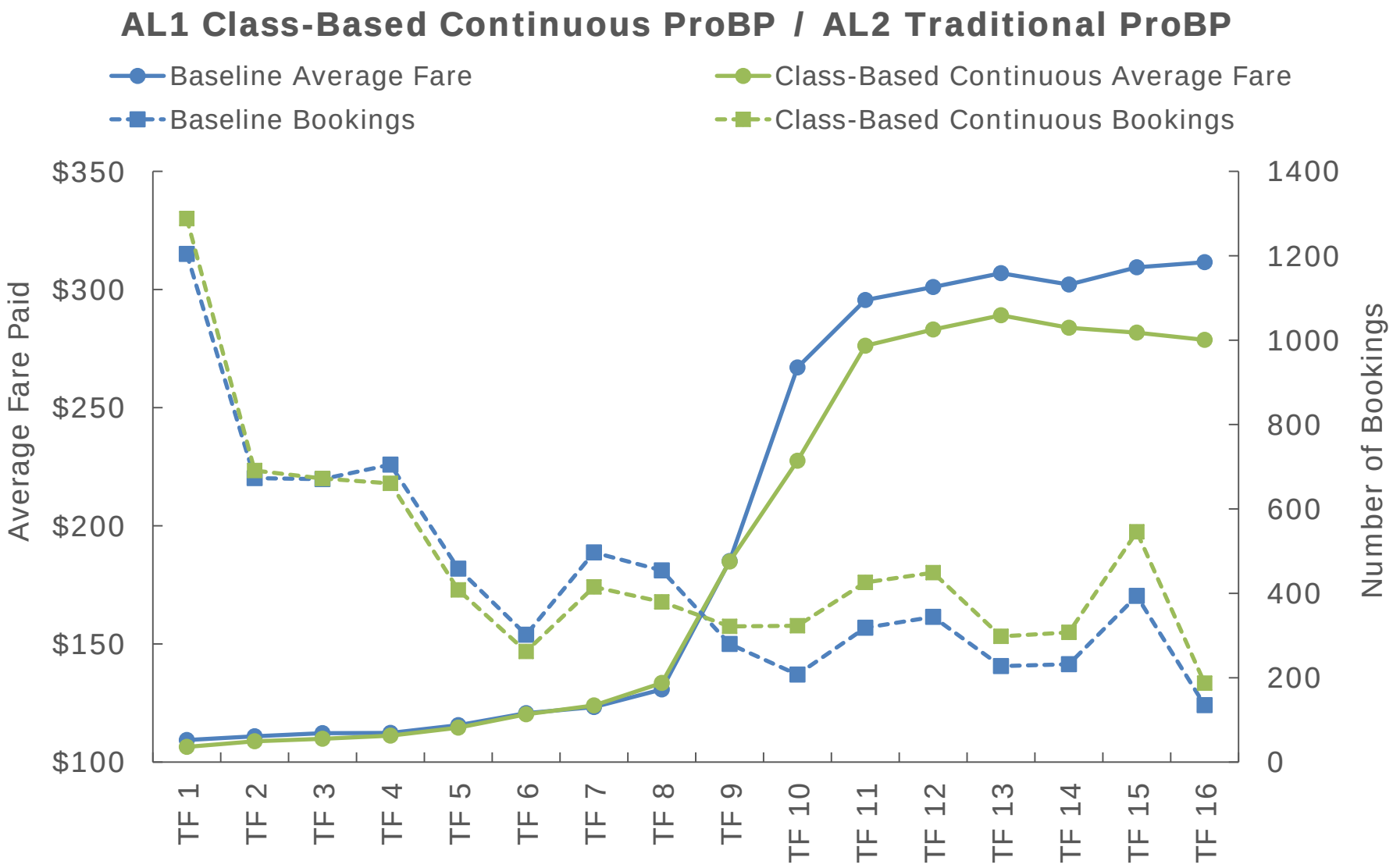
* In the asymmetric cases, Airline 2 always uses Traditional Class-Based RM

Airline 1 Implementing Either Form of Continuous Pricing Sees Large Increase in Load Factor

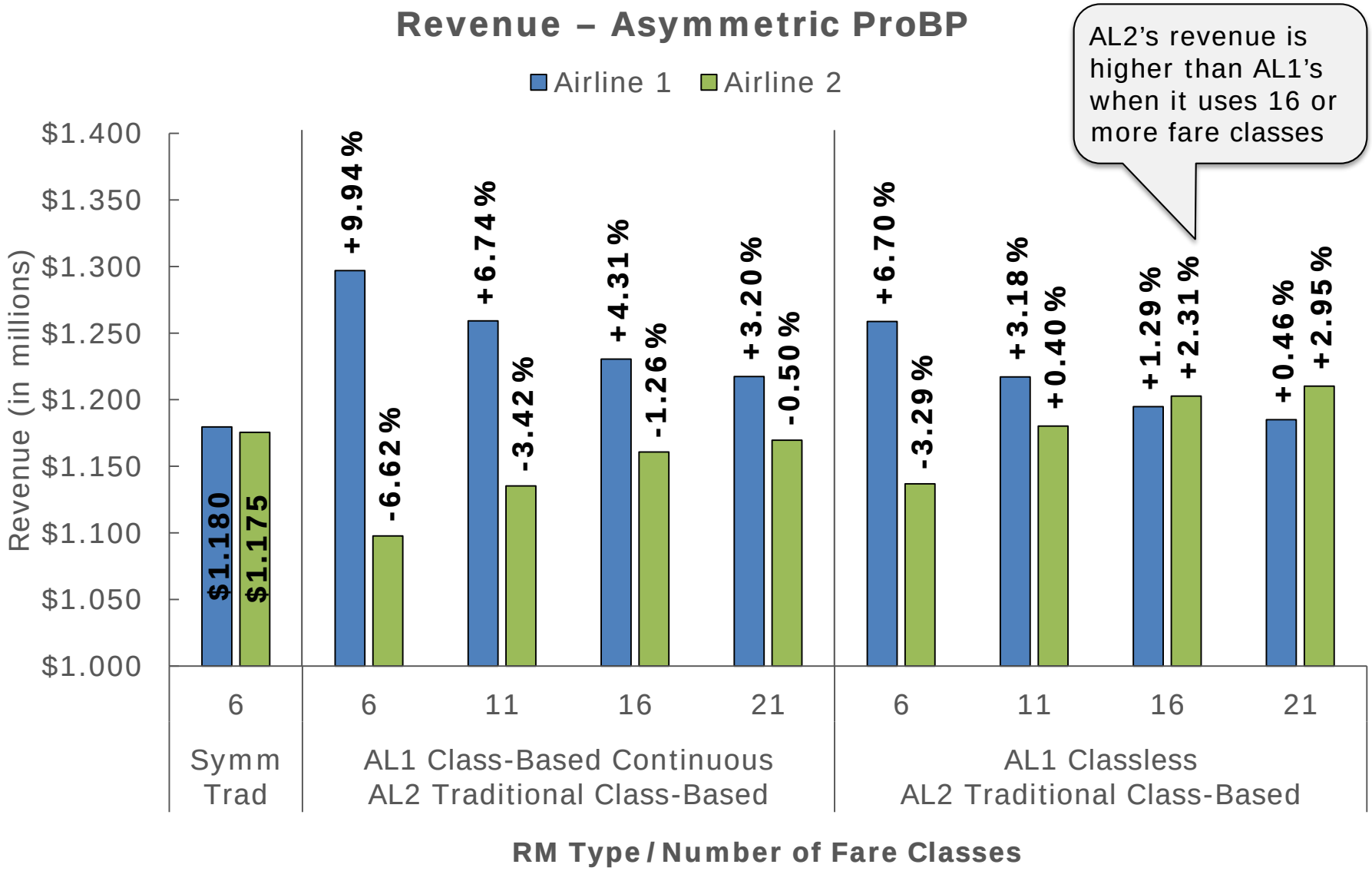


* In the asymmetric cases, Airline 2 always uses Traditional Class-Based RM

Airline 1 With Continuous Pricing Takes More Bookings at Lower Fares Closer to Departure



For Either Form of Continuous ProBP, Revenue Gap Between AL1 and AL2 Decreases with More Fare Classes



Lessons from PODS: Continuous Pricing

- Simulation results are for specific RM algorithms:
  - Traditional RM with Q-forecasting by WTP, EM detruncation, Marginal Revenue Transformation and ProBP bid price O-D controls
  - Class-based RM or Classless RM algorithms for continuous pricing
  - In all cases, we assumed no discounting below lowest nominal published fare
- Revenue gains of continuous pricing affected by number of fare classes in baseline, as well as competitive factors
  - Class-based method can increase revenues by about 1% when both competitors implement it, while Classless algorithm performs a little better
  - Revenue gains when only one airline implements can reach almost 10%, but at the expense of revenue and load factor loss for the competitor
  - Much of this gain is due to competitive price discounting and ability to offer more price points, rather than price optimization

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- Wittman, M. D. and Belobaba, P. P. (2018), *Dynamic pricing mechanisms for the airline industry: a definitional framework,* Journal of Revenue and Pricing Management.
- Belobaba, P., Liotta, N.J and Hopperstad, C. (2018), *Classless RM Forecasting and Optimization: PODS Consortium Developments,* AGIFORS RM Study Group Meeting, Hong Kong, May 16-17.

ACKNOWLEDGEMENTS

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APPENDIX:
Forecasting and Optimization Details

Baseline for Comparisons: Class-Based RM

- Class-Based RM provides a baseline for comparisons
  - Both airlines use same RM scheme in symmetric baseline scenario
- "Q-forecasting" of Willingness to Pay [Hopperstad, 2004]
  - With no differentiation, all passengers buy lowest available fare
  - Test different airline estimates of WTP: FRAT5 parameters A, C, E
- Marginal Revenue Transformation [Fiig et al, 2010]
  - "Fare Adjustment" to account for probability of buy-down
  - With 1.0 or 0.5 scaling to adjust aggressiveness in competitive markets
- Probabilistic Bid Price (ProBP) Optimization [Bratu, 1998]
  - Nested probabilistic network convergence algorithm developed at MIT
  - Estimates "critical EMSR" of remaining capacity for each leg by accounting for complete nesting of ODF availabilities
  - Daily re-optimization of bid prices

New ProBP Classless RM Algorithm

- ProBP Classless RM uses an iterative algorithm based on Q-forecasts of WTP by time frame (DCP)
  - Q-forecast of “maximum demand” at lowest fare, with estimates of sell-up to all higher fares
- Basic logic
  - Given any initial bidprice, an optimal fare can be calculated in each time frame based on the Q-forecast for that TF (day)
  - Given that optimal fare, demand can be calculated based on estimated sell-up to that fare
  - Given demand and a fare, a new bid price can be calculated
  - Calculations are performed by time frame (current and future) in that sell-up changes across time frames
  - Iterate over all time frames (and legs) until leg bid prices converge (to +/- $10, for example)

Source: Craig Hopperstad