Naval Center for Cost Analysis

Workload-Adjusted Labor Cost Model

The Partial Adjustment Rate Model (PARM)

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Statement A: Approved for release. Distribution is unlimited

Acknowledgements

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  - Dr. Brian Flynn
  - Mr. Harold Dagel
  - Mr. Ben Breaux
  - Mr. Tony Pignone
  - Ms. Krystian Jenkins

Overview

- Background and History
- Technical Foundations
- Applications
- Pitfalls
- Way forward

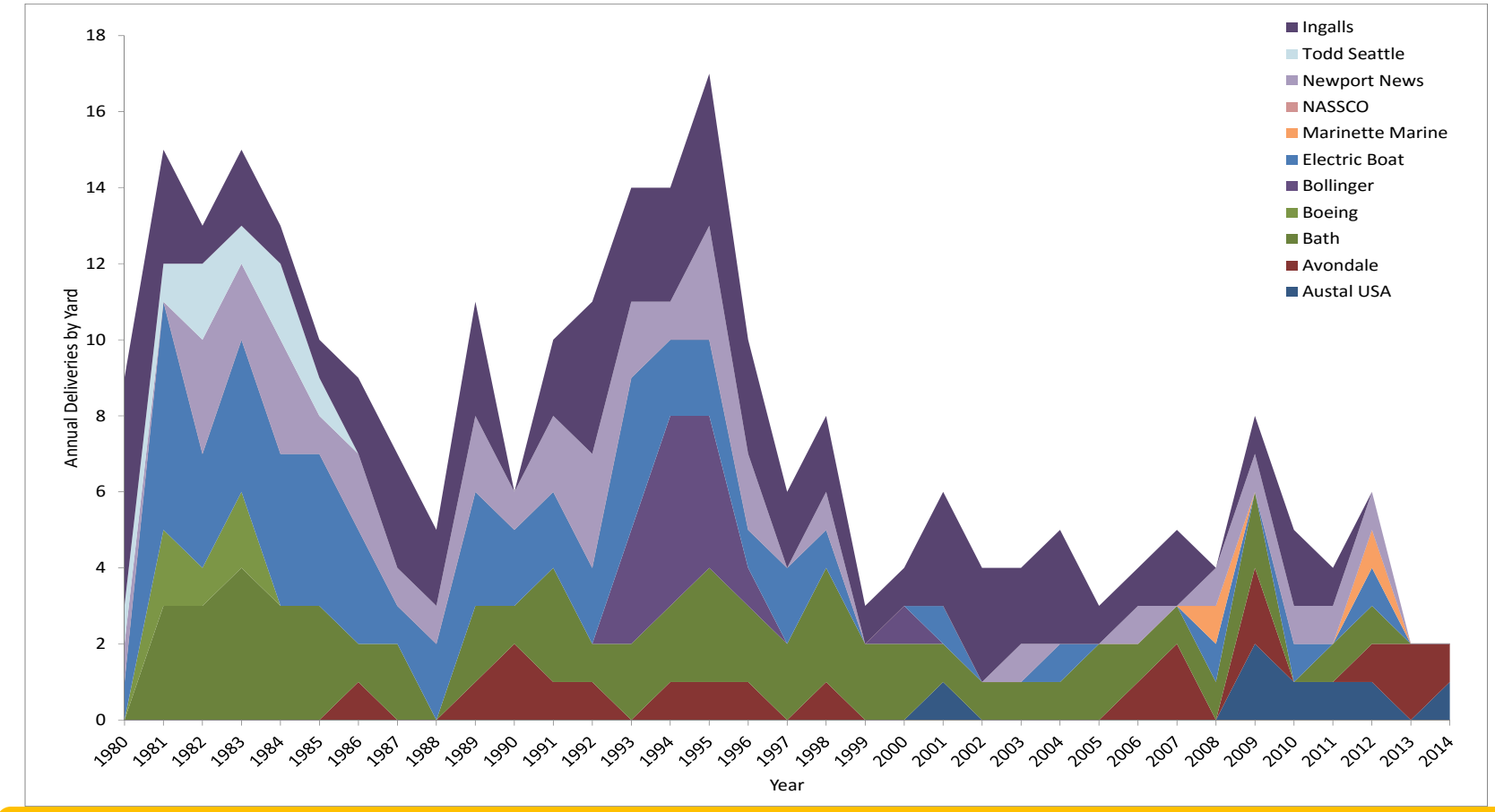
Background and History

Background

- Developed by Naval Center for Cost Analysis in 1995 to allow for assessment of rapid changes in the business base tied to the end of the Cold War
  - Part of a package of tools developed by NCCA to inform decision makers on key economic and financial issues caused by the end of the Cold War
- Navy use pioneered by Dr. Brian Flynn and Mr. Harold Dagel
  - Original partial adjustment model developed by Nerlove in 1956 for use in agricultural economics

The Post Cold War Draw Down

Example: Shipbuilding



The end of the Cold War resulted in an unprecedented and permanent decrease in workload for all DoD suppliers

Restructuring and the Government

- The “Peace Dividend” resulted in chaos for the entire defense industry
- DoD relies on its vendors, so this became a government problem as well
- Examples:
  - A key contractor sees a large decline and is on the verge of bankruptcy (and wants help)
  - Key contractors downsize business units, causing large changes in program overhead costs

To enable decision makers to address these issues, NCCA developed several tools to inform leadership on these topics

Forward Rates

- A Forward Pricing Rate Agreement (FPRA) is an agreement between a contractor and a government agency in which certain indirect rates are established for a specified period of time. These rates are estimates of costs and are used to price contracts and contract modifications. The use of a FPRA can speed up the contracting process by eliminating the need to audit or analyze the rates.

- Use of forward rates simplifies estimating process
  - Labor and overhead rate modelling is very complex

Problem with Forward Rates

- Forward Rates require accurate projections of both direct labor and overhead costs
- Overhead costs are a complicated thing to project
  - Overhead = all the other costs of the business, recovered as an additional charge to labor
  - Complicated to estimate because the whole business needs to be modeled
  - Linked to workload
- Forward rates are based on specific assumptions about future workload
  - If workload changes, the forward rates will rapidly diverge from reality
  - The Cold War drawdown created a perfect storm scenario for this
  - Decision makers and cost estimators needed a quick way to estimate the

Enter the Partial Adjustment Model…

Technical Foundations

Regression Modeling of Overhead

- Linear regression can be used to model the relationship between overhead and direct labor

- Single Variable Linear Regression is the most popular form
  - Form: Overhead Cost = Fixed $ + Variable $ * Direct Workload
  - Example on the next slide

- Partial Adjustment Model is a multivariate lagged regression model that builds upon the above

Single Variable Model Example

- The following data was obtained on a recent site visit
- You have normalized the data and understand the underlying allocation scheme
- What are your next steps?

Year	Manufactuing Base	Manufactoring Pool
1982	$85,284,257	$63,645,429
1983	$97,429,252	$67,589,130
1984	$103,924,215	$75,743,393
1985	$101,447,448	$85,143,876
1986	$99,232,082	$83,078,133
1987	$91,343,546	$84,791,979
1988	$70,661,370	$79,648,299
1989	$77,332,550	$86,791,546
1990	$84,644,183	$82,627,548
1991	$92,172,006	$81,555,419
1992	$94,448,139	$78,227,299
1993	$91,592,587	$86,050,598
1994	$72,854,529	$68,436,844
1995	$80,976,139	$57,127,017
1996	$60,068,034	$48,474,601
1997	$42,452,629	$41,203,057
1998	$37,208,209	$37,749,337
1999	$36,138,476	$34,476,998
2000	$37,101,279	$36,638,373
2001	$40,143,584	$41,214,157
2002	$47,420,397	$41,214,157
2003	$57,204,318	$46,700,045
2004	$68,209,714	$48,786,683
2005	$65,378,955	$50,652,852
2006	$59,829,857	$46,651,301
2007	$60,951,375	$49,375,193
2008	$65,639,736	$56,990,873
2009	$71,855,839	$62,952,315
2010	$72,646,197	$63,025,517
2011	$73,891,651	$65,878,044
2012	$73,778,894	$69,626,173
2013	$86,373,262	$76,279,779

When All You Have Is A Hammer…

I. Model Form and Equation Table

Model Form:	Unweighted Linear model
Number of Observations Used:	31
Equation in Unit Space:	Manu_Pool = 7793419 + 0.7646 * Manu_Base

II. Fit Measures (in Fit Space)

Coefficient Statistics Summary

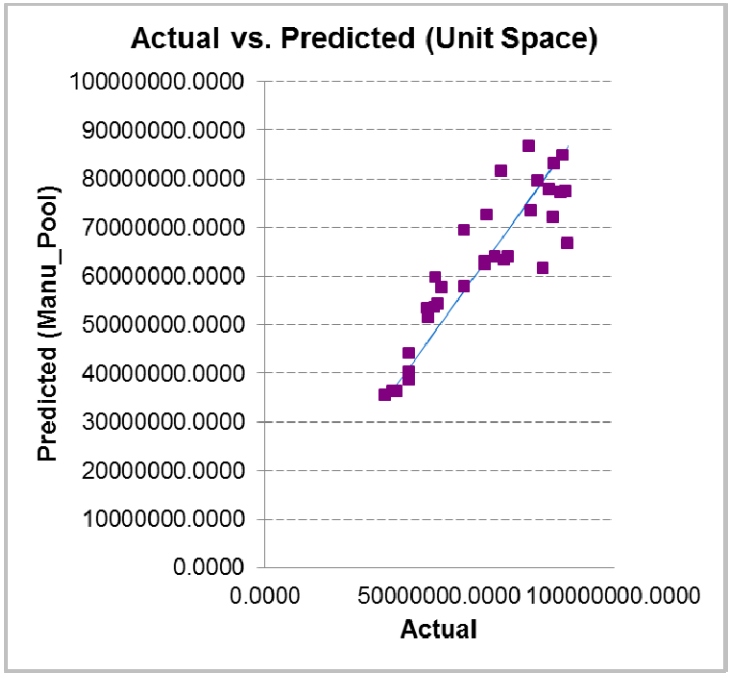
Variable	Coefficient	Std Dev of Coef	Beta Value	T-Statistic (Coef/SD)	P-Value	Prob Not Zero
Intercept	7793418.6197	5310809.4335		1.4675	0.1530	0.8470
Manu_Base	0.7646	0.0716	0.8929	10.6781	0.0000	1.0000

Goodness-of-Fit Statistics

Std Error (SE)	R-Squared	R-Squared (Adj)	Pearson's Corr Coef
7959173.6718	79.72%	79.02%	0.8929

Analysis of Variance

Due To	DF	Sum of Sqr (SS)	Mean SQ = SS/DF	F-Stat	P-Value	Prob Not Zero
Regression	1	##############	##############	114.0214	0.0000	1.0000
Residual (Error)	29	##############	##############			
Total	30	##############				



Summary of Predictive Measures

Average Actual (Avg Act)	62409694.7097
Standard Error (SE)	7959173.6718
Root Mean Square (RMS) of % Errors	11.46%
Mean Absolute Deviation (Mad) of % Errors	8.77%
Coef of Variation based on Std Error (SE/Avg Act)	12.75%
Coef of Variation based on MAD Res (MAD Res/Avg Act)	8.97%
Pearson's Correlation Coefficient between Act & Pred	89.29%
Adjusted R-Squared in Unit Space	79.02%

Reasonably accurate, but leaves something to be desired

What's Wrong?

- Single variable model assumes that overhead costs change instantaneously to changes in workload
- Real work doesn't work this way, overhead costs are "sticky"
- Partial adjustment model accounts for this stickiness by making the overhead a function of this year's workload and last year's

The Partial Adjustment Model

- Primarily used in the field of Econometrics
- Partial adjustment model concept:
  - While a dependent variable Y may be related to an explanatory variable X, there is inertia in the system and the actual value of Y_t is a compromise between its value in the previous time period, Y_{t-1}, and the value justified by the current value of the explanatory variable.

$$Y_t = A + B X_t + C Y_{t-1}$$

The Trick!

Observations	Variable 1	Variable 2	Variable 3
Variable ID	Manu_Base	Manu_Pool	Manu_Lagged
	Manu_Base	Manu_Pool	Manu_Lagged
Year			
1982	$85,284,257	$63,645,429	
1983	$97,429,252	$67,589,130	$63,645,429
1984	$103,924,215	$75,743,393	$67,589,130
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2005	$65,378,955	$50,652,852	$48,786,683
2006	$59,829,857	$46,651,301	$50,652,852

Copy the variable column and shift it down one row

The Results

I. Model Form and Equation Table

Model Form:	Unweighted Linear model
Number of Observations Used:	31
Equation in Unit Space:	Manu_Pool = 6.342e+004 + 0.331 * Manu_Base + 0.6243 * Manu_Lagged

II. Fit Measures (in Fit Space)

Coefficient Statistics Summary

Variable	Coefficient	Std Dev of Coef	Beta Value	T-Statistic (Coef/SD)	P-Value	Prob Not Zero
Intercept	63421.6580	3543893.9505		0.0179	0.9858	0.0142
Manu_Base	0.3310	0.0790	0.3865	4.1918	0.0003	0.9997
Manu_Lagged	0.6243	0.0932	0.6175	6.6973	0.0000	1.0000

Goodness-of-Fit Statistics

Std Error (SE)	R-Squared	R-Squared (Adj)	Pearson's Corr Coef
5021571.5151	92.21%	91.65%	0.9602

Analysis of Variance

Due To	DF	Sum of Sqr (SS)	Mean SQ = SS/DF	F-Stat	P-Value	Prob Not Zero
Regression	2	##############	##############	165.6502	0.0000	1.0000
Residual (Error)	28	##############	##############			
Total	30	##############				

Summary of Predictive Measures

Average Actual (Avg Act)	62409694.7097
Standard Error (SE)	5021571.5151
Root Mean Square (RMS) of % Errors	7.76%
Deviation (Mad) of % Errors	5.98%
n based on Std Error (SE/Avg Act)	8.05%
n based on MAD Res (MAD Res/Avg Act)	5.85%
lation Coefficient between Act & Pred	96.02%
Adjusted R-Squared in Unit Space	91.65%

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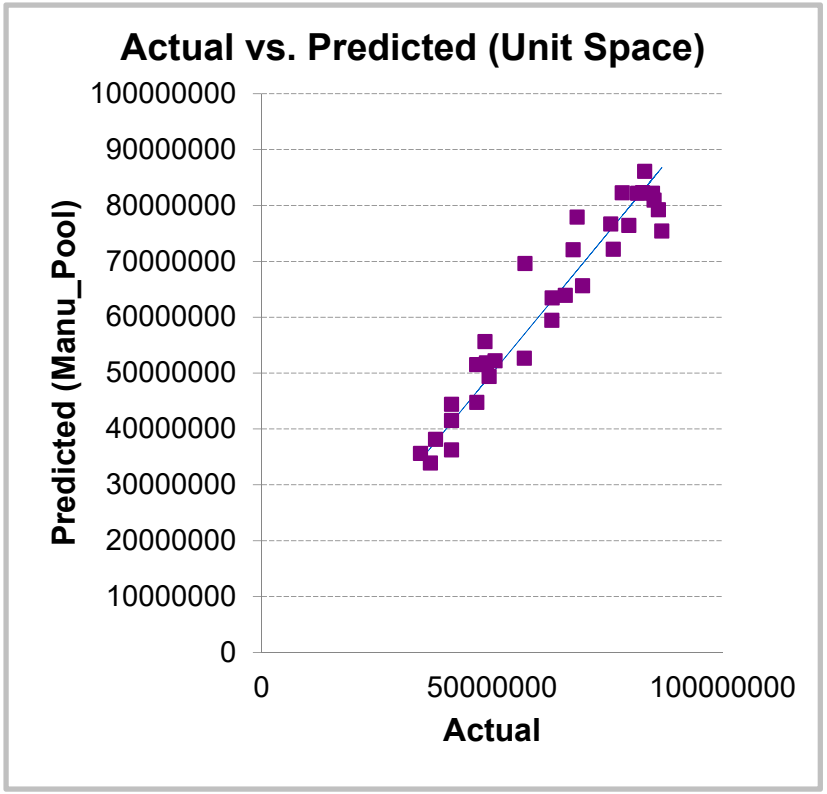


Significantly more accurate – 92% vs. 79%

Applications

Application of Partial Adjustment Model

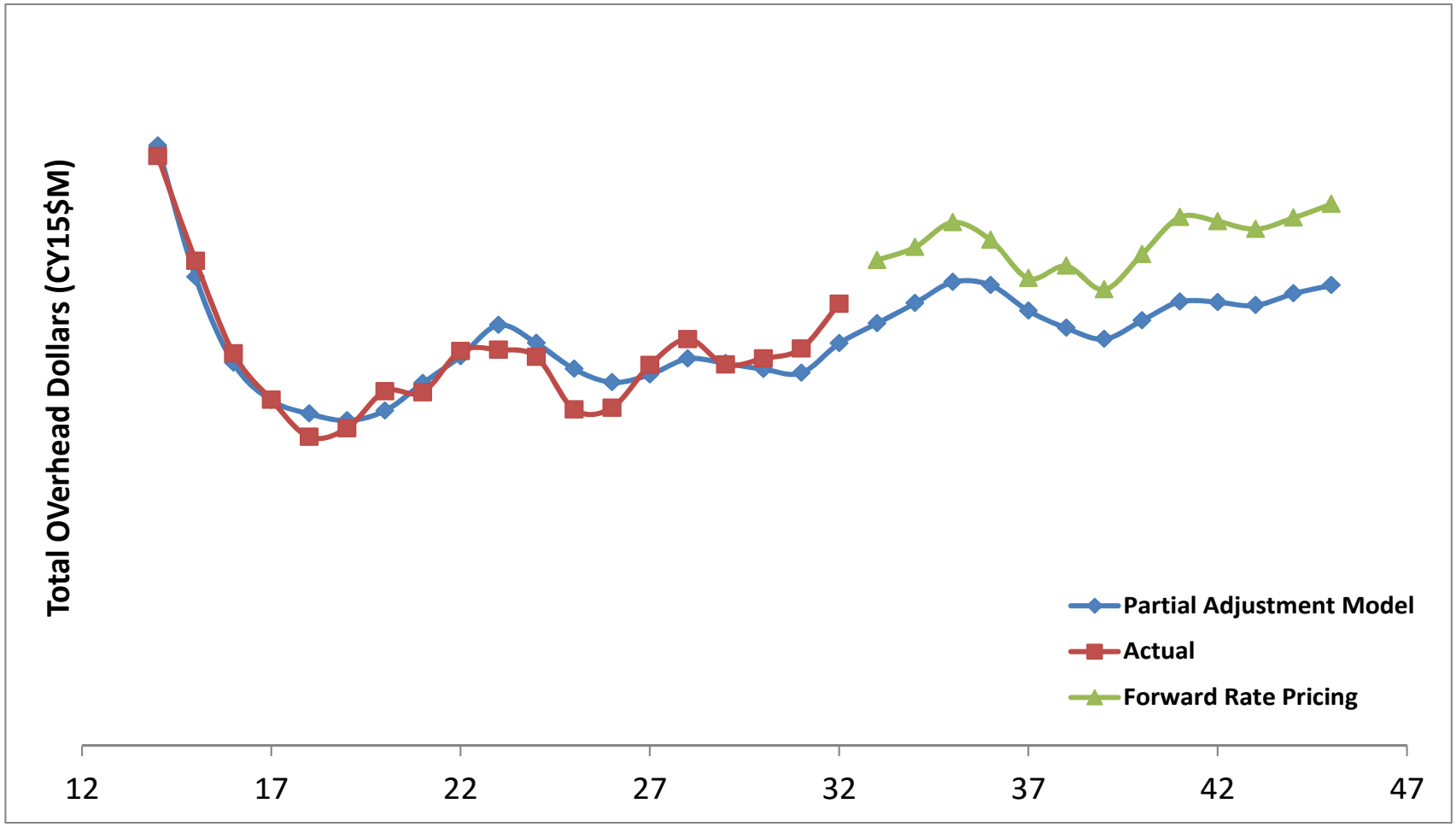
- Primary use is to assess reasonableness of rate projections incorporated into Navy estimates
  - Model is generally “good” at predicting historical data (there is a strong relationship)
  - Deviations between model projections and forward rates (or other projections) often indicates something requiring further review
- Secondary use is to serve as a quick tool to assess the impact of changing workload on Navy programs
  - Can improve shipbuilding strategy decisions by more accurately capturing workload driven cost impacts

Following slides relay a generic case study based on NCCA experience

Case Study: Background

- Collected detailed overhead and direct cost data for a company over several decades
- Worked with government subject matter experts to map data and normalize for accounting changes
- Created partial adjustment models that fit normalized data well (i.e., 98% plus R^2)
- Compared models to projections

Case Study: Partial Adjustment Model



Partial Adjustment Model indicated a discrepancy in the projected rates

Case Study: Conclusions from model

- Discrepancy became one of the NCCA assessment focus areas
- Drove further in-depth review of the rate forecast process utilized by the government
  - Included review of current and projected costs at the account level
- Uncovered key information that has improved the way we estimate
  - Also revealed the one key pitfall

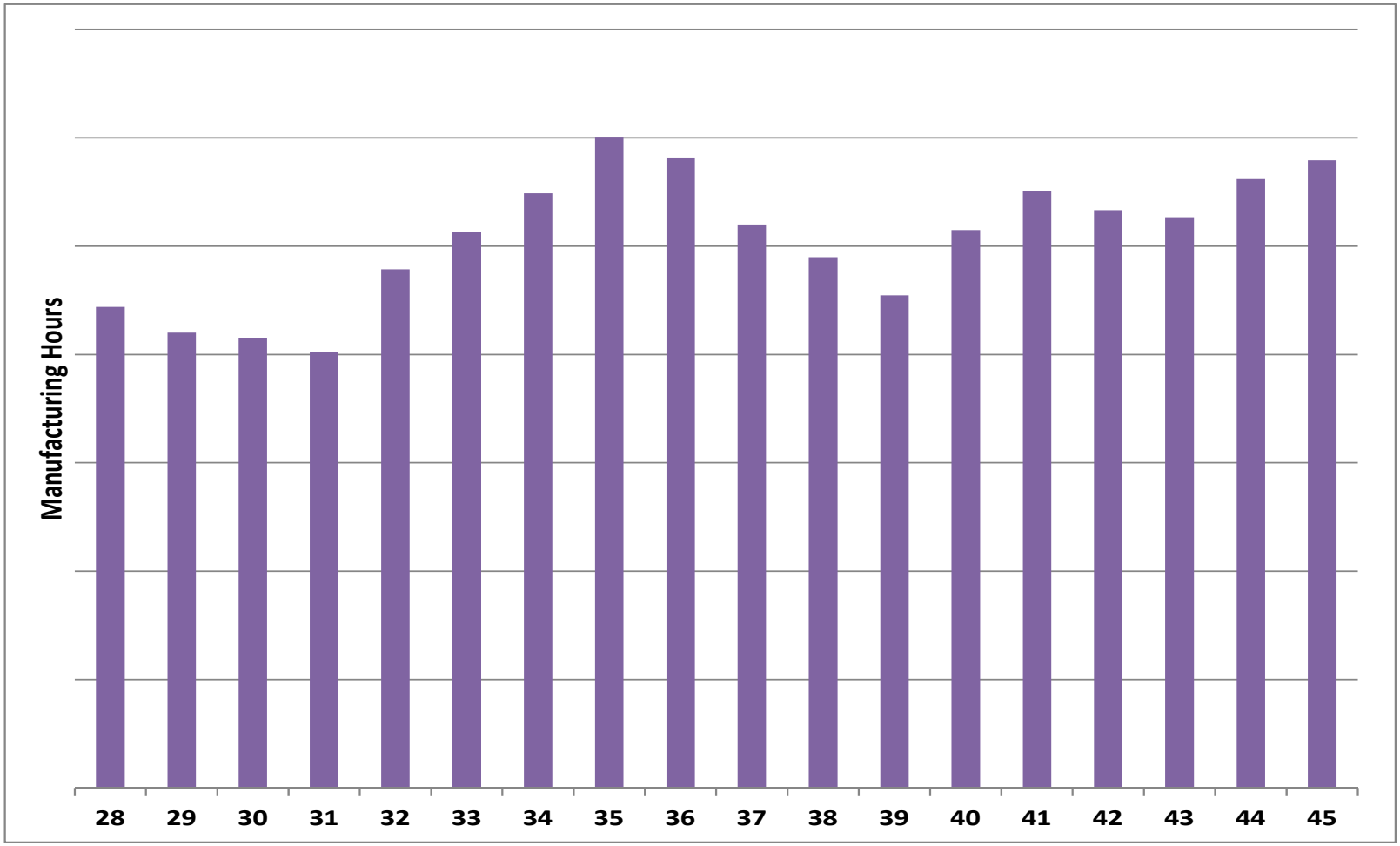
Pitfalls

Pitfalls

- Reliance on historical data in an industry that has seen significant changes is a challenge
- Business restructuring means changes to the way costs are tracked and managed over time
  - Closing and merging of cost centers
  - Shifting of overhead costs to direct costs
  - Shifting of fixed to variable costs
- Cold War driven restructuring means data sets cannot include dates earlier than ~1995
- Other on-going changes may not be best handled by the Partial Adjustment Model
  - I.e., program start-up overhead costs

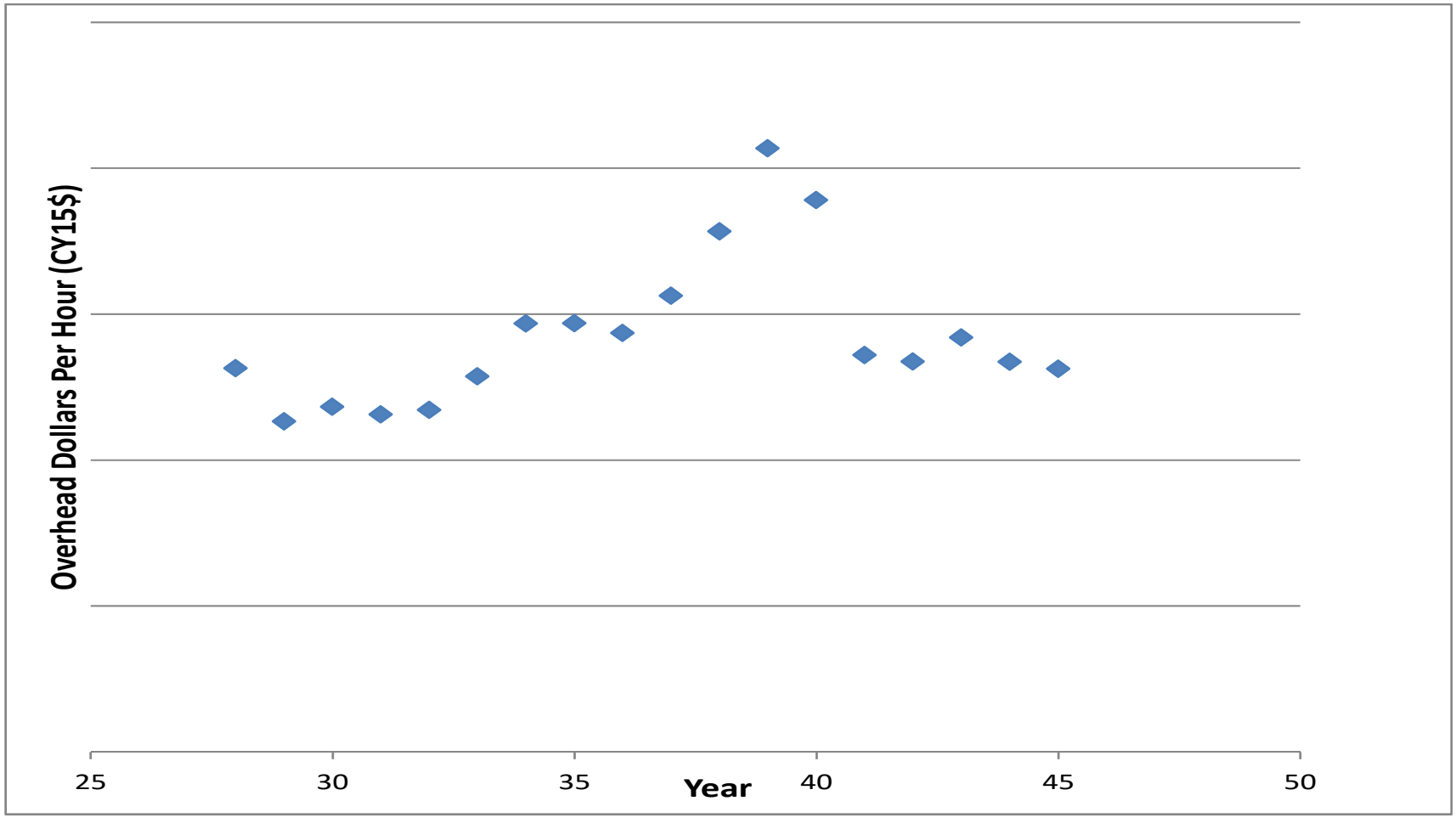
Case study problem was being impacted above - required more than model to identify

Case Study: Work Load Analysis



Workload was expected to increase by roughly 25% between 30 and 35

Case Study: Overhead Account Analysis



An account by account analysis indicated that overhead costs were spiking at the same time workload was increasing

Case Study: The Pitfall

- Overhead costs should be inversely correlated to workload
  - Fixed costs get “spread” over a large number of hours
  - Reduces the per-unit fixed cost
- Key caveat
  - No costs are truly fixed in the long run!
  - Each level of fixed costs supports a certain level (or range of workload)
  - Sufficient deviation from the workload means that fixed costs must change

Key issue: The facility had not been invested in since the end of the cold war and a major new program was coming up. Spike in cost was associated with project start up

Way Forward

Areas of Future Research

- Collect data and validate model against a larger number of contractors and projects
  - In recent history, NCCA has successfully used this model for 3 contractors
- Develop a more sophisticated model that can handle things like project start-up costs
- Work with the wider Navy community to improve the model and encourage adoption in a wider range of applications (i.e., contracting, programming, etc…)

Way Forward: Navy Escalation IPT

- In 2015, NCCA was directed by Navy Leadership to charter a overarching Integrated Product Team to standardize Navy processes for labor rate, overhead rate and material cost escalation
- The pilot project, jointly being done by NCCA and NAVSEA 05C is currently in-progress
- The results of this project will inform and enhance current Navy methods such as the PARM

Questions?