Project Labor Agreements' Effect on School Construction Costs in Massachusetts

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Abstract

This paper investigates the impact of Project Labor Agreements on school construction cost in Massachusetts. While simple models exhibit a large positive effect of PLAs on construction costs, such effects are absent from more completely-specified models. Further investigation finds sufficient dissimilarity in schools built with and without PLAs that it is difficult to distinguish the cost effects of PLAs from the cost effects of factors that underlie use of PLAs.

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Introduction

Construction-industry Project Labor Agreements (PLAs) are collectively bargained pre-hire labor contracts negotiated between property owners and building trades unions. The essential features of PLAs are that successful bidders – even those operating non-union – must adhere to requirements for union referral, union security, and collectively-bargained compensation. In exchange, unions assure timely access to labor and typically agree to harmonize work scheduling provisions among the trades, forego certain types of premium pay or pay increases, and give up the right to strike for the duration of the project. Building trades unions have increasingly used PLAs to protect and expand their position in construction markets. Open shop contractors and their trade organizations have responded with legal and political challenges to many publicly-funded PLAs such as the Boston Harbor and New York State Thruway projects. The debate over PLAs has focused on project timeliness, quality, safety, training, minority employment, employee benefits and labor peace however the central issue has been their effects on public construction costs. The zigzags in federal policy on PLAs over the last twenty years reflect the intensity of this debate. [1]

The current research investigates the effect of PLAs on the cost of new school construction in Massachusetts between 1996 and 2002. Using models with few explanatory variables, prior research on school construction found that PLAs increased bid price between \$12.91 and \$25.67 per square foot, or 14 to 17 percent in the Greater Boston area (Bachman, Chisholm, Haughton, and Tuerck, 2003—Henceforth Bachman, et. al.). A concern with leanly-specified models is that the PLA variable may proxy omitted characteristics that also influence construction costs. To correct for this, the current authors collected unique data on new school construction in Massachusetts. Using these detailed data, we develop a more complete model of school construction costs incorporating information on features such as swimming pools, mechanical systems, non-classroom space and athletic facilities that architects and engineers use to estimate project costs. Our initial estimates suggest that (1) much of the PLA effect is attributable to the higher costs of building within the city of Boston and (2) although PLAs are associated with substantially higher costs in leanly specified models, there is not a statistically significant relationship between the PLAs and construction costs in more complete models.

While more completely- specified models are preferred in establishing the *ceteris paribus* effect of PLAs, our research finds substantial multi-collinearity between the PLA variable and measures of school characteristics in the more complete models. This is a product of the relationship between project complexity and the decisions to use a PLA; more complex and expensive projects are more likely to use PLAs. In combination with the relatively small number of observations in construction data sets, this precludes accurate estimation of cost effects of PLAs in an adequately specified model. In essence, using extant data it is not possible to estimate the effect of PLAs *holding all else equal.*

Background and Research on PLAs

Although nascent PLAs date to World War I, PLAs came into widespread use following World War II on atomic energy, defense and space projects (McCartin,1997; Dunlop, 2002). These agreements banned work stoppages and provided uniform premium pay, shift, and holiday provisions across trades. Project owners and contractors operating in the densely-organized industrial and heavy construction sector favored PLAs as they banned contract and jurisdictional strikes and often provided more favorable terms than local agreements (Belman, Bodah and Philips, 2007). This began to change with the increasing capacity of the open-shop sector in the 1970s and 1980s (Allen, 1988; Linder, 1999). Non-union contractors viewed PLAs requirements as an impediment to competing for work. Working through the Associated Builders and Contractors, the open-shop sector has mounted legal, political and media challenges to public sector PLAs. The legal strategy foundered when U.S. Supreme Court allowed public bodies to sign PLAs in their role as construction owners in its *Boston Harbor* decision (1993). Parallel decisions by in New York and Massachusetts courts have upheld the right of public bodies to use PLAs where they can be shown to provide advantages.

Conflict over PLAs has then moved into the political arena of administrative and legislative bodies. There, public debate has centered on the effect of PLAs on construction costs. Opponents of PLAs argue that the requirement to follow union employment practices raises costs by compelling open shop contractors to pay higher wages and benefits and adopt inefficient labor practices. PLAs are also theorized to raise bid costs by reducing the number of competitors bidding on projects when open shop firms decide not to compete for work. Proponents argue that PLAs improve projects timeliness and reduce costs by providing access to skilled labor on a timely basis, by improving labor productivity by harmonizing hours of work across trades, providing favorable overtime rates, replacing strikes with dispute resolution procedures, and sometimes providing wage concessions. These are theorized to reduce costs by shortening time to completion, avoiding delays and reducing labor input. The effects are especially important on time-sensitive projects such as airports, hospitals and manufacturing facilities. Timely completion allows projects to begin earning revenues sooner and avoid logistical problems such those that occur when schools are not completed on time.

The Current Research

The current research is not, in construction parlance, a greenfield project. Prior research found PLAs raised school construction costs by 14 to 17 percent in the Greater Boston area (Bachman et. al.). These results were obtained from leanly-specified models: the favored specification included only a PLA indicator, a measure of project size and whether the project was new construction or a renovation.[2] The current research extends this work by measuring the cost impact of PLAs within a more complete model of school construction costs, enlarging the area under study from Greater Boston to all of Massachusetts, limiting the sample to new construction, using final cost rather than bid price, and investigating the relationship between project complexities, use of PLAs and cost measures. In developing a more complete model of school construction costs, we explore the claim made by Bachman et. al. that PLA and nonPLA schools are similar and little is to be gained from extensive control for the characteristics of construction.

The principle source of data for project based-construction research has been the F. W. Dodge Construction Reports. Dodge Reports include virtually every project with a bid price of over one million dollars, with several reports issued during the course of a construction project. All provide the project name, location, type, size, owner, architect and, after the contract award, the general contractor. Depending on when a report is issued, successive reports will also provide an architect's estimate of project costs, the low bid or the final offered cost. While the Dodge Reports have long been used by contractors, they can be inadequate for construction research. The specification information is non-uniform and incomplete. Dodge Reports do not include the final cost of the project when completed or information on how the project changed after the final cost offer. The cost measures available from Dodge are then noisy proxies of completed cost – the true measure of concern to the public.[3]

Given these deficiencies in Dodge construction information, we identified factors believed to affect school construction costs from estimating guides and discussions with construction professionals.[4] The basic unit of a school is the classroom, which occupies the majority of school space and accounts for the bulk of school costs. In addition to classrooms, cost is affected by other types of spaces -- including offices, libraries, cooking and dining areas and athletic facilities. Gymnasiums and auditoriums are more costly than classrooms, and exterior appurtenances such as playing fields add to the bottom line. Site preparation, such as demolition and abatement, also increase project costs, as does extensive grading and foundation work. Mechanical systems typically comprise about 15-20 percent of project costs, and systems, such as boilers for heating and water-fed coolers for air conditioning, are more expensive than others. The number of floors in a building has an impact on cost, as does the quality of the construction materials selected. Finally, the educational level of the school is an important determinant of cost as high and middle schools include expensive amenities, such as science and computer laboratories, as well as more elaborate library facilities and auditoriums.

Given our focus on final cost, we used Dodge reports to identify completed projects from the Dodge List of 2001-2002 starts as well as projects included in prior research. Our study was limited to new construction and projects with both new and renovation where the costs of renovations could be separated from the cost of new construction. We contacted architects, contractors and school officials and, using a consistent list of potential school characteristics, surveyed these parties about project features including the final cost, type of school, type of contract, number of stories, roof pitch, particulars of each project (library, science labs, athletic fields, etc.), site grading, type of mechanical system(s) installed, materials used, and bidding process and process and whether there was a liquidated damage clause in the school construction contract. [5] Our survey obtained information on 70 of the 75 new schools in Massachusetts for which construction was completed by fall 2003.[6] Information regarding the presence of Project Labor Agreements was obtained from the Massachusetts Building Trades Council.

Characteristics of PLA and nonPLA Schools

Of the 70 schools in our sample, nine, or 12.9 percent, were built under a PLA (Table 1). PLA schools were larger than nonPLA schools, 172,000 feet against 118,000 square feet; taller, 3.3 against 2.6 stories; more likely to have vocational classrooms, 77.8 vs. 24.6 percent, and more likely to have science classrooms, 100 vs. 65.6 percent. Every PLA project involved demolition work against only half of the nonPLA schools. All nine schools built under a PLA installed chillers against 45.9 percent of the nonPLA schools. However, nonPLA schools were more likely to have tennis courts, 16.4 vs. 0.0 percent. PLA schools also had higher total final costs, $26.8 million against $17.4 million, and cost per square foot, $164.91 against $147.86. Given these differences, distinguishing the effect of differences in characteristics from the cost effects of a PLA *per se* is central to this research.

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Table 1 about here
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Estimation Strategy and Results

We begin by comparing estimates of PLA effects from leanly and more fully-specified models using both linear and log cost models. The second section investigates the sensitivity of estimates to controls for construction in the city of Boston as well as difficulties, related to multi-collinearity and over-determination, in distinguishing the effect of PLAs on school costs from the effects on cost-affecting factors that also affect the adoption of PLAs. Finally, we compare the current research with that of Bachman et. al .

Final Cost Models

We estimate our final cost models with two dependent variables: final cost per square foot and log of total cost. Cost per square foot is widely used in construction research but requires costs be proportional to project size. Although appropriate for characteristics such as classrooms, other features, such as athletic fields and demolition, may not be proportional. As such, log total cost models estimate the percent increase in total cost associated with a feature.

Cost per square foot models

Our initial specification is similar to prior work with cost per square foot determined by area in square feet, area squared and an indicator that takes a value of one when a school is built under a PLA (Table 2, Model 1). Project size has a negative convex relationship to cost per square foot. Larger projects cost less per square foot but the decline attenuates as project size increases. PLAs are estimated to increase construction costs by $28.57 per square foot; the null of no PLA effect is rejected in better than a five-percent, one-tailed test. This model accounts for 24 percent of the variation in school costs.

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Table 2 & 3 about here
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Model 2 adds five characteristics that our interviews suggested should have a large effect on school costs: the number of stories, whether the school was an elementary school, a private school, had a basement, or involved demolition work. Elementary schools cost $25.85 less per square foot, the coefficient is significant in any conventional test. Basements add $13.46 per square foot to school cost, the coefficient is significant in a 10 percent one-tailed test. The private school, story and demolition coefficients are correctly signed but are not individually statistically significant. r^2 increases, from 24.1 percent in Model 1 to 35.1 percent in Model 2. An F-test for the significance of the additional variables rejects the null of all of the coefficients being zero in better than a 1 percent test. [7] With the addition of these variables, the effect of PLAs declines to $24.10 per square foot and is only significant in a one-tailed, 10-percent test.

Model 3 provides a more comprehensive model of school costs with the addition of school and project characteristics. With few exceptions, coefficients are correctly signed and are of moderate magnitude. For example, swimming pools, a particularly expensive amenity, are estimated to add $33.01 per square foot while auditoriums add $14.80 per square foot. Many variables are not statistically significant of themselves, but r^2 rises to 62.9

percent; an F-test that the coefficients on the additional variables are all equal to zero rejects the null in better than a 1 percent test. The PLA coefficient is smaller in Model 2 and is no longer significant in conventional tests.

Models 4 and 5 add a control for construction in the Boston school district to Models 2 and 3, respectively. Four schools were built in the Boston School District during the period under study; three were public schools built under PLAs, one was a private school. Urban construction is typically more expensive than construction in suburban or rural areas because of the difficulties of working in urban areas. For example, marshalling yards have to be established away from the construction site. Renting yards is costly in itself, moving materials and equipment from yards to the construction site also consumes time and resources. In addition, the more rigorous building standards of central cities also increase costs, as does the need to guard against theft and damage.[8]

Our estimates suggest that construction in Boston adds between $34.11 (Model 4, Table 2) and $39.65 (Model 5, Table 2) to the square foot cost of a school, the null is rejected in a 5 percent test in Model 4 and a 1 percent test in Model 5. Addition of the Boston variable improves the fit of the model; r^2 increases to 38.8 percent in Model 5 and 65.12 percent in Model 6. The Boston variable causes a marked decline in the PLA coefficient, from $23 - $24 per square foot in Models 2 and 3 to $13.80 - $13.90 in Models 4 and 5, the PLA coefficient is not significant in conventional tests. These results suggest that the PLA coefficient was proxying for effect of construction in Boston in the leaner models.

Log total cost models:

Estimates from the log total cost models, Table 3, parallel those in the cost per square foot models, but the effect of PLAs is statistically weaker in all but the first specification. Results are consistent with the form of the model: total cost is convex in project size; there are economies of size in construction. An additional thousand square feet is estimated to increase school costs by 1.39 percent for a 50,000 square foot school, by 1.26 percent for a 100,000 square foot school and by 1.1 percent for a 150,000 square foot school. Given the parallelism between the models, we focus discussion on the PLA measures.

In Model 1, which controls only for the size of the construction project, PLAs are estimated to increase the cost of construction by 16.6 percent, the coefficient is significant in better than a five-percent, one-tailed test. Addition of controls for the type of school, ownership and features including story, basement and demolition (Model 2) reduces the magnitude of the PLA effect to 12.5 percent, it is no longer significant in even a ten percent one-tailed test. The PLA coefficient to decline to 9.7 percent in Model 3, the null hypothesis that PLAs do not affect school construction costs is not close to rejection in conventional tests. [9] Models 4 and 5 add the Boston variable to

Models 2 and 3, respectively. The Model 4 coefficient on PLA is 6.4 percent; the Model 5 coefficient is 3.3 percent. Neither is close to statistical significance. In both of these models, schools in Boston are estimated to have a large positive effect on school construction costs.

In summary, the large effects associated with PLAs in the leanly specified Model 1 are a consequence of omitted variable bias. Consistent with this explanation, the size, and particularly the statistical significance of the PLA variable declines in both sets of estimates as we move toward a specification that is more in keeping with that suggested by architects and engineers. There is however evidence of both multi-collinearity and over determination in the more complete models. Despite the higher r^2 and the results of the F-tests, many of the variables in Models 2 – 5 are not individually statistically significant. The decline in the PLA coefficient in the cost per square foot model is smaller than the increase in the standard error of the coefficient. Given the relatively small sample, there is reason to be concerned that over controlling for characteristics, and the consequent increase in standard errors, is the cause of the decline in the impact of the PLA variable.

Issues with Estimates

The prior estimates bring out two distinct issues: the effect of controlling for construction in the city of Boston and over determination. With respect to the Boston variable, we need to determine whether its apparent impact on the PLA coefficient is due to attributing special properties to one-third of our sample of PLAs. With respect to the issue of over-determination, we face a trade-off between sufficient specification and reducing the degrees of freedom for standard errors and statistical significance (Johnston, pages 259-264).

Control for Construction in Boston

While central city construction is more expensive than other construction, Boston construction costs may be particularly high as projects may require pilings, much of Boston is built on fill, and requires 24 hour security. Boston Public Schools are also more expensive than their suburban counterparts as they are permanent buildings.[10] The small data set and the complexity of the interaction between public schools, PLAs and construction in Boston make separating the effects of PLAs from those of construction in Boston challenging. Three of the nine PLAs in our data are Boston schools. The only nonPLA school built in Boston was one of three private schools in our sample. To better distinguish the effects of location and PLA, we estimate two additional versions of the models that include Boston variables: one with a Boston Public School variable but without the Boston variable and one with both a Boston Public School and Boston variable. We estimate these models for the Models 1, 2 and 3 specifications of the cost per square foot and log total cost for models that (Table 4). Although these models will not be able to distinguish a Boston Public School and Boston School PLA effect, it will measure PLA effects outside Boston.

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Table 4 about here
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Considering the models with just the Boston Public School variable, the PLA coefficient in Models 1', 2' and 3' is about half the size of the estimate obtained in models reported in Tables 2 and 3 and is never statistically significant. The decline in significance is not the result of an increase in the standard error of PLA. The PLA coefficient is estimated with greater precision, a smaller standard error, in models including the Boston Public School variable, but the decline in the standard error is smaller than the decline in the PLA coefficient. Estimates of the PLA effect in models with both the Boston and Boston Public School variable -- the lower half of Table 4 -- are qualitatively similar to models with just the Boston Public School variable. In all models the cost of Boston Public School construction is substantially higher than other schools. In sum, these models indicate that PLAs do not affect school costs outside of the Boston area, but it is not possible to distinguish between the Boston public school cost effect and any effect that PLAs have on the cost of Boston public schools.

Sorting Out Multicollinearity and Over-Determination

There is evidence of multi-collinearity and over-determination in our more complete specifications. Although the R-squares for the models are reasonable, and F-tests consistently reject the null that additional coefficients are zero, many coefficients are not significant in t-tests and some effects seem large. The variance inflation factor for PLA for Models 2 and 3 were 1.73 and 3.19 respectively, suggesting multi-collinearity between the PLA and other variables. Further, the loss of degrees of freedom in models with large numbers of explanatory variables may inflate standard errors (Johnson, 1984, 259-264). The concern is then that the decline in the significance of the PLA coefficient in more complete models is driven more by collinearity and the reduced degrees of freedom in a regression with a modest sized data set than by the elimination of omitted variable bias.

Although even our most complete model would be viewed as inadequate by a contractor bidding on a school project, the statistical issue differs from such concerns. Our goal is to determine whether a more completely-specified model improves our PLA estimates. As our direct approach, adding a reasonable set of variables, has proven problematic, we attempt to explore the data by defining a set of PLA and nonPLA schools that are sufficiently similar that we can compare their costs with few controls.[11] This is implemented using a two-stage propensity score methodology. We first estimate a discrete dependent variable model of the factors determining the use of a PLA on school projects. This model generates the predicted probability, ϶(Z), that the school will be built with a PLA and this is used to weight the second stage cost regression.[12] Schools that are almost certain to use or not use a PLA have propensity weights of 1, weights for schools for which there is less certainty about using a PLA are larger. In essence, schools that are strongly dissimilar in their likelihood of using a PLA, are given less importance than those that, but for the PLA, are reasonably similar. The latter schools form the "region of common support" (Morgan and Harding 2006).

The first-stage was estimated with a logistic model. An issue in estimating discrete choice models on small data sets is that explanatory variables may predict success or failure perfectly, and the perfectly-predicted observations, are removed from the estimate. For example, as only nonPLA schools were built without demolition, the demolition variable predicted not having a PLA perfectly for 31 schools and these observations were eliminated. We initially used the very complete set of explanatory variables for our estimates but, because so many variables were perfect predictors, this specification eliminated all observations. Shorter specifications were also tried with a similar outcome. Finally, we used our prior logistic models to remove variables that were perfect predictors from the logistic model and were able to estimate a model which retained all observations.[13] Even in this greatly simplified model, 62 of the 70 observations were predicted perfectly, having probabilities of 0 (nonPLA) or 1 (PLA). Of the eight remaining, only one PLA school had a probability lower than that of some nonPLA schools. PLA and nonPLA schools are then strongly dissimilar and there is no region of common support.

Although this approach did not obtain a set of weights useful for second-stage estimates, it provided insights into the limits of the regression models. PLA and nonPLA schools have different and largely non-comparable characteristics. As the characteristics of PLA and non-PLA schools tend to cluster, there is inherent multi-collinearity and, at least in small data sets, regression analysis cannot distinguish the PLA effect on costs from the effect of characteristics that affect both whether a PLA is used for a school and school costs. It is not possible to make a PLA/nonPLA comparison *other things equal without expanding the size and variability of the data.*[14]

Our results are consistent however with emerging legal doctrine on the use of PLAs. The New York Court of Appeals and the Rhode Island Supreme Court have required that there be an adequate reason to apply a PLA to a project and that sufficient analysis be done to determine whether a PLA advances the purposes of the state's competitive bidding statute. Our finding that PLA projects are fundamentally different from nonPLA projects is consistent with this requirement countering the view that PLAs are used principally to exclude competitors.

Comparison to Prior Research

How do our results compare to that of Bachman et. al ? Bachman considers the effect of PLAs on the bid price for school construction for 126 schools built in the Boston area between 1995 and 2001 allowing for the effects of project size, the number of stories, and whether the project was new construction or a renovation. The study was limited to schools with a construction price of at least $5 million and between 40,000 and 400,000 square feet. Seventeen percent of the 126 construction projects were bid with PLAs.[15] Regressing Dodge cost per square foot against area, whether the project was new construction, and whether the school was built under a PLA, PLAs were estimated to increase the cost of school projects by $18.83 per square foot (Table 5). This estimate suggests that the typical PLA project of 132,000 square feet would cost $2.6 million, 14.0 percent, more than had it been built without a PLA. Models limited to the 85 new schools in the sample find PLAs increase the cost of construction by $14.90 per square foot (Table 5, column 2).

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Table 5 about here

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How do our estimates compare with these? The PLA coefficient in the most comparable model in our research, Model 1 in Table 2, is $28.77, twice that of Bachman et. al. However, our dependent variable is final cost, not bid cost. Substituting costs from the Dodge reports for final cost for the 61 schools for which we have this data, we find PLAs increase cost per square foot by $16.77, similar to the Bachman's et al. new school estimates.[16] These results provide reasonable assurance that the differences between our work and that of Bachman et. al. is not driven by differences in samples or estimation techniques; our finding on the conflation of PLA effects with those of school characteristics associated with the use of PLAs in lean specification extends to prior research.

Conclusion

The effect of PLAs on the performance of school construction has become increasingly controversial. Prior work has found that PLAs substantially increase the cost of school construction. The current research extends this earlier work by examining the effect of more complete specifications and considers the interaction between school characteristics, adoption of PLAs and distinguishing the cost of characteristics from the cost of PLAs. Our estimates suggest that, although lean specifications find that PLAs raise the cost of school construction, this does not characterize more complete specifications that better fit the data. However, the more complete specifications suffer from multi-collinearity and over determination. Detailed analysis of the data suggests that the measured PLA effect is due to three public schools in Boston and that PLAs do not affect school costs outside of the Boston School district. Further, propensity analysis suggests it is not possible to disentangle the effect of PLAs on school costs from the effects of school characteristics that underlay the decision to adopt a PLA. While it should be possible to disentangle these cost effects with a substantially larger data set, assembling such a data set would be challenging.

This study does not provide a certain answer to the question "why PLAs'? Belman, Bodah and Philips (2007) suggest that PLAs are often used where there are hard deadlines for the completion of projects, where the success of a construction project depends on timely access to qualified labor, and where delay has large costs.[17] It may then be that PLAs are neutral on direct construction costs, but are advantageous to owners for whom timeliness is paramount.

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Table 1. Variable names, definitions, and means by PLA status, Massachusetts						
Variable	*Description*	*Min.*	*Max.*	*Mean All*	*Mean w/PLA*	*Mean non- PLA*
PLA	Project built under a PLA	0	1	0.129	1	0
Dodge Total Cost	Total cost, Dodge Reports	$2.6 mil.	$42.0 mil.	$17.5 mil.	$24.4 mil.	$16.5 mil.
Dodge Area (sq. ft.)	Square foot area from Dodge Reports	20,000	284,000	125,337	172,093	117,955
Dodge Cost Per Square Foot	dodgetotalcost / dodgeareaft2	$82.76	$1,099.54	$155.34	$141.67	$157.40
Adjusted Total Cost	Survey total cost, 2002 prices by ENR Cost Index	$2.9 mil.	$47.0 mil.	$18.6 mil.	$26.8 mil.	$17.4 mil.
Area (sq ft)	Survey square foot of the project	23,000	284,000	127,109	162,724	121,855
Cost/Square Foot, Adjusted 2002	totalcostadjusted2002 / areaft2	$96.68	$293.15	$150.05	$164.91	$147.86
Elementary	Elementary school	0	1	0.486	0.444	0.491
Other	Other type of school	0	1	0.171	0.333	0.148
Private	Private school dummy	0	1	0.043	0.000	0.049
Story	Number of stories	1	4	2.686	3.333	2.590
Basement	Basement in school	0	1	0.071	0.111	0.066
Demolition	Demolition performed	0	1	0.557	1.000	0.492
Boiler	Boiler installed	0	1	0.971	1.000	0.967
Chiller	Chiller installed	0	1	0.529	1.000	0.459
Central Air	Central air installed	0	1	0.386	0.222	0.410
Unit Ventilators	Unit ventilators installed	0	1	0.629	0.667	0.623
Ground Coupled Heat Pump	Ground coupled heat pump installed	0	1	0.043	0.000	0.049
Unitary Package	Unitary Package installed	0	1	0.214	0.333	0.197
Steep	Roof pitch – steep	0	1	0.157	0.000	0.180
Low	Roof pitch – low	0	1	0.500	0.889	0.443
Combination	Roof pitch – combination	0	1	0.343	0.111	0.377
Swimming Pool	Swimming pool erected	0	1	0.029	0.111	0.016
Cafetorium	Cafetorium erected	0	1	0.614	0.333	0.656
Bandroom	Band room erected	0	1	0.800	0.667	0.820
Auditorium	Auditorium erected	0	1	0.386	0.889	0.311
Elevators	Elevators installed	0	1	0.957	1.000	0.951
Gymnasium	Gymnasium erected	0	1	0.929	0.889	0.934
Kitchen	Kitchen erected	0	1	0.886	1.000	0.869
Library	Library erected	0	1	0.971	1.000	0.967
ScienceLabs	Science labs erected	0	1	0.700	1.000	0.656
Vocational Rooms	Vocational shops and labs	0	1	0.314	0.778	0.246
Extensive Grading	Leveling of hills, filling of valleys or similar scale work	0	1	0.543	0.333	0.574
Normal Grading	Clearing urban site, grading a corn field or similar	0	1	0.457	0.667	0.426
Athletic	Athletic field(s) created (football, soccer, track, etc.)	0	1	0.686	0.667	0.689
Tennis Courts	Tennis courts erected	0	1	0.143	0.000	0.164
Boston	Boston school district	0	1	0.057	0.333	0.016

Table 2. Estimation of Massachusetts School Construction Cost, Actual Cost Per Sq. Foot										
	MODEL 1		*MODEL 2*		*MODEL 3*		*MODEL 4*		*MODEL 5*	
	Coef	*t*	*Coef*	*t*	*Coef*	*t*	*Coef*	*t*	*Coef*	*t*
PLA	28.57	*2.18*	24.10	*1.53*	23.28	*1.19*	13.80	*1.18*	13.88	*0.81*
Area (sq ft)	-0.0008	*-2.30*	-0.0010	*-4.31*	-0.0006	*-1.19*	-0.0011	*-4.63*	-0.0008	*-1.59*
Area squared	2.02E-09	*2.20*	2.42E-09	*3.68*	1.11E-09	*0.71*	2.76E-09	*4.00*	1.75E-09	*1.12*
Elementary			-25.85	*-3.17*	-26.90	*-2.15*	-27.10	*-3.33*	-29.88	*-2.45*
Private			-20.97	*-0.54*	9.10	*0.30*	-39.34	*-0.82*	-12.45	*-0.35*
Story			6.16	*0.89*	-1.73	*-0.24*	7.92	*1.12*	-0.31	*-0.04*
Basement			13.46	*1.29*	10.34	*0.76*	7.81	*0.65*	5.02	*0.32*
Demolition			5.47	*0.74*	-0.22	*-0.02*	3.69	*0.50*	-1.67	*-0.18*
Boiler					69.68	*2.22*			70.85	*2.34*
Chiller					9.11	*0.95*			6.76	*0.72*
Central Air					1.56	*0.21*			0.39	*0.05*
Unit Ventilators					0.38	*0.04*			1.26	*0.13*
Ground Coupled					10.57	*0.75*			12.17	*0.74*
Unitary Packaged					4.58	*0.38*			-0.34	*-0.03*
Steep					17.23	*1.23*			16.89	*1.23*
Combination					10.41	*1.27*			11.97	*1.34*
Swimming Pool					33.02	*1.85*			19.02	*1.23*
Cafetorium					1.90	*0.23*			0.44	*0.05*
Band Room					-3.04	*-0.21*			-7.56	*-0.53*
Auditorium					14.80	*1.45*			14.92	*1.43*
Elevators					12.51	*0.84*			13.68	*0.89*
Gymnasium					-53.07	*-2.56*			-55.81	*-2.57*
Kitchen					11.05	*0.62*			8.99	*0.48*
Library					29.70	*0.74*			42.30	*1.01*
Science Labs					1.21	*0.12*			-1.93	*-0.18*
Vocational Rooms					-10.94	*-0.92*			-9.73	*-0.81*
Extensive Grading					0.56	*0.04*			1.63	*0.12*
Athletic					-3.01	*-0.28*			-0.05	*0.00*
Tennis Courts					18.02	*1.01*			16.51	*0.91*
Boston							34.11	*2.10*	39.65	*2.78*
Constant	197.51	*7.57*	213.23	*9.22*	132.17	*2.21*	219.57	*9.27*	140.25	*2.22*
r-square	0.2409		0.3513		0.6259		0.3878		0.6512	
F statistic 1/ p value	*3.11/0.0156*		*3.39/.0001*		*3.39/.0001*		*8.59/.0043*		17.02/.0000	
F statistic 2/ p value			*2.73/.0017*		*4.40/.0407*		7.74/.0075			

t-statistic in ( )
All models estimated with 70 observations.
F-test 1 tests the current model's specification against Model 1. F-test 2 tests the current specification against the immediately prior specification. For Models 4 and 5, the prior specification is the Model omitting the Boston variable. Estimates allow for random error components by school district where there is more than one project in a district and for heterogeneity in the error term with the Huber-White correction. Costs are deflated using the Engineering New Record construction cost index for Boston (Engineering News Record).

Table 3. Estimation of Massachusetts school construction cost, ln(total cost), actual cost

Table 3. Estimation of Massachusetts School Construction Cost, ln(Actual Total Cost)

	MODEL 1		MODEL 2		MODEL 3		MODEL 4		MODEL 5	
	Coef	*t*	*Coef*	*t*	*Coef*	*t*	*Coef*	*t*	*Coef*	*t*
PLA	0.1539	*2.38*	0.1181	*1.20*	0.0928	*0.76*	0.0620	*0.77*	0.0313	*0.29*
Area (sq ft)	1.52E-05	*6.29*	1.11E-05	*5.95*	1.25E-05	*3.69*	1.05E-05	*5.48*	1.11E-05	*3.35*
Area squared	-2.58E-11	*-3.60*	-1.60E-11	*-2.96*	-2.15E-11	*-2.18*	-1.41E-11	*-2.56*	-1.74E-11	*-1.79*
Elementary			-0.0988	*-1.90*	-0.0897	*-1.23*	-0.1056	*-2.05*	-0.1092	*-1.56*
Private			-0.5083	*-2.30*	-0.2317	*-1.46*	-0.6083	*-2.23*	-0.3728	*-2.09*
Story			0.0651	*1.44*	0.0038	*0.08*	0.0747	*1.62*	0.0131	*0.28*
Basement			0.0270	*0.59*	0.0705	*0.73*	-0.0038	*-0.07*	0.0356	*0.32*
Demolition			0.0444	*0.90*	0.0295	*0.49*	0.0347	*0.70*	0.0201	*0.32*
Boiler					0.4749	*2.24*			0.4826	*2.38*
Chiller					0.0358	*0.59*			0.0204	*0.34*
Central Air					-0.0203	*-0.36*			-0.0280	*-0.49*
Unit Ventilators					-0.0019	*-0.03*			0.0039	*0.07*
Ground Coupled					0.0362	*0.29*			0.0467	*0.3 4*
Unitary Packaged					0.0390	*0.44*			0.0068	*0.08*
Steep					0.1278	*1.44*			0.1255	*1.43*
Combination					0.0541	*1.02*			0.0643	*1.08*
Swimming Pool					0.2234	*2.06*			0.1317	*1.48*
Cafetorium					0.0440	*0.82*			0.0345	*0.60*
Band Room					-0.0544	*-0.57*			-0.0840	*-0.91*
Auditorium					0.1548	*2.17*			0.1556	*2.14*
Elevators					0.0865	*0.75*			0.0942	*0.78*
Gymnasium					-0.2742	*-2.39*			-0.2922	*-2.45*
Kitchen					0.0595	*0.49*			0.0461	*0.36*
Library					0.5024	*1.72*			0.5849	*2.01*
Science Labs					0.0413	*0.58*			0.0208	*0.30*
Vocational Rooms					-0.0957	*-1.22*			-0.0879	*-1.10*
Extensive Grading					0.0287	*0.35*			0.0357	*0.43*
Athletic					-0.0243	*-0.36*			-0.0049	*-0.07*
Tennis Courts					0.1041	*0.96*			0.0942	*0.86*
Boston							0.1856	*1.98*	0.2597	*2.93*
Constant	15.1747	*156.0*	15.3622	*81.35*	14.5063	*34.70*	15.3967	*80.68*	14.5592	*33.74*
r-square	0.8849		0.9015		0.9421		0.9055		0.9461	
F statistic 1/p value			*3.46/ .0088*		*7.42/.0000*		*3.03/ .0127*		*13.47/.000*	
F statistic 2/p value					*5.45/.0000*		*3.94/.0524*		*8.66/.0050*	

t-statistic in ( ):
All models estimated with 70 observations.
F-test 1 tests the current model's specification against Model 1. F-test 2 tests the current specification against the immediately prior specification. For Models 4 and 5, the prior specification is the Model omitting the Boston variable. All estimates allow for random error components by school district where there is more than one project in a district and for heterogeneity in the error term with the Huber-White correction. Costs are deflated using the Engineering New Record construction cost index for Boston (Engineering News Record).

Table 4. PLA Effects of Controlling for Boston Public School Construction

	MODEL 1'		*MODEL 2'*		*MODEL 3'*	
	Coef	*t*	*Coef*	*t*	*Coef*	*t*
	Model with PLA and Boston Public School Indicator					
	Cost Per Square Foot					
PLA	12.00	*0.94*	8.34	*0.88*	8.40	*0.47*
Boston Public	*50.51*	*2.42*	*48.37*	6.66	48.69	*4.16*
	Log Total Cost					
PLA	.079	*0.92*	.027	*0.40*	.0158	*0.14*
Boston Public	.228	*1.63*	*.2779*	5.67	.2521	*2.94*
	Model with PLA, Boston and Boston Public School Indicator					
	Cost per Square Foot					
PLA	12.24	*0.95*	8.11	*0.86*	5.50	*0.29*
Boston	-30.77	*-0.98*	*-9.71*	*-0.15*	-47.73	*-0.82*
Boston Public	81.90	*2.14*	*58.03*	0.91	95.24	*1.69*
	Log Total Cost					
PLA	.083	*0.99*	.025	*0.36*	.032	*0.27*
Boston	-.463	*-2.26*	-.097	*-0.28*	.269	*0.69*
Boston Public	.700	*2.81*	*.375*	1.08	-0.104	*-0.03*

Table 5. Comparison of Bachman et. al. to Similarly Specified Model Using Current Data

Variable	Bachman et. al.		Current Research
	Preferred Model	New School Sample	Dodge Bid Cost Sample
PLA	18.83 (4.79)	14.90 (significant at 1%)	16.77 (1.32)
New	-17.89 (6.6)		
Square Feet (100,000s)	-12.36 (2.5)	a	-30.0 (1.24)
Sq Ft. Squared (100,000)		a	7.87E-09 (1.20)
Constant	138.7 (28.0)	a	358.70 (2.03)

Source: Bachman, Paul, Chisholm, Diane C., Haughton, Jonathan and David G. Tuerck. 2003. *Project Labor Agreements and the Cost of School Construction in Massachusetts.* Boston: Beacon Hill Institute. www.beaconhill.org/BHIStudies/PLApolicystudy12903.pdf.

[a.] Variable included but estimates not reported.

[1] PLAs were widely used as a federal contracting tool from the 1950s on. President George H.W. Bush barred use of PLAs on new federal or federally funded projects immediately prior to the 1992 election (Executive Order 12818). President Clinton revoked 12818, restoring the prior status quo, in early 1993 (Executive Order 12836). This was augmented in 1997 with a memorandum providing criteria for use of a PLA and the minimum terms to be incorporated into an agreement. President George W. Bush banned the use of Project Labor Agreements on federal projects shortly after taking office in 2001 (Executive Order 13202). In turn, President Obama revoked 13202 and restored the use PLAs in Federal contracting on February 6, 2009.

[2] Other models included measures of whether the school was an elementary school, the number of floors and the distance from Boston. The basic model was also estimated by type of school (elementary/non-elementary) and project size. (Bachman, et. al., 2003)

[3] As the primary Dodge audience uses reports to learn about opportunities to bid on projecs, timeliness, rather than absoluate accuracy, is an overriding concern. Comparisons of Dodge square footage with final size reported to our survey found that the Dodge reports were within 1,000 square feet for 39 of the 70 schools, between 1,000 and 5,000 feet off for 7 schools, between 5,000 and 10,000 feet off for 4 schools, between 10,000 and 20,000 feet off for 5 schools, and more than 20,000 feet off for 6 schools.

[4] See Square Foot Costs (Means, 2005) and Building and Renovating Schools (Macaluso, Lewek, and Murphy, 2004).

[5] Renovation projects were excluded because of their inherent heterogeneity and the problems in defining and measuring key data such as the physical area of the renovation.

6 We were unable to get responses from contractors or architects for five of the schools on our list.

7 We provide two F-tests for group significance. As the ordering of the addition of variables to Model 1 is arbitrary, the upper test in Table 2 compares the specification for the column with Model 1 specification. The lower F-test is a comparison to the immediately previous specification. As we allow for non-independence and heterogeneity in our error structure we only calculate r^2 and do not calculate $\bar{r}^2$.

[8] The 24 hour protection of public building sites in Boston add about $3.00 per square foot to costs.

[9] Some coefficients seem large, notably those on boiler and library. We suspect they proxy for omitted characteristics associated with these features. In both cases, few schools were built without these features. The only school without a library was a private religious school for low-income students built at a low cost per square foot. The library indicator may proxy for all of the low cost features of this school.

[10] Because of these differences, Boston schools, firestations and police stations are designed by a city bureau.

[11] See Rosenbaum & Rubin, D. B. (1983), Morgan & Harding, (2006), Hirano & Imbens (2001), or Robins, (1987).

[12] The weight, known as a propensity score, is 100/э(Z) for schools with PLAs, 100/(1-э(Z)) for nonPLA schools.

[13] The explanatory variables included in this logistic model were size in square feet, story, elementary school unitventilators, unitarypackaged, combination, cafetorium, bandroom, vocationalshopslabs, extensivegrading, athletic, ibctype2a, ibctype2b. Comparison of this list with the variable list in Table 1 shows that, once features uniquely associated with PLAs were eliminated from the model, the remaining variables tended to be less important construction characteristics.

[14] The problem may be illustrated with an example from our cost estimates. In some of our work we estimated Model 2 in two stages, first adding elementary and private and then story, basement and demolition variables. Contrary to expectations by our experts, a referee and ourselves, it was not possible to reject a null of zero coefficients in an F-test of the latter three variables, two out of three of the coefficients were not close to significant individually. Nevertheless, addition of these variables to Model 2 caused a substantial decline in the coefficient on PLA, from about $32 to $24 a square foot. In models that omitted demolition, story and basement had large positive coefficients. The logistic estimates indicate that each of these variables is, in our data set, strongly related to whether a school adopts a PLA. In the final version of the Model, story had a coefficient of 6×10^{23}, indicating a strong relationship with adoption of a PLA. There is then an issue of “fundamental” multicollinearity; our problem in getting clear estimates is not caused by chance correlations but rather by underlying causal relationships.

[15] Bachman et. al report PLA projects averaged 151,000 square feet against 134,000 square feet for nonPLA projects. PLA schools cost $152 per square foot against $134 for nonPLA schools. The average bid price was $22.92 million and $16.95 million for PLA and nonPLA schools, respectively.

[16] The estimated effect of the PLA variable for the final cost of new schools is $23.28, about $5.00 per square foot lower, in the sample of 61 schools for which we have the Dodge bid price.

[17] Toyota has used PLAs on all of its major construction projects, more than 38 million hours of construction labor, since the mid-1980s.