A Comparison of Multiple and Single Attribute Auctioning Methods in the California Department of Transportation

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Abstract

This paper examines multiple attribute auctions for procurement contracts in the California Department of Transportation where firms bid on both project cost and duration, and compares these projects to single attribute auctions where firms bid solely on project cost. Two specific questions are addressed: why are projects selected for a multiple attribute auction, and what is the relationship between auction type and project length. Statistical comparisons of the two auction types support a hypothesis that Caltrans faces asymmetric information when determining optimal project length. Furthermore, regression estimates find a significant difference in project length between projects from the two auction types with multiple attribute auctions having a shorter length of about eighty days.

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1. Introduction

Auctions are an important distribution mechanism in numerous markets worldwide. They are popular in online markets, and are often used for a variety of government procurement purposes. They are important in the development of economic theory because auctions present a market system where various hypotheses can be tested. In addition to their usefulness in theory formulation, auction sales represent a large volume of good and service distribution. The California Department of Transportation is one such government agency that allocates public work projects through an action system, and in the third quarter of 2007 has offered over 40 project proposals with a value of over 200 million dollars.[2] The significant amount and value of procurement auctions supports the importance of understanding auction design, allocation, and efficiency. This paper examines an auction method used by the California Department of Transportation (Caltrans) where bidders bid on both project cost and duration (multiple attribute) and compares this auction method to an auction method where the bidders bid solely on cost (single attribute). This paper also asserts that the presence of asymmetric information concerning project length can explain both the selection of an auction method and the difference of project length between projects bid out under the different auction methods.

The presence of asymmetric information in both government procurement and auction settings has been extensively developed by numerous individuals. In their important work, Athey and Haile have developed a variety of models concerning various auction structures (2002). Laffont and Tirole have addressed the existence of asymmetric information between governmental organizations and private firms, and discussed methods of increasing efficiency in

[2] Caltrans' quarterly project summaries are available online. Please see:

<http://www.dot.ca.gov/hq/esc/oe/contract_progress/cpr.pdf>

public procurement (1986). Porter and Hendricks have also tested important theories regarding the existence of asymmetric information in an auction setting with a focus on the existence of information asymmetries between the firms (1988).

Information regarding multiple attribute auctions, which is the primary focus of this paper, is a relatively understudied area. One of the few significant works on the topic was completed by Bichler who developed a method to compare electronic multiple and single attribute auctions (2000). In the experiment, the utility scores were higher for the multiple attribute auctions, and both auction methods were similar in efficiency. Another important work was completed by David and Kraus where they begin to derive the buyer and sellers' utility functions related to multiple attribute auction system (2003).

This paper presents two primary theses. The first seeks to address why Caltrans selects projects to be bid under the multiple attribute auction system rather than a single attribute one. The presented hypothesis is that Caltrans selects projects for the multiple attribute structure when they face incomplete information regarding optimal project length and lets the firms decide the project length through the auction, rather then fix project length. The second seeks to determine what the effect is on project time when it is determined through a multiple attribute auction rather than set by Caltrans. The corresponding hypothesis is that if Caltrans is faced with incomplete information regarding optimal project length then when they fix project length, it would be expected to vary from lengths for projects determined under multiple attribute auctions.

An ideal experiment would compare identical projects that were auctioned out under both single and multiple attribute methods. There is one project that I found in Caltrans' bid summary database where this was the case. Contract 04-247504 was bid out June 23, 2004 under the multiple attribute method, and again later that year on October 4th under the single attribute method.[3] While this singular instance is not enough information to generate theoretical support, it provides an interesting introduction to the analysis. The auctions were for a surfacing project in Oakland estimated by Caltrans to cost $636,000. The multiple attribute contract was awarded for $649,039 and was projected to take 25 working days. In contrast, the single attribute contract was awarded for $653,672 and the project time allocated by Caltrans was 60 working days. In this case study, the project had both a shorter length and was less expensive under the multiple attribute auction compared to the single attribute auction.

Unfortunately, because of the unique characteristics of the projects completed under Caltrans, it is not possible to compare identical projects to contrast the two auction methods as desired. Instead, a variety of statistical procedures will be used to compare the auction methods and address the two primary objectives including means tests and regression analysis. It is important to address the fact that the selection method for determining a project's auction type is not random because it is determined by Caltrans. This indicates the presence of a selection problem regarding the data sample. A number of variables that will be used to account for a range of project attributes in the statistical analyses in an attempt to increase the accuracy of the results, but this will not overcome the initial selection problem. As a result of this selection bias, the results will be constrained to correlation relationships between the variables rather than being indicative of causation relating to the different auction methods.

Means tests and Probit regression analysis will be used to address the question concerning why Caltrans selects certain projects to be auctioned out in a multiple attribute fashion. Project attributes will be compared across the two auction methods to determine if the

[3] It is not clear why the project was bid out multiple times.

results favor the hypothesis that Caltrans selects projects for a multiple attribute auction when they face incomplete information regarding optimal project length.

Regression analysis will be used to estimate the difference in project length between the two auction structures. A number of project attributes will be included in the analysis to better estimate the correlation between the two variables. The results will then be compared to the hypothesis concerning asymmetric information regarding project length between Caltrans and the private bidding agents.

2. Research Methods

2.1 The Sample

Caltrans uses an auctioning method of procurement that is popular in other government agencies. When Caltrans determines that a project needs to be completed, they send out engineers who determine the required project specifications. The project specifications are advertised though Caltrans' website where firms can obtain project plans prior to the start of the auction.[4,5] The firms can then begin drafting project estimates prior to auction opening. Upon auction opening, firms are allowed to place sealed bids for the project, and the lowest bidder at auction completion is awarded the project. Those familiar with auction literature will recognize this auction structure as a first priced closed Dutch auction.

Caltrans also uses another auctioning method where bidders must also bid on project length in addition to overall project cost. Caltrans refers to these projects as A+B projects, but for

[4] For the current list of advertised projects please see: <http://www.dot.ca.gov/hq/esc/oe/weekly_ads/attach_a.html>

[5] Projects are often advertised for a month prior to the start of the auction.

the purposes of this analysis, this auction type will be referred to as a multiple attribute auction.[6] The structure for these auctions is similar to the one discussed earlier where bidders bid on project cost, except that project length is determined by the firms through the bidding processes rather than predetermined by Caltrans. This is achieved by Caltrans assigning a cost per day for the project, and then the bidding firms must also bid on project length in addition to project cost. Each firm's submitted project length bid is multiplied by the assigned cost per day and added to their bid for project cost, and the firm with the lowest total bid wins.[7] However, the winning firm does not receive monetary compensation for the cost associated with project length; the firm only receives a monetary value equal to their project bid. This auction type is used less frequently than the projects where bidders submit bids based solely on project cost.[8] A comparison of projects bid under the multiple and single attribute auction will provide the basis of analysis for this paper.

Data on Caltrans' procurement auction summaries is available online and is the source of data for this analysis. For each individual procurement auction, Caltrans completes a document that summarizes the details of the project and the bidding outcomes. These bid summaries are then uploaded onto the Caltrans website as public information. Data was collected directly from these bid summaries with the purpose of analyzing multiple attribute auctions. Specifically, I collected data on individual aspects that were thought to help describe any difference between the multiple and single attribute auctions.

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[6] A+B label was determined through personal email correspondence with Caltrans' Office of the Engineer.

[7] Caltrans refers to the project cost as the "A" portion of the bid and the cost relating to project length is referred to as the "B" portion. Hence the label of A+B auction.

[8] Estimates from the data collection give about ten single attribute actions for every multi attribute one.

The individual attributes that were collected were contract number, date, county, city, number of line items, line item cost of mobilization, project description, engineer estimate, the winning bid amount, the time allocated for the project, the cost per day for multiple attribute auctions, and the number of bidders. A few additional variables were created using information from these initial attributes. These additional variables include county population density, percent mobilization costs of total bid, percentage change from winning bid and engineer estimate, as well as a set of binary dummy variables for different project types.

A number of these variables will not be included in the analysis, but it is important for each of the variables that will be used to be properly defined. Auction type is a binary variable that corresponds to whether the auction was a multiple or single attribute auction, with a value of one representing a multiple attribute auction. This variable captures the main focus of the paper, and will be used in a variety of ways.

The engineer estimate of the project is an estimation of cost completed prior to the auctions start by an engineer from Caltrans. For the purposes of this analysis, it is represented in hundred thousand dollars for the Probit regression analysis, but in actual value for the means tests.

The winning bid corresponds to the monetary amount allocated to the winning bidder. Although final cost can vary greatly from initial bid amount, I am only concerned with initial bid amount in this analysis. It is also represented in hundred thousand dollars in the regression analysis.

The number of line items is the amount of individual project work items that are encompassed in the project. Each project has a detailed list of individual work item specifications to be completed that bidders bid on to arrive at the final total, which the basis for number of line items. These correspond to the project specifications determined by Caltrans engineers discussed earlier. This variable is thought to account for project complexity with the intuition being that a project with more line items will have more individual tasks that needed to be completed compared to a similar project with less line items.

The project time is the number of days that are either already allocated for the project for single attribute auctions, or the winning number of days for multiple attribute auctions. This does not take the actual or ending project duration into account; just the days estimated or allocated at the time of bid completion. Furthermore, it is understood that some project contracts contain elements that affect the project time such as bonuses for early completion, and penalties for time extensions. These elements were omitted in the analysis.

The number of bidders is the total number of firms that submitted bids for a project. When there are bidders who withdraw from the project, or enter erroneous bids, they are still included in the number.

Population density is the population density of the county where the project will be completed measured in average number of persons per square mile. When a project is listed to be completed in multiple counties, the first county listed is the one used. The data on population density was obtained from the 2000 government census information.[9]

Percent change in engineer estimate is a measure of the difference of winning bid compared to engineer estimate. This measurement is important because it can help account for two different project aspects. The first is that it can help account for bid amount variation because if the difference between winning bid and engineer estimate is large, one might expect

[9] <http://factfinder.census.gov/servlet/GCTTable?_bm=y&-geo_id=04000US06&-_box_head_nbr=GCT-PH1&-ds_name=DEC_2000_SF1_U&-format=ST-2>

differences between bid amounts to be large as well. The second possibility is that it may account for errors in Caltrans' ability to effectively predict project cost. This can be incorporated into the asymmetric information theories to help explain auction type and project length differences.

Finally, a set of dummy variables was created that corresponds to different project types. These categories were created at my discretion after data collection based on the brief project description from the bid summary. Seven major project categories were created including: bridge work, lane construction, median work, roadway rehabilitation, surfacing, landscaping, and roadway widening projects. The project types are not mutually exclusive, so a project that dealt with both widening and resurfacing would be placed accordingly. The number of projects that fit in each category varied from fifteen to thirty eight. All of the project types were present in both the auction types except for landscaping projects, which was included because of their unique project lengths. Projects that could not be classified into one of above categories will be included in the analysis by providing the dummy variable comparison category.

Data on multiple attribute auctions was collected first. The method used to separate the less common multiple attribute auctions from their single attribute counterparts was achieved through the use of an online search engine.[10] Specifically, the term "days x" was used to search the Caltrans' bid summary database because the term appears almost exclusively in the multiple attribute auctions. This search yielded 93 instances of multiple attribute auctions, and data was collected on each of these projects.

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[10] "Days X" was searched in Google and results were limited to the site:

http://www.dot.ca.gov/hq/esc/oe/awards/bidsum/

Data was then collected on single attribute auctions. The search engine was used to search for the term “total number of working days” in the Caltrans bid summary database.[11] This was completed in order to organize the bid summary files in list form. The search returned 964 results which were then compiled into a list in excel. Integers 1-964 were then assigned to each of the bid summary files. An online random number generator was used to generate random integers from 1-964, and provided the random basis for determining which projects would be used for data collection.[12] Data was collected on 101 of the 964 projects.

Based on my collection method it is assumed that the data represents all of the multiple attribute auctions and a random sample of about one tenth of single attribute auctions available online. The total number of projects included in the data set is 193, with 92 of them being from multiple attribute auctions. The dates for the available online bid summaries used in this analysis range from January 2002 to November 2007. This sample is assumed to represent contracts issued during time periods not included in the analysis.

2.2 Analysis Method

There are two primary theses regarding the data and two corresponding objectives in the data analysis. I will use statistical and regression analysis to compare attributes between projects bid out under the different auction structures in order to address the question regarding why Caltrans selects projects for a particular auction type. I will also use regression analysis to

[11] The term “total number of working days” was used as opposed to another term because the resulting text summary from Google was consistent between results which increased the ease in the conversion to list format. Results were also limited to bid summaries in PDF format because there is no assumed difference between the two bid summary results, but the PDF results were easier for data collection.

[12] The random number generator was provided by random.org.

answer the second question concerning the potential differences in project length between the two auction types. Both results will be discussed and related to relevant economic theories.

First, I will compare project attributes that vary between contracts bid out under the different auction methods. This will provide a platform for hypothesizing what project attributes Caltrans looks for in a project when they chose to make it a multiple attribute auction. The analysis method to answer this question involves means tests and Probit regression analysis. Specifically, variables that both the single and multiple attribute auctions have in common will be compared to determine which attributes are significantly different between the two types. The variables to be analyzed are: engineer estimate, number of line items, population density, number of bidders, and percent change from engineer estimate. The different project types will be included in the Probit regression, but not in the means tests because they represent proportions. However, landscaping projects will not be included in the regression because they are only present in single attribute auctions.

It is important to note that engineer estimate, number of line items, and population density are project attributes that are determined prior to bid opening, whereas number of bidders and percent change from engineer estimate are determined after bid completion. With this in mind, the variables determined prior to bid opening will be particularly useful in determining why the project is selected for a certain auction type simply because the selection of auction type is also made prior to bid opening.

The other two variables included in the analysis will provide additional information. Number of bidders may not be as useful in determining why the selection criterion for project auction type, but it will show if there is a significant difference in number of bidders between project types. It is possible that because of the more complex auction structure of a multiple attribute auction, there are less firms that bid on these projects. It is also possible that a change in number of bidders would indicate the presence of asymmetric information between bidders regarding the different auction types. The results concerning number of bids will be included for discussion but will be difficult to link to support for or against the hypothesis.

Percent change from engineer estimate will be useful in estimating if there is a significant difference in the predicted cost and actual cost of a project between the two auction types. While this variable is determined after the bidding process is completed, it can still be useful in supporting the asymmetric information hypothesis because the results can suggest inconsistencies in how the bidders and Caltrans value the project between the different auction types.

A Probit regression model will also be used to analyze the data in order to determine differences in project attributes between the two auction methods. The Probit method of regression will be useful because it will allow regression analysis to be applied to estimate the relationship between various project attributes and auction type, which is a binary variable. The Probit regression model is shown below in Figure 2.1

2.1 Auction type (Multi = 1 | Single = 0) = β_0+ β_1(Engineer Estimate) + β_2(Number of Line Items) + β_3(Population Density) + β_4(% Δ from EE) + β_5(Lane Construction Projects) + β_6(Median Work Projects) + β_7(Road Rehabilitation Projects) + β_8(Surfacing Projects) + β_9(Widening Projects) + β_{10}(Bridgework) + ε.

An additional regression was completed to determine the relationship between auction type and project cost. The primary reason for completeing this was to determine if there is a potential effect of auction type on project cost. While the regression will only be indicative of correlation, its results will be important. The equation is shown below in Figure 2.2.

2.2 Winning bid = β_0 + β_1(Auction Type) + β_2(Winning Bid) + β_3(Number of Items) + β_4(Population Density) + β_5(% Δ from Engineer Estimate) + β_6(Number of Bids) + β_7(Lane

Construction Projects) + β_8(Median Projects) + β_9(Road Rehabilitation Projects) + β_{10}(Surfacing Projects) + β_{11}(Bridgework) + β_{12}(Widening Projects) + β_{13}(Landscaping Projects) + ε

The second objective in the data analysis is to determine the effect of auction type on project time and the related implications. Linear least squares regression analysis will be used to estimate the relationship. The dependent variable that will be analyzed for the purpose of comparison between the two auction methods is project time. Project time is an appropriate variable for analysis considering that it is the additional attribute in the multiple attribute auctions. The primary dependent variable will by the auction type so as to estimate the effect of auction type on project time. The resulting regression equation is shown in Figure 2.3.

2.3 Project time = $\beta_0 + \beta_1$Auction type + ε

To minimize the error, a number of other variables will be added to the regression. The additional variables are winning bid, number of line items, population density, percent change from engineer estimate, number of bids, and a variety of different project types. The resulting regression equation is shown below in Figure 2.4.

2.4 Project Length = β_0 + β_1(Auction Type) + β_2(Winning Bid) + β_3(Number of Items) + β_4(Population Density) + β_5(% Δ from Engineer Estimate) + β_6(Number of Bids) + β_7(Lane Construction Projects) + β_8(Median Projects) + β_9(Road Rehabilitation Projects) + β_{10}(Surfacing Projects) + β_{11}(Bridgework) + β_{12}(Widening Projects) + β_{13}(Landscaping Projects) + ε

It is important to note that the projects bid under the multiple attribute system are not selected at random which indicates a selection bias. While the regression noted in Figure 1.3 includes numerous variables about project specifications that will make the results substantially more accurate from the regression in Figure 1.2, the selection problem is still present. An example of this problem would be that there is an unquantifiable variable such as a project's political influence which could both cause the auction to be a multiple attribute one, and decrease project length. Since it is not possible to account for these possibilities, the results will only be indicative of correlation between the variables and not causation.

3. Results

As discussed earlier, means tests were completed to determine attributes that were significantly different between the two auction types. The tests were two tailed and assumed unequal variances between the two auction types. The results are shown below in Figure 3.1.

3.1

Means Tests						
	Single Attribute Projects		Multiple Attribute Projects			
Variable	Mean	Variance	Mean	Variance	t-Stat	% Prob
PopDens	869.43	1,466,771	1,858.43	10,878,148	-2.714	0.768%
EngEst	$4,368,677	1.47843E+14	$25,309,602	1.46286E+15	-5.025	0.000%
No.Items	45.91	1,693.26	102.23	5,594.35	-6.394	0.000%
% Δ from EE	-8.49%	0.0543	-0.86%	0.0555	-2.259	2.501%
No.Bids	6.44	9.69	4.51	3.70	5.216	0.000%

There appears to be a significant difference between the two auction types in all the variables included in the analysis. Specifically, multiple attribute auctions have significantly higher engineer estimates, number of line items, percent change from engineer estimate and are in areas with increased population density. However, multiple attribute auctions also have significantly less bidders than single attribute auctions.

The results on population density, engineer estimate, and number of items provide support for the theory that the multiple attribute auction structure is chosen for projects where there is asymmetric information regarding project length. Specifically, each of the variables represents a project attribute that is expected to affect information asymmetry regarding optimal project length.

The population density where a project is to be completed would affect project length because of differences in expected road usage during construction. This is expected to change a project's complexity by adding another feature for a firm to consider during construction. There are other potential differences that could arise with changes in population density such as changes in a regions political structure and influence. However, in this analysis we are primarily concerned with expected changes in road usage related to changes in population density. It is assumed that an increase in population density for a project will make increase a project's complexity by increasing road usage during construction, and thereby make it more difficult to predict project length.

The engineer estimate measures the monetary size of a project, and one would expect a larger project to require additional construction time. This assumption is supported later by the relationship between winning bid and project length in the regression shown in Figure 2.4.[13] It is assumed that it is more difficult for Caltrans to determine appropriate project length for larger projects.

Number of line items is a rough approximation of project complexity, because of it measures the number of individual work specifications. Intuitively, one would expect the marginal cost or benefit in time associated with completing an additional task to be either positive or negative (Gaver & Zimmerman, 1977, p. 283).[14] These potential changes in project length that arise from changes in project complexity can make it more difficult for Caltrans to effectively set project length.

It is important to further clarify why each of these variables would be expected to adversely affect Caltrans' ability to determine the appropriate project length. Asymmetric

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[13] Engineer Estimate is usually a close approximation to Winning Bid

[14] While this assertion is not directly addressed in the analysis, the regression analysis between number of line items and project time implies a positive relationship of about a one day increase in length corresponding to the addition of one line item.

information in a procurement setting can arise when, “the purchasing authority may be unaware of the private sector company’s cost structure and face[s] … [a] problem in fixing a price for a project” (Hillier, 1997, p. 143). However, in this case, Caltrans is unaware of the cost structure that firms associate with the length of a project, and so faces a problem of setting length. As discussed, each of these variables represents either a change in project size or complexity which would in term change the complexity of a firm’s corresponding cost structure for a given project. Changes in these variables would affect a firms’ cost structure which will make it more difficult for Caltrans to effectively fix a project length.

An increase in these three variables represents a project change that would increase the difficultly for Caltrans to effectively determine project length. This association is apparent in the means tests. Projects bid under the multiple attribute bidding structure have significantly greater engineer estimates, number of line items, and population densities.

Multiple attribute auctions appear to have a significantly lower number of bids than single attribute auctions. This could indicate the presence of asymmetric information regarding the multiple attribute projects between competing firms. It could also indicate a presence of another variable that adversely affects number of bidders for multiple attribute projects such as project size. It is difficult to draw conclusions regarding this result without further analysis, but the outcome is still noteworthy.

The result for percent change from engineer estimate does not support the theory that a multiple attribute auction is used for projects where Caltrans cannot effectively fix the length. As discussed earlier, asymmetric information can arise when Caltrans is not aware of the private sector’s cost structure, which makes it difficult for Caltrans to effectively fix project length. One would then expect that if Caltrans is unaware of the private sector’s cost structure then the winning bids should stray from engineer estimate more for projects bid under a multiple attribute auction. However, this is not the case. The percent change from engineer estimate is closer to zero for multiple attribute auctions which would indicate that Caltrans' estimate for project cost is more accurate for these projects. Additionally, the variance is not significantly different between the auction types, which means that the magnitude of the percent changes were similar between the auction types.

Two regressions were completed to analyze differences in project attributes between the two auction types. A Probit method of regression was completed to further determine projects attributes that were significant between the two auction types. A linear least squares regression was completed to estimate the relationship between project cost and auction type. The results are shown below in Figure 3.2.

3.2*

Regressions				
1. Auction type (Multi = 1 | Single = 0) = β_0+ βn*Xn + ε			Binary, Probit	
2. Winning Bid = β_0+ βn*Xn + ε			Linear Least Squares	
	1		2	
Variable	Coefficient	Std. Error	Coefficient	Std. Error
Constant	-1.35958	0.275826	-227.298	60.33585
Engineer Estimate	0.001102	0.001014	-	-
Number of Line Items	0.013528	0.003922	1.403	0.395529
Population Density	0.000171	8.34E-05	0.020702	0.006654
% Δ from Engineer Estimate	0.331551	0.483935	59.36683	71.83472
Lane Construction Projects (Binary)	-0.61036	0.472077	31.45452	62.21756
Median Work Projects (Binary)	0.602736	0.400644	51.23069	62.98827
Road Rehabilitation Projects (Binary)	0.67998	0.398782	48.93643	54.93212
Surfacing Projects (Binary)	0.567222	0.296424	90.89822	46.16623
Widening Projects (Binary)	-0.14481	0.37934	-92.5895	49.89842
Bridgework (Binary)	-0.91761	0.466861	38.73882	58.44668
Landscaping Projects (Binary)	-	-	-436.629	84.70772
Project Length	-	-	0.881659	0.103217
Number of Bids	-	-	4.324819	6.534725
Auction Type	-	-	61.34792	37.95574
McFadden R-squared		0.276726	R-Squared	0.638941
Obs with Dep=0		101	n	193
Obs with Dep=1		92		

*Auction type is coded as multiple attribute being 1 and single attribute being 0. Engineer estimate and winning bid are measured in hundred thousand dollars.

The results obtained from the Probit regression show a number of important distinctions when compared to the means tests. Each of the variables has a relatively lower level of significance when analyzed individually in the means test. This is likely explained in the ability of the Probit regression to better account for relationships between variables when analyzing their effect on auction type. The results also account for the relationship between different project types and auction type, which were not taken into consideration in the means tests.

The asymmetric information hypothesis regarding project selection is further supported by the Probit regression results. Specifically, the most significant variable remains number of line items. While the significance has diminished as compared to the means tests, it still has the most significant relationship with auction type. Furthermore, the second most significant project attribute has become population density. These two variables are thought to affect the complexity of a project, as discussed in their significance in the means tests. With this in mind, the two project attributes that have the highest correlation with auction type are ones that affect project complexity. Both of the relationships are positive which indicates that projects with an increase in variables that indicate greater project complexity are more likely to be bid out under the multiple auction structure.

The Probit regression shows a substantial change from the means tests for the relationship between engineer estimate and auction type. The relationship is only slightly positive and is no longer significant at a ninety percent confidence level. It is likely that other attributes that were included in the analysis were able to capture compounding variables between engineer estimate and auction type. For instance, one would expect the different project types to differ in engineer estimates, and so now the analysis is better able to account for these relationships.

The decrease in the significance of engineer estimate provides less support for the asymmetric information hypothesis. As discussed earlier, one would expect it to be more difficult for Caltrans to set project time for larger projects. Given the decrease in the significance level, it is difficult to conclude a relationship between engineer estimate and auction type which does not support the hypothesis. However, there is still a small positive relationship between the two variables, which provides some amount of consolation, but the weakness of the association does not provide enough evidence to support a theory.

The loss of support for the asymmetric information theory regarding the decrease in significance of engineer estimate is minimal in light of the support already discussed regarding the significance of variables that account for project complexity. One would expect it to be more difficult to predict the corresponding change in project time arising from a change in a project's complexity compared to a change in a project's size. This is logical because a change in project size would likely require an increased amount of effort to complete the bigger project, but a change in project complexity would not only require a different amount of effort, but would also change the complexity of the work being completed. [15] As a result, the change in significance in engineer estimate becomes less important than the results discussed earlier concerning changes in project complexity.

An important result is the new significance of percent change in engineer estimate because it resolves the problem that arose from the means tests. Recall that change from engineer estimate represents Caltrans' ability to correctly predict project cost, so one would expect a greater difference in projects bid out under the multiple attribute auction method. However, this was not supported in the means tests where the difference was greater for single attribute projects. The Probit result works to resolve this outcome because the variable is no longer significant with a very weak t-Stat of about 0.685.

A number of dummy variables for different project types were included in the Probit Regression to account for the idea that certain project types might be more likely to be selected for the multiple attribute auction structure. The results for median, road rehabilitation, and

[15] Hillier states the firm has a cost function of the form C=R-e+f(e) with R representing difficulty in carrying out the project, e representing effort level cost for the firm's employees, and f(e) being the benefits of the employee effort (1997, p.143). One would expect a larger project to affect the firm's effort level (e) more than project difficulty (R), and a change in project complexity to affect both R and e. With this in mind, it would be easier for Caltrans to predict the cost function of a larger project than a more complex one. While this is indicative of project cost, one might expect similar results regarding project length.

surfacing projects show that they are more likely to be in multiple attribute auctions, while bridgework and lane construction projects are more likely to be in single attribute auctions. The results for bridgework, surfacing projects, and road rehabilitation are all significant at 90% confidence, while the other categories are not as significant. These results are difficult to incorporate into theories regarding asymmetric information regarding the project. While the project type results are still noteworthy regarding which types are more common in each auction type, they were mainly included to help increase the accuracy of the other variables included in the analysis.

The results from the means tests and the Probit regression both support the hypothesis that projects are selected for the multiple attribute auction structure when Caltrans does not have complete information regarding the optimal project length. This is primarily because projects that have higher variables that account for an increase in complexity show a positive relationship with selection for the multiple attribute auction type.

A linear regression was also completed with the results shown above in figure 3.2 to estimate the relationship between auction type and project cost. The results show a moderately strong positive relationship between auction type and project cost. Specifically, the estimates find that one could expect multiple attribute auctions to cost about $6.13 million more than single attribute projects while controlling for a variety of project differences.

The estimate that finds a large and moderately significant difference in cost of the two auction types has some important implications. Importantly, the fact that there is a relationship between auction type and cost could potentially signify a causal relationship between the two, and specifically that the multi attribute auction method causes firms to bid higher than they normally would have under a single attribute auction structure. This would dramatically affect any potential policy implications concerning selection of auction type.

It is important to consider how the selection problem affects these results, and it is likely that there are aspects that could be affecting both auction type and winning bid that were not included in the analysis such as a project's political considerations. So while the relationships and implications can be interesting to discuss, their practical application is very limited.

Regression analysis was completed to estimate the effect of auction type on project time. The results are shown below in Figure 3.3.

3.3*

Regressions (Linear Least Squares)				
Project Length = $\beta_0 + \beta n{*}Xn + \varepsilon$				
	Regression 1		Regression 2	
Variable	Coefficient	Std. Error	Coefficient	Std. Error
Constant	213.9208	22.94684	202.4638	35.13817
Auction Type (Binary)	28.09008	33.23591	-80.3628	22.54855
Winning Bid	-	-	0.328446	0.038452
Number of Line Items	-	-	1.134837	0.234908
Population Density	-	-	0.00421	0.004158
% Δ from Engineer Estimate	-	-	38.72041	43.83274
Number of Bids	-	-	-9.80032	3.925615
Lane Construction Projects (Binary)	-	-	-72.8265	37.60998
Median Work Projects (Binary)	-	-	-55.3706	38.29313
Road Rehabilitation Projects (Binary)	-	-	-55.6878	33.3435
Surfacing Projects (Binary)	-	-	-92.8521	27.62275
Bridgework (Binary)	-	-	-8.46396	35.71132
Widening Projects (Binary)	-	-	-32.8392	30.64909
Landscaping Projects (Binary)	-	-	443.5471	44.39325
R-squared	0.003726		0.719985	
n	193		193	

*Multiple Attribute Auctions are measured as a 1 in Auction Type. Winning Bid is measured in hundred thousand dollars.

The first regression shows the correlation between auction type and project time without taking other project attributes into consideration. This regression shows a very weak association between the two variables. The regression shows that one would expect the length difference between the two auction types to be about 28 days longer for multiple attribute auctions. Furthermore, this statistic is not significantly different than zero. While a 28 day difference may seem substantial to agents involved in the projects such as Caltrans and motorists, it is important to consider that since the average project length of both auction types is 227 days, the statistical importance of the 28 day difference is further diminished.

Additional project attributes were added as variables to the regression in order to better estimate the effect that auction type has on the project time. The results are shown in Table 2.3 in regression two.

The resulting regression outcome fits the data substantially better than the previous attempt. Most importantly, the significance of auction type on project time has increased dramatically. Furthermore, the majority of the variables included in the analysis has a significant relationship with project length and illustrate other important correlations.

The primary concern in completing the regression is estimating the correlation between auction type and project length. The regression shows a significant negative relationship between the two variables. Specifically, the projects bid under a multiple attribute auction have a decreased project length of 80 days compared to single attribute auction projects when comparing for a variety of project attributes. The eighty day difference is also significant with a standard error of about 22 days which means that one completing a similar random regression would be expected ninety percent of the time to find that length for multiple attribute auction projects is between 43 and 117 days shorter than single attribute projects.

The existence of asymmetric information regarding project length can explain the observed difference in project time. It is important to remember that the project length is determined differently under the two different auction methods. For single attribute auctions, auction length is set by Caltrans prior to bidding start. In multiple attribute actions, project time is determined through the auctioning process and is the length associated with the winning bid. The presence of asymmetric information was used to hypothesize about the reason for the initial selection of auction type for a project. However, this does not mean that Caltrans has complete information regarding the optimal project length for projects bid under the single attribute method. While Caltrans can hire engineers who have experience in estimating project length in the private sector, variations in each firm's cost structure make it difficult for these estimations to be perfect. The difference in project length between the two auction types illustrate the average difference between project length when determined by Caltrans in the absence of complete information regarding the private sector's cost structure regarding project length, and by private firms who can determine their own optimal length based on their unique cost function.

It is important to discuss the implications of bidding out a project under a fixed predetermined length compared to one that is determined by competing firms. For multiple attribute auctions the competing firms must account for the daily cost of the project at an amount set by Caltrans, and incorporate it into their cost structure to determine the optimal project length. In contrast, firms that bid for projects under the single attribute auction method do not take this additional aspect into consideration and merely bid for completing the project under the specified project length. It is possible that firms bid higher in multiple attribute auctions than they ordinarily would because of the added aspect minimizing project length. This can potentially make projects more expensive for Caltrans, but minimize the cost on external agents such as motorists.[16] This potential should be considered for policy implications.

A number of other project attributes are noteworthy regarding their relationship to project length. Both winning bid and number of line items have significant positive relationships with project length. An increase in number of line items is expected to correspond to almost a one for one increase in project length in days. Similarly, an increase in winning bid by thirty thousand dollars is related to an increase in project length of about one day.

Surprisingly, the population density shows a small, weak, positive relationship with project length. The coefficient can be interpreted to meaning that an increase of population density of one would be expected to correspond to an increase of project time of 0.00421 days. This can be converted to meaning that an increase of population density of 237 persons per square mile would correspond to an increase of project length by a day. However, the high level of error regarding this attribute diminishes the usefulness of the result because it is not statistically different than zero.

An interesting result is the relationship between number of bids and project length. An increase of one bid corresponds to a decrease of project length by 9.8 days. It is possible that there is some causation present in the multiple attribute auction structure because the more bids submitted, the closer the project length is to optimal project length.[17] However, a likely explanation for the observed correlation is that bidders are more attracted to shorter projects.

[16] Caltrans will have to pay the increase of project cost that arises from minimizing both overall project cost and project length, instead of just overall cost. However, minimizing project length will decrease the time that motorists face the costs associated with construction such as increased traffic congestion.

[17] This is similar to how an increase in number of bidders can result in a lower project cost resulting from a decrease in collusion between bidding firms (Gupta, 2002).

Six of the seven dummy variables for project type show a negative relationship. This indicates that lane construction projects, median work projects, road rehabilitation projects, surfacing projects, bridgework, and widening projects are expected to have a shorter project length than other type of projects. Importantly, this means the comparison category which included an assortment of project types that did not fit into the other categories are expected to have an longer project lengths compared to the other categories.

The most significant variable in determining project length is the dummy variable that accounts for landscaping projects. It is important to note that in the sample, landscaping projects were only bid out under the single attribute method, and their inclusion in the regression was primarily to increase the accuracy of the other variables. Landscaping projects represent projects with very high project durations, which explains the substantial correlation with project time. Specifically, five of the ten projects with the longest construction period were landscaping projects.

4. Conclusion

Statistical analysis of projects procured under multiple and single attribute auction methods by the California Department of Transportation support a theory regarding the existence of asymmetric information concerning project length. Specifically, two primary theses were presented comparing the two auction structures. The first sought to answer why Caltrans selects certain projects to be bid out in a method where firms bid on both project cost and length, instead of solely on project cost. The second speculated on if there is a difference in project length between the two auctioning methods, and reasons behind a potential difference. In each case, the existence of asymmetric information regarding project length between Caltrans and the private sector was used to explain the results.

In order to address the first thesis concerning auction selection, different attributes were compared across projects bid out under the two auction types through means tests to see if the significant differences in attributes between the projects supported the existence of asymmetric information regarding project length. The tests determined that population density, engineer estimate, number of line items, and percent change from engineer estimate showed significant difference between the two types at a 95% confidence level. The results for the means tests generally supported the existence of asymmetric information regarding project length for Caltrans. The main support was that the variables that showed a significant difference between the two auction types were ones that are thought to either affect project size and complexity, which would also affect asymmetric information between Caltrans and the private firms.

The means tests results regarding percent change from engineer estimate did not support the hypothesis because if Caltrans has less information available to effectively determine project length based on the cost structures of private firms, then one would expect for the estimates for cost to vary greater under a multi attribute auction, which was not observed. Furthermore, there was a very small difference in the variances between the two auction types which implied that the estimates did not vary substantially more for multi attribute projects.

Probit regression analysis was used to complement the results from the means tests in determining why Caltrans selects projects for a certain auction method. The results were similar to the means test in that variables that were thought to affect asymmetric information regarding project length showed significant differences between the multiple and single attribute auctions. The regression provided additional support for the asymmetric information hypothesis because it resolved the discrepancy that arose in the means test regarding percent change from engineer estimate between the two auction types.

The results of the means tests and Probit regression supported the hypothesis that Caltrans selects projects for a multi attribute auction method when they have incomplete information regarding project length. The support included a significant difference between the two auction types in project attributes, specifically number of line items, that were thought to increase the difficulty of determining the optimal project length.

Regression analysis was completed to address the second thesis concerning project length between the two auction methods. The regression estimates that projects bid out under the multi-attribute auction structure on average have a shorter length of about 80 days. Given the significance of the result, one can form a 90% confidence interval estimating that similar regressions will find the relationship to be between 43 and 117 days shorter for projects bid out under a multi attribute structure.

The significant difference in length between projects auctioned out under the two different methods can be explained by the existence of asymmetric information regarding project length. Specifically, if Caltrans as a public agency is not aware of the private sector's cost structure and importantly, how a project's length factors into this cost structure, then one would expect project lengths to vary when determined by either Caltrans or by firms. Indeed the observed difference in project time is significant and shows that one would expect a project auctioned out under a multiple attribute auction to finish significantly faster than a project bid out under a single attribute method.

This second set of findings can potentially have important implications for policy development. If projects bid out under a multiple attribute structure generally have shorter construction lengths, then it might be desirable to increase the number of projects bid out under this method in an effort to decrease construction time.

However it may not always be optimal for a project's length to be minimized, with such examples as when minimizing a projects cost adversely affects a project's quality or if the cost for minimizing length substantially increases overall cost. The relationship between auction type and project cost indeed shows a positive relationship between the two with multiple attribute projects typically costing about $6.13 more than single attribute ones. While this is not indicative of causation, it provides support that auction type could have an effect on project cost. It would be important for this relationship to be better understood for its obvious policy implications.

There are a number of additional considerations that dilute the ability of the findings to potentially affect auction policy. It is important to remember that the relationship is only indicative of correlation, and it is possible that there are other important factors regarding project length and auction type selection that were not include in the analysis. An important possibility to consider is the effect that political influence can have on a project, which was not included in the analysis because of the extreme difficulty required to quantify such a variable.

There was one instance where a project that was the same was bid out under both auction methods, which represented an ideal experiment. This one instance was not enough to draw conclusions, but the case showed similar results from the regression analysis. Specifically, the regression estimated a decrease in project length for multiple attribute auctions, and this relationship was apparent in the case study. However, the project costs were similar in the case study, while the regression analysis would expect the multiple attribute project to have a higher cost.

Given the relative lack of research regarding multiple attribute auctions, there is a great opportunity to further develop the subject. An important area of further research will include developing theories addressing when and why it may be beneficial to use a multiple attribute auction as opposed to a single attribute one. Often government procurement contracts have set lengths that are either preset by the procuring agency, or arrived at through negotiation between the buyer and seller. Multiple attribute auctions have the potential to become a viable alternative to predetermining project length. Furthering the understanding of the multiple attribute auction method can allow buyers and sellers to better understand the costs and benefits associated with using a particular auction type.

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