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Exploring Drivers of Better Strategic Sourcing in the Air Force Using Analytics

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Introduction

The U.S. Department of Defense (DoD) annually obligates billions of dollars for the procurement of supplies and services in support of the national military strategy. In fiscal year (FY) 2016, the DoD obligated approximately $239 billion on contracts for defense-related supplies and services. Specific to the U.S. Air Force (USAF), over $50 billion were obligated on contracts for supplies and services in FY2016 (USA Spending, 2016). Services typically account for over half of the DoD procurement budget, compared to the acquisition of supplies. In the current environment of budget and manpower cuts, the DoD is transforming its acquisition process to ensure that critical supplies and services are sourced cost-effectively.

The DoD has been undergoing a transformation of its procurement function from a transaction-oriented perspective to a strategic-oriented enterprise. The procurement function is no longer seen as a tactical, clerical, or administrative function, but more of a strategic function. This transformation can be attributed to the fact that the DoD has begun to understand and realize the importance of procurement in achieving the strategic objectives as well as the impact of procurement on reducing costs. One aspect of this transformation in the DoD is the use of a strategic sourcing approach, specifically category management, for the procurement of services at military installations. Category management is a federal government initiative that emphasizes a focus on "increased efficiency and effectiveness, lessening costs, and reducing redundancies" (Sharkey, 2015). Category management emphasizes leveraging buying power, improving efficiencies, and managing consumption. The Air Force is leading the DoD in its category management initiative through category planning, category execution, and category performance management. Specific to category execution, the use of performance levers such as total cost management and the identification of specific cost drivers in service acquisitions can result in increased efficiency and effectiveness and a reduction in costs.

Purpose of Research

The purpose of this research is to analyze the price drivers for one of the DoD's most commonly procured installation-level services, integrated solid waste management (ISWM). Specifically, we focus on the procurement of ISWM services within the Air Force to identify the relationship between service-related price drivers, contract-related price drivers, price, and contractor performance. Our focus is to study the effect that price drivers (both service and contract) have on contract price and contractor performance. We test seven hypotheses to determine the effect that service and contracting variables have on price and contractor performance. Based on our research findings, we provide recommendations to the Air Force for strategically sourcing ISWM services that will result in increased efficiency, effectiveness, and a reduction in costs.

Our Previous Work

In our previous research on the Air Force strategic sourcing process, we developed an optimization model for selecting a set of proposals from among multiple offerors for services to be performed at multiple installations (Apte, Rendon, & Salmerón, 2011). The selection achieved the most favorable objective by balancing the confidence level in an offeror's past performance with the cost of services to the Air Force. The research findings, which were based on a realistic scenario, demonstrated improvements over the sourcing process in both overall performance and cost.

We continue our research stream with this current research methodology using analytics, specifically statistical analysis, to explore price drivers for optimal strategic sourcing of ISWM services. We focus on price as the principal driver and use performance

data to understand the correlation between pricing and performance of the contractors. Our basis for this research is that insight into pricing and performance will help strategize the sourcing of contracts for the decision-makers. We use three statistical methods to determine how service-related and contract-related independent variables (tonnage of waste, number of containers, wage rates, number of offers, and type of completion) affect the dependent variables (total price and contractor performance).

Literature Review

Procurement Transformation

The transformation of the procurement function from a transaction-oriented perspective to a strategic-oriented focus was first discussed by Henderson (1975, p. 44) when he predicted that there would be greater importance placed on the procurement function in corporate management. Kraljic (1983) purported that "purchasing must become supply management" and that organizations should develop specific sourcing strategies for products/services based on the strategic importance of the procured supply/service to the organization and the complexity of the market for that product/service. Kraljic developed a systematic framework for incorporating environmental and other strategic factors into procurement strategy formulation for procured products/services. The use of the Kraljic framework results in a contingency-based model for formulating the appropriate sourcing strategy for products/services. The Kraljic framework has been widely applied throughout the industry. Rendon and Templin (1992) explored the application of the Kraljic framework to National Cash Register's (NCR's) supply management program. The use of the Kraljic framework enables the organization to determine the appropriate sourcing strategy for specific products/services. The market complexity and importance of the product/service to the organization may indicate that a strategic sourcing strategy is appropriate.

Strategic Sourcing and Category Management

One aspect of the purchasing transformation to a strategic function is the use of a strategic sourcing approach for the procurement of product/services. Strategic sourcing involves taking a strategic approach to the selection of suppliers—an approach that is more aligned with the organization's strategic objectives and reflects the integration of sourcing with corporate strategy (Rendon, 2005, p. 9). Closely related to strategic sourcing is category management, which is concerned with the strategic sourcing of a specific category of product/services to ensure the sourcing of those products/services meet corporate-level strategic objectives. Strategic sourcing is differentiated from category management in that strategic sourcing is a one-time event that is focused primarily on leveraging to drive down costs. Category management is an ongoing process that is focused on value elements that go beyond simple price savings. Category management involves engaging stakeholders and fully understanding their product/service requirements, market intelligence on market trends, cost drivers, and risks pertaining to those product/services, and developing a sourcing strategy that aligns stakeholder requirements with the realities of the market (Monczka et al., 2015, pp. 199–201).

Federal Government and Air Force Initiatives

The federal government has implemented both strategic sourcing and category management as part of its initiatives to reduce costs and increase efficiency and effectiveness. The U.S. Government Accountability Office (GAO) identifies five principles of strategic sourcing: maintaining spend visibility, centralizing procurement, developing category strategies, focusing on total cost of ownership, and regularly reviewing strategies and tactics (GAO, 2016). As reported by the Office of Management and Budget (OMB), federal agencies have

> saved money by pooling their spending, either by centralizing the agency's contracting decisions or by using government-wide strategic sourcing vehicles, in order to lower prices and reduce duplication and administrative costs. Since FY 2010, government-wide contracts for office supplies have saved over $140 million by offering lower prices than any single agency could negotiate on its own. Similar vehicles for domestic delivery services saved over $31 million in fiscal year (FY) 2011 over what agencies were paying under previous agreements. (OMB, 2012, p. 1)

Through its initiatives such as "Buying as One Through Category Management," the OMB is focusing on "managing commonly purchased goods and services … by implementing strategies to drive performance, like developing common standards in practices and contracts, driving greater transparency in acquisition performance, improving data analysis, and more frequently using private sector (as well as government) best practices" (OMB, 2014, p. 2).

The U.S. Air Force is leading the DoD in its category management initiative by focusing on strategic sourcing savings levers of "leveraging buying power, improving efficiencies, and managing consumption" (Sharkey, 2015, p. 7). The Air Force's category management operating model includes category planning, category execution, and category performance management.

Category planning involves conducting a spend analysis, requirement analysis, market analysis, and risk analysis. This phase also includes analyzing the four major performance levers (demand management, supplier management, strategic sourcing, and total cost management) to identify category improvement initiatives. Category improvement initiatives within total cost management includes the identification of specific price drivers in the acquisition that can result in increased efficiency and effectiveness and a reduction in costs. Price drivers can be either product/service-related or contract-related and impact savings associated with rate (getting more for less), process (getting more with less), and demand (getting less) (Sharkey, 2015, pp. 21–24). The product/service-related price drivers impact rate savings, process savings, and demand savings. Contracting-related price drivers impact rate savings.

Category execution involves the execution of selected performance levers identified in the planning phase. This would include executing changes associated with the product/service-related or contract-related price drivers (Sharkey, 2015, pp. 25–30).

Category performance management includes the performance tracking, benchmarking, and continuous improvement of the management of the specific category of product/service (Sharkey, 2015, pp. 31–33).

Academic Research

As previously stated, the purpose of this research is to analyze the price drivers for the Air Force's procurement of integrated solid waste management to identify the relationship between service-related price-drivers, contract-related price drivers, price, and contractor performance. Our focus is to study the effect that price drivers (both product/service-related and contract-related) have on contract price and contractor performance. Our research fills a gap in the ISWM literature. Past research has focused mostly on solving waste management social and environmental problems. For example, Achillas et al. (2013) conducted a literature review on multi-criteria decisions aiding in waste management problems for all reported waste streams. Their review provides decision-makers with a thorough list of practical applications of the multi-criteria decision analysis techniques that are used to solve real-life waste management problems.

The waste management literature also includes research exploring the most cost-effective waste collection system. For example, Boskovic et al. (2016) developed a management tool to determine waste collection costs for different waste collection schemes and input data (waste quantity and composition, the number of waste bins, the location of collection points, the type of collection vehicle, crew, and collection route). The tool can calculate the time and costs of waste collection (per vehicle, collection point, or ton of collected waste).

Additionally, Arribas, Blazquez, and Lamas (2010) conducted case study research which proposed a methodology for designing an urban solid waste collection system which uses combinatorial optimization and integer programming and geographic information system tools to minimize collection time and operational and transport costs while enhancing the current solid waste collection system. Their methodology establishes feasible collection routes, determines an adequate vehicle fleet size, and presents a comparative cost and sensitivity analysis of the results. Their research findings yielded significant cost savings in the total solid waste collection system.

Finally, Solano et al. (2002) developed an integrated solid waste management model to assist in identifying alternative solid waste management strategies that meet cost, energy, and environmental emissions objectives. They categorize waste into 48 items and their generation rates were defined for three types of sectors: single-family dwelling, multifamily dwelling, and commercial. The model is flexible to allow representation of waste diversion targets, mass flow restrictions and requirements, and targets for the values of cost, energy, and emission.

As previously stated, the purpose of this research is to analyze the price drivers for the USAF procurement of integrated solid waste management services to identify the relationship between service-related price-drivers, contract-related price drivers, price, and contractor performance. The next section is a discussion of our research methodology.

Methodology

Data

We used data from USAF contracts for ISWM across 63 bases. These data were originally collected by the Facilities and Construction Category Management Team, Facility Related Services subcategory. The team's goal in collecting the data was to better understand the ISWM needs across all pertinent bases in order to strategically source the service. Specifically, the team was looking for potential rate (i.e., price), process (i.e., ordering and delivery of the service), and demand (i.e., ordering the right amount of the service to meet needs) savings.

In this study, we use the data to determine the relative importance of each of the ISWM price drivers. Price of the contract is from the viewpoint of the customer, USAF, whereas the cost of providing the service is from the viewpoint of the vendor. Further, we examine the effect of small business set-asides on the price of the service by comparing price premiums of contracts that used one of five different small business set-aside categories to the price paid for contracts that used full and open competition (i.e., no small business set-asides).

The data pertinent to this study consist of 17 variables and 57 samples. Variable descriptions and types (dependent variable, DV, or independent variable, IV) are given in Table 1. For performance DVs, the buyer rates the contractor's performance on a 1-to-5 scale, where: 1 = Unsatisfactory; 2 = Marginal; 3 = Satisfactory; 4 = Very Good; and, 5 =

Exceptional. Basic descriptive statistics are given in Table 2. Correlations are provided in Table 3.

Hypotheses

Using these data, we test seven hypotheses. We begin with the price-related hypotheses, then move to the performance-related hypotheses.

Table 1. List of DVs and IVs Used in the Study

Variable name	Description (including units or rating scale)	Type
Total Price	Total price of the ISWM contract ($)	DV
Contractor Performance—Quality	Buyer-rated assessment of the contractor's performance related to quality (1-5)	DV
Contractor Performance—Cost	Buyer-rated assessment of the contractor's performance related to cost (1-5)	DV
Contractor Performance—Schedule	Buyer-rated assessment of the contractor's performance related to schedule (1-5)	DV
Contractor Performance—Small Business Subcontracting	Buyer-rated assessment of the contractor's performance related to meeting small business subcontracting requirements (1-5)	DV
Contractor Performance—Management	Buyer-rated assessment of the contractor's performance related to management (1-5)	DV
Contractor Performance—Average Rating	Average of all available performance ratings (quality, cost, schedule, small business subcontracting, management) (1-5)	DV
Tons of Waste	Annual amount of solid waste (tons)	IV
Number of Containers	Number of dumpsters serviced by the ISWM contract (dumpsters)	IV
Wage Rate	Dollars per hour paid to ISWM contractors ($/h)*	IV
Number of Offers	Number of offers received and evaluated prior to contract award (offers)	IV
8(a) Sole Source—SB Set-Aside**	Contract was provided without competition to a qualified 8(a) contractor (yes or no)	IV
8(a) Competed—SB Set-Aside**	Contract was competed among qualified 8(a) contractors (yes or no)	IV
HUBZone—SB Set-Aside	Contract was competed among qualified HUBZone contractors (yes or no)	IV
Service-Disabled Veteran-Owned—SB Set-Aside	Contract was competed among qualified SDVOSB contractors (yes or no)	IV
Total Small Business Set-Aside	Contract was competed among all qualified small businesses (yes or no)	IV
Full & Open Competition	Contract was competed among all qualified contractors (large and small) (yes or no)	IV

* Wage rate was determined using the Department of Labor rates required for all federal contracts.
** 8(a) (named after legislation that created the program) is for a special category of disadvantaged, small businesses that require significant development. The program assists those companies by offering special set-asides and even sole-source awards.

Table 2. Basic Descriptive Statistics

Variable name	Number of observations	Mean	Standard deviation	Minimum	Maximum
Total Price ($)	57	255,321.60	219,698.90	9,234	1,091,814
Contractor Performance—Quality	32	4.31	.69	3.00	5.00
Contractor Performance—Cost	10	4.00	.82	3.00	5.00
Contractor Performance—Schedule	32	4.28	.63	3.00	5.00
Contractor Performance—Small Business Subcontracting	5	3.60	.89	3.00	5.00
Contractor Performance—Management	32	4.31	.82	2.00	5.00
Contractor Performance—Average Rating	32	4.28	.63	3.00	5.00
Tons of Waste (tons)	54	1,868.77	1,937.73	75.00	10,320.00
Number of Containers	50	124.06	103.46	8.00	494.00
Wage Rate ($/h)	57	14.95	3.01	9.72	22.92
Number of Offers	50	3.24	2.54	1.00	10.00
8(a) Sole Source—SB Set-Aside	57	.19	.40	0 (no)	1 (yes)
8(a) Competed—SB Set-Aside	57	.09	.29	0 (no)	1 (yes)
HUBZone—SB Set-Aside	57	.05	.23	0 (no)	1 (yes)
Service-Disabled Veteran-Owned—SB Set-Aside	57	.02	.13	0 (no)	1 (yes)
Total Small Business Set-Aside	57	.28	.45	0 (no)	1 (yes)
Full & Open Competition	57	.25	.43	0 (no)	1 (yes)

Table 3. Correlations

Correlations									
	Total Price	CP Quality	CP Cost	CP Schedule	CP Mgmt.	Tons	Number of Containers	Wage Rate	Number of Offers
Total Price	1.00								
CP Quality	.46	1.00							
CP Cost	.30	.67	1.00						
CP Schedule	.03	.71	.42	1.00					
CP Mgmt.	.53	.91	.79	.42	1.00				
Tons	.46	.39	.01	-.22	.43	1.00			
Number of Containers	.72	-.08	-.06	-.17	.01	-.10	1.00		
Wage Rate	-.49	.06	.35	.11	.22	-.46	-.26	1.00	
Number of Offers	.03	.36	.26	.53	.26	-.24	-.20	-.01	1.00

*Note: “Contractor Performance—Small Business Subcontracting” is not included due to the small number of observations.

Price-Related Hypotheses

The first hypothesis seeks to determine the relative importance of each of the price drivers of the ISWM service. Knowing the price drivers is important in determining how the organization can control, and if possible, reduce price. We are interested in understanding whether ISWM service-related variables or contracting-related variables contribute, and if so, identifying the largest price drivers. Service-related price drivers may be able to be controlled or reduced by changing certain organizational activities. Similarly, identifying significant contracting-related price drivers can help the organization craft better acquisition strategies to control or reduce overall price. We test that the ISWM service-related variables will have more effect on the price than the contracting-related variables. Specifically, we hypothesize that the tonnage of waste, number of containers, and wage rate will influence price more than the number of offers received or the type of small business set-aside (if any).

H1: ISWM service-related variables have a greater effect on price than contracting-related variables.

The second hypothesis tests the relative effects the service-related variables have on price. While both tonnage of waste and the number of containers to be emptied logically contribute to overall price of the contract, we speculate that tons of waste has a greater effect on price because more tonnage requires more contracted trucks to dispose of the waste, and it also increases landfill costs (assuming the landfills have either a "per truck" or "per ton" fee). Further, because federal contractors are required to use standard Department of Labor wage rates (in dollars per hour) when estimating their costs, we test that wage rates will have less effect on the overall price of the service (because the wage rates are pre-determined).

H2a: Tonnage of waste has a greater effect on price than number of containers.

H2b: Number of containers has a greater effect on price than wage rate.

The third hypothesis tests the relative effects the contracting-related variables have on price. Again, while both small business set-asides and the number of offers received logically affect overall price of the contract, we posit that limiting competition through the use of set-asides has a greater effect on price because, unlike large businesses, small businesses typically do not have the volume of work required to offer deep discounts. Therefore, even if a small business set-aside contract were to receive the same (or more) offers than a full and open competition contract (i.e., a contract that allows any business to compete, regardless of size), the prices offered by small businesses are likely to be higher than prices offered by large businesses.

H3: Small business set-asides have a greater effect on price than number of offers.

The fourth hypothesis tests the effect small business set-asides have on price. As described above, small businesses typically cannot match or beat the prices of larger businesses. We use two standardized price variables to examine the effect of small business set-asides on price: (1) price per ton, and (2) price per container.

H4a: Small business set-asides result in a higher price per ton than full and open competition.

H4b: Small business set-asides result in a higher price per container than full and open competition.

Finally, the fifth hypothesis tests the relative effect the small business set-aside categories have on price per ton. There are five different small business set-aside categories represented in the data: 8(a) Sole Source, 8(a) Competed, HUBZone, Service-Disabled Veteran-Owned Small Business (SDVOSB), and Total Small Business set-aside. Of these five categories, the first four are less inclusive than the fifth. The category "Total Small Business" allows for any small business to compete for the contract—including any businesses that are in the first four categories—however, the reverse is not true. For example, if the contracting officer were to specify that the contract is a Total Small Business set-aside, any small business category is able to compete for the contract. However, if the contracting officer were to specify that the contract is a HUBZone set-aside, only those small businesses that qualify for HUBZone status are eligible to compete. Thus, the less inclusive the small business set-aside category, the fewer contractors are eligible to compete for the contract. We, therefore, hypothesize that restriction on competition is expected to increase the price per ton and price per container of waste removal.

H5a: Less inclusive small business set-asides (i.e., 8(a) Sole Source, 8(a) Competed, HUBZone, and SDVOSB) result in a higher price per ton than the more inclusive small business set-aside (i.e., Total Small Business).

H5b: Less inclusive small business set-asides (i.e., 8(a) Sole Source, 8(a) Competed, HUBZone, and SDVOSB) result in a higher price per container than the more inclusive small business set-aside (i.e., Total Small Business).

Among the less inclusive small business set-aside categories, one category is particularly exclusive: 8(a) Sole Source. In this situation, the contracting officer can choose not to compete the requirement at all; instead he or she can simply award the contract to an eligible 8(a) contractor. Therefore, we hypothesize that without competition, the price per ton and price per container of waste removal is expected to increase.

H6a: Among the less inclusive small business set-asides, the sole source set-aside (i.e., 8(a) Sole Source) results in a higher price per ton than the competed set-asides (i.e., 8(a) Competed, HUBZone, and SDVOSB).

H6b: Among the less inclusive small business set-asides, the sole source set-aside (i.e., 8(a) Sole Source) results in a higher price per container than the competed set-asides (i.e., 8(a) Competed, HUBZone, and SDVOSB).

Performance-Related Hypotheses

Similar to our first hypothesis, in our seventh hypothesis we seek to determine if each of the ISWM- and contracting-related variables affect contractor performance. Because the ISWM-related variables (i.e., tons of waste, number of containers, and wage rate) were provided to the contractors early in the acquisition process, were understood prior to vendor bidding, and tend to remain stable throughout the life of the contract, we do not expect to find that ISWM-related variables significantly affect performance.

H7a: ISWM-related variables do not affect contractor performance.

On the other hand, because adequate competition is known to simultaneously decrease price and increase performance, we do expect to find a significant relationship between the contracting-related factors (i.e., small business set-asides and number of offers) and performance.

H7b: Contracting-related variables affect contractor performance.

Methods

To test the hypotheses, we use three different statistical methods. We first describe the price-related methods and then move to the performance-related methods.

Sequential Multiple Regression

For H1 to H3, we use sequential multiple regression to determine the amount of variance in price (i.e., increase in R2) captured by each variable.

> In sequential regression (sometimes called hierarchical regression), independent variables enter the equation in an order specified by the researcher. Each IV (or set of IVs) is assessed in terms of what it adds to the equation at its own point of entry. … The researcher normally assigns order of entry of variables according to logical or theoretical considerations. (Tabachnick & Fidell, 2007, p. 138)

To test the amount of variance in price each IV captures, we entered them in sequence with the hypotheses. Specifically, we made five groups of predictors: Group k =

1 consists of v_1 = Number of Tons; Group $k = 2$ consists of v_2 = Number of Containers; Group $k = 3$ consists of v_3 = Wage Rate; Group $k = 4$ consists of $v_4, \ldots, v_8$ = Small Business Set-Aside categories; and, Group $k = 5$ consists of v_9 = Number of Offers.

Accordingly, we perform $k = 1 \ldots 5$ linear regressions given by Equation 1:

$$p_k = a_k + \sum_{i \in \text{Group } 1 \ldots k} b_{ik} v_i + e_k, \quad \forall k = 1 \ldots 5 \tag{1}$$

where, at the k-th stage in the sequence: p_k is dependent variable Price; a_k is the intercept regression coefficient; b_{ik} is the slope regression coefficient associated with dependent variable i; v_i is the value of the i-th variable; and, e_k is the error term.

Note that in this sequential approach, the group order in which the new variable(s) are added to explain the DV matters. Given our knowledge of the problem, we posit that Number of Tons should have the leading role, and so on. We later revise this assumption based on the results.

Also, like any regression analysis, certain assumptions about the data were met prior to performing the regressions. First, the Small Business Set-Aside categories are dummy variables. We exclude Full & Open Competition in order to compare the set-asides to full competition. Also, we started with 63 observations; however, in the course of testing our assumptions, we removed 6 outliers, thus reducing our useful observations to n = 57. Normality, linearity, and homoscedasticity of the residuals were verified. Multicollinearity was ruled out and the errors were deemed to be independent (i.e., non-correlated).

Wilcoxon Rank Sum Test

For H4 through H6, we use the Wilcoxon Rank Sum Test to determine if the median prices of the groups are statistically different. The Wilcoxon Rank Sum Test is the non-parametric equivalent of the independent t-test, which is used to determine if there is a statistically significant difference between the means of two unrelated groups. We use this non-parametric test because the price for each of the categories was not normally distributed; however, the general shape of the distributions for each group were the same. The null hypothesis for this test is that there are no differences in price between the groups being compared—that they have equal medians. The groups we compare and associated results are displayed in the next section.

Ordered Logistic Regression

For H7a and H7b, we use ordered logistic regression to determine whether or not the ISWM- and contracting-related variables affect contractor performance. Ordered logistic regression is appropriate given the categorical (i.e., non-continuous) nature of the DVs. The categorical nature of the performance scale makes it inappropriate for multiple regressions. Ordered logistical regression is like the more typical binary logistic regression in that it makes probabilistic predictions that an observation belongs in a given category; however, ordered logistic regression is appropriate for outcomes with multiple (vice the binary two) categories. Ordered logistic regression uses a series of equations to determine the probability that the observation is above the first category (i.e., above Unsatisfactory), above the second category (i.e., above Marginal), and so on. Equation 2 shows this multiple-category approach. The right-hand side of the equation represents the more common logistic regression (here *u* represents a linear regression calculation involving any number of predictors). The equation predicts the probability that the actual outcome *Y* exceeds category *j*.

$$\Pr\{Y > j\} = \frac{1}{1+e^{-u}}, \quad \forall j \tag{2}$$

With the hypotheses specified and the methods described, we turn to the results and implications.

Results

Price-Related Results

Sequential Multiple Regression Results

The results of the sequential multiple regressions are provided in Table 4. When using price as the DV, we found that ISWM variables account for 45% of the variance in price, while contracting-related variables accounted for 32%.[1] Further, the total η^2 for the ISWM-related variables was 0.21, while the total η^2 for the contracting-related variables was 0.14. These results suggest that the ISWM service-related variables (tons of waste, number of containers, and wage rate) influence price more than the contracting-related variables (small business set-asides and number of offers). Thus, H1 is supported. This is welcome news for buying organizations, as most desire to make their processes as efficient as possible in order to have minimal effect (if any) on price.

Testing the relative effects the service-related variables have on price, we find that number of tons (η^2 = 0.02) does not have a greater effect on price than number of containers (η^2 = 0.18). Thus, H2a is not supported. However, H2b is supported, as number of containers (η^2 = 0.18) has a greater effect on price than wage rate (□2 = 0.01). These results suggest that the largest service-related price driver is the number of containers, followed by the number of tons of waste, and finally wage rate. Clearly, organizations receiving the ISWM service should examine the number of containers they are using, as reducing containers may significantly reduce price.

Testing the relative effects the contracting-related variables have on price, we find that the small business set-asides (total η^2 = 0.11) have a greater effect on price than the number of offers received (η^2 = 0.03). Thus, H3 is supported. This result is intuitive, but also important in the sense that buying organizations cannot simply reduce price by stirring up competition. Buying organizations should understand the price premium they can expect to pay for meeting certain socio-economic goals so they can make informed acquisition decisions.

[1] To account for the fact that there is declining available DV variance the later a variable is input into the regression, we performed a second sequential multiple regression whereby the contracting-related variables were entered first. In this analysis, we found that the ISWM-related variables accounted for 40% of the variance in price, and the contracting-related variables accounted for 37% of the variance.

Table 4. Sequential Regression Results

Sequence (*k*)	Variables (*i*) in Sequential Regression	Regression Coefficient	Standard Coefficient	η^2	Total R^2	Change in R^2
1	Number of Tons	59.62***	.60***	.36	.36	--
2	Number of Tons	36.25**	.34**	.09	.45	.09
	Number of Containers	802.19**	.44**	.15		
3	Number of Tons	35.83*	.34*	.09	.45	.00
	Number of Containers	810.13**	.44**	.15		
	Wage Rate	-2501.98 ns	-.04 ns	.00		
4	Number of Tons	36.31*	.34*	.08	.50	.05
	Number of Containers	654.84*	.36*	.08		
	Wage Rate	2839.61 ns	.04 ns	.00		
	8(a) Sole Source	39480.93 ns	.08 ns	.00		
	8(a) Competed	124260.60 ns	.16 ns	.02		
	HUBZone	158374 ns	.20 ns	.03		
	SDVOSB	-84663.86 ns	-.06 ns	.00		
	Total SB	35033.08 ns	.08 ns	.00		
5	Number of Tons	13.75 ns	.17 ns	.02	.77	.27
	Number of Containers	776.41***	.54***	.18		
	Wage Rate	-7178.45 ns	-.13 ns	.01		
	8(a) Sole Source	121095.20**	.33**	.06		
	8(a) Competed	97168.88 ns	.16 ns	.01		
	HUBZone	122387.10 ns	.20 ns	.03		
	SDVOSB	-61995.22 ns	-.06 ns	.00		
	Total SB	43398.03 ns	.13 ns	.01		
	Number of Offers	18275.81*	.30*	.03		

*p < .05; **p < .01; ***p < .001; ns stands for non-significant
R^2 is the % of variance in the DV (price) that is explained by the IVs.
η^2 is the % of variance in the DV (price) that is explained by each IV.

Wilcoxon Rank-Sum Test Results

The results of the Wilcoxon Rank-Sum Test did not support H4, H5, or H6. Table 5 illustrates the results.

H4a and H4b test whether there is a difference in price per ton and price per container, respectively, between small business set-asides and full and open competition contract awards. For H4a, contracts solicited as small business set-asides did not result in significantly higher prices per ton than contracts that were solicited using full and open competition. In these data, the price per ton for small business set-asides is $198/ton, while the price per ton for all others is $132/ton. Although the difference may appear large, it is not statistically significant.

However, there were significant differences in the price per container between small business set-asides and full and open competitions. These results support H4b. The price per container for small business set-asides is $2,101/container, while the price per container for full and open competitions is $1,407/container. In these data, the buying organization appears to be paying approximately $700 more per container on small business set-asides. This result again calls for the organizations receiving the service to carefully examine the number of containers they are using, particularly given the fact that the differences in price per ton were not significant. In other words, it is not the amount of waste disposed that affects the price difference between small business set-asides and full and open competition; rather it is the number of containers being serviced.

H5a and H5b test the notion that less inclusive small business set-asides would result in higher price per ton and price per container, respectively, than a simple Total Small Business set-aside. In these data, the price per ton for less inclusive small business set-

asides is $156/ton, while the price per ton for Total Small Business set-asides is $249/ton. Although not statistically significantly different, the results are actually counterintuitive, with the more inclusive category having a higher price per ton of waste removal. Thus, H5a is not supported.

For H5b, the less inclusive set-asides did result in a higher price per container ($2,132/container) than the more inclusive set-asides ($2,063/container), however the difference was not statistically significant. Thus, H5b is not supported.

Finally, H6a and H6b test the notion that sole source small business set-asides would result in higher price per ton and price per container, respectively, than the other less inclusive small business set-asides. In these data, the price per ton for 8(a) sole source set-asides is $139/ton, while the price per ton for the other less inclusive small business set-asides is $174/ton. Although not statistically significant, these results are also counterintuitive—the sole source price per ton is less than the competed price per ton amongst less inclusive small business set-aside categories. Thus, H6a is not supported.

The results of H6b were the same as H6a. Again, although not statistically significantly different, the sole source price per container ($2,116/container) is slightly less than the competed price per ton ($2,156/container) amongst less inclusive small business set-aside categories. Thus, H6b is not supported.

The results of H5 and H6 suggest that once the buying organization has chosen to solicit the requirement using a small business set-aside, the type of set-aside does not affect price per ton or price per container. This information is critical to the buying organization, as they often try to spread their budgets among the different set-aside categories in order to meet Small Business Administration goals. Using less inclusive set-asides may help organizations meet their SBA goals faster, assuming the organization is able to meet the requirements for fair and reasonable pricing (see FAR 19.502-2(b)).

Table 5. Wilcoxon Rank-Sum Test Results*

Hypothesis	Group 1	Group 2	Result
	Contracts with Small Business Set-Aside Categories 8(a) Sole Source 8(a) Competed HUBZone SDVOSB Total Small Business Set-Aside	Contracts with No Small Business Set-Aside Full & Open Competition	
H4a Price/Ton	$198.39 *n*=35	$131.61 *n*=14	ns
H4b Price/Container	$2,100.78 *n*=31	$1,406.78 *n*=13	p<.01
	Less Inclusive Small Business Set-Aside Categories 8(a) Sole Source 8(a) Competed HUBZone SDVOSB	More Inclusive Small Business Set-Aside Category Total Small Business Set-Aside	
H5a Price/Ton	$155.76 *n*=19	$249.02 *n*=16	ns
H5b Price/Container	$2,132.03 *n*=17	$2,062.82 *n*=14	ns
	Sole-Source Small Business Set-Aside Category 8(a) Sole Source	Competed Small Business Set-Aside Categories 8(a) Competed HUBZone SDVOSB	
H6a Price/Ton	$139.07 *n*=10	$174.30 *n*=9	ns
H6b Price/Container	$2,115.51 *n*=10	$2,155.63 *n*=7	ns

* Note. *n* refers to the sample size used in each case. The result column indicates the significance level or non-significant (ns).

Performance-Related Results

Interestingly, we found that neither the ISWM- nor contracting-related variables affected contractor performance. These results support H7a, but not H7b. The results suggest that there are no differences in quality, cost, schedule, or management performance[2] based on (1) the amount of the service required (i.e., large versus small tonnage, large versus small number of containers), (2) the prevailing wage rate in a given area, (3) whether the requirement was solicited and awarded using a small business set-aside or full and open competition, or (4) the size of the competition (i.e., large number of offers versus small number of offers). It should be noted that only 32 of the remaining 57 observations had contractor performance data. More of these data would be required to confirm these results.

[2] Given the few performance ratings available for small business subcontracting, the ordered logit could not converge, thus small business subcontracting was removed from the individual DV analysis. We also tested the combined average performance score across all five performance categories (to include small business subcontracting); however, the results were not different from those reported. A larger set of performance data is needed to confirm these results.

A summarized version of our hypotheses and their related results are presented in Table 6.

Table 6. Summary of Hypotheses and Results

Hypothesis	Description	Supported?
H1	ISWM service-related variables have a greater effect on price than contracting-related variables.	Y
H2a	Tonnage of waste has a greater effect on price than number of containers.	N
H2b	Number of containers has a greater effect on price than wage rate.	Y
H3	Small business set-asides have a greater effect on price than number of offers.	Y
H4a	Small business set-asides result in a higher price per ton than full and open competition.	N
H4b	Small business set-asides result in a higher price per container than full and open competition.	Y
H5a	Less inclusive small business set-asides (i.e., 8(a) Sole Source, 8(a) Competed, HUBZone, and SDVOSB) result in a higher price per ton than the more inclusive small business set-aside (i.e., Total Small Business).	N
H5b	Less inclusive small business set-asides (i.e., 8(a) Sole Source, 8(a) Competed, HUBZone, and SDVOSB) result in a higher price per container than the more inclusive small business set-aside (i.e., Total Small Business).	N
H6a	Among the less inclusive small business set-asides, the sole source set-aside (i.e., 8(a) Sole Source) results in a higher price per ton than the competed set-asides (i.e., 8(a) Competed, HUBZone, and SDVOSB).	N
H6b	Among the less inclusive small business set-asides, the sole source set-aside (i.e., 8(a) Sole Source) results in a higher price per container than the competed set-asides (i.e., 8(a) Competed, HUBZone, and SDVOSB).	N
H7a	ISWM-related variables do not affect contractor performance.	Y
H7b	Contracting-related variables affect contractor performance.	N

Conclusion

This first-of-kind study empirically tested the impact small business set-asides have on contract price and contractor performance. When all ISWM service- and contracting-related variables are included in a regression, we find that the number of containers (a service-related variable) has the largest effect on price. This result is particularly important, as it suggests that the USAF may be able to significantly reduce the price of their ISWM contracts simply by managing the number of containers that must be serviced on each base.

Two contracting-related variables, 8(a) Sole Source set-aside and number of offers, also significantly affect price. Ironically, the results suggest that as the number of offers increases, the total price also increases. These results are particularly counterintuitive, as the ISWM requirement would typically be subject to the lowest cost technically acceptable source selection method, where price is the main determinant of award.

Interestingly, we find no differences in price per ton between (1) small business set-asides and full and open competition, (2) less inclusive small business set-asides and the more inclusive Total Small Business set-aside category, and (3) the 8(a) Sole Source set-aside category and the less inclusive competed set-asides. Using the same comparison categories, we find only one difference in price per container: between small business set-asides and full and open competition. These results once again highlight the importance of number of containers as a price driver, and suggest that buying organizations can choose to target their small business set-asides without significantly affecting price per ton or price per container.

It should be noted that while most differences in prices are not statistically significant, there are still differences. Knowing the median prices paid across USAF bases, as well as the difference in the median prices between comparison categories, may help acquisition teams craft their strategies and understand whether or not received proposals represent a relatively good or a relatively bad deal, as compared to historical prices paid.

Like all research, there were limitations to our analyses. Data limitations do not allow us to account for other factors that may affect the price and performance of the ISWM service, such as distance from the Air Force base to the landfill, the cost to dispose of waste in a given geographical area, and the size and capacity of the trucks being used to pick up and dispose of the waste. We suggest those variables be captured for future analyses.

Data limitations also limit the generalizability of the Wilcoxon Rank-Sum Test results. For adequate statistical power, each comparison group should contain at least 15 observations. That criterion was only met for five of the 12 groups. Finally, more contractor performance data are needed to reach more accurate conclusions concerning contractor performance and ISWM- and contracting-related variables.

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