Sequencing Strategic Sourcing Initiatives at a Large, Public University

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This article describes the application of binary programming to optimally sequence strategic sourcing initiatives at a large, public university. Given a list of commodities that can be strategically sourced, the model selects which ones ought to undergo sourcing initiatives each year so as to maximize potential savings over a five-year horizon while meeting constraints on resource availability, technical difficulty, and commodity priority. The article is based on actual data and events at the University of California, during which time outreach was made to universities in Michigan, Texas, and Washington to compare common practices. Implementation of the model's recommendations would result in potential savings of $145 million over five years, a 3% improvement, and a more feasible program than that produced by current practices.

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I. INTRODUCTION

The University of California (UC) Strategic Sourcing Unit, a small team of people within the UC central administration, is responsible for leveraging the dollars spent to drive down costs while maintaining high quality and service levels. This group, which the first author worked with for six years, aims to continuously improve all aspects of the purchasing process, as recommended by Cooper (2004): "best practice in purchasing strives to leverage the data collection capabilities of financial planning systems to profile what organizations buy and from whom organizations buy. Strategic sourcing seeks to isolate common commodities across business units, define a universal specification and determine the best supplier and manner to deliver these commodities."

The need for modeling becomes apparent when the differences between private and public sector requirements are considered. Private sector companies often begin the process by conducting Pareto analyses to identify the 20% of items that represent 80% of their costs and then focus on negotiating favorable contracts with specific vendors of these items to maximize *potential* savings. Realized savings often fall short of potential due to significant purchases that are made outside of the contractual agreements. Kulp *et al.* (2006) examine the reasons behind such exceptions and offer ways to improve purchasing compliance to increase savings.

Public sector organizations often struggle more with sourcing improvements for several reasons. First, many public sector organizations, such as research universities, purchase an enormous variety of commodities; the UC San

Francisco (UCSF) campus alone has 20,000 vendors. Another reason is that public entities are typically funded by sources which stipulate procurement practice in the acquisition of goods and services. Additionally, selecting target commodities requires a method that reflects both internal and external priorities. For example, the U.S. Department of Homeland Security requires annual reporting on the acquisition and inventory of "chemicals of interest" that *can* be used in the manufacture of weapons of mass destruction, but which have benign uses at universities conducting research in the life sciences, semiconductor fabrication, and micro-electromechanical systems. Another example of external pressures is the National Institutes of Health regulations on animal feed and cage systems to preserve animal health and living conditions. These increase the complexity of strategic sourcing with additional conditions to accommodate in a Request for Proposal and post-award contract management.

In their review of the purchasing literature, Ellram and Carr (1994) find that widespread effort to strategically source materials has been underway only since the early 1990s. Prior to that time, top managers tended to view purchasing as more of a passive, administrative function, rather than as a strategic one requiring expertise. For sourcing to play a strategic role, suppliers must be selected for long-term partnerships focused on continuous improvements in cost, quality, service and reliability. Toward the end of the 1990s, Anderson and Katz (1998) conclude that procurement has "become an increasingly significant driver of corporate financial performance" with a much greater ability to improve profit compared to the downsizing of staff. They describe how a variety of innovative procurement practices, rather than cost-cutting, generated profitable and sustained growth at Dell, Wal-Mart, General Electric and Honda.

While most strategic sourcing methodologies in current practice are subjective, Talluri and Narasimhan (2004) indicate that a few objective decision models have been developed, especially for decisions regarding supplier evaluation and selection. Their methodology uses data envelopment analysis to categorize suppliers into groups suitable for strategic partnerships, supplier development initiatives, or pruning. An even more sophisticated, industry-tested approach for efficiently matching buyers and suppliers is presented by Sandholm *et al*. (2006), who report that Procter and Gamble saved $295 million with this approach in two and a half years. Dwyer and Limberakis (2011) provide results from a survey of 315 enterprises to give a picture of the current state of affairs in strategic sourcing around the world. They find, for example, that the average company has 62% of its total spend under the management of a procurement department, 30% of procurement contracts in compliance with sourcing agreements, and realized cost savings of 8%, with the largest savings due to innovative e-sourcing technologies. While progress continues to be made, few companies (and probably fewer public sector organizations) have achieved the full potential of strategic sourcing.

Motivated by a desire to save millions of dollars annually in purchasing costs, the research question addressed in this paper is: given a list of commodities that can be strategically sourced by an organization, in what order should the commodities be selected to undergo sourcing initiatives each year so as to maximize total potential savings over a five-year horizon? We present a binary programming approach to sequencing strategic sourcing initiatives that we have not seen elsewhere in the literature. Clark *et al*. (2011) describe a related effort undertaken by the UC Strategic Sourcing Unit to optimally schedule vendor shows.

II. UC STRATEGIC SOURCING PROCESS

In 2004 UC commenced a system-wide Strategic Sourcing Initiative across all 18 of its business units: 10 campuses, 5 medical centers and 3 national laboratories (UC Office of

Strategic Communications, 2011). The UC Board of Regents expected to maximize savings by leveraging its vast system-wide purchasing power of more than $7 billion per year. To implement strategic sourcing among its business units, UC adopted the eight-step process shown in Fig. 1 below.

In Step 1, resources (staff and funding) are assembled to launch the sourcing team which makes site visits and meets with subject matter experts (SME) to determine what is procured, from whom it is purchased, how it is purchased, and other attributes of the commodity. For example, the Animal Care team consists of veterinary and purchasing professionals, with a two-year projected activity time.

An analysis of spending is done in Step 2 to determine what attributes of the commodity may be affected. For example, the Animal Care commodity includes laboratory animals, ventilated racks and cages to house animals, feed and bedding for the animals, diagnostic services for determining animal health, and activity aids for animal fitness. The largest expense is for rodents, while the expense associated with other species is comparatively small or is highly regulated, as in the case of primates. During this analysis, we found that an animal breed is not identical between suppliers due to genetic drift, and such inexactness can diminish the ability to duplicate prior research or otherwise adversely affect research studies. We also discovered that one UC campus specializes in animal diagnostics while others use out-of-state diagnostic centers. We proposed centralizing animal diagnostics to one campus to eliminate the high cost of interstate shipment of animals and animal fluids, a regulated activity. The SME agreed with this recommendation, and the UC decided to consolidate animal diagnostics on just one campus. Ultimately, the team reduced its scope to soliciting bids for storage racks and cages, and for feed and bedding, but deleted animal procurement from further consideration due to regulatory and research continuity issues.

Step 3 determines UC's requirements for the commodity while Step 4 reviews the market for suppliers along with critical factors affecting procurement: regulations, transportation, order frequency, order size, etc. Step 5 develops a strategy to go forward; for example, the team chose to focus on only two aspects of Animal Care.

In Step 6 UC publishes a solicitation for responses from the supplier community, a Request for Proposal (RFP). Responses are evaluated against criteria determined prior to publishing the RFP, and suppliers who best satisfy UC's needs are selected. After negotiating agreements with selected suppliers in Step 7, the process concludes by engaging in a Supplier Relation Management (SRM) program and identifying key performance measures such as on-time delivery, invoice accuracy, product quality, and customer satisfaction. In the SRM program, suppliers are regularly contacted in order to enable continuous improvement and maintain high standards of supplier performance.

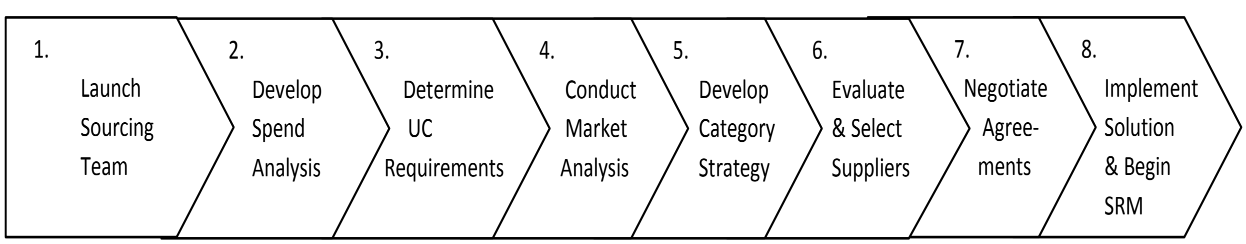

FIGURE 1. UC STRATEGIC SOURCING METHODOLOGY (UNIVERSITY OF CALIFORNIA, 2005)

In addition to the broad spectrum of commodities purchased, there are other challenges for strategic sourcing in a public university. In particular, as a state-run entity and one of the largest recipients of National Institute of Health funding (Bole, 2010), UCSF must conform to both state and federal purchasing regulations designed to prevent fraud and promote public policy. The California Public Procurement Code sets a low mandatory bid threshold of $50,000 annual purchases, termed "spend," with one supplier (University of California, 2010), well below the federal threshold of $550,000 (NDAA 2006, 2010). Federal grants and awards also stipulate that at least 23% of procurements must come from small businesses, including small disadvantaged businesses (5%), women-owned small businesses (5%), and disabled veteran-owned small businesses (3%) (U.S. Small Business Administration, 2011).

Finally, public sector sourcing must also contend with budget uncertainties, as most state budgets, including California's, have fluctuated greatly, especially in recent years. In the public environment, selecting from a vast array of commodities, conducting competitive bidding, meeting regulations, and adjusting to annual budget gyrations make strategic sourcing more complex than in the private sector, where companies can primarily focus on commodity spend.

III. ASSESSING AND SELECTING COMMODITIES

Before initiatives can be undertaken, we must determine which commodities to evaluate. UC retained a consulting firm to assist the strategic sourcing process and provide actionable data; they compiled annual purchases for every vendor and every business unit based on paid invoice data, and then consolidated vendors by commodity to establish commodity spend, the total spend per commodity. Each commodity represents an opportunity for UC to implement an initiative by directing staff to analyze spending patterns, formulate negotiating strategies, and enter into system-wide agreements on behalf of all 18 business units. The consultants identified 39 general procurement commodities, listed in column B of Table 1, and another 15 commodities for Information Technology (IT). This was consistent with experiences at the University of Washington (Christensen, 2009) and the University of Michigan (Webber, 2009), both of which had isolated about 40 non-IT commodities for their strategic sourcing teams to study.

The list of 39 commodities served as a general, though not definitive, set of commodities that UC would investigate for strategic sourcing. Here, we treat the list as static but recognize that, in reality, such a five-year program may have unforeseen circumstances that alter the content of the commodity list. The first 13 of 39 commodities were already in the process of being strategically sourced; the remaining 26 (listed in no particular order) lacked agreements or had agreements that were expired or were about to expire. Other commodities not included on this list had agreements in place or were not within the purview of campus purchasing, such as capital projects, or were already handled by another group, such as Information Technology acquisition (due to technical complexity).

Column C of Table 1 lists the annual spend (in $1,000s) for each general procurement commodity; all but three have an annual spend in excess of $1 million. Material managers from each UC campus, who are typically the most senior purchasing professionals, met and added data to indicate "Target Spend," Savings Range," and "Target Savings." Target spend values in column E estimate how much of the commodity spend could be put to bid: the amount that could be impacted by a sourcing initiative. These targets recognize that end-users, usually department requesters who actually process orders for goods and supplies, may not choose to use agreement suppliers or some portion of the

TABLE 1. UC NON-INFORMATION TECHNOLOGY COMMODITY LIST

A	B	C	D	E	F	G	H	I	J	K	L	M	N	O
	Products & Services	Initiative	Target Spend		Savings Range (%)			Target Savings ($)			Difficulty			Pri
No.	Commodity	Spend	%	$	Low	Ave.	High	Low	Ave.	High	Tech	Res	Mult	
1	Janitorial Products & Services	16,358	80	13,086	10%	15%	20%	1,309	1,963	2,617	3	7	21	3
2	MRO	70,326	50	35,163	10%	15%	20%	3,516	5,274	7,033	1	10	10	8
3	Carpet	8,397	80	6,718	7%	9%	10%	470	571	672	4	6	24	4
4	Gases	8,128	75	6,096	5%	8%	10%	305	457	610	6	5	30	9
5	Hazardous Waste	2,973	100	2,973	5%	10%	15%	149	297	446	8	3	24	10
6	Specialty Lab Supplies	77,086	50	38,543	3%	5%	7%	1,156	1,927	2,698	10	8	80	10
7	Expedited Mail Services	11,811	80	9,449	15%	20%	25%	1,417	1,890	2,362	3	6	18	5
8	Office Furniture	28,152	80	22,522	3%	7%	10%	676	1,464	2,252	3	8	24	4
9	Color Copiers	3,340	30	1,002	20%	25%	30%	200	251	301	4	6	24	1
10	Travel - Hotels Conference Events	30,559	57	17,418	9%	20%	30%	1,568	3,397	5,226	3	10	30	6
11	Travel - Car Rentals	4,229	80	3,384	5%	8%	10%	169	254	338	2	8	16	5
12	Travel - Agency On-line Booking	1,701	70	1,191	10%	13%	15%	119	149	179	8	10	80	4
13	Travel - Airlines	43,946	62	27,247	8%	18%	27%	2,180	4,768	7,357	7	9	63	3
14	Labor - Nursing/ Health Staff & Admin	10,819	98	10,603	4%	6%	7%	424	583	742	5	7	35	5
15	Lab Equipment	171,553	50	85,777	3%	5%	7%	2,573	4,289	6,004	7	8	56	8
16	Bulk Gases	2,032	80	1,626	5%	8%	10%	81	122	163	4	7	28	4
17	Water Purification	411	90	370	5%	8%	10%	18	28	37	6	4	24	3
18	Food - Producers, Distributers & Services	64,145	89	57,089	6%	9%	11%	3,425	4,853	6,280	6	4	24	2
19	Lab Furniture	10,127	80	8,102	3%	7%	10%	243	527	810	6	4	24	8
20	Caging Equipment, Animals & Feed	21,760	80	17,408	5%	5%	5%	870	870	870	10	10	100	10
21	Classroom Furniture	7,678	80	6,142	3%	7%	10%	184	399	614	5	4	20	7
22	Bio Waste	991	100	991	5%	10%	15%	50	99	149	10	3	30	10
23	Radioactive Waste	991	100	991	5%	10%	15%	50	99	149	10	3	30	10
24	Newspapers	3,902	80	3,122	10%	13%	15%	312	390	468	2	5	10	1
25	Publishers	24,160	80	19,328	8%	12%	15%	1,546	2,223	2,899	4	4	16	2
26	Commercial Printing	17,626	80	14,101	10%	13%	15%	1,410	1,763	2,115	3	4	12	4
27	Executive Search	3,163	100	3,163	20%	23%	25%	633	712	791	4	7	28	2
28	Custom Stationery	7,554	80	6,043	10%	13%	15%	604	755	906	5	5	25	1
29	Fleet - Buses, Cars/Vans & Specialty Vehicles	12,251	80	9,801	4%	8%	12%	392	784	1,176	6	8	48	6
30	Audio/Visual	10,938	70	7,657	10%	11%	12%	766	842	919	6	4	24	2
31	Relocation	4,747	75	3,560	5%	10%	15%	178	356	534	5	7	35	3
32	Marketing Companies	7,803	75	5,852	10%	15%	20%	585	878	1,170	6	5	30	2
33	Advertising Agencies	9,104	70	6,373	5%	8%	10%	319	478	637	4	8	32	2
34	Security Services	3,233	100	3,233	10%	18%	25%	323	566	808	9	6	54	7
35	General Storage	4,746	90	4,271	10%	15%	20%	427	641	854	4	5	20	3
36	Electrical Services	17,497	25	4,374	5%	8%	10%	219	328	437	7	7	49	4
37	Roofing Services	4,678	90	4,210	10%	13%	15%	421	526	632	5	4	20	3
38	Legal Services	33,827	40	13,531	15%	20%	25%	2,030	2,706	3,383	9	5	45	8
39	Business Consultants	51,942	40	20,777	10%	15%	20%	2,078	3,117	4,155	7	5	35	6

commodity could not be put to bid. Another form of "leakage" from using agreement suppliers occurs when end-users must meet federal grant requirements for small business and small disadvantaged business.

The material managers also estimated savings ranges, expressed as a percentage of the target spend, and applied them to target spend to estimate target savings. All estimates for actionable spend and savings potential reflect the collective experience of the group of material mangers. Collecting system-wide spend data had never been done before and this effort represented a golden opportunity. We focused solely on the non-IT, general procurement commodities, which exclude construction, rent, leases or other local obligations not covered by system-wide agreements.

To illustrate, consider Animal Care (commodity 20) with its estimated annual total spend of $21,760,000. By consensus among the material managers, up to 80% of the total, or about $17,408,000, could be affected by an initiative for this commodity. Of this amount, the group believed that a sourcing initiative would achieve a 5% cost reduction, saving up to $870,000 annually. For other commodities where the expected savings were less certain, the group estimated a low and high savings percentage; the model described below makes use of the average target savings (s_i) of each commodity shown in column J.

Table 1 also gives the first author's assessments (ratings from 1 to 10) of technical difficulty, resource demands, and importance of each commodity to the operations of the UC system in columns L, M, and O, respectively. These assessments are based on his participation in the compilation of spend data and discussions with the material mangers when they estimated actionable spend and savings potential, and picked the initial set of initiatives. They are used in the constraints of the optimization model described in the next section. Prior to this effort, UC considered all commodity initiatives as *equal* to one another in terms of difficulty, staffing requirements, and time needed to complete.

Technical difficulty represents how much a particular commodity will depend on SME to assist an initiative. Janitorial Products and Services scores low (3) except for the effort to reduce the use of harsh chemicals, such as chlorine bleach, or use bleach in lower concentrations. This initiative would require assistance from the sustainability group on every campus, as well as from the purchasing and strategic sourcing staff who participate in every initiative.

Resource difficulty reflects the number of staff required system-wide to support an initiative. Some commodities, such as office supplies, are used by all campuses while others are used by only a few campuses, such as bio-waste. Janitorial Products and Services represents a ubiquitous need and is given a moderately high score (7). An initiative for Animal Care, which is highly regulated and closely monitored by government agencies and the research community, requires support and input from each campus's Laboratory Animal Research Center. This includes veterinary staff, facility managers and support staff to develop specifications for feed and bedding, and the racks and cages used to house the animals. Thus, Animal Care was given the highest resource difficulty rating (10). Resource and technical difficulty were then *multiplied* together in column N (d_i in the model) to increase the visibility of the corresponding commodity and its inherent challenges.

Priority values (p_i in the model) were assigned to reflect the importance of a commodity to campus operations. For example, every campus that conducts animal research with human pathogens must have a bio-waste company on contract or cease that operation, so Bio Waste (commodity 22) was given the highest priority value (10). Color copiers, on the other hand, are not essential for operations so this commodity was given the lowest priority value (1).

Initiatives can take as little as three months to complete or as long as two years. Staff members work on multiple initiatives simultaneously. However, savings do not fully accrue in the year when an initiative is completed. The initiative may end nine months into a fiscal year leaving only three months to achieve any savings. If the initiative awards business to new suppliers, there will also be a time lag for the end-user community to accept and begin using the new supplier. To accommodate this reality, some assumptions are made: (1) initiatives take one year on average, and both begin and end in the year assigned; and (2) completed initiatives do not achieve 100% of savings in the first year; instead, savings increase over four years. In particular, we assume that 25% of savings potential is achieved in year 1, 50% in year 2, 75% in year 3, and 100% in year 4 and thereafter.

Under UC's existing process, material managers from all business units meet to determine the sequence of commodities to convert into initiatives following the 8-step process of Fig. 1. The selection process is based first on the expiration of current agreements and continuing with essential services. Commodities with high spend and/or high visibility are selected next. Beyond this, local interests prevail. While straightforward, the current process keeps priorities fixed and fails to consider resource demands. Urgency is based on perceptions and politics during the annual review. UC's current process does not provide the opportunity to consider other scenarios, such as the impact of available resources on the number of initiatives that can feasibly be undertaken in a given year.

Other universities fare differently but none studied have developed a better approach. The University of Washington and the University of Texas have less-developed strategic sourcing programs and have not done system-wide spend analyses, nor do they have the infrastructure to generate these data (Christensen and Watkins, 2009; Gross, 2009). Their efforts are based primarily with one lead campus with other units lending *ad hoc* support. The University of Michigan is similarly situated but has the benefit of an experienced strategic sourcing person who once ran the main storehouse; this wealth of experience in a key, influential position reduces the need for sophisticated and detailed analysis. The University of Michigan practices savvy vendor management through its use of a punch-out e-commerce system, which allows it to access multiple suppliers' catalogs directly from one application, backed by standard cost review for all purchases. Standard costs are set for a Pareto analysis-based list of part numbers, and the lower of standard cost and vendor's punch-out price is automatically entered into orders. Their approach avoids the cost and effort to review a hosted, static catalog listing hundreds of thousands of part numbers from which less than 10,000 will actually be purchased in any year. However, in terms of systematically selecting commodities to address, none of the three universities has developed a program.

IV. MODEL FORMULATION

While it is a large institution, UC has finite resources and cannot pursue sourcing initiatives for all 39 commodities at once: an annual maximum load exists. On the advice of the consultant and approval from a consensus of material managers, UC used a five-year rolling horizon for planning with the expectation that commodities not completed in the first five years would roll into the next five years. After the first two years, the materials managers met to review progress and, although headway had been made, not all commodities were completed as originally scheduled and some priorities had changed. New commodities, such as General Lab Supplies, had to be added to the list, highlighting the need for a more objective process. We wanted to develop an objective method of choosing commodities to work on each year based not solely upon total annual spend. Our approach incorporates constraints to deal with resources limitations, the difficulty posed by each commodity, and the urgency to complete an initiative. We include constraints on the minimum and maximum number of initiatives to undertake each year. The algebraic formulation of our mathematical model uses the following notation.

Indices:

i = Initiative (commodity) index, $i = 1, 2, \ldots, 39$

j = Program year (PY) index, $j = 1, 2, \ldots, 5$

Data:

d_i = Difficulty of bidding on commodity i (col. N in Table 1)

p_i = Priority of getting an agreement on commodity i (col. O in Table 1)

s_i = Average annual projected savings from undertaking initiative i (col. J in Table 1)

$maxInit_j$ = Maximum allowed number of initiatives to be undertaken in year j

$minInit_j$ = Minimum required number of initiatives to be undertaken in year j

$maxDiff_j$ = Maximum allowed total difficulty of initiatives undertaken in year j

$maxPri_j$ = Maximum allowed total priority of initiatives undertaken in year j

f_{jk} = Fraction of total potential savings from initiatives undertaken in year j earned in year k; Initiatives are assumed to take four years to achieve their full potential savings:

$$f_{jk} = \begin{pmatrix} 0.25 & 0.50 & 0.75 & 1.00 & 1.00 \\ 0 & 0.25 & 0.50 & 0.75 & 1.00 \\ 0 & 0 & 0.25 & 0.50 & 0.75 \\ 0 & 0 & 0 & 0.25 & 0.50 \\ 0 & 0 & 0 & 0 & 0.25 \end{pmatrix}$$

Decision variables:

$$X_{ij} = \begin{cases} 1, \text{ if an initiative for commodity } i \text{ is undertaken in year } j; \\ 0, \text{ otherwise.} \end{cases}$$

The Binary Integer Linear Program (BILP)

Maximize $\quad \Sigma_k \Sigma_j f_{jk} \, TPS_j \quad (1)$

subject to:

$TPS_j = \Sigma_i \, s_i \, X_{ij}$, for $j = 1, 2, \ldots, 5 \quad (2)$

$\Sigma_i \, X_{ij} \geq minInit_j$, for $j = 1, 2, \ldots, 5 \quad (3)$

$\Sigma_i \, X_{ij} \leq maxInit_j$, for $j = 1, 2, \ldots, 5 \quad (4)$

$\Sigma_i \, d_i \, X_{ij} \leq maxDiff_j$, for $j = 1, 2, \ldots, 5 \quad (5)$

$\Sigma_i \, p_i \, X_{ij} \leq maxPri_j$, for $j = 1, 2, \ldots, 5 \quad (6)$

$\Sigma_j \, X_{ij} \leq 1$, for $i = 1, 2, \ldots, 39 \quad (7)$

$X_{ij} \, \varepsilon \, \{0, 1\}$, for $i = 1, 2, \ldots, 39$ and $j = 1, 2, \ldots, 5 \quad (8)$

The objective function (1) maximizes the total potential savings accrued across all five program years. Due to the relatively short planning horizon we ignore the time value of money and do not discount later years' savings. For clarity, (2) defines intermediate variables, TPS_j , as the estimated total potential savings in year j. Constraint sets (3) and (4) keep the total number of initiatives undertaken each year between desired lower and upper bounds. Constraint sets (5) and (6) prevent the total difficulty and total priority, respectively, of the initiatives undertaken every year from exceeding desired upper bounds, while (7) permits each commodity to be undertaken as an initiative in at most one program year. With 195 binary variables (8) and 64 linear constraints, this BILP is small enough that an optimal solution can be found with Microsoft Excel 2010 using the well-known Solver add-in (Fylstra *et al.*, 1998).

V. MODEL RESULTS

The base case version of the model reflects the fact that, prior to this research being undertaken, UC material managers had already selected 13 initiatives for the first year based on political visibility, expiration of existing agreements, and basic operational needs such as addressing hazardous waste disposal. Thus, we set $X_{i1} = 1$ for $i = 1, 2, \ldots, 13$ in the base case, and let the model select among the remaining 26 initiatives to maximize savings over years 2 through 5. Constraint right-hand side values (top half of Table 2) were set so that the sourcing program would engage in five to seven initiatives in each of the last four years to achieve some degree of workload balance; the maximum difficulty and priority values in years 2 to 5 reflect the Strategic Sourcing Group's limited resources while permitting feasible solutions to be found.

Base case output (bottom half of Table 2) recommends all 39 initiatives be undertaken within five years, potentially saving $138.4 million. However, the corresponding schedule is unbalanced, with anywhere from six to thirteen initiatives undertaken each year. Total savings improve when initiatives with high savings potential are scheduled to occur earlier rather than later. Often such initiatives are among the most difficult, *e.g.*, Specialty Lab Supplies (6), and Travel-Agency/On-line Booking (12) because of the IT complexity and the differences in infrastructure between campuses. As seen in column N of Table 1, these commodities both have high difficulty ratings (80 out of a possible maximum of 100), yet they were scheduled together along with 11 other initiatives in the first year. Four years after starting this process, the Specialty Lab Supplies initiative was still in process, while On-line Bookings was finished but suffering from low adoption.

TABLE 2. BASE CASE MODEL INPUT AND OUTPUT (*PY1 INITIATIVES PRE-SELECTED)

	Program Year					
Input Parameters	*PY 1**	*PY 2*	*PY 3*	*PY 4*	*PY 5*	*Total*
minInit	13	5	5	5	5	33
maxInit	13	7	7	7	7	41
maxDiff	444	220	220	220	220	1,324
maxPri	72	38	35	32	29	206
Output						
Commodities Selected	1-13	15, 18, 25, 26, 32, 38, 39	19, 28, 29, 30, 34, 35, 37	20, 21, 23, 24, 27, 33	14, 16, 17, 22, 31, 36	
Total Selected	13	7	7	6	6	39
Total Difficulty	444	218	215	220	201	1,298
Total Priority	72	32	30	32	29	195
Total Savings ($K)	5,665	16,288	28,070	40,590	47,828	138,436

We next consider allowing the model to select commodities starting in the first year instead of waiting until the second year. In this "ideal" scenario, the model selects initiatives in all five years while better balancing the workload and resource limitations. To achieve this, initiatives for either seven or eight of the 39 commodities should be undertaken each year (see Table 3). Here, *maxDiff* is held constant at 290 for all five years, while *maxPri* declines linearly over the planning horizon; high-priority commodities are undertaken sooner rather than later.

Output from the ideal sequencing plan shows that eight initiatives with the highest savings potential are selected to occur in the first year, including four not selected as in the base case: Lab Equipment (15), Food (18), Legal Services (38) and Business Consultants (39). After five years, the expected total savings from this plan are $145 million, an increase of $6.6 million, or 4.8%, over the base case plan. Moreover, the ideal sequencing plan has a much more manageable and balanced workload, undertaking the same number of initiatives each year except for the last.

Comparing Tables 2 and 3 reveals that initiatives for some commodities are pushed back in the ideal case, *e.g.*, Carpet (3), Gases (4), Hazardous Waste (5), Specialty Lab Supplies (6), Color Copiers (9), Car Rentals (11) and Travel-Agency/On-line Booking (12), while four others are brought forward into the first year (Lab Equipment, Food, Legal Services and Business Consultants). Commodities moving up in the ideal sequence have a higher priority, higher savings potential, and/or lower difficulty than those moved back, *e.g.*, Food, with a difficulty rating of 24 and savings potential of $4,853,000, moves ahead to year 1 while Specialty Lab Supplies, with corresponding values of 80 and $1,927,000, respectively, is pushed back to the second year.

TABLE 3. IDEAL CASE MODEL INPUT AND OUTPUT

	Program Year					
Input Parameters	*PY 1*	*PY 2*	*PY 3*	*PY 4*	*PY 5*	Total
minInit	7	7	7	7	7	35
maxInit	8	8	8	8	8	40
maxDiff	290	290	290	290	290	1,450
maxPri	50	45	40	35	30	200
Output						
Commodities Selected	2, 7, 10, 13, 15, 18, 38, 39	1, 6, 8, 19, 25, 26, 29, 34	3, 4, 5, 20, 27, 28, 30, 32	14, 21, 22, 24, 33, 35, 36, 37	9, 11, 12, 16, 17, 23, 31	
Total Selected	8	8	8	8	7	39
Total Difficulty	281	279	285	216	237	1,298
Total Priority	46	44	40	35	30	195
Total Savings ($K)	7,573	17,950	29,673	42,258	47,583	145,038

VI. CONCLUSION

The potential for judicious use of modeling to find savings within such a large institution as the University of California is enormous. UC's *total* annual spend on the 39 non-IT commodities in column C of Table 1 is nearly $815 million, or $4.75 billion over five years. Sequencing strategic sourcing initiatives using output from our base case model could potentially save $138.4 million, or 2.9%, over five years. Furthermore, sequencing according to the ideal model could have potentially saved another $6.6 million for a total of $145 million, reducing the total commodity spend by 3.1%, while spreading the workload more evenly over the five years and initiating higher priority commodities early.

Beyond estimating monetary savings under resource limitations, the model's most important benefit may be that it provides a powerful "what if" analysis tool to consider alternatives periodically and to realign priorities as facts change. We envision selecting and scheduling commodities into initiatives when existing agreements expire, when a shift in commodity spend triggers the need for a competitive award, or when there is dissatisfaction with an incumbent supplier. The materials management community can weigh the urgency, technical difficulty and resource demands needed to operate each initiative prior to the semi-annual gathering. Prior to the meeting, the results could be tallied, with a mock schedule created and then presented at the face-to-face meetings. Since the BILP is flexible and solves quickly, various scenarios could also be tried in real time until a consensus is reached. Such a process would provide a rational approach that does not attempt to undertake 13 initiatives in one year. In practice, it is nearly impossible to maintain or complete even 10 initiatives in one year, particularly if RFPs have to be processed. To this point, strategic sourcing has been a subjective, political process in need of greater objectivity and concern for resource realities, both of which are provided by our proposed modeling solution.

Possible next steps include (1) approaching the material managers to evaluate resource demands and using their consensus values instead of the first author's estimates; (2) incorporating a larger number of commodities, such as new commodities gaining spend prominence and current commodities coming due for renewal; and (3) extending the model framework to accommodate a longer planning horizon. We anticipate that a similar magnitude of savings would be possible were our model adopted in the future, and the more the program were expanded, in either commodities or planning horizon, the greater would be the benefits

VII. REFERENCES

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