**DECISION SCIENCES INSTITUTE**

# Optimizing healthcare strategic sourcing with vendor diversification and sensitivity to physicians' preferences

Parimal Kulkarni
University of Missouri, St. Louis
Email: pskf44@umsl.edu

L. Douglas Smith
University of Missouri, St. Louis
Email: ldsmith@umsl.edu

**ABSTRACT**

This research focuses on the design of a procurement strategy to create optimal grouping of products to leverage contractual opportunities such as tiered pricing, while accommodating physician preference, desired diversity in product sources, and required vendor performance on balanced scorecards. A deterministic optimization model is used to develop this procurement strategy using a healthcare setting. The optimization model reveals the extent to which higher product substitutability and lower supply base diversity may help the healthcare system to reduce total procurement costs. The various parameter combinations may be used in negotiating contracts for better pricing.

KEYWORDS: Healthcare, Analytics Approaches to Supply Chain and Production Operations, Strategic Sourcing

## INTRODUCTION

Supply chain management is the second largest area of expense for healthcare organizations, with high-value medical devices alone creating an estimated $5 billion in annual waste ("Why executives are demanding", 2010). Most healthcare organizations have recognized the importance of healthcare supply-chain management. By reducing costs through effective supply-chain management, institutions can prevent fiscally motivated reductions in medical staff and services. Healthcare IT systems, however, are not geared to facilitate consideration of alternative sourcing strategies and physician preferences complicate strategic sourcing initiatives ("3 Most Common Healthcare Supply Chain Management Challenges", 2010). Physicians' unwillingness to consider alternative devices or supplies that have been demonstrated to be equally effective may increase purchasing costs and pose risks of disruption in the healthcare supply chain. Needed are analytical tools that can help healthcare organizations explore alternative strategies and demonstrate the costs of various procurement constraints. In this paper, we present a deterministic MILP optimization model to meet this need.

The MILP model is used to explore contractual opportunities such as tiered pricing for product groups. The model accommodates physician preference, desired diversity in product sources, and required vendor performance on balanced scorecards. The optimization model reveals the extent to which higher product substitutability and lower supply base diversity may help the healthcare system to reduce total procurement costs. It also helps to identify how various procurement constraints affect supply-chain efficiency and risk.

## RELATED RESEARCH

Quantitative models for strategic sourcing generally address (1) from whom (vendors/suppliers) particular products should be bought, (2) from whom products should be bought and in what quantities, or (3) the aforementioned decisions with consideration of the subsequent risk. Bui et al (2001) contend that negotiations should optimize both buyer and supplier interests by addressing quantitative and qualitative attributes such as product quality, speed, reputation, after sales service, etc. A review of literature regatding quantitative models for contract negotiation indicates that such models generally range from cost based approaches (focused on minimizing and competing on cost) to multi-attribute models that explore attributes beyond pricing competitiveness.

In the early work, there was some discussion of tradeoffs between diversification and favorable pricing, but research focused on total cost as the only criterion in supplier selection. From a risk-management perspective, however, there are other supplier attributes that should be included in the selection processes. A supplier that provides the best price may not provide the necessary flexibility in volume and delivery time in case of an adverse event. Poor historical performance regarding timeliness and quality signal risks of disruption. Further, the attributes that make a vendor attractive in a portfolio (e.g., to diversify risk) may differ from the prime attributes that qualified the vendor to be on the supplier list (Lee and Chien, 2014).

Choudhary and Shankar (2014) presented a goal programming model, in a manufacturing setting, for joint decision making of inventory lot sizing (i.e. order allocation), supplier selection and carrier selection with consideration of transportation costs. They demonstrated trade-offs between service level requirements and total costs incurred. Karsak and Dursun (2015) tested a fuzzy-logic supplier selection model that considered three supplier selection attributes: cost, quality, and delivery. They emphasized the importance of employing a group decision making process when deciding which supplier attributes should be chosen when developing procurement strategies.

In building and applying our MILP model, we integrate many of these ideas and apply then in a healthcare setting. We incorporate information from a balanced scorecard for vendors and information about physician preferences that is revealed in historical purchasing records to explore opportunities to contain purchasing costs while meeting the multidimensional demands of medical practice.

## THE STRATEGIC SOURCING MODEL

Our deterministic optimization model minimizes total spend with consideration of four key decision parameters: vendor market share to assure supply-base diversity, vendor performance scores on several dimensions, rigidity in physician preference (as indicated by product non-substitutability), and parameters for quantity discounts.

### Data

Supporting data were collected from eight facilities in a large healthcare system with academic and community hospitals. The hospital system has a central supply-chain department that negotiates contracts for medical devices and supplies through the central Sourcing team. In this paper, we concentrate on products in the Cardiac Rhythm Management category. This category includes expensive items such as cardiac pacemakers, defibrillators, lead wires etc. There are nine product categories, four vendors, and 218 unique products. Table 1 shows the product categories under consideration and the number of SKUs in each category.

| TABLE 1 : PROUCT CATEGORIES *(These are categories as defined by the hospital)* | |
|---|---|
| CATEGORY | NUMBER OF INDIVIDUAL SKUS |
| Cardiac resynchronization therapy pacemaker | 11 |
| Cardiac pacing leads or electrodes (PM) | 47 |
| Cardiac pacing leads or electrodes (LV) | 28 |
| Cardiac pacing leads or electrodes (HV) | 35 |
| Cardiac resynchronization therapy defibrillator | 23 |
| Implantable Cardioverter Defibrillator Dual Chamber | 21 |
| Implantable Cardioverter Defibrillator Single Chamber | 22 |
| Pacemaker-Dual | 19 |
| Pacemaker-Single | 13 |

An annual vendor scorecard is used to collect vendor scores on five dimensions. These scores are defined at the SKU level. The average scores at the category level are used in the model. The scorecard metrics under consideration are quality, service, delivery, innovation, and operational excellence. The vendors are rated on each of these criteria by the managers and directors of the respective areas. For example, the innovation scores are assigned to the vendor by the sourcing manager and director while the delivery scores are assigned by the logistics and distribution manager and director.

Potential magnitudes of quantity discounts and the purchase quantities to qualify for them were estimated levels from past purchases of similar products and product categories. Table 2 shows a portion of the scorecard for vendor 1 for all nine product categories.

| TABLE 2 : SAMPLE VENDOR SCORECARD *(Maximum score possible on any metric is 5)* | | | | | |
|---|---|---|---|---|---|
| Category | Avg. quality score | Avg. service score | Avg. innovation score | Avg. delivery score | Avg. operational excellence score |
| Cardiac Resynchronization Therapy Defibrillator | 2.00 | 4.00 | 1.00 | 3.00 | 2.00 |
| Cardiac Resynchronization Therapy Pacemaker | 2.80 | 3.60 | 3.00 | 3.00 | 2.00 |
| Implantable Cardioverter Defibrillator | 1.50 | 4.75 | 3.00 | 3.00 | 2.00 |
| Implantable Cardioverter Defibrillator | 2.57 | 3.86 | 3.00 | 3.00 | 2.00 |
| Leads High Voltage | 2.40 | 3.80 | 3.00 | 3.00 | 2.00 |
| Leads Low Voltage | 2.80 | 3.80 | 3.00 | 3.00 | 2.00 |
| Leads pacemaker | 2.60 | 3.80 | 3.00 | 3.00 | 2.00 |
| Cardiac Resynchronization Therapy Defibrillator | 1.75 | 4.25 | 2.00 | 3.00 | 2.00 |
| Cardiac Resynchronization Therapy Pacemaker | 2.00 | 4.00 | 2.00 | 3.00 | 2.00 |

**Model assumptions**

Every product is a unique SKU and is associated with a particular product category. Rebates are applied as a percentage of total dollars spent in a category but qualification for rebates are determined by the number of items purchased in a category. Vendor scorecards may conceivably be assigned to each product but we recognize that they are more likely to be assigned to a vendor's offerings in a category (i.e. all products on a category for an individual vendor will generally receive the same score on a particular dimension). Physician preference is indicated by assigning a certain percentage of demand as being non-substitutable.

**Optimization Model Formulation**

Sets

P: Set of individual product SKUs
C: Set of product categories
V: Set of vendors
CV(v): Set of product categories offered by vendor v
VC(c): Set of vendors offering products in category c
PCV(c,v): Set of products offered in category c by vendor v

Parameters

$demc_c$: Expected demand of category c (in units over the planning horizon)
$demp_p c_c v_v$ : Expected demand of product p in category c from vendor v (in units over the planning horizon)
$befdiscp_p c_c v_v$: Unit price of product p from vendor v before quantity discount is applied
$aftdiscp_p c_c v_v$: Discounted price of product p from vendor v according to contract after total qualifying dollar volume has been achieved
$bulkvolc_c v_v$: Total unit volume of purchases in category c required to qualify for bulk buy discount from vendor v
M: Large number used to relax constraints
$qualscop_p c_c v_v$ : Quality score of vendor v for a product p within category c
$maxqualscoc_c v_v$ : Highest possible quality score granted for items in category c
$lbqualc_c$: Lower bound on index representing achievement of quality goal for products used in category c
$servscop_p c_c v_v$ : Service score of vendor v for a product p within category c
$maxservscoc_c v_v$: Highest possible service score granted for items in category c
$lbservc_c$: Lower bound on index representing achievement of service goal for products used in category c
$innoscop_p c_c v_v$: Innovation score of vendor v for a product p within category c
$maxinnoscoc_c v_v$: Highest possible innovation score granted for items in category c
$lbinnoc_c$: Lower bound on index representing achievement of innovation goal for products used in category c
$delscop_p c_c v_v$ : Delivery score of vendor v for a product p within category c
$maxdelscoc_c v_v$: Highest possible delivery score granted for items in category c
$lbdelc_c$: Lower bound on index representing achievement of delivery goal for products used in category c

$opexscop_p c_c v_v$ : Operational excellence score of vendor v for a product p within category c
$maxopexscoc_c v_v$: Highest possible operational excellence score granted for items in category c
$lbopexc_c$: Lower bound on index representing achievement of operational excellence goal for products used in category c
$rebatec_c v_v$ : Magnitude of rebate earned for products in category c from vendor v

Decision Variables
$qp_p c_c v_v$: Quantity of product p from category c to be purchased from vendor v
$selvenc_c v_v$: Binary variable indicating whether vendor v is selected to provide products in category c
$qtdisc_c v_v$: Binary variable indicating whether purchases from vendor v in category c are sufficient to qualify for a quantity discount on purchases in that product category

Objective Function
Minimize total spend defined as the total purchase amount less the rebate

$$\sum_{v\in V\{v\}}(\sum_{c\in CV\{v\}}\sum_{p\in PCV\{c,v\}}\left(qp_p c_c v_v * befdiscp_p c_c v_v\right) - (\sum_{c\in CV\{v\}} rebatec_c v_v)) \quad (1)$$

Subject to the following constraints

The rebate (in dollars) can only be achieved if the purchase quantity meets the stipulated bulk buy volume for quantity discounts.

$rebatec_c v_v \leq$ M* $qtdisc_c v_v$ ∀c $\forall v$ where M is a large number (2)

Equation (3) sets a binary rebate qualifying variable to be less than or equal to the total purchased amount from the vendor (or vendor category) divided by the minimum product volume required to qualify for rebate

$qtdisc_c v_v \leq \sum_{p\in PCV\{c,v\}}(qp_p c_c v_v)\ /bulkvolc_c v_v \forall v$ , CV{v} (3)

Total potential rebate is the magnitude of the difference between before discount price and after discount price times the purchase quantity. The RHS of Equation (4) indicates the upper bound on the dollar magnitude of rebate.

$rebatec_c v_v \leq \sum_{p\in PCV\{c,v\}}(befdiscp_p c_c v_v - aftdiscp_p c_c v_v) * qp_p c_c v_v\ \forall v$ ∀c (4)

Equations (5) – (9) impose the scorecard requirements on the vendors.

**Quality metric constraint**

The weighted average product-quality score on products ordered across all categories from a vendor must exceed the lowest acceptable value.

$\sum_{c\in CV\{c\}}\sum_{p\in PCV\{c,v\}}(qualscop_p c_c v_v * qp_p c_c v_v)$ / $(\sum_{c\in CV\{c\}}\sum_{p\in PCV\{c,v\}}(qp_p c_c v_v))$ ≥ (5)

( $maxqualscoc_c v_v$ * $lbqualc_c$) for each vendor.

**Service metric constraint**

The weighted average service score on products ordered across all categories for a vendor must exceed the lowest acceptable value.

$$\sum_{c \in CV\{c\}} \sum_{p \in PCV\{c,v\}} ( servscop_p c_c v_v * qp_p c_c v_v ) / ( \sum_{c \in CV\{c\}} \sum_{p \in PCV\{c,v\}} (qp_p c_c v_v)) \geq \quad (6)$$

$(maxservscoc_c v_v * lbservc_c)$ for each vendor.

**Innovation metric constraint**

The weighted average innovation score on products ordered across all categories for a vendor must exceed the lowest acceptable value.

$$\sum_{c \in CV\{c\}} \sum_{p \in PCV\{c,v\}} ( innoscop_p c_c v_v * qp_p c_c v_v ) \quad / \quad ( \sum_{c \in CV\{c\}} \sum_{p \in PCV\{c,v\}} (qp_p c_c v_v)) \geq \quad (7)$$

$(maxinnoscoc_c v_v * lbinnoc_c)$ for each vendor.

**Delivery metric constraint**

The weighted average score for delivery reliability on all product categories for a vendor must exceed the lowest acceptable value.

$$\sum_{c \in CV\{c\}} \sum_{p \in PCV\{c,v\}} ( delscop_p c_c v_v * qp_p c_c v_v ) \quad / \quad ( \sum_{c \in CV\{c\}} \sum_{p \in PCV\{c,v\}} (qp_p c_c v_v)) \geq \quad (8)$$

$(maxdelscoc_c v_v * lbdelc_c)$ for each vendor.

**Operational Excellence metric constraint**

The weighted average score for operational excellence on all product categories for a vendor must exceed the lowest acceptable value.

$$\sum_{c \in CV\{c\}} \sum_{p \in PCV\{c,v\}} ( opexscop_p c_c v_v * qp_p c_c v_v ) \quad / \quad ( \sum_{c \in CV\{c\}} \sum_{p \in PCV\{c,v\}} (qp_p c_c v_v)) \geq$$

$(maxopexscoc_c v_v * lbopexc_c)$ for each vendor. (9)

**Non Substitutable demand constraint:** Constraint to indicate physician preference, represented by a substitutability parameter indicating the proportion of substitutable products in a category.

$qp_p c_c v_v \geq demp_p c_c v_v$ * (1-%substitutability/100) for each p, c, v (10)

**Demand Constraint**: Total products purchased from all vendors should be greater than or equal to the demand for a category

$$\sum_{v \in VC\{c\}} \sum_{p \in PCV\{c,v\}} \left(qp_p c_c v_v\right) \geq demc_c \quad \text{for each c} \quad (11)$$

**Market share constraint:** Indicates constraint on a vendor's market share (in dollars) for a product category. This constraint ensures that one vendor does not get all the purchase quantity allocated to them every quarter. Total products purchased from vendor v for category c has to be less than or equal to allowed market share times total products purchased in all categories for all vendors.

$$\sum_{p\in P\{p\}}(qp_p c_c v_v * \ befdiscp_p c_c v_v) \leq \ \text{\%marketshare*} \sum_{p\in P}\sum_{v\in V}(qp_p c_c v_v * befdiscp_p c_c v_v) \text{ for each v and c} \tag{12}$$

**Model output**

The optimization model is run using various combinations of the four key decision parameters listed below

i. Minimum number of vendors required for supply diversity (defined by market share)
ii. Minimum vendor scores required for each performance scorecard dimension
iii. Rate of product substitutability (which depends on flexibility of physicians to accept alternative devices or accessories in the same category)
iv. Bulk buy parameters for quantity discounts

The actual product costs and total supply spend have been masked to protect the hospital's financial data. Instead, the "cost index" indicates the relative product price offered by a vendor in comparison to other vendor prices in the same product category. Thus a higher cost index indicates a more expensive product. Figure 1 and 2 show sample model outputs for procurement recommendations by category and vendor respectively. The output also shows the "Historic Usage" indicating the historic purchases from the vendor and "Usage" indicating the model's recommendation of purchase quantities allocated to the vendor. Similarly, "Historic Dollar Share" and "Dollar" share indicate the percentage of past dollars spend on a vendor's product and the current dollar spend on a vendor's products, respectively.

Figure 1 shows recommendations for product category 1. The model recommends reducing vendor 4 market share (with the highest cost index) and moving the procurement volume to other vendors like vendor 2 (with a lower cost index). It is also important to note that cost is not the only decisive factor and hence not all market share would move to vendor 1, who has the lowest product cost. This highlights that the model is taking into consideration the interaction of product price and vendor performance metrics when allocation purchase quantities.

Figure 1 : Sample category report

*Category Vendor report comparing optimization output to input*
*with 20 pct substitutability allowed, 30 pct max market share allowed*
*scorecard minimum indices qual = 30, service= 30,innovation= 30,delivery= 30,oper exc= 30*

| Category | Vendor | Cost Index | Historic Usage | Usage | Hist Unit Share | Unit Share | Hist Dollar Share | Dollar Share |
|---|---|---|---|---|---|---|---|---|
| 1 | 1 | 0.07940 | 15 | 23 | 11.4 | 11.8 | 9.5 | 10.0 |
| | 2 | 0.09277 | 23 | 58 | 17.4 | 30.2 | 16.6 | 30.0 |
| | 3 | 0.09316 | 27 | 58 | 20.5 | 30.1 | 20.1 | 30.0 |
| | 4 | 0.10057 | 67 | 54 | 50.8 | 27.9 | 53.8 | 30.0 |
| 1 | | | 132 | 192 | 100.0 | 100.0 | 100.0 | 100.0 |

| Category | Vendor | Cost Index | Historic Usage | Usage | Hist Unit Share | Unit Share | Hist Dollar Share | Dollar Share |
|---|---|---|---|---|---|---|---|---|
| 2 | 1 | 0.01699 | 112 | 1,055 | 6.2 | 33.7 | 5.2 | 29.9 |
| | 2 | 0.01940 | 443 | 927 | 24.4 | 29.6 | 23.3 | 30.0 |
| | 3 | 0.02092 | 897 | 860 | 49.4 | 27.5 | 50.9 | 30.0 |
| | 4 | 0.02086 | 363 | 290 | 20.0 | 9.3 | 20.5 | 10.1 |
| 2 | | | 1,815 | 3,133 | 100.0 | 100.0 | 100.0 | 100.0 |

Figure 2: Sample vendor report

*Vendor report comparing optimization output to input*
*with 20 pct substitutability allowed, 30 pct max market share allowed*
*scorecard minimum indices qual = 30, service= 30,innovation= 30,delivery= 30,oper exc= 30*

| Vendor | Category | Cost Index | Historic Usage | Usage | Hist Unit Share | Unit Share | Hist Dollar Share | Dollar Share |
|---|---|---|---|---|---|---|---|---|
| 3 | 1 | 0.020430 | 27 | 58 | 1.2 | 2.8 | 1.5 | 3.9 |
| | 2 | 0.001430 | 897 | 860 | 38.2 | 41.8 | 3.5 | 4.0 |
| | 3 | 0.007084 | 166 | 133 | 7.1 | 6.5 | 3.2 | 3.1 |
| | 4 | 0.010762 | 208 | 166 | 8.9 | 8.1 | 6.0 | 5.9 |
| | 5 | 0.059863 | 244 | 195 | 10.4 | 9.5 | 39.4 | 38.2 |
| | 6 | 0.044740 | 137 | 110 | 5.8 | 5.3 | 16.5 | 16.0 |
| | 7 | 0.040014 | 80 | 64 | 3.4 | 3.1 | 8.6 | 8.4 |
| | 8 | 0.013779 | 526 | 421 | 22.4 | 20.5 | 19.6 | 19.0 |
| | 9 | 0.009903 | 61 | 49 | 2.6 | 2.4 | 1.6 | 1.6 |
| 3 | | | 2,346 | 2,056 | 100.0 | 100.0 | 100.0 | 100.0 |

## Results and Discussion

We find that the optimization model solutions are highly sensitive to the four key parameters. “Savings percentage” is used as a parameter to assess the various combinations of market share and product substitutability. Savings percentage is defined as difference in previous year spend compared to post rebate spend from optimization model. As illustrated, higher vendor diversity leads to decreased savings. This is expected, of course, since the allocation of purchase quantities across multiple vendors leads to fewer opportunities to purchase the least-costly item and to reach quantities for bulk discount prices from individual vendors. This however helps mitigate the risks associated with single sourcing. Figure 3 shows the spread of savings percentage across various vendor market shares. The base case is considered where a vendor's allowable market share is a 100% with no product substitutability allowed. Compared to the base case, the highest savings are realized when a vendor's allowable market share is 75%.

Figure 3: Cost Savings Depending on Vendor Market Share

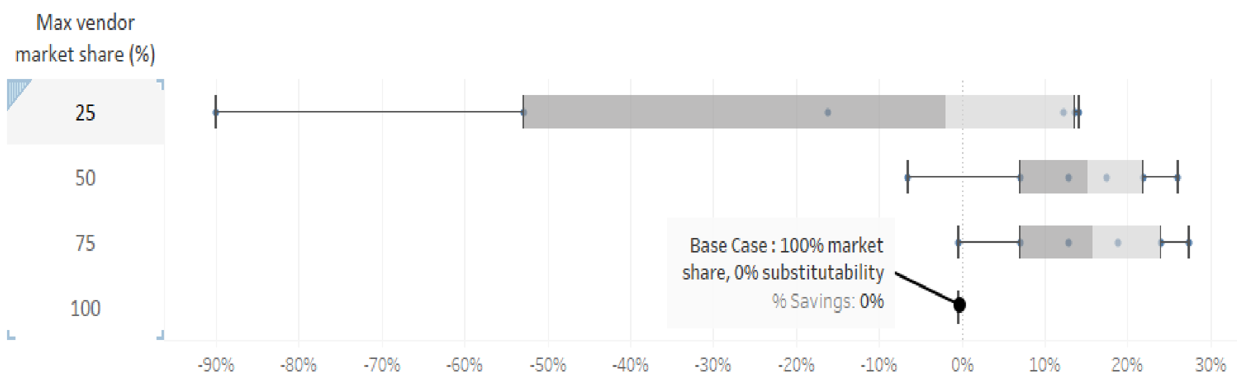
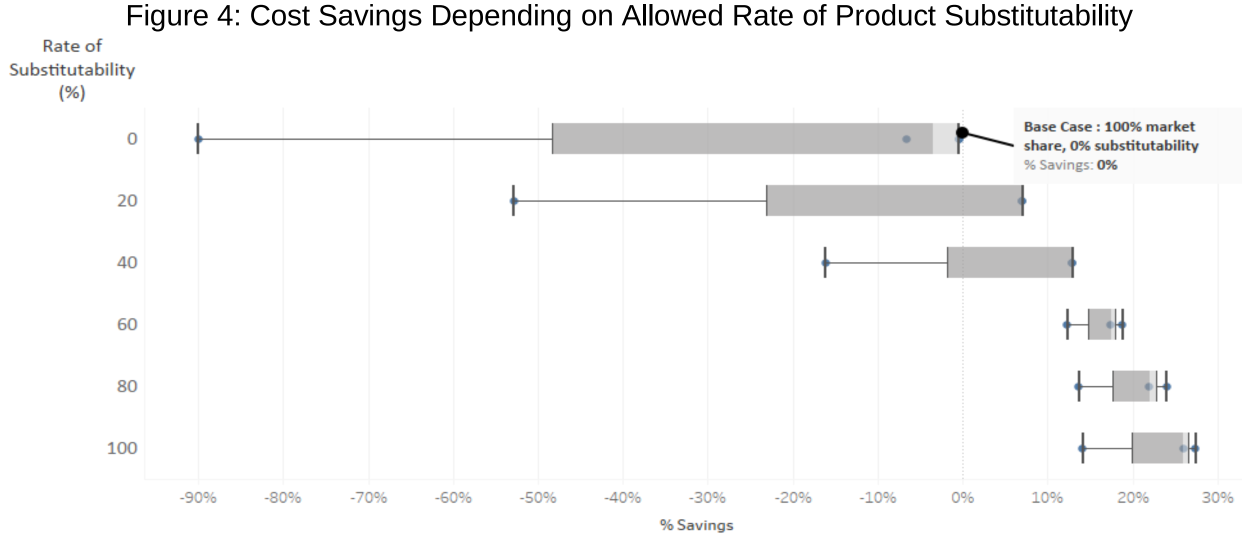



Figure 4 shows the spread of savings percentage across various rates of substitutability. The base case is considered where a vendor's allowable market share is a 100% with no product substitutability allowed. Compared to the base case, the highest savings are realized when complete product substitutability is allowed. This represents a scenario where all demand can be satisfied using comparable (less expensive product) possible sourced from a single vendor, thus allowing for savings on individual purchases and better quantity discounts.

Figure 4: Cost Savings Depending on Allowed Rate of Product Substitutability



## Conclusion

This research highlights the opportunities to leverage analytical techniques for healthcare contract negotiations and procurement planning. It considers diversification to contain supply-chain risk and market power of individual vendors. It reveals how greater flexibility in physician preferences for particular devices and supplies can produce substantial savings. We also see how applying subjective scorecards with rigid standards can have an enormous impact on purchasing costs. For vendors not meeting the minimum score requirements, supplier development programs can be designed to work with vendors willing to invest the time and effort in improving their respective scores. Our model is intended to stimulate data-driven consideration of important constraints on strategic sourcing. It provides objective decision support to "right-size" the supplier base. In continuing research, we are investigating the effects of further constraints on product substitutions, such as limitations on specific substitutions of one vendor's products for another in a product category.

## References (Bibliography)

Bui, T., Yen, J., Hu, J., & Sankaran, S. (2001). A multi-attribute negotiation support system with market signaling for electronic markets. *Group Decision and Negotiation*, *10*(6), 515-537.

Choudhary, D., & Shankar, R. (2014). A goal programming model for joint decision making of inventory lot-size, supplier selection and carrier selection. *Computers & Industrial Engineering*, 71, 1-9.

Karsak, E. E., & Dursun, M. (2015). An integrated fuzzy MCDM approach for supplier evaluation and selection. *Computers & Industrial Engineering*, *82*, 82-93.

Lee, C. Y., & Chien, C. F. (2014). Stochastic programming for vendor portfolio selection and order allocation under delivery uncertainty. *OR spectrum*, *36*(3), 761-797.

Revcycleintelligence. (2016, February 05). Why Executives are Demanding Supply Chain Management Value. Retrieved May 11, 2017, from http://revcycleintelligence.com/news/why-executives-are-demanding-supply-chain-management-value

Revcycleintelligence. (2017, January 04). 3 Most Common Healthcare Supply Chain Management Challenges. Retrieved May 11, 2017, from http://revcycleintelligence.com/news/3-most-common-healthcare-supply-chain-management-challenges