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Essays in Physicians Preference Items and Inventory Management within the Healthcare Supply Chain

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Essays in Physicians Preference Items and Inventory Management within the Healthcare Supply Chain

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Abstract

This work is composed of a number of topics in the healthcare area, which are approached separately with appropriate methodologies. The two topics deal with physician preference items via two different approaches. The first one investigates stock keeping unit (SKU) proliferation in healthcare organizations due to physician preference items (PPI). It captures perspectives of physicians and supply chain professionals about this problem through two surveys. The second topic builds a decision-making framework for the PPI selection process that can be used by healthcare organizations to make more objective decisions. A Multi-criteria decision making technique is implemented to illustrate the framework.

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Dedication

This work is dedicated to my family, especially …

To my mother, Khawlah Shbool, and father, Ahmad Shbool, for their support, encouragement, and unconditional love which made me become the man I am today and without which none of this would have been possible.

To my wife, Fatima Khazaleh, for her love, patience and support all of which make me a good father, stronger person, and successfully achieve my PhD.

To my son, Adam, and daughter, Jouri, for their beautiful and exceptional existence in my life,

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M.A.S

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1 Chapter 1: Introduction and Overview

A study done by (Shbool, et al. 2013) on the gap between healthcare and retail supply chains showed that the retail sector is more efficient. The focus on improving supply chain, inventory control, logistics, and material handling processes in other sectors, and the extensive technological evolution in healthcare makes the healthcare sector lagging in logistics innovation and in need for enhancements from a management perspective.

The problems chosen for investigation in this work are inspired by similar topics in other sectors and by the need of healthcare stakeholders to address such issues. The two topics investigate the management of physician preference items (PPI) from two perspectives, physicians and supply chain professionals, and the selection decision process as a multi-criteria decision making process within healthcare organizations. This chapter provides a brief review of topics including: motivation of choosing each problem, contributions, and finally the organization of this document.

Motivated by the stock keeping unit (SKU) proliferation problem found in the retail sector, the first topic is an investigation of how healthcare providers manage physician preference items (PPIs). Physician preference items are costly medical/surgical items, such as hip and knee implants, cardiac stents, mechanical devices etc., that are selected/preferred by the physician to use for a specific patient and procedure. PPIs are selected by the physician and thus present management challenges for the supply system of a healthcare provider. The increasing number of items used for the same purpose in a healthcare organization will increase the cost and lower efficiency of the supply chain. One reason for that is the need to order lower quantities for more items which means more time to deal with orders, higher cost, and added difficulty to manage items within the system. There is a lack of literature found on this topic, and no rigorous

modeling or methodology to deal with the problem can be found. Most of the work done is opinions of professionals and experiences of people involved in case studies/projects to investigate potential solutions.

The problem of PPI is investigated in this research from a management perspective. Survey is the method used, with two surveys developed for both physicians and healthcare supply chain professionals. The survey helps in developing an understanding of and measuring some of the factors needed to describe the PPI problem. In addition, it may provide a framework for describing approaches for addressing the issue in the healthcare sector. Being a health related problem implies two major issues, first the ethics and sensitivity of collected data, and second the difficulty of obtaining the data. Confidentiality was guaranteed through following University of Arkansas (UARK) procedure for conducting surveys, the Institutional Review Board (IRB) with approval number (IRB# 14-04-706 MOD 1406). The IRB approval is included in Appendix B.1: IRB Approval, and the signed protocols can be found in Appendix B.2: Survey Protocol. Researchers faced difficulty in gaining participants to contribute by filling out the survey. Appropriate statistical tests for the small sample size were used in analyzing the results.

Since the PPI selection process involves multi-stakeholders and is based on multiple factors, it can be seen as a multi-criteria decision making (MCDM) process. The second investigation builds a decision making framework that can be followed by healthcare organizations to make better decisions. MCDM techniques have different capability with different features and characteristics. The use of a technique over another depends on the problems elements, and the result may not be an optimal choice, rather it improves the quality of the decision taken. A comprehensive review of different techniques and their features is necessary to choose the most appropriate one. The challenge is not in choosing the technique, but in the implementation

process. In other words, choosing criteria, combining them into a single key performance indicator, weighting factors, and consolidating stakeholders' input are all challenges in this work.

A MCDM technique is used on a case study and implemented to evaluate applicability in the healthcare area. Forms and templates are developed to survey feedback from stakeholders on the effectiveness of the decision process framework. The framework has been tested in a case study along with the evaluation process of professionals' thoughts about the process resulting in the main contribution.

The work in the dissertation is composed of a set of articles. The first paper concerns (physician preference items – management perspectives) and is found in chapter two. The chapter starts with an introduction that acquaints the reader with the motivation and background about the subject. Then, a literature review of work done and professionals' opinions is summarized. The next section articulates the purpose of the survey, the survey construction process, and the dissemination/distribution procedures. Another section summarizes the results after conducting the survey and the main insights. The same outline is followed in the second article (Physician preference items – A Decision Making Framework) which is found in Chapter 3. Definitions of terms used in this research can be found in Appendix A: Terms' Definitions.

2 Chapter 2: Characterizing Physician and Supply Chain Perspectives for Managing Physician Preference Items

Abstract

The purpose of this work is to better understand the role that physician preference items (PPIs) play within the healthcare supply chain. Physician preference items are costly medical/surgical items, such as hip and knee implants, cardiac stents, mechanical devices, etc., that are selected/preferred by the physician to use for a specific patient and procedure. PPIs make up to 61% of total supply expenditure (Schneller and Smeltzer 2006), which (supplies) accounts for about 30% of total spend in a typical hospital (Tyson 2010). PPIs cause stock keeping unit (SKU) proliferation due to the variety of items used for the same purpose. There is a lack of literature found on this topic, and no rigorous modeling or methodology to deal with the problem was found. The problem of PPI is investigated in this research from a management perspective using survey methods. The purpose of the surveys is to gather information about the management process from two points of view: from the physicians and from the materials managers. The results of the survey help to document the critical issues in managing physician preference items, as well as recommendations based on results.

2.1 Introduction

Dramatic changes in the healthcare industry are going to take place within the next 5-10 years (Dudas and Widhalm 2012). Hospitals will need to significantly reduce operational costs due to the effect on the reimbursement process caused by economic reform. In a typical hospital, the largest expense is incurred by labor (Schoen, et al. 2010) while the supplies represent the second largest expense (Moon 2004). “Supplies can account for about 30 percent of hospital’s total spend and represent a hospital's second-highest cost” (Tyson 2010) and (Jebson and Sweat 2010). It is not an easy or straightforward task to reduce labor in a service organization;

consequently, this will likely increase the pressure on reducing expenses due to supplies. One of the most recent and active practical problems in inventory management is stock-keeping-unit (SKU) proliferation. Better management of this process has the potential to introduce savings in the supply chain system.

SKU proliferation occurs when there is more than one brand in the inventory for the same product, or in other words many brands with equivalent functionality. The problem of SKU proliferation has been a growing issue for decision makers of the supply chain in healthcare as well as other sectors of industry. Brand competition, in addition to consumer preference factors can lead to an increase in the number of SKUs stocked by a company, which can be harmful if not managed properly. Healthcare is the target field of this research; hence the elements of the system are analyzed according to the appropriate characterization of problem parameters. However, it is likely that the methodology can be translated to other sectors of industry to address the same problem. Unfortunately, the literature found on this problem is very scant. A very limited amount of work has been done on this problem. This adds difficulty when developing a research framework for this problem due to the fact that there is a lack of underlying models.

In the healthcare sector, a major cause of SKU proliferation is the physician's preferences factor. The focus of this research is on investigating how healthcare providers manage physician preference items (PPIs) from a supply chain performance perspective. PPIs are costly medical/surgical items, such as hip and knee implants, cardiac stents, mechanical devices…etc., that are selected/preferred by the physician to use for a specific patient and procedure. Due to preference in selecting PPIs, these items are not standardized. Standardized items are those which organizations have on stock or purchase when necessary and are used by the entire

organization. They can be modeled with traditional inventory policies since ordering quantities and time can be decided from the forecasting models and demand patterns; obviously we wish to have all items standardized. Some examples of these items are: injections, gloves, stethoscopes … etc., dealing with these items is not the interest of this research.

On the other hand, PPIs are difficult to manage and cannot be easily modeled as in the standard items with conventional theory; because the demand is affected by another factor which is physicians' preference. Physician preference is the major obstacle standing in the way of standardizing these items, that is a healthcare organization can standardize stock and choose low cost, efficient items, if physician's preference is ignored. However, failure to satisfy physicians' preferences implies the threat of physicians leaving the organization, or unsatisfied physicians who may become unmotivated. Some examples of PPIs are heart valves, orthopedic and cardiovascular implants.

PPIs exist in a variety of treatment areas: neurosurgery, urology, vascular, oncology, plastic surgery, ophthalmology, and most widely in orthopedics and cardiovascular. Within each area of treatment, they are classified into more specialized categories according to their purpose of use, and for each purpose there are many items (brands) for the same item type which are functionally equivalent but have different features, or in other words are produced by different manufacturers. For instance, orthopedic implants can be classified into many categories according to use such as: Austin-Moore prosthesis (for fracture of the neck of femur), Baksi's prosthesis (for elbow replacement) … etc. (List of orthopedic implants 2014). Within each category, there are many items available in the market from different manufacturers. In addition to being expensive, orthopedics and cardiovascular implants showed big jumps in prices (Jebson and Sweat 2010), therefore they dominate other categories and are a major concern.

In hospitals, more than 40% of expenses are attributed to supply chain activities in North America (Nachtmann and Pohl 2009), same result was also found by (Chow and Heaver 1994). Within supply chain costs, (DeJohn 2005) stated that a great deal of savings in hospitals is held in PPIs, which are supplies and expensive disposable items used in procedures. PPIs are selected by the physician and thus present management challenges for the supply system of a healthcare provider. The physician's preferences cause the organization to hold more than one brand for the same item, and as a result, the total supply chain cost increases and efficiency decreases (in terms of labor utilization, space utilization, and fill rate). Why do physicians prefer different brands? Understanding the causes and factors affecting the preference may help in constructing directions to some potential solutions. The purpose is to characterize the problem, and propose a framework which the organization can follow to address areas that can be attributed to minimizing the PPIs and consequently increasing the efficiency of the supply chain.

The remaining sections of this paper are structured as follows; first a literature review presents the work done on PPI and opinions about the topic. Then, an overview of how organizations deal with PPI issues is discussed. Then the methodology used in this research is discussed. The research objectives are stated and then the results are presented.

2.2 Literature Review

The PPI issue is a recent problem; hence the amount of work done on this problem is almost negligible. The following literature spans work done into two parts. The first describes literature from industry regarding the SKU proliferation problem caused by PPI. The second part describes example literature that has addressed parts of the problem and which may be used to better understand how the healthcare industry has addressed the problem.

Mentioning the problem from the practitioners' point of view can give a very good insight about the elements of the problem and factors included in the items' selection process from practical perspective. In (Siddel 2012), the rising cost of PPI is stated as one of the reasons for losses in hospitals. This provides evidence that the PPI issue is causing a problem for healthcare organizations. According to (Jebson and Sweat 2010) three factors mainly cause PPIs. The first factor is the continual pressure to use the newest technology from implant vendors. The second factor is the approach of one treatment for one disease that some medical doctors MDs are using. This is mainly because they may not be willing to expand the effort of learning a new technology, or they are comfortable with their current treatment. Finally, MDs usually do not necessarily consider financial matters in hospitals and/or they are not involved in this kind of analysis. Consequently, they may not realize the impacts of helping a hospital with cutting its costs.

Also (Jebson and Sweat 2010) mentioned some factors that make physicians use a specific item (brand). The first factor is how convenient a physician is with utilizing specific instruments and implants during residency training, in other words the physician's preference is developed during the early stages of their career. Another factor is the incentives a physician receives due to using a specific implant type. Third, a physician who is a member in the design or trials team tends to adopt that item. Within industry, it is common for physicians to work directly with companies, testing new items, and then to eventually adopt the item. The fourth factor is the vendor-physician relationship: physicians tend to order items from vendors based on a good relationship. Finally, physicians say that representatives add clinical educational value and expertise to routine and complex cases. In a survey of 200 orthopedic physicians, 96% indicated that the representative is essential for learning about the new item. 93% prefer to have the

representative inside the room during the surgery. Finally, 96% said the selection will be based on the better representative.

Healthcare organizations aim to reduce spending on PPIs and work to pull the leverage from the vendor side to their side. With that being said, the review indicates that vendors have the advantage through their physician relationships. Consequently, significant savings in cost is not feasible without cooperation from physicians.

Due to lack of technical knowledge about items by supply chain and materials management, hospitals are pushed to make purchasing decisions with little information about quality and cost. To better control this spend, two suggested practices by (Jebson and Sweat 2010) may help in reducing PPIs. The first practice is to prevent or minimize purchasing implants and expensive supplies from vendors by physicians directly. That is MDs commonly purchase implants directly from vendors and then charge the hospital. Second, to quantify the degree of PPIs effect on organization, a report that includes type of case, surgery dates, physician name, item name, quantity and list price may be shared with physicians to focus on most cost contributors. They also mentioned some implant management methods namely: consignment, demand matching, standardization, group purchasing, price ceiling, and pricing matrix.

Factors considered by physicians when selecting PPIs are mostly cost unrelated according to (Montgomery and Schneller 2007) such as, experience with a specific product, their judgment of what is best for particular patient, and their relationship with the representative of the manufacturer. In a survey carried out by Premier (Siddel 2012), they found that the top three factors influencing PPI purchasing decisions are clinical outcomes, cost, and physician's past experience with suppliers or device manufacturers.

Another survey to see if value analysis is effective or not showed that 79% of the respondents were positive about it. Value analysis (VA) is the "examination of each procurement item to ascertain its total cost of acquisition, maintenance, and usage over its useful life and, wherever feasible, to replace it with a more cost effective substitute" (Chavan 2013). As opposed to a simple technique, value analysis is considered to be a process; this is because it is both an organized approach to improving the profitability of product applications and it makes use of many different techniques for the purpose of achieving this objective.

Value analysis practice is examined in the survey developed for this research to investigate if organizations are adopting it and if they think it is useful. At the very heart of the VA process review is the task to determine and eliminate item product features that add no true value to the patient but incur cost to the healthcare provider and patient (Rich and Holweg 2000). According to the survey, three characteristics of the supply chain should exist in order to benefit from using VA. First is to have a skilled data analyst to support the process. Second is implementing the process to every PPI. Third is to provide value training on value analysis to members and contributors to the process.

At the Mayo Clinic, a standard procedure methodology is followed during the process of contracting with suppliers for purchasing items as indicated by (Dudas and Widhalm 2012). The Mayo Clinic has restructured their approach to physician preference items, as it is the most difficult contracting category. The contract portfolio manager (CPM) is responsible for contracting with suppliers, and should be knowledgeable of the product category. The process should involve medical staff at key decisions points and follow a time line from contract planning to contract launch. The process of contracting for PPIs at Mayo clinic is a 9 – 12 months period, depending on the complexity of the product. The CPM begins preparing six

weeks before starting the contracting initiative. During this time, the CPM collects, reviews and analyzes data from many sources, including literature for similar items, meetings with supplier, and feedback from physicians. A stakeholder team is formed of physicians from Mayo clinic's three locations and the Mayo clinic health system to serve as technical experts to the CPM. The stakeholder team meets with the CPM four times during the planning process to provide clinical success factors, potential strategy of bid, analysis of bid, and final contract value. Acceptable quality and the outcome of products are ensured based on physician's recommendations.

Finally, the Mayo clinic delivers the plan to the supplier and defines the timeline for each stage of the process. As a result, the physicians have been satisfied and involved in the decision process, and the process helps them understand both product quality and cost. A similar approach was discussed by (Tyson 2010) with more emphasis on data analysis and team based techniques to bring down the costs. The first step is to review all cost related aspects of physician preference-related procedures, including device item cost and utilization, clinical outcomes and physician variations. The next step is to share the assessment with the leadership. Before reviewing clinical outcomes and cost data achieved from the assessment, a discussion among the staff, hospital leadership and the physician is necessary to obtain their buy-in. The team approach is an efficient strategy to identify the products that will deliver the best outcome for each patient.

More formal academic work on this problem was done and published by (Rossetti and Liu 2009). Two types of proliferation were defined namely: acceptance and adoption. The acceptance case is when the requested item is not carried by the system, whereas the adoption case occurs when another hospital in the system happens to have the requested item but not the one that requested it. The research falls under the simulation context, and the SKU problem was tackled with object oriented modeling using the JSL library developed by (M. D. Rossetti 2008).

The work showed that both cases affect the hospital supply chain performance, specifically, service level (demand fill rate) and cost. With fixed combined proliferation rate (acceptance + adoption), the fill rate increases when decreasing the acceptance rate (increasing the adoption rate). Total cost behaved differently showing a minimum value when both rates are equal. The reader can refer to (Liu 2008) for more details on this work.

On the other hand, (Bayus and Putsis, Jr. 1999) studied the effect of new products' introduction and products' varieties from a marketing point of view. The target of the research was the personal computer industry. The researcher investigated the effect from the seller perspective. They proposed a three-equation simultaneous system that captures both the determinants and market outcomes from decisions of a product line in a company. While marketing is trying to measure the outcomes from introducing a new item and estimate profit margins from selling the item, the purpose of this research is to understand effects of introducing a new item and the cost of adopting it in a healthcare provider. Healthcare organizations want to adopt/drop items that minimize total cost associated. This research investigates the problem from two perspectives (physicians and supply chain professionals in healthcare) to first provide insight on the problem. Then to address areas and practices that can be investigated more to make progress in building solutions.

Lack of research done on the PPI problem, especially solid mathematical modeling and even problem characterization with its attributes, is what triggered choosing the survey methodology. Justification and explanation of the methodology chosen in this study are found in the next section.

2.3 Method of Research

To gain insight into factors and practices affecting PPIs selection and management processes from physicians and supply chain professionals' perspectives, the survey method was employed. Due to limit in time and budget, just two interviews were conducted with two supply chain teams from two different main hospitals in the area of North West Arkansas. An understanding of the problem was developed to help in structuring the questions in the surveys. As a result of these interviews, researchers' discussions and literature review, two different surveys were developed targeting two different populations namely, physicians and supply chain professionals. Both surveys were pretested for poorly worded questions, redundant questions, as well as missing questions by a physician, supply chain professional from the healthcare sector, graduate students, self-critiques and finally by the research committee. Responses to requests for feedback were considered in improving the survey, as well as refining questions to use language consistent with healthcare sector terminologies. The final survey instrument contained 25 questions for physicians, and 44 for supply chain professionals and were both administrated online. Specific surveys' items were tailored to respondents; that is, conditional and skip logic was employed to show questions based on responses to previous items.

Data Collection

The survey was implemented and distributed electronically using the web-based tool from Qualtrics through University of Arkansas license (uark.qualtrics.com). It was released on June 2014 and was available through June 2015. It was distributed to two hospitals in the North West Arkansas region, as well as to a list of randomly selected 4000 surgeons through a database company, and through agencies like AHRMM and SMI for the supply chain professionals' survey. Individuals received an email that stated the purpose of the survey, how long it is

expected to take, contact information of researchers, and a link to take to the online survey. Respondents for the physicians survey were often surgeons (general, orthopedic, cardiovascular, and other specials), and for the supply chain survey were mainly vice presidents and directors (few managers and executives).

Survey Sample

Responses were received from 41 physicians and 47 supply chain professionals, and more than total 20 responses from physicians and 30 from SC which were deleted because no answers were provided, indicating the survey was opened and closed but not completed, and 7 responses from physicians and 8 from SC were also deleted as they partially answered the survey with very few questions. Final counts are 39 completed and 2 partially completed surveys from physicians, and 46 completed and 1 partially completed from SC. The median response time for the physicians' survey was 7 minutes, mode was 5 minutes, and trimmed mean of 12 minutes. The median response time for the supply chain professionals' survey was 10 minutes, mode of 8 minutes, and trimmed mean of 15 minutes. Expected time was 5-10 minutes for the physicians' survey and 10-15 minutes for the SC professionals' survey. The lowest physicians question's response rate was for the specialization question with 60%; this could be due to the fact that specialization is not easy to explain with one or two words. For the supply chain survey, the lowest response rates were for the questions asking about ABC classification practice (56%). This could be due to lack of knowledge about the practice or because the practice is not employed explicitly.

These responses were received from a total of 16 states, with highest contribution from Arkansas, Missouri, and Ohio. Table 2.1 below shows a breakdown of Physicians' based on

specialty, region, and gender with the corresponding breakdown reported by (Erikson, Jones and Tilton 2012).

Table 2.1 Physicians' Survey Respondents breakdown and comparison

Characteristic	Type	Respondents' n (%)	Comparison %
Specialty	General surgery	10 (34.5)	3.3
	Orthopedic Surgery	5 (17.2)	2.5
	Cardiovascular Disease	2 (6.9)	2.7
	Hematology & Oncology	2 (6.9)	1.6
	Plastic Surgery	2 (6.9)	0.9
	Other	8 (27.6)	89
State	AR	15 (39.5)	0.7
	MO	5 (13.2)	1.9
	OH	4 (10.5)	3.8
	NY	2 (5.3)	8.5
	Other	12 (31.6)	85.1
Sex	Male	27 (71.1)	69.6
	Female	11 (28.9)	30.4

Except for the sex percentages, the survey response set shows a notable difference than the expected percentages according to active physicians in the US. The total estimated number of active physicians in the US as of 2012 is 799472; which explain the deviation due to the small sample collected. A possible explanation for the higher response rate from AR is the direct relationship of researchers with a local network of hospitals.

Table 2.2 presents a breakdown of SC respondents' healthcare organizations characteristics with a comparison to the actual percentages for US hospitals found in (National Center for Health Statistics 2011).

Table 2.2 SC professionals survey respondents' breakdown and comparison

Characteristic	Type	Respondents' n (%)	Comparison %
Size of Organization (Number of beds)	< 100	4 (9.8)	51.1
	100-300	6 (14.6)	32.8
	>300	31 (75.6)	16.1
Size of Organization (Revenue)	<$100M	6 (16.2)	
	$101M - $500M	5 (13.5)	
	$501M - $1B	5 (13.5)	
	>$1B	21 (56.8)	
Department's Annual Purchasing Budget	<$5M	9 (20.9)	
	$5M - <$20M	9 (20.9)	
	$20M - <$50M	4 (9.3)	
	>$50M	21 (48.4)	
Organization setting	National	9 (20)	
	Rural	10 (22.2)	35
	Suburban	13 (28.9)	
	Urban	8 (17.8)	
	Other (Small Community)	5 (11.1)	

Data Analysis

The physicians' survey contained 25 items which can be categorized as: demographic, preference characterization, role in the decision, and cost information. The supply chain professionals' 44-item survey consisted of the categories: demographic, SKU and PPI influence, and a major component about practices in managing PPIs. Where appropriate, the "other" option was provided in a subset of both surveys' questions giving respondents the opportunity to add text and clarify their response provided. The provided text in these "other" responses were analyzed and assigned to predefined categories when possible. Most questions were provided using a Likert scale of 1-7, where 4 was the midpoint or neutral.

Observations of the two populations about interesting problem's variables were reported using appropriate descriptive techniques like: frequency tables, bar charts, and measures of

central tendency and dispersion. Each survey's responses were segmented where appropriate by specific responses' or organization's characteristics to recognize/capture any association that existed in how physicians and SC professionals manage PPI to these characteristics. Physicians' survey responses were segmented where appropriate by available characteristics like years of experience (<2, 2-5, 6-10, 11-20, >20), organization's setting (rural, suburban, urban), employment type (hospital employed, contracted physician group, community physician), gender (male, female), and compensation model (Per wRVU, percentage of net collections, percentage of practice, percentage of gross charges, per encounter, guaranteed base plus incentives). SC survey responses were also segmented by years of experience (<2, 2-5, 6-10, 11-20, >20), organization's setting (rural, suburban, urban), job title (Executive, vice president, director), gender (male, female), and annual purchasing budget (<$500k, $500k-$1M ...) to identify any pattern that existed in how SC professionals are managing PPIs and how they think it should be managed to these characteristics. Organization's size is a characteristic that may be considered for both surveys. Interesting variables could be tested for any expected relationship with other variables that may be expected to be a cause other than the mentioned characteristics. Similar variables in both surveys were investigated for any differences between the perspectives from the two populations.

Appropriate inferential statistical tests were employed throughout the analysis to investigate interesting hypotheses. Statistical tests were selected based on the fact that the data in this research is basically ordinal or nominal, which implies the use of nonparametric techniques. However, when appropriate, Likert scale data type was treated as interval data for purposes of using parametric tests. Researchers have stated that it is acceptable to be considered as interval data (Rea and Parker 2005). This is a debatable issue, and according to the same source, there are

three assumptions that should be made in order to consider a Likert scale as interval data. In this research these assumptions were adopted. For example, median or mode are used with ordinal data, however, mean was calculated sometimes from Likert scale data. Manipulating scaled responses (ex, Likert scale) as interval data has become accepted because the costs associated with overlooking these technicalities are far outweighed by the power of information obtained (Rea and Parker 2005). Appropriate nonparametric tests were employed to analyze data and investigate any significant result. It is known, nonparametric tests are more robust than corresponding parametric ones, however they lack the power (making type II error) when sample size <15. However, nonparametric tests become as powerful as the parametric tests when sample size is higher than 15 which is the case in this research. Consequently, it is an advantage in this research to use nonparametric tests, since the sample size is >15.

A one-way χ^2 test was used for many questions to identify if sizes of categories (number of responses in each category) are statistically different within the same question. One-sample sign test was also used to test if the median scored is statistically significantly different than the neutral score. Contingency tables were used along with a two-way χ^2 analysis, to verify any relationship between two interesting variables by determining if the association/dependence between these two variables is statistically significant. Specifically, patterns were investigated for variables by characteristics which were mentioned earlier. Cramer's *V* is a measure of the strength if any association found by the χ^2, which was calculated for each association that was found to be statistically significant. Due to the small sample size, a major part of response categories received fewer responses than required to make expected count values for each cell of the contingency table, fall above generally accepted threshold values. A Likert scale 1-7 was used in most questions in both surveys, consequently, response categories of scale 1, 2 and 3

were combined together, and 5, 6, and 7 were combined together to eliminate the problem. Also for this reason, all "other" responses that did not fall in well-defined categories were excluded from this analysis. A 95% confidence level was adopted in the analysis; it represents a reasonable balance between the risks associated with type I & II errors and that makes it fairly well accepted by researchers (Rea and Parker 2005). Each contingency table included corresponding χ^2 values with their associated *p* values. Since $\alpha=0.05$, *p* values of less than 0.05 implies a statistically significant relationship between the two variables.

Chi-square test is built for nominal data, it identifies significance in data when observed values differ sufficiently from expected ones. It does not tell anything about any trend behavior the data may have when dealing with categorical data. When the data is categorical and trends being analyzed, as mostly in this research, Gamma (γ) is a more appropriate test (Rea and Parker 2005). Gamma is the measure of association strength, like Cramer's *V* in the χ^2 case, and a z score calculated from γ is the significance test. A Gamma test was performed along with the χ^2 for every contingency table where a significant relationship was detected; this will give more support for any conclusion.

The Mann-Whitney U-test was used to compare rankings of both populations for common questions between the two populations. The Kruskal-Wallis test, the nonparametric test analogue to the one-way independent measures ANOVA (parametric test), was also used to compare groups' medians for a specific variable within the same population. The one-way ANOVA itself was also used whenever the Kruskal-Wallis test was used.

2.4 Survey Research Findings

Results for selected items like demographic, factors affecting physicians' preference, physicians perspective of the decision process, supply chain professionals' perspective, and SC

best practices potentially affect the management of PPIs items are discussed. Items are discussed for each population separately, except where there were common questions/variables for both; the results will be compared and discussed directly.

Demographics

The physicians' demographic information collected included specialization, healthcare provider type, compensation model, size of organization, years of experience, gender, employment type, and organization's settings. Most common specializations of those who responded are orthopedic surgery, general surgery, and plastic surgery. Of the total physicians who responded, 71% were males and 29% females. Compensation model types of responded physicians in along with years of experience are indicated in Table 2.3. Of the total physicians, 56% have experience more than 20 years, and 89% have experience of 11 years or more. This result is particularly good since more experienced physicians probably have faced more issues and used more items, and they are more likely to give a more realistic input. Physicians with compensation model "Guaranteed base plus incentives" and "Per wRVU (work relative value units)" make up 51.4% and 23.1% of respondent, respectively.

Table 2.3 Compensation model and years of experience

	Compensation model					
Years of Experience	Per wRVU (per work relative value units)	Percentage of net collections	Percentage of practice "bottom line"	Per encounter	Guaranteed base plus incentive	n (%)
<2	1	0	0	0	0	1 (2.6)
2-5	0	1	0	0	2	3 (7.7)
6-10	0	0	0	0	0	0 (0.0)
11-20	6	1	1	1	4	13 (33.3)
>20	2	1	4	1	14	22 (56.4)
n (%)	9 (23.1)	3 (7.7)	5 (12.8)	2 (5.1)	20 (51.3)	

Breakdown of organizations' settings and employment types is shown in Table 2.4. Physicians from organizations located in urban areas contributed most to the questionnaire with 59% of total responses. Participants from other areas are close in number of responses. Hospitals' employed and community physicians were the major employment types for physicians, with 51.3% and 23.1%, respectively.

Table 2.4 Organizations' settings and employment model

	Organization's Settings					
Employment Type	National	Rural	Suburban	Urban	Other (Small Community)	n (%)
Hospital Employed	3	3	2	11	1	20 (51.3)
Contracted physician group	0	0	0	3	0	3 (7.7)
Community physician	1	1	4	3	0	9 (23.1)
Other (Academic and Private practice)	1	0	0	6	0	7 (17.9)
n (%)	5 (12.8)	4 (10.3)	6 (15.4)	23 (59.0)	1 (2.6)	39 (100.0)

Regarding the healthcare provider type, academic institution was mentioned 18 times, hospital/medical center was mentioned 22 times, acute care facility 5 times, health system/Network (IDS/IDN) 5 times, and Military/VA/Government affiliated 3 times. In terms of

organization's size, most common (47%) number of beds was (301-600), while number of employees reported was for the category (301-600 ~ >1500) with 31%.

The supply chain professionals' demographic information collected included type of healthcare provider, size of organization, years of experience, job title, gender, department's annual purchasing budget, and organization's setting. Regarding the healthcare provider type, hospital/medical center was mentioned 19 times, acute care facility 12 times, academic institution was mentioned 8 times, and health system/Network (IDS/IDN) 23 times. Size of organization question included 4 drop down menus: number of beds, annual revenue, number of employees, and percentage of spend on PPIs. A breakdown of number of employees by number of beds, and percentage of spend on PPI items by annual revenue are shown in Table 2.5.

Table 2.5 Breakdown of number of employees by number of beds and % of spend on PPI items by annual revenue

	Number of employees						Percentage of spend on PPI items					
Number of beds	1-99	100-499	500-1500	>1500	n (%)	Annual Revenue	<10%	10%-20%	21%-30%	31%-40%	>40%	n (%)
< 100	1	1	2	0	4 (9.8)	<$100M	1	0	2	3	0	6 (16.2)
100-300	0	3	2	1	6 (14.6)	$101M - $500M	1	1	1	2	0	5 (13.5)
301-600	0	1	0	8	9 (21.9)	$501M - $1B	0	1	1	1	2	5 (13.5)
601-1000	0	0	0	4	4 (9.8)	>$1B	2	7	7	3	2	21 (56.8)
>1000	0	0	0	18	18 (43.9)							
n (%)	1 (2.4)	5 (12.2)	4 (9.8)	31 (75.6)	41 (100)	n (%)	4 (10.8)	9 (24.3)	11 (29.8)	9 (24.3)	4 (10.8)	37 (100)

From the first part, it is obvious that the SC professionals from the very big healthcare organizations contributed more to the input. This put the importance of this problem in the top tier issues and big scale problems of large size healthcare organizations. With regard to the spend on PPI items, more than 35% said their spend on PPI items is more than 30% of total spend. Such a result by its own establishes the importance of this problem and justifies the big concern and interest in this issue by healthcare organizations.

Male respondents were 70% of the total respondents, while females were 30%. Respondents' job titles showed that 89% have a director position or higher, with 45% of total respondents are

directors and 39% vice presidents; this gives a more validity to responses since that these are the kind of stakeholders who are generally involved in the decision process. Department's annual purchasing budget was greater than $50M for 49% of total respondents. More than 81% have experience in the healthcare industry of or more than 11 years, 50% of total responses indicated they have experience of 20 years or more. This demographic info is supportive, since we can rely on the fact that respondents have enough experience to recognize the SKU problem and also have faced the issue of PPIs. More results and graphs from both surveys, which were not discussed in the body of this chapter can be found in Appendix E: Surveys' Extra Results and Analysis.

2.4.1 **Physicians Perspective**

A table that summarize the results from all individual questions showing median, low score and high score percentages, and both the one-sample sign and one-way χ^2 tests is shown in Appendix E.1: Physicians.

Preference characterization/behavior

Information collected regarding physicians' preference behavior included awareness of the term PPI, willingness to use available brands in stock other than the preferred, permission to order preferred brand, factors affecting physicians' preference, willingness to use functionally equivalent item which comes from a different manufacturer, and reasons that make a physician switch to another brand.

When asked how aware you are of the term PPI, on a scale of 1-7, around 73% of physicians indicated that they are aware with 38% are highly aware, the median score was 5. A one-sample sign test was performed with null hypothesis H_0 that median equals 4 (The neutral score), versus

H_1 that the median is greater than 4. The resulting p-value was 0.001; H_0 was rejected in favor of H_1, this means that the calculated median is significantly greater than 4, which supports the conclusion that physicians have some feelings of awareness. A one-way $\chi 2$ test was also performed to check if data obtained is not uniformly distributed and representing the population. The H_0 is that the distribution of categories is uniform, versus H_1 not uniformly distributed. The resulting p-value was 0.00, H_0 was rejected in favor of H_1, the awareness level is not uniformly distributed across the population, this could mean that results were not obtained by chance, and there is a little skewness of awareness level toward highly aware. The same two tests will be done on each question, and the results will be mentioned in a shorten format. A breakdown of the awareness of physicians in the term PPIs by related characteristics is shown in Table 2.6 below. The awareness (dependent variable) was supposed to be in rows and the characteristics (independent variables) were supposed to be in columns, but both were swapped for formatting purposes. The same contingency table setup will be followed in all following analysis for consistency. The results indicate that awareness of the term PPI does not depend on any of these characteristics.

Table 2.6 Awareness of the term PPI by physicians' characteristics

Characteristic	Categories	Not aware 1, 2, 3 n (%)	Neutral 4 n (%)	5, 6, 7 Highly aware n (%)	Total	χ^2 Analysis	Gamma Analysis (If applicable)
Compensation model	Per wRVU	2 (22.2)	0 (0)	7 (77.8)	9	χ^2 = 10.47 df=10, p= 0.40	
	% of net collections	0 (0)	0 (0)	3 (100)	3	Cramer's V = NA	
	% of practice "bottom line"	1 (20)	0 (0)	4 (80)	5	**No Association**	
	% of gross charges	0	0	0	0		
	Per encounter	0 (0)	1 (50)	1 (50)	2		
	Guaranteed base plus incentive	5 (25)	1 (5)	14 (70)	20		
	Total	8	2	29	39		
Years of experience	< 2, 2 - 5, 6-10	3 (75)	0 (0)	1 (25)	4	χ^2 = 8.34 df=4, p= 0.08	γ = 0.49
	11-20	2 (15.4)	1 (7.7)	10 (76.9)	13	Cramer's V = NA	Z = 0.88
	> 20	3 (13.6)	1 (4.5)	18 (81.8)	22	**No Association**	**No Association**
	Total	8	2	29	39		
Gender	Male	4 (14.8)	1 (3.7)	22 (81.5)	27	χ^2 = 3.33 df=4, p= 0.50	
	Female	4 36.4)	1 (9.1)	6 (54.5)	11	Cramer's V = NA	
	Prefer to not answer	0 (0)	0 (0)	1 (100)	1	**No Association**	
	Total	8	2	29	39		
Employment type	Hospital employed	4 (20)	1 (5)	15 (75)	20	χ^2 = 3.56 df=4, p= 0.47	
	Contracted physician group	2 (66.7)	0 (0)	1 (33.3)	3	Cramer's V = NA	
	Community physician	2 (22.2)	1 (11.1)	6 (66.7)	9	**No Association**	
	Total	8	2	22	32		
Organization's setting?	National	1 (20)	1 (20)	3 (60)	5	χ^2 = 2.92 df=6, p= 0.82	
	Rural	1 (25)	0 (0)	3 (75)	4	Cramer's V = NA	
	Suburban	1 (16.7)	0 (0)	5 (83.3)	6	**No Association**	
	Urban	5 (21.7)	1 (4.3)	17 (73.9)	23		
	Total	8	2	28	38		

On the SC side, when they were asked about their awareness in the PPI term, 100% of SC professionals indicated that they are aware with 94% are fully aware. The one-sample sign test gave a p-value of 0.00, and one-way χ^2 test also gave a p-value of 0.00, this means that SC professionals are highly aware of the term and the data represents the population. The SC professionals' awareness of the term was found to have no association with any of the characteristics mentioned earlier.

Both populations have strong feelings toward awareness of the term, however a Mann-Whitney U-test showed that the ranks from the two populations are statistically significantly different with p = 0.00 and Z=-4.719. Since the sample size is greater than 20, MW U-test follows a z distribution; and for the two-tail test, H_0 is rejected if $Z < -Z\alpha/2$ or $Z > Z\alpha/2$. The H_0 that there is no difference was rejected in favor of the H_1. Higher awareness within physicians' population was expected as the term was thought to be more related to clinical staff than SC. However, a higher awareness within SC professionals' community was observed; this makes more sense that this is essentially a SC issue and its ramifications directly affect the SC performance within the organization. Physicians focus more on getting items and do not necessarily consider the effects of their decision on SC performance.

Regarding physicians' willingness (Q2) to use available items in stock even if it is not their preferred brands, 59% indicated that they are willing to use available items. A one-sample sign test gave a p-value of 0.00, and a one-way χ^2 test also gave a p-value of 0.00. This indicates that the median is statistically significantly greater than 4 and the data is significant, which mean that physicians have noticeable willingness to adopt available items in stock. A breakdown of physicians' willingness to use available items by related characteristics is show in Table 2.7 below. The results show that physician's willingness to use available items in stock only depends

on how many years the physician has worked. Strong association was recognized by the gamma analysis, and since γ is positive, this means that the more experienced the physician is, the more he/she is willing to use whatever items are available in stock. Physician's skills gained through experience increase their ability to use other non-preferred items and adapt to the item with minimal effort. Organizations may want to pay more attention to training physicians to better manage PPIs, and consequently more effectively moving to standardized items. Figure 2.1below shows a bar stack chart for the physicians' willingness versus experience.

Table 2.7 Physicians' willingness to use available items by physicians' characteristics

		Not willing 1, 2, 3	Neutral 4	5, 6, 7 Very willing	Total	χ^2 Analysis	Gamma Analysis (If applicable)
Characteristic	Categories	n (%)	n (%)	n (%)			
Compensation model	Per wRVU	3 (33.3)	2 (22.2)	4 (44.4)	9	χ^2 = 16.18 df=10, p= 0.09	
	% of net collections	0 (0)	2 (66.7)	1 (33.3)	3	Cramer's V = NA	
	% of practice "bottom line"	0 (0)	3 (60)	2 (40)	5	**No Association**	
	% of gross charges	0	0	0	0		
	Per encounter	1 (50)	0 (0)	1 (50)	2		
	Guaranteed base plus incentive	0 (0)	5 (25)	15 (75)	20		
	Total	4	12	23	39		
Years of experience	< 2, 2 - 5, 6-10	1 (25)	2 (50)	1 (25)	4	χ^2 = 9.34 df=4, p= 0.05	γ = 0.68
	11-20	3 (23.1)	5 (38.5)	5 (38.5)	13	Cramer's V = 0.346	Z = 1.98
	> 20	0 (0)	5 (22.7)	17 (77.3)	22	**Moderate Association**	**Strong Associatio**
	Total	4	12	23	39		
Gender	Male	4 (14.8)	7 (25.9)	16 (59.3)	27	χ^2 = 4.28 df=4, p= 0.37	
	Female	0 (0)	4 (36.4)	7 (63.6)	11	Cramer's V = NA	
	Prefer to not answer	0 (0)	1 (100)	0 (0)	1	**No Association**	
	Total	4	12	23	39		
Employment type	Hospital employed	1 (5)	5 (25)	14 (70)	20	χ^2 = 1.99 df=4, p= 0.74	
	Contracted physician group	0 (0)	1 (33.3)	2 (66.7)	3	Cramer's V = NA	
	Community physician	1 (11.1)	4 (44.4)	4 (44.4)	9	**No Association**	
	Total	2	10	20	32		
Organization's setting?	National	2 (40)	1 (20)	2 (40)	5	χ^2 = 7.36 df=6, p= 0.29	
	Rural	0 (0)	2 (50)	2 (50)	4	Cramer's V = NA	
	Suburban	0 (0)	3 (50)	3 (50)	6	**No Association**	
	Urban	2 (8.7)	6 (26.1)	15 (65.2)	23		
	Total	4	12	22	38		

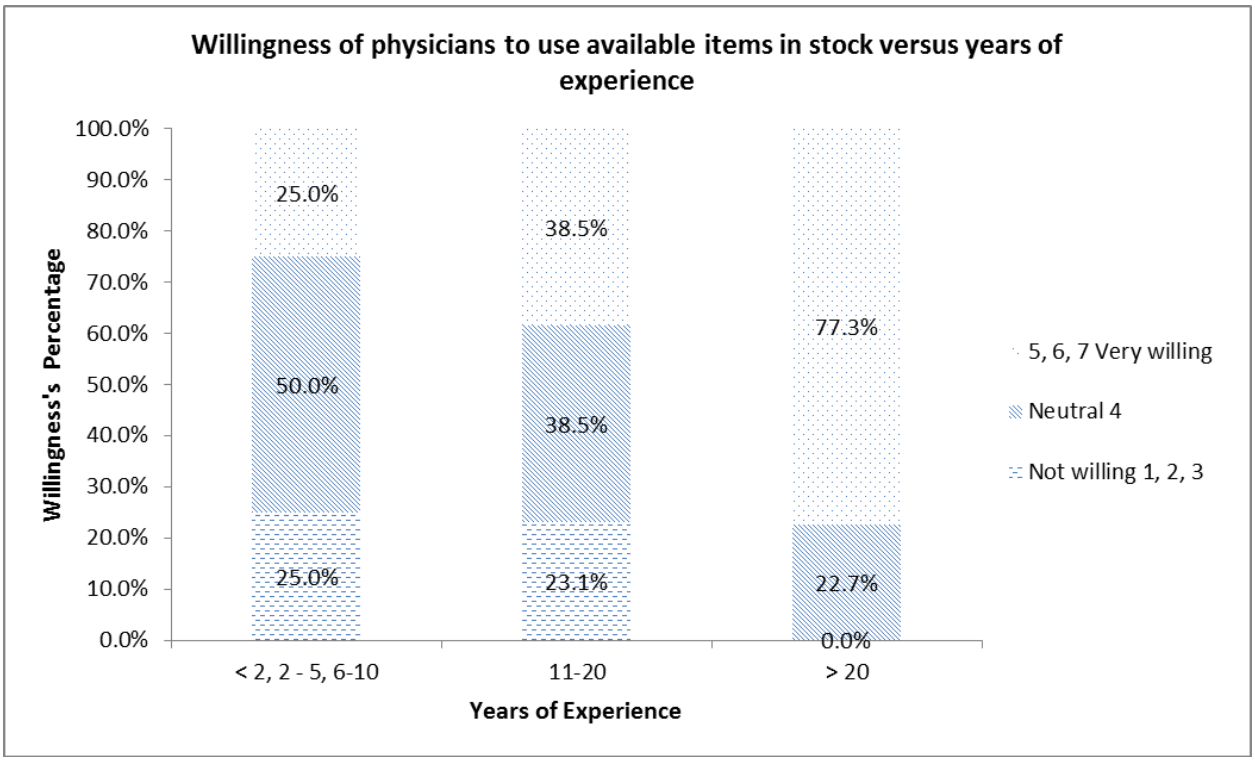

Figure 2.1 Willingness of physicians to use available items in stock versus experience

When asked if they are permitted to order whatever they want if the item in stock is not their preferred brand, 83% said they are sometimes permitted to order, while 10% said they are not permitted and 7% said yes. Both one-sample sign and one-way χ^2 tests gave p-values of 0.00, which means that the result is statistically significant and indeed the majority is partially allowed to order their preferred brands. No association of ordering permission with any characteristic was recognized by the two-way χ^2.

A breakdown of physicians' willingness to use available items in stock by two variables, namely awareness of the PPI term and ordering permission is shown in Table 2.8 below. Results show that there is not an association with the physicians' level of awareness in the term, while there is a relatively strong association according to Cramer's V, with the ordering permission. When limitation on what physicians are permitted to order takes place, they will be more willing to use available items.

Table 2.8 Willingness to use available items in stock by permission to order and years of experience

Characteristic	Categories	Not willing 1, 2, 3 n (%)	Neutral 4 n (%)	5, 6, 7 Very willing n (%)	Total	χ^2 Analysis	Gamma Analysis (If applicable)
Awarness of PPI term	Not aware 1,2,3	2 (20)	4 (40)	4 (40)	10	χ^2 = 5.88 df=4, p= 0.21	γ = 0.43
	Neutral 4	1 (50)	0 (0)	1 (50)	2	Cramer's V = NA	Z = 0.76
	Highly aware 5,6,7	2 (6.3)	9 (28.1)	21 (65.6)	32	**No Association**	**No Association**
Total		5	13	26	44		
Ordering permission	Yes	2 (66.7)	1 (33.3)	0 (0)	3	χ^2 = 17.6 df=4, p= 0.00	
	No	2 (40)	0 (0)	3 (60)	5	Cramer's V = 0.447	
	Sometimes	1 (2.8)	12 (33.3)	23 (63.9)	36	**Relatively Strong Association**	
Total		5	13	26	44		

A key goal for this research was to determine the factors that affect physician's preference. When asked, physicians rated factors as shown in Figure 2.2 below. *Items' effectiveness* and *previous experience* are the highest rated factors, and other factors mentioned were *ease of application* and *long term availability*. The Kruskal-Wallis (K-W) test, a nonparametric test, was performed to investigate if the differences among the groups' medians are statistically significant. Null and alternative hypothesis are H_0: the population medians are all equal, and H_1: the medians are not all equal. The test statistic (H) had a p-value of 0.000, both unadjusted and adjusted for ties, providing sufficient statistical support to reject H_0 in favor of H_1, and concluding that there is at least one statistical significant difference among factors. The sample medians for the five factors affecting physician's item selection preference were calculated and shown on Figure 2.2. A box-plot for the same results is included below in Figure 2.3.

The z-value for "knowledge of item cost" factor is -0.77, the smallest absolute z-value, which indicates that the average rank for this factor differed least from the average rank for all observations. With the lowest z-value of -7.69, the average rank for "relationship with sales representative" was lower than the average rank for all other factors. With a z-value of 5.76, the average rank for "Item's effectiveness" factor was higher than the mean rank for all factors. Assuming that the data can be manipulated with parametric tests as discussed earlier, ANOVA was also performed and showed that there is statistical evidence (p=0.00) of at least one

significant difference among factors' means, which is consistent with the result from the K-W test. In other research, factors affecting and considered in the PPI selection decision process by physicians and other stakeholders as well, are analyzed in detail. The purpose is to develop a decision framework to improve the item's selection process.

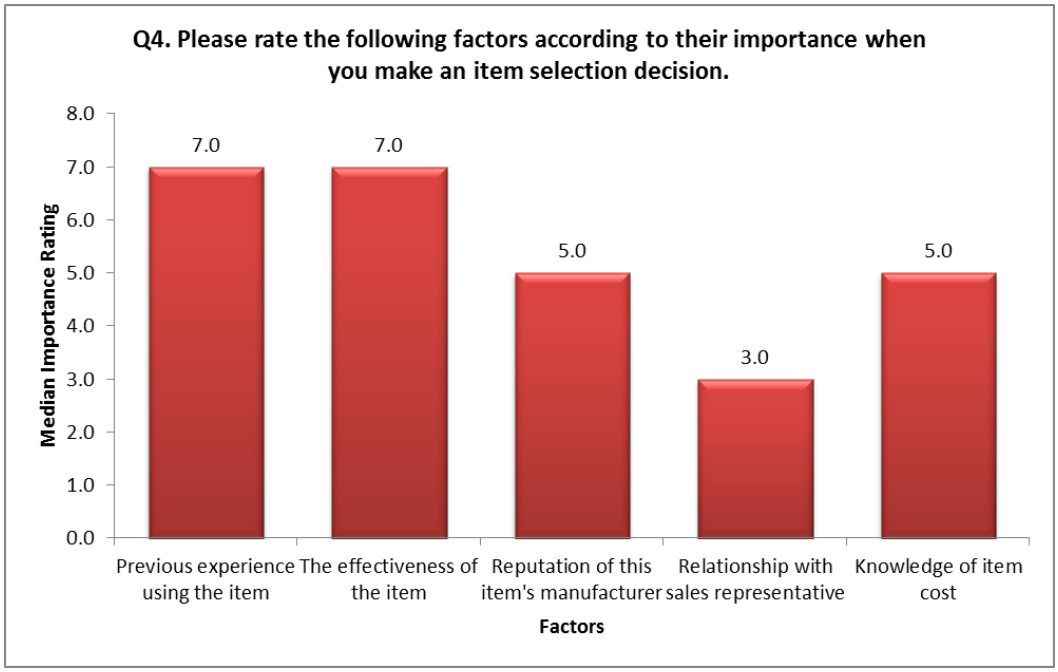

Figure 2.2 Factors that affect physician's selection (preference)

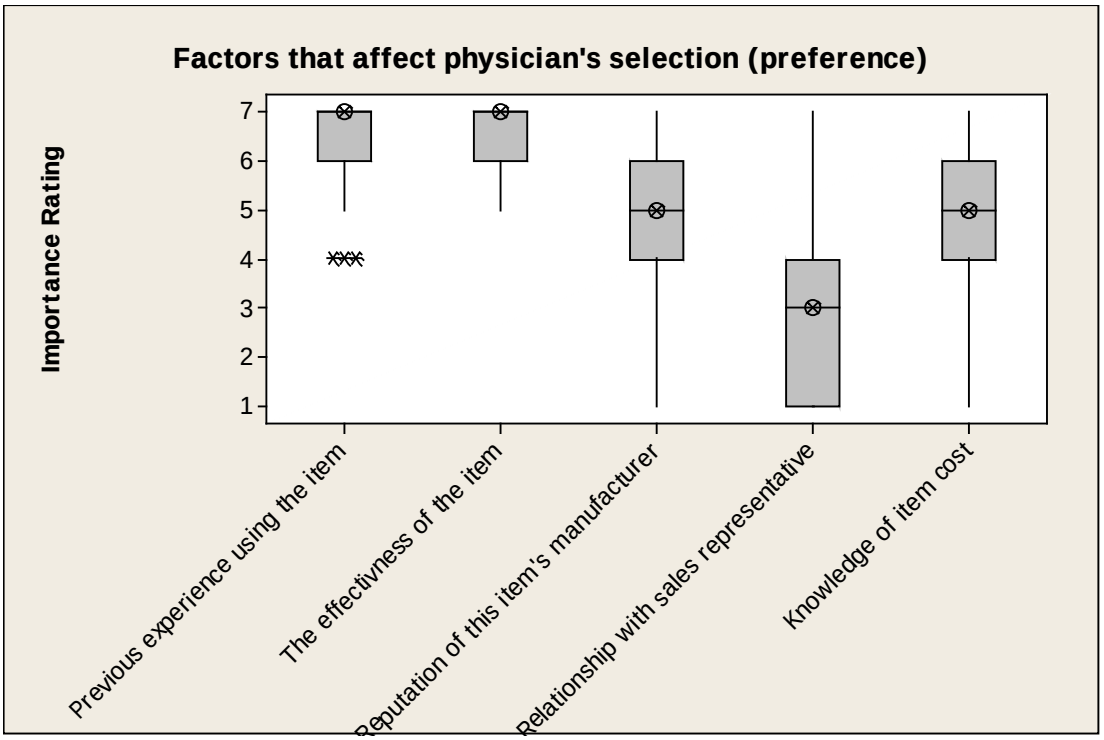

Figure 2.3 Box-plot of factors that affect physician's selection (preference)

All factors were analyzed using one-sample sign test and one-way χ^2 test, both tests gave p-values <0.05 for all factors except the χ^2 for the "Item's manufacturer reputation" factor. Factors' medians are statistically significantly deviated from the neutral, which means all factors are important except the "Relationship with sales representative" which is not important. Scoring for all factors is significant and non-uniformly distributed except for the "Item's manufacturer reputation" which indicates a uniform distribution among rankings; it could be unrepresentative of the true population or the physicians are not agreeing on this direction. A breakdown of all factors by all characteristics were conducted and results indicated that there is no association between any of the factors with any of the characteristics, except for the "Item's cost knowledge" with the years of experience. The following table, Table 2.9, is a breakdown of the "Knowledge of item's cost" factor by years of experience. The χ^2 indicates that there is a moderate association, which means a more experienced physician may consider the item's cost significantly more important in his decisions than a lower experienced physician. This specific

result is consistent with the one obtained in Table 2.7, where more experienced physicians are more willing to use whatever is available in stock.

Table 2.9 Factors affecting physician's preference (knowledge of item's cost) by experience

Characteristic	Categories	Not important 1,2,3 n (%)	Neutral 4 n (%)	5,6,7 Very important n (%)	Total	χ^2 Analysis	Gamma Analysis (If applicable)
Years of experience	< 2, 2 - 5, 6-10	0 (0)	0 (0)	4 (100)	4	χ^2 = 10.46 df=4, p= 0.03	γ = 0.38
	11-20	2 (15.4)	6 (46.2)	5 (38.5)	13	Cramer's V = 0.366	Z = 0.61
	> 20	0 (0)	4 (18.2)	18 (81.8)	22	**Moderate Association**	**No Association**
Total		2	10	27	39		

Another survey item (Q8) collected information on physicians' willingness to substitute an item from stock which is not their preferred brand but functionally equivalent. This is similar to the item in Table 2.7, but that item was general while this item added the word "functionally equivalent". Of the total 40 respondents who answered this question, 90% indicated that they are very willing to substitute their preferred brand, 2.5% said not, and 7.5% were neutral. A one-sample sign test and one-way χ^2 test both gave p-value of 0.00. This indicates that the results are significant and not uniformly distributed, and that the median score is statistically significantly greater than 4. This result is consistent with the one in question 2, except that physicians became more willing to use another brand given it is functionally equivalent. A Mann-Whitney U-test was performed to investigate if there is a difference between the ranks of the two items. The resulting test statistic U=457.5, Z=-3.43, and p-value=0.00 provide enough statistical evidence to reject H_0 and accept H_1, which means that there is a difference between the ranks. In other words, a physician became more willing to substitute his/her preferred brand once he is convinced that it is functionally equivalent. According to the two-way χ^2 analysis, physician's willingness to use another functionally equivalent brand is moderately associated with the physician's experience.

A follow-up item collected information on how willing physicians are to permanently drop a brand and adopt another one. A significant portion (70.7%) said they are highly willing, when 19.5% were unsure (neutral) and (9.8%) were not willing to drop their preferred brand. This result supports the findings from the previous results found above in this research in that physicians are more than willing to drop their preferred brand. A one-sample sign test and one-way χ^2 test gave p-values of 0.00 and 0.04, respectively. This confirms that the willingness level is not uniformly distributed or in other words the results were not obtained by chance, and the score median is significantly greater than 4. The breakdown contingency table and χ^2 analysis showed that there is no association between the physicians' willingness to drop their preferred brand and any of the characteristics.

Examining item 4, on rating factors' importance for physicians when selecting an item, another item was asked to collect information on reasons that would cause physician switching to another brand. The available options were (easier to use, more features, being produced by a reputable manufacturer, safer for patient, cheaper, and expected to give better results for the patient). Scores' means for all factors are shown below in Figure 2.4. As expected, patient's related aspects are the most important followed by the ease of use. Respondents also mentioned product support as an important factor in encouraging the physician to switch. The Kruskal-Wallis (K-W) test was performed and the resulting test statistic (H) had a p-value of 0.000, both unadjusted and adjusted for ties, providing sufficient statistical support to reject H_0 in favor of H_1, and concluded that there is at least one statistical significant difference among factors.

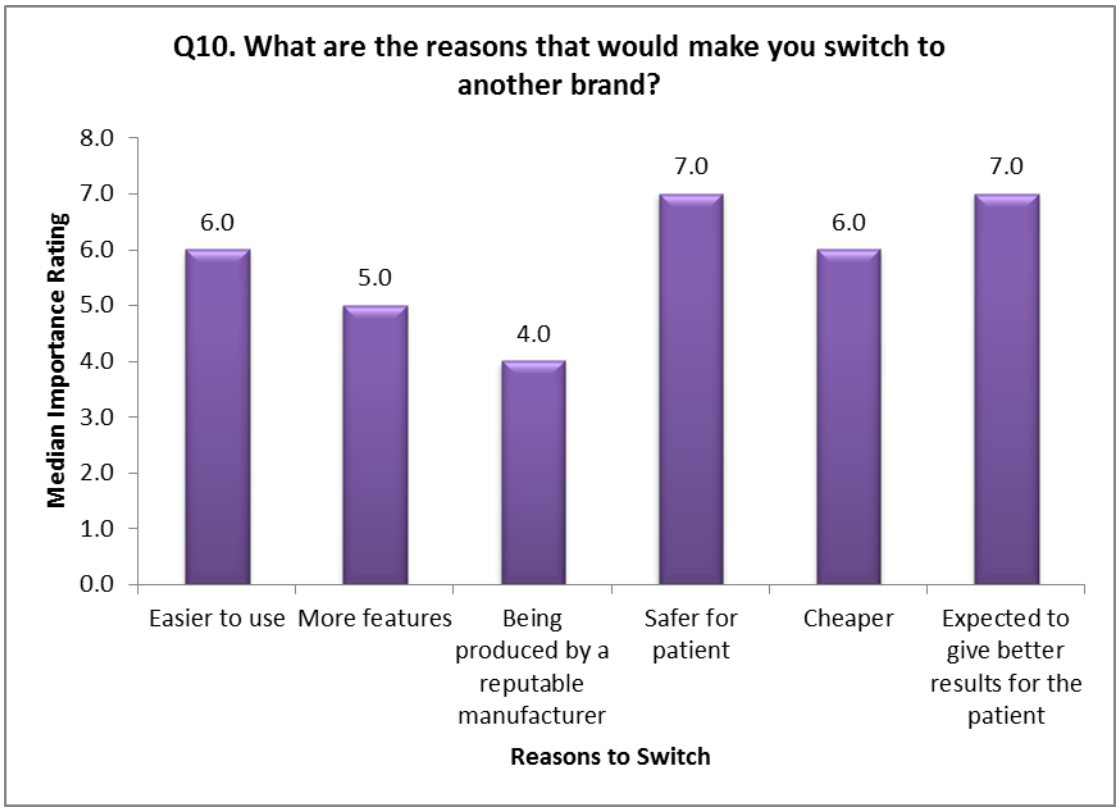

Figure 2.4 Factors that would make a physician to switch to another brand

The z-value for the easiness of use factor was 1.08, the smallest absolute z-value, which indicates that the average rank for this factor differed least from the average rank for all observations. With the lowest z-value of -6.39, the average rank for "Being produced by a reputable manufacturer" was lower than the average rank for all other factors. With a z-value of 5.2, the average rank for "Expected to give better results for the patient" factor was higher than the mean rank for all factors. Assuming that the data can be manipulated with parametric tests as discussed earlier, ANOVA was also performed and showed that there is statistical evidence ($p=0.00$) of at least one significant difference among factors' means which is consistent with the results from the K-W test. All factors were analyzed using the one-sample sign test, the p-value was <0.05 for all except for "Being produced by a reputable manufacturer". This indicates that all reasons could contribute to make the physician switch except knowing that it is from a

reputable manufacturer with score's median at neutral. This result is actually consistent with the previous indications found above in this research in that the manufacturer reputation being not important to physicians. A one-way χ^2 test was also conducted and gave p-values <0.05 for all factors which indicates that results were significant and were not obtained by chance. Two-way χ^2 analysis of the contingency tables of all factors by all characteristics indicated that there is no association between any of the factors with any of the characteristics. This means that physicians agree on the importance pattern of these factors when considering switching to another brand.

Another item was included in the questionnaire to learn to what extent physicians consider patients' preference when selecting the right item. When asked how important the patient's preference is to you in deciding which item will be used directly on the patient, 32.5% said it is very important, 42.5% said it is not important, and 25% were neutral. A one-sample sign test and one-way χ^2 test resulted in p-values>0.05, which indicates that the importance levels are uniformly distributed and the median actually equals 4. The unimportance of patient's preference for physicians could come from the physician's experience and knowledge of what is more appropriate for the patient. Patient's opinion is important for those extra features and life quality issues with the item. A breakdown of patient's opinion importance to physicians when selecting their preferred items by question 10 (reasons that make a physician switch – specifically the reason "being produced by a reputable manufacturer") is shown in Table 2.10 below. A moderate association was recognized by the χ^2 analysis. This means that for those who said patient's preference is *not important*, manufacturer reputation is *important* when selecting the item. This could mean that when physicians totally depend on their opinion, it is more likely that they are affected by manufacturer reputation factor. Yet, gamma analysis has indicated that there is no association between the two aspects.

Table 2.10 Reason for a physician to switch (Being produced by a reputable manufacturer) by patient's preference

Characteristic	Categories	Not important 1, 2, 3 n (%)	Neutral 4 n (%)	5, 6, 7 Very important n (%)	Total	χ^2 Analysis	Gamma Analysis (If applicable)
Patient's preference	Not important 1,2,3	7 (41.2)	0 (0)	10 (58.8)	17	χ^2 = 12.08 df=4, p= 0.02	γ = -0.30
importance to	Nuetral 4	2 (20)	4 (40)	4 (40)	10	Cramer's V = 0.389	Z = -0.50
physicians decision	Very important 5,6,7	8 (61.5)	1 (7.7)	4 (30.8)	13	**Moderate Association**	**No Association**
Total		17	5	18	40		

Role in decision

Information collected regarding the physicians perspective of their role in the organization's decision included how knowledgeable the physician was about how the selection process takes place, physician's perceived ability to influence the decision, and their opinion about important factors that are considered by the organization when making the decision.

When asked how knowledgeable they are about how the organization decides to select the item, 53.7% of respondents said they are knowledgeable, 29.3% said they are not, and 17.1% were neutral (unsure). The median score was 4 and a one-sample sign test confirmed this result by giving a p-value of 0.12. Physicians in general think they are not knowledgeable enough on the decision process. A one-way χ^2 test indicated that the results are not significant and uniformly distributed. The breakdown of physicians' knowledge level with physicians' characteristics did not show any significant association, and the only close association was with experience with a p-value of 0.06.

When asked about their ability to influence the decision to stock and use an item, 48.8% of physicians indicates that they are highly able to influence the decision, 26.8% said they are not, and 24.4% are not sure (neutral). Both one-sample sign and one-way χ^2 tests gave p-values>0.05, which indicates that the data is uniformly distributed across the population and the score median is actually 4. A χ^2 and γ analyses were conducted to determine whether the physicians' ability to influence the decision depends on physicians' characteristics. The results, presented in

Table 2.11, indicate that there is association with two characteristics, which are experience and employment type. A relatively strong association with physician's experience was recognized, the more experience the physician has, the more able he/she is in influencing the organization decision in item's selection decision, this result is especially important.

Table 2.11 Physicians ability to influence the organization's decision by different characteristics

Characteristic	Categories	Low ability 1, 2, 3 n (%)	Neutral 4 n (%)	5, 6, 7 High ability n (%)	Total	χ^2 Analysis	Gamma Analysis (If applicable)
Compensation model	Per wRVU	2 (22.2)	2 (22.2)	5 (55.6)	9	χ^2 = 4.06 df=10, p= 0.94	
	% of net collections	1 (33.3)	1 (33.3)	1 (33.3)	3	Cramer's V = NA	
	% of practice "bottom line"	0 (0)	1 (20)	4 (80)	5	**No Association**	
	% of gross charges	0	0	0	0		
	Per encounter	1 (50)	0 (0)	1 (50)	2		
	Guaranteed base plus incentive	7 (35)	4 (20)	9 45)	20		
	Total	11	8	20	39		
Years of experience	< 2, 2 - 5, 6-10	4 (100)	0 (0)	0 (0)	4	χ^2 = 14.89 df=4, p= 0.00	γ = 0.64
	11-20	5 (38.5)	2 (15.4)	6 (46.2)	13	Cramer's V = 0.437	Z = 1.85
	> 20	2 (9.1)	6 (27.3)	14 (63.6)	22	**Relatively Strong Association**	**No Association**
	Total	11	8	20	39		
Gender	Male	7 (25.9)	5 (18.5)	15 (55.6)	27	χ^2 = 2.13 df=4, p= 0.71	
	Female	4 (36.4)	3 (27.3)	4 (36.4)	11	Cramer's V = NA	
	Prefer to not answer	0 (0)	0 (0)	1 (100)	1	**No Association**	
	Total	11	8	20	39		
Employment type	Hospital employed	9 (45)	3 (15)	8 (40)	20	χ^2 = 9.37 df=4, p= 0.05	
	Contracted physician group	0 (0)	2 (66.7)	1 (33.3)	3	Cramer's V = 0.383	
	Community physician	1 (11.1)	1 (11.1)	7 (77.8)	9	**Moderate Association**	
	Total	10	6	16	32		
Organization's setting?	National	3 (60)	0 (0)	2 (40)	5	χ^2 = 7.57 df=6, p= 0.27	
	Rural	0 (0)	2 (50)	2 (50)	4	Cramer's V = NA	
	Suburban	2 (33.3)	0 (0)	4 (66.7)	6	**No Association**	
	Urban	6 (26.1)	6 (26.1)	11 (47.8)	23		
	Total	11	8	19	38		

The importance of this result comes from the previous finding that a more experienced physicians is more willing to use whatever is available in stock and more willing to switch to another brand. this suggests that solutions to the PPI issue are more likely to be addressed if the organization focuses on influencing highly experienced physicians' preference since they are the more influential on the organization's decision, yet more flexible. Another moderate association was found with the employment type. Community physicians seem to be more able to influence the decision. A breakdown of physicians' ability to influence the selection decision by their knowledge of the decision process is shown in Table 2.12. Obviously, a strong relationship was

recognized by the tests, χ^2 and γ, meaning that the more knowledgeable the physician, the more the physician may influence the decision.

Table 2.12 Physicians ability to influence the decision by their knowledge of the decision process

Characteristic	Categories	Low ability 1, 2, 3 n (%)	Neutral 4 n (%)	5, 6, 7 High ability n (%)	Total	χ^2 Analysis	Gamma Analysis (If applicable)
Physicians knowledge of how the organization decides to select	Not knowledgeable 1,2,3	6 (50)	5 (41.7)	1 (8.3)	12	χ^2 = 14.42 df=4, p= 0.01	γ = 0.70
	Neutral 4	3 (42.9)	1 (14.3)	3 (42.9)	7	Cramer's V = 0.419	Z = 2.49
	Very knowledgeable 5,6,7	2 (9.1)	4 (18.2)	16 (72.7)	22	**Relatively Strong Association**	**Strong Association**
	Total	11	10	20	41		

The third item in this category asked physicians to rate a list of factors according to their importance in influencing the organization's item selection decision. Factors and mean score for each are shown in Figure 2.5. Total cost was the dominant factor according to physicians, followed by patient's outcome, then they consider it as an administration decision, and physician's preference came at 4th place with manufacturer reputation and required storage space as being not important. A one-sample sign test gave a p-value of <0.05 for all factors which confirms that scores' medians are statistically significantly deviated from the neutral. A one-way χ^2 test also gave a p-value <0.05 for all factors, this means that scoring on factors is not uniformly distributed and the results are significant.

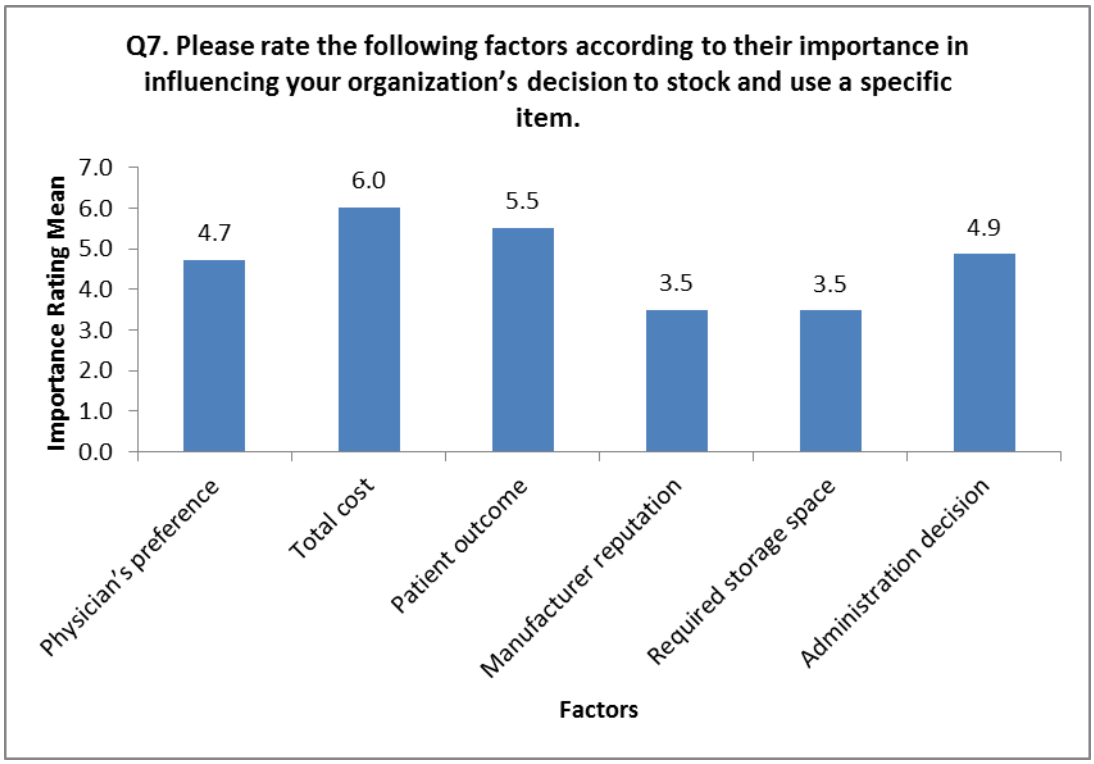

Figure 2.5 Factors influencing organization's decision from physicians' perspective

A χ^2 analysis was conducted to determine whether the factors influencing the organization's selection decision depend on any of the physicians' characteristics. The only association according to $\alpha = 0.05$ significance level is between the "administration decision" factor and physicians employment type characteristic as shown in Table 2.13 below. Relatively strong association was found, and community physicians think that item's selection is an administration decision. Community physicians do not really do major treatments or surgeries and generally are hired by government, and most probably they are neither included in the decision process nor have the need to work with PPIs. This explains their opinion and at the same time could not be adopted.

Table 2.13 Importance of "Adminstration decision" factor to the organization's decision by employment type

Characteristic	Categories	Low importance 1, 2, 3 n (%)	Neutral 4 n (%)	5, 6, 7 Very important n (%)	Total	χ^2 Analysis	Gamma Analysis (If applicable)
Employment type	Hospital employed	6 (31.6)	7 (36.8)	6 (31.6)	19	χ^2 = 11.23 df=4, p= 0.02	
	Contracted physician group	2 (66.7)	0 (0)	1 (33.3)	3	Cramer's V = 0.426	
	Community physician	0 (0)	1 (11.1)	8 (88.9)	9	**Relatively Strong Association**	
	Total	8	8	15	31		

The difference among groups (factors) was tested using K-W test. The test statistic (H) had a p-value of 0.000, both unadjusted and adjusted for ties, providing sufficient statistical support to reject H_0 in favor of H_1, and concluded that there is at least one statistical significant difference among factors. The z-value for “Physician’s preference” factor is -0.20, the smallest absolute z-value, which indicates that the average rank for this factor differed least from the average rank for all observations. With the lowest z-value of -5.23, the average rank for “Required storage space” was lower than the average rank for all other factors. With a z-value of 5.84, the average rank for “Total Cost” factor was higher than the mean rank for all factors. Parametric test ANOVA was also performed and showed that there is statistical evidence (p=0.00) of at least one significant difference among factors’ means, which is consistent with the result from K-W.

This same question was asked (Q5) to the SC group and results are as shown in Figure 2.6, they rated “patient outcome” as highly important, followed by “physicians’ preference”, and “total cost”. The other three factors namely, “manufacturer reputation”, “required storage space” and “admiration decision” were not important. One-sample sign test gave a p-value of 0.00 for all factors with H_1 as greater than 4 for the first three factors, and less than 4 for the other three factors, which confirms that scores’ medians are statistically significantly deviated from the neutral. A one-way χ^2 test also gave a p-value of 0.00 for all factors, this means that scoring on factors is not uniformly distributed and the results are significant. A χ^2 analysis was performed to

determine whether the factors influencing the organization's selection decision depend on any of the SC characteristics. No association was recognized with any of the characteristics.

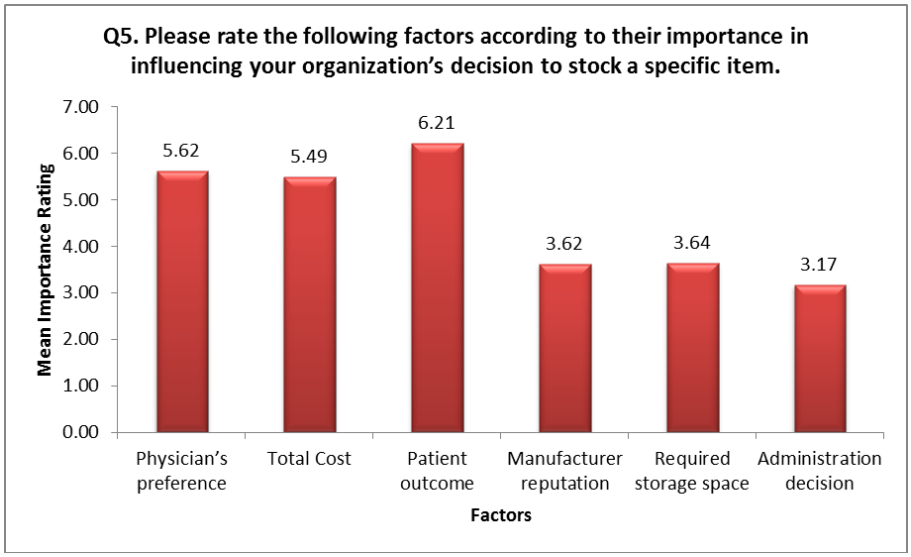

Figure 2.6 Factors influencing organization's decision from SC perspective

The difference among groups (factors) was tested using K-W test. The test statistic (H) had a p-value of 0.000, both unadjusted and adjusted for ties, providing sufficient statistical support to reject H_0 in favor of H_1, and concluded that there is at least one statistical significant difference among factors. The z-value for "Total cost" factor is 3.46, the smallest absolute z-value, which indicates that the average rank for this factor differed least from the average rank for all observations. With the lowest z-value of -5.90, the average rank for "Administration Decision" was lower than the average rank for all other factors. With a z-value of 7.09, the average rank for "Patient outcome" factor was higher than the mean rank for all factors. The one-way ANOVA was also performed and showed that there is statistical evidence (p=0.00) of at least one significant difference among factors' means, which is consistent with the result from K-W.

Mann-Whitney U-test was performed on each factor for the two groups (SC and physicians) and results are shown below in Table 2.14. There is not enough statistical evidence to reject null

hypothesis and conclude that rankings of the populations are different for the "patient outcome", "manufacturer reputation", and "required storage space". This means that they are both agreeing on the importance of the patient outcome and unimportance of the other two. On the other hand, ranks from the two populations are statistically significantly different for "physicians' preference" for which the SC professionals think it is more influential than what physicians themselves think. SC professionals could be more perceptive to this since they have a big picture of the whole ordering process and more awareness of total cost, while physicians underestimated their preference influence. Ranks are also statistically significantly different for "total cost" factor, where for physicians it is more important than what SC professionals think. Again, physicians think that total cost is more important than their preference, while SC who purchases items said that physicians' preference is usually taken into consideration more than the cost which could be true since physicians are not totally aware of the total cost. The last factor "administration decision" has also shown a difference between the two groups' ranks with physicians rating it as an important factor while SC did not.

Table 2.14 Mann-Whitney U-test results on factors influencing organization's decision, for the two populations

Factor	Z - value	P-value	Decision and conclusion
Physicians' preference	-3.24	0.00	Reject H_0. There is a difference
Total cost	-2.69	0.00	Reject H_0. There is a difference
Patient outcome	-1.62	0.11	Fail to reject H_0. There is no difference
Manufacturer reputation	-0.35	0.73	Fail to reject H_0. There is no difference
Required storage space	-0.30	0.76	Fail to reject H_0. There is no difference
Administration decision	-4.35	0.00	Reject H_0. There is a difference

Cost information

Information collected regarding cost information included physicians' awareness of items' costs, costs' ranges of procedures they perform, their willingness to substitute an item in each range, percentage of PPIs from the items they use, costs of these PPIs.

When asked how knowledgeable they are about actual costs of items they use, 48.8% said they are highly aware, 29.3% said they are not, and 22% were neither which could mean that they are aware of some items but not all, or roughly aware. A one-sample sign test gave a p-value of 0.22 which indicates that the mean is not different than the neutral 4. A one-way χ^2 test also gave 0.32 which means that scores' categories are uniformly distributed and results could be not representative of the population. This could be due to the fact that data was based mainly on few healthcare organizations and did not include others who might have different policies. A relatively strong association was determined by the two-way χ^2 between physicians' knowledge level with items cost and their experience level, as shown in Table 2.15. It makes sense to be more aware of items cost when having more experience.

Table 2.15 Physicians' awareness of items' actual costs

Characteristic	Categories	Low importance 1, 2, 3 n (%)	Neutral 4 n (%)	5, 6, 7 Very important n (%)	Total	χ^2 Analysis	Gamma Analysis (If applicable)
Years of experience	< 2, 2 - 5, 6-10	4 (100)	0 (0)	0 (0)	4	χ^2 = 17.88 df=4, p= 0.00	γ = 0.47
	11-20	1 (7.7)	6 (46.2)	6 (46.2)	13	Cramer's V = 0.479	Z = 1.01
	> 20	5 (22.7)	3 (13.6)	14 (63.6)	22	**Relatively Strong Association**	**No Association**
Total		10	9	20	39		

The same question, awareness of the actual costs of items, was asked to the SC group. Of the total SC respondents, 100% indicated they are highly aware of the items' cost, which is an expected result. The score median is 7 and the one-sample sign test confirmed this result with a p-value of 0.00, also the one-way χ^2 gave a p-value of 0.00 indicating significance of data. The

two-way χ^2 analysis indicated that SC awareness of items' cost does not depend on any of the characteristics. The two subjects were compared for their awareness of actual items' cost, the Mann-Whitney U-test showed that the ranks from the two populations are statistically significantly different with p = 0.00 and Z=-6.6. The H_0 that there is no difference was rejected in favor of the H_1. Higher awareness within SC professionals' community was determined, this is because they directly issuing orders and negotiate prices with vendors.

When asked about the cost range of the procedures/surgeries that the physicians perform (Q13), 32% of total respondents perform procedures with cost greater than $10,000. The Physicians' willingness to substitute an equivalent item when performing a procedure in each of different cost categories was asked in a separate item, in Q14. The two-way χ^2 and γ tests were performed, and the resulting analysis showed an association between the first cost category (<$1,000) and the physicians' experience. A relatively strong relationship and a very strong relationship were determined by both, the χ^2 and γ, respectively as shown in Table 2.16. A possible explanation for this is that these kinds of surgeries are done by less experienced physicians as well as by highly experienced physicians. Highly experienced physicians, in contrast to less experienced physicians, may not really care about PPIs when doing low cost surgeries as when they do expensive surgeries. The K-W test was performed, and the test statistic (H) had a p-value of 0.90 and 0.89, both unadjusted and adjusted for ties, respectively. Hence, there was not enough statistical evidence to reject H_0, which means that there was no difference among groups' medians for willingness to substitute items. The physicians' willingness to substitute an item was initially thought to have some sort of a relationship with the cost range of procedures the physician works on. The reason behind this hypothesis was the assumption that the physician will have more restrictions on his preference when doing big value procedures.

However, they showed equal willingness, which is higher than neutral, across the different cost ranges. One-way ANOVA was also performed and came with a p-value of 0.966, which confirms the result from the K-W test.

Table 2.16 Willingness of physicians to substitute an equivalent item in the <$1,000 surgeries category by experience

Characteristic	Categories	Not willing 1, 2, 3 n (%)	Neutral 4 n (%)	5, 6, 7 Very willing n (%)	Total	χ^2 Analysis	Gamma Analysis (If applicable)
Years of experience	< 2, 2 - 5, 6-10	1 (50)	0 (0)	1 (50)	2	χ^2 = 9.75 df=4, p= 0.04	γ = 0.82
	11-20	1 (16.7)	3 (50)	2 (33.3)	6	Cramer's V = 0.57	Z = 2.20
	> 20	0 (0)	0 (0)	7 (100)	7	**Relatively Strong Association**	**Very Strong association**
Total		2	3	10	15		

A question about percentages from all items that are considered as PPIs was asked to physicians to have an idea about the size of the problem. More than 93% of physicians use items that can be classified as PPIs. This is consistent with the previous result of ordering permission, when just 10% said they are not permitted while the rest say they do. A pie-chart showing percentages of physicians who utilize items that fall in the category of PPIs for each PPIs percentage category is shown below in Figure 2.7.

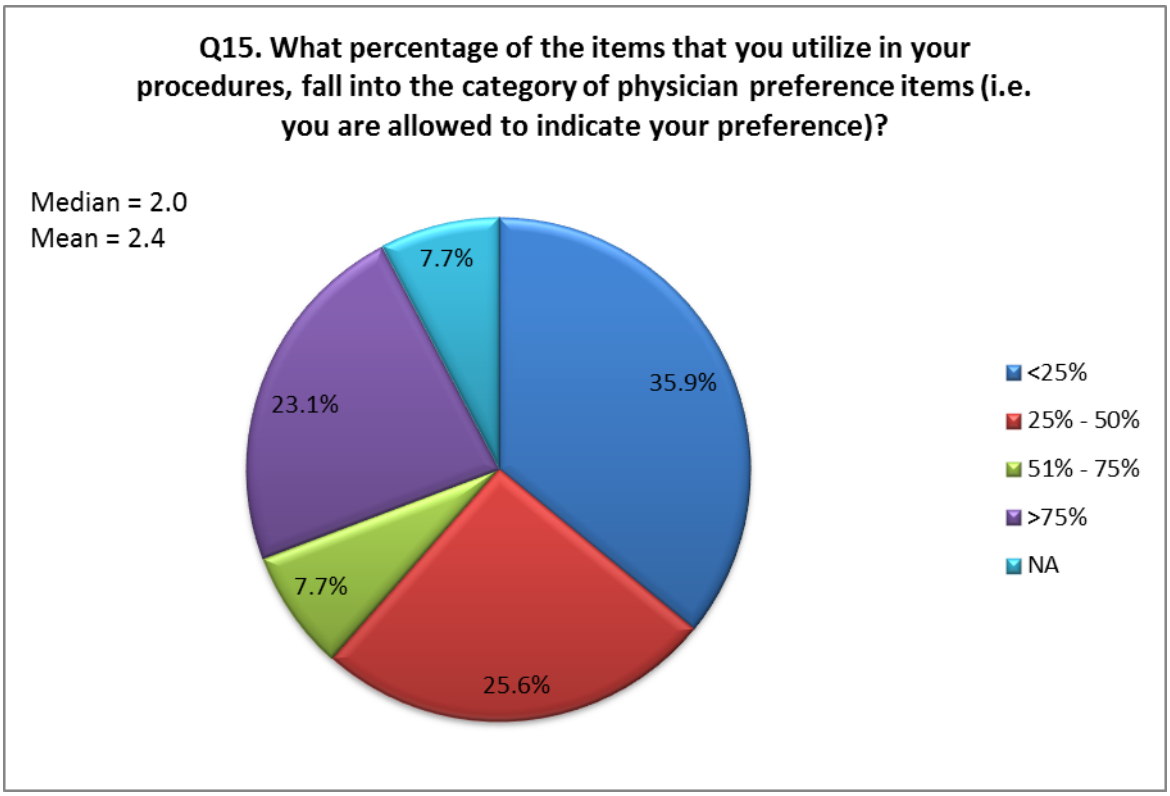

Figure 2.7 Breakdown of PPIs percentages from total items the physicians who utilize in their procedures

The median is (25%-50%) and the one-way sign test confirms this result with a p-value of 0.5. The one-way χ^2 test showed that the categories are not uniformly distributed. Overall weighted average of PPIs is 39.1% of total items. Regarding the costs of these PPIs items, the physicians were asked about their PPIs cost's characteristics and 90% of them indicated that it falls in one of the three categories (low, medium, or high) while 10% said it is not applicable. Of the total responses, 13% indicated a high cost category while 64% said it is in the medium cost category. With more than 77% of PPIs being medium expensive to very expensive, this issue is certainly of concern for healthcare organizations.

2.4.2 **Supply Chain Professionals' Perspective**

A table that summarize the results from all individual questions showing median, low score and high score percentages, and both the one-sample sign and one-way χ^2 tests is shown in Appendix E.2: Supply Chain Professionals.

SKU and PPI Influence

Information collected regarding SC professionals' knowledge about SKU and PPI terms and effects included awareness of the term SKU, possible cause for the SKU proliferation, awareness of the PPI term, awareness of the actual items' cost, and their opinion about important factors that are considered by the organization when making the decision. The last three items were discussed within the context of physicians' perspective as they were common questions to both populations.

When asked about their awareness of the term SKU proliferation, on a scale of 1-7, 91.5% of the SC professionals indicated that they are highly aware, and the median was 7. The one-sample sign test was performed and the resulting p-value was 0.00, H_0 was rejected in favor of H_1, concluding that the calculated median is significantly greater than 4 which support the conclusion that SC professionals are actually aware of the SKU proliferation concept. The one-way χ^2 test gave a p-value of 0.00; H_0 was rejected in favor of H_1. Both results conclude that the results are significant. A breakdown of the SC awareness in the term SKU proliferation by SC characteristics did not recognize any association between the awareness and any of these characteristic.

To learn more about what SC professionals think about what causes the SKU proliferation problem, they were asked to rank three possible factors (PPIs, growing size with limited space, unpredicted schedules of needed items) which are thought to be main potential reasons for the

SKU proliferation, results are shown in Figure 2.8. Despite the effect of big size organizations and forecasting on managing SKUs, SC professionals indicated that PPIs is the major reason for SKU proliferation with a score median of 6, while the unpredicted schedules of needed items came second with a score of 5, and finally the growing size with a score of 4. All factors were analyzed using one-sample sign test and one-way χ^2 test, both tests gave p-values <0.05 for all causes. Causes for proliferation scores' medians are statistically significantly deviated from the neutral; this confirms that both PPIs and unpredicted schedules are relatively important causes while the growing size is not. Also, scoring for all causes is significant and non-uniformly distributed. A breakdown of the three causes by all characteristics was conducted and results indicated that there is no association between causes and any of the characteristics; this tells that the SC group actually agrees on this ranking.

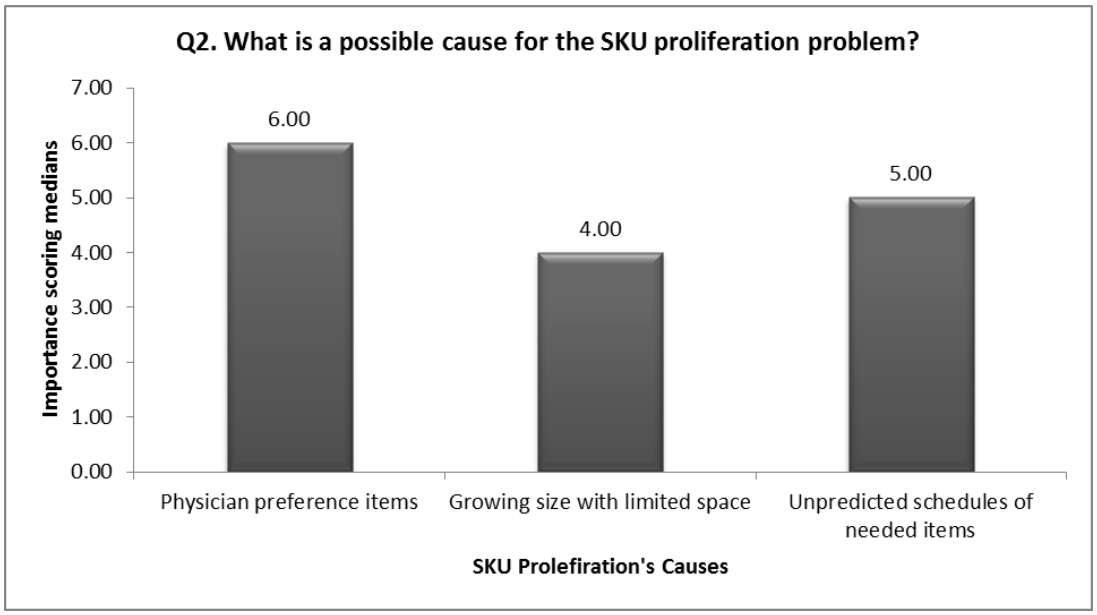

Figure 2.8 Causes of SKU proliferation according to SC professionals

The K-W test was performed, the test statistic (H) had a p-value of 0.000, both unadjusted and adjusted for ties, providing sufficient statistical support to reject H_0 in favor of H_1, and concluding that there is at least one statistical significant difference among SKU proliferation causes' medians. The z-value for the "unpredicted schedules of needed items" cause is -1.19, the smallest absolute z-value, which indicates that the average rank for this cause differed least from the average rank for all observations. The average rank for "Growing size with limited space" was lower than the average rank for the other two. Finally, with a z-value of 7.06, the average rank for the "PPI" cause was higher than the mean rank for all causes. The one-way ANOVA confirmed the results from the K-W.

Other causes for the SKU proliferation mentioned by respondents were: direct sales representative influence with physicians, variation in practice, lack of driving commitment on choices, new clinical technologies, and backorders/unavailability. These other reasons mentioned by SC professionals are mainly part of the PPIs. When the sales representative affects the physician's opinion, the item will become a PPI. New technology is another example of PPI.

Supply chain practices

This is the major body of the SC survey, where it captures in general three aspects of many practices in the supply chain context. Information collected about SC practices included the awareness of SC professionals about each practice, the extent to which this practice is implemented in the organization, and potential impact of implementing it. Practices investigated were sharing item's cost and total supply cost, spend analysis, capitated pricing, monitoring spending of individual physicians, ABC classification, cross-functional teams, and finally value analysis. These practices were identified from literature, see ((Wright 2006), (Alguire 2016),

(Baty, et al. 2014)), feedback from professionals who reviewed the survey before conducting it, as well as from the researchers experience and knowledge of supply chain. The survey attempted to understand f these practices are effective or not, and which one can be recommended as a best practice for SC within healthcare organizations.

When asked to what extent they share item cost and total supply cost with physicians, over 76% of the SC professionals indicated they highly share item's cost with physicians and near 12% said they do not, while near 23% said they do share the total supply cost and more than 59% they do not. The median score of sharing the item's cost is 6 while for the total supply cost it is 3. A one-sample sign test gave a p-value of <0.05 for both costs which confirms that scores' medians are statistically significantly deviated from the neutral. A one-way χ^2 test also gave a p-value of 0.00 for the item's cost and a p-value of 0.18 for the total supply cost. This means that scoring on sharing item's cost is not uniformly distributed and the results are significant, while a uniformly distributed scoring on sharing the total supply cost was detected meaning that the SC professionals are indefinite. A χ^2 analysis was conducted to determine whether sharing any of the two costs depends on any of the SC characteristics; no association was detected.

Mann-Whitney U-test showed that the ranks from the two cost types are statistically significantly different with p = 0.00 and Z=-4.8. The H_0 that there is no difference was rejected in favor of the H_1. It could be assumed that they do not know the total cost information, or it is too much detail to share the total supply cost with physicians. However, it is important to learn what SC professionals think about the potential impact of sharing each of these costs. Two separate questions were asked to them about their perspective of the perceived potential impact of sharing item's cost and total supply cost with physicians. Of the total responses, 92% and 72% think that sharing item cost and total supply cost, respectively, have high potential impact. The

one-sample sign test and χ^2 tests gave p-values of 0.00 for both questions, which means that the results are significant. The two-way χ^2 analysis showed that there is no association with any of the characteristics for both variables.

Results for potential impact of sharing item cost were filtered by those who share it and those who do not, Mann-Whitney U-test gave a z value of -0.77 and associated p-value of 0.44, which means there is no significant statistical difference between the two rankings and all believe that sharing item cost has high potential impact on managing PPIs. Same was done on the perceived potential impact of sharing total supply cost with physicians, and all SC professionals either they share it or not, they think it has a high potential impact on managing the PPIs, z value of -1.08 and p-value of 0.28. Since just 23% are sharing the total supply cost, it becomes clear that healthcare organizations need to adopt this practice and activate the sharing channel with physicians, especially for the total supply cost.

The second practice being discussed is the spend analysis. Over 95% of the total respondents indicated that they are highly aware of this practice and none said they are not. The one-sample sign test and one-way $\chi 2$ test both gave p-value of 0.00, which indicates that scoring is significant and the median is statistically significantly deviated from the neutral. A χ^2 analysis was conducted to determine whether SC professionals' awareness of spend analysis practice depends on any of the SC characteristics; no association was detected. In another question when they were asked about implementing spend analysis on their PPIs, with a score median of 6, 85% of the total respondents indicated that they always do. The one-sample sign and one-way χ^2 tests both gave p-values of 0.00, this validates the significance of the results that healthcare organizations perform spend analysis on their PPIs. A two-way χ^2 analysis was performed to investigate any association between applying spend analysis on PPIs and any of

characterizations. A very strong positive association between applying spend analysis practice within the department's annual purchasing budget was detected by the gamma test. The same result was detected by the χ^2 as shown in Table 2.17 . Clearly, when the department's purchasing budget increases, the organization pays more attention to analyze spending on PPIs for more savings opportunities.

Table 2.17 Applying spend analysis practice by healthcare characterstics

Characteristic	Categories	Not at all 1, 2, 3 n (%)	Neutral 4 n (%)	5, 6, 7 Always n (%)	Total	χ^2 Analysis	Gamma Analysis (If applicable)
Department's annual purchasing budget	<$5M	0 (0)	4 (44.4)	5 (55.6)	9	χ^2 = 14.70 df=6, p= 0.02	γ = 0.76
	$5M - <$20M	1 (11.1)	1 (11.1)	7 (77.8)	9	Cramer's V = 0.413	Z = 2.34
	$20M - <$50M	0 (0)	1 (25)	3 (75)	4	**Relatively Strong Association**	**Very Strong positive association**
	>$50M	0 (0)	0 (0)	21 (100)	21		
Total		1	6	36	43		

A following question about frequency of conducting spend analysis on their PPIs relative to other items was asked for those who said they do spend analysis. of total respondents, 64% said they perform spend analysis on their PPIs more than other regular items, while near 21% said they do it the same, and 15% less than other items. The 64% indicates that PPIs is indeed an issue and potential savings could be made by focusing more on PPIs than on other standardized items. Frequency of performing a spend analysis on PPIs relative to other items does not depend on any of the healthcare organization's characteristics according to the two-way χ^2. Another two-way χ^2 analysis was performed to investigate any association between frequency of performing spend analysis on PPIs relative to other items and the previous two variables (awareness of the practice and if they perform it on their PPIs). A moderate association was determined by the χ^2 with the SC professionals' awareness of the practice, and a strong association with whether they perform spend analysis on their PPIs or not was detected by both χ^2 and gamma. Results are shown in Table 2.18. This means that with increased awareness among SC professionals the practice, they will perform it more on their PPIs, also if they do it on their PPIs, they will do it

more on PPIs than on other items. This provides evidence that they have realized the good impact on managing PPIs using this practice. This argument is telling healthcare organizations increase awareness of this practice and encourage SC to perform it on their PPIs as an advice from peers.

Table 2.18 Frequency of applying spend analysis on PPIs relative to other items by awareness and performing the practice

Independent Variable	Categories	Less n (%)	The same n (%)	More n (%)	Total	χ^2 Analysis	Gamma Analysis (If applicable)
Q9. To what extent are you aware of spend analysis practices?	Not aware 1,2,3	0	0	0	0	χ^2 = 11.94 df=4, p= 0.02	γ = 1.00
	Neutral 4	2 (100)	0 (0)	0 (0)	2	Cramer's V = 0.356	Z = N/A
	Highly aware 5,6,7	5 (11.1)	10 (22.2)	30 (66.7)	45	**Moderate Association**	**No Association**
	Total	7	10	30	47		
Q10. To what extent do you perform spend analysis on your PPIs?	Not at all 1,2,3	0 (0)	0 (0)	1 (100)	1	χ^2 = 25.93 df=4, p= 0.00	γ = 0.74
	Neutral 4	5 (83.3)	0 (0)	1 (16.7)	6	Cramer's V = 0.525	Z = 2.01
	Always 5,6,7	2 (5)	10 (25)	28 (70)	40	**Relatively Strong Association**	**Strong positive Association**
	Total	7	10	30	47		

A validation and support or vice versa of the above argument could be obtained by asking SC professionals directly about their perceived potential impact of this practice on managing PPIs. More than 89% of the total respondents indicated that spend analysis has a high potential impact on managing PPIs, while just 2% said it does not and 8.5% were in between. The score median is 6, and both the one-sample sign and one-way χ^2 tests gave p-values of 0.00, indicating significant results. A χ^2 analysis was conducted, a relatively strong association of the perceived potential impact was determined with the department's annual purchasing budget. The higher the department's purchasing budget, the higher the perceived potential impact as seen by SC professionals. Negative very strong association of the perceived potential impact with the job title was found by the γ analysis. Higher job titles believe more in this practice. Another χ^2 analysis determined that a moderate association exist between the perceived potential impact of spend analysis on managing PPIs and the frequency of performing spend analysis on PPIs. Those who are conducting the spend analysis on their PPIs more than regular items have more faith in

its potential impact on managing PPIs. Actually, they will not spend the time and effort on doing this practice if they did not find it fruitful.

To look more in the process of spend analysis, SC professionals were asked about sharing spend analysis data with physicians, 74.5% said they do share the data with physicians while 10.6% do not and 14.9% were in between. The one-sample sign and one-way χ^2 tests both gave p-value of 0.00 indicating significance of results. A two-way χ^2 analysis showed that perceived potential impact of spend analysis practice has a relationship with whether spend analysis data is shared with the physicians or not, as shown in Table 2.19. Those who share the spend analyses data with physicians, have more faith in the potential impact of this practice. No association between level of sharing spend analysis data with physicians with any of the characteristics was captured. In another question, SC professionals were asked about if they think the spend analysis data should be shared with physicians or not, 95.7% indicated that it should be shared. One-sample sign test and one-way χ^2 test gave p-values of 0.00 which indicates that data is significant. No association with any of the SC characteristics was recognized for this question.

Table 2.19 Perceived potential impact of spend analysis by sharing spend analysis data with physicians

Characteristic	Categories	No impact 1, 2, 3 n (%)	Neutral 4 n (%)	5, 6, 7 High impact n (%)	Total	χ^2 Analysis	Gamma Analysis (If applicable)
Q13. Sharing spend analysis data with physicians	Not at all 1,2,3	1 (20)	0 (0)	4 (80)	5	χ^2 = 9.18 df=4, p= 0.05	γ = 0.37
	Nuetral 4	0 (0)	1 (14.3)	6 (85.7)	7	Cramer's V = 0.313	Z = 0.37
	Always 5,6,7	0 (0)	3 (8.6)	32 (91.4)	35	**Moderate Association**	**No Association**
	Total	1	4	42	47		

The third practice was looked at is the capitated pricing. When asked about awareness of the practice, more than 91% indicated they are aware while the rest were divided between unaware and neutral. Both the one-sample sign and one-way χ^2 tests gave 0.00 for the p-values, indicating

that data is significant and further investigation for following questions can be trusted. No association with any of the healthcare organization characteristics was recognized. In another question, they were asked on the frequency of implementing capitated pricing on PPIs relative to regular items, and near 70% said they use it more on PPI than on other items, while 21.7% use it with the same frequency. No association of the frequency of applying capitated pricing with any of the healthcare organization characteristics was recognized. To learn more about the benefit of using this practice, SC professionals were asked about the potential of utilizing capitated pricing on controlling PPIs. Of total respondents, 73.9% indicated a high potential impact of using capitated pricing on controlling PPIs, while17.4% neutral 8.7% no impact. Both the one-sample sign and one-way χ_2 tests gave 0.00 for the p-values, indicating that data is significant. No association with any of the healthcare organization was recognized.

A χ^2 and gamma analysis were performed to determine if SC professionals perceived potential impact of using capitated pricing depends on awareness and/or frequency of use. The results, presented in Table 2.20, indicate that the perceived potential impact of using capitated pricing practice on controlling PPIs depend on both the awareness of the practice and frequency of use. A moderate association with the awareness was recognized by the χ^2, which mean that the more awareness the SC professionals have, the more understanding of it capabilities and therefore the more appreciation of its potential impact.

Table 2.20 Potential impact of using capitated pricing on controlling PPIs by awareness and frequency of use

Characteristic	Categories	No Impact 1, 2, 3 n (%)	Neutral 4 n (%)	5, 6, 7 High Impact n (%)	Total	χ^2 Analysis	Gamma Analysis (If applicable)
Awareness of capitated pricing	Not aware 1,2,3	0 (0)	0 (0)	2 (100)	2	χ^2 = 10.50 df=4, p= 0.03	γ = 0.33
	Nuetral 4	0 (0)	2 (100)	0 (0)	2	Cramer's V = 0.338	Z = 0.29
	Highly aware 5,6,7	4 (9.5)	6 (14.3)	32 (76.2)	42	**Moderate Association**	**No Association**
	Total	4	8	34	46		
Frequency of using capitated pricing on PPIs relative to	Less	1 (25)	2 (50)	1 (25)	4	χ^2 = 11.24 df=4, p= 0.02	γ = 0.74
	The same	2 (20)	3 (30)	5 (50)	10	Cramer's V = 0.35	Z = 2.35
	More	1 (3.1)	3 (9.4)	28 (87.5)	32	**Moderate Association**	**Strong Positive Association**
	Total	4	8	34	46		

Potential impact of using capitated pricing also depends on the frequency of using it, as captured by both tests with the gamma analysis indicating it as strong association. The average and median scores of potential impact for the frequency of use categories (less, the same, more) are: (3.5, 4.6, and 5.7) and (4, 4.5, and 6), respectively. The K-W test was performed and the resulting test statistic (H) had a p-value of 0.01, both unadjusted and adjusted for ties, providing sufficient statistical support to reject H_0 in favor of H_1, and concluded that there is at least one statistical significant difference among the categories. The z-value for "the same" category was 1.76, the smallest absolute z-value, which indicates that the average rank for this group differed least from the average rank for all observations. With a z-value of -2.18, the average rank for "less" category was lower than the average rank for "the same" and "more" categories. With a z-value of 2.91, the average rank for "more" category was higher than the mean rank for the other two groups. ANOVA was also performed and resulted in a p-value of 0.01 which confirms the same result of the K-W. Those who practice capitated pricing on their PPIs more than regular items have indicated a more potential impact of the practice on controlling PPIs. Increasing awareness and frequency of use on this practice is recommended for healthcare organizations.

Spending by individual physicians could be a sign on how much the physician use PPIs. When SC professionals were asked about monitoring individual physicians spending when making decisions regarding PPIs, 71.7% said they do, while 17.4% do not, and 10.9% in between. Results are significant according to the one-sample sign and one-way χ^2 tests. A χ^2 analysis was performed to determine if there is any association between monitoring spending of individual physicians and the perceived potential of utilizing the capitated pricing on controlling PPIs. A relatively strong association was determined, meaning that those who monitor individual spending see a potential impact on controlling their PPIs.

Another related question was if physicians' spending is compared to budgeted amounts. Of total respondents, 45.6% said they do, 34.8% do not, and 19.6% were neutral. The score median is 4 (neutral) which was confirmed by the one-sample sign test with a p-value of 0.51. Also the one-way χ^2 gave a p-value of 0.73 indicating a uniform distributed scoring across the scale. Organizations in general do not set up budgets for their physicians to refer to when monitoring individual spending. Setting budgets is not easy due to the nature of service and variability in forecasting. One last question on this practice was if the organizations compare physicians to each other on their spending habits, 70% said they do, while 15.2% do not. This is seen as benchmarking with performance measure as the lowest spending relative to amount worked (revenue generated). The score median was 5, and both the one-sample sign and one-way χ^2 tests gave p-value of 0.00. A χ^2 analysis showed an association between comparing physicians to each other and job title of the respondents as shown in Table 2.21. The moderate association shows that higher positions said they do compare physicians on their spending habits, this means we can confidently say that this is actually done. More importantly, it indicates that this practice is done on higher management levels and healthcare organizations do watch physicians on their spending and compare them to each other in a step to evaluate their performance.

Table 2.21 Comparing physicians to each other on their spending habits by job title

Characteristic	Categories	Not at all 1, 2, 3 n (%)	Neutral 4 n (%)	5, 6, 7 Always n (%)	Total	χ^2 Analysis	Gamma Analysis (If applicable)
Job Title	Executive (CEO, CFO, CIO, President)	0 (0)	1 (50)	1 (50)	2	χ^2 = 14.06 df=6, p= 0.03	γ = -0.29
	Vice president	0 (0)	3 (17.6)	14 (82.4)	17	Cramer's V = 0.4	Z = -0.45
	Director	7 (35)	1 (5)	12 (60)	20	**Moderate Association**	**No Association**
	Manager	0 (0)	2 (40)	3 (60)	5		
	Total	7	7	30	44		

The fourth practice which was investigated is ABC classification. When asked about their awareness of the ABC practice, more than 82% said they are aware and 11% are not. The score median was 7 and both the one-sample sign and one-way $\chi 2$ tests gave p-values of less than 0.05.

The frequency of conducting an ABC classification was asked in next question with options (Never, daily, weekly, monthly, and yearly). More than 70% do it at least yearly, half indicated they do it yearly, while 29% have never done it, see Figure 2.9 below.

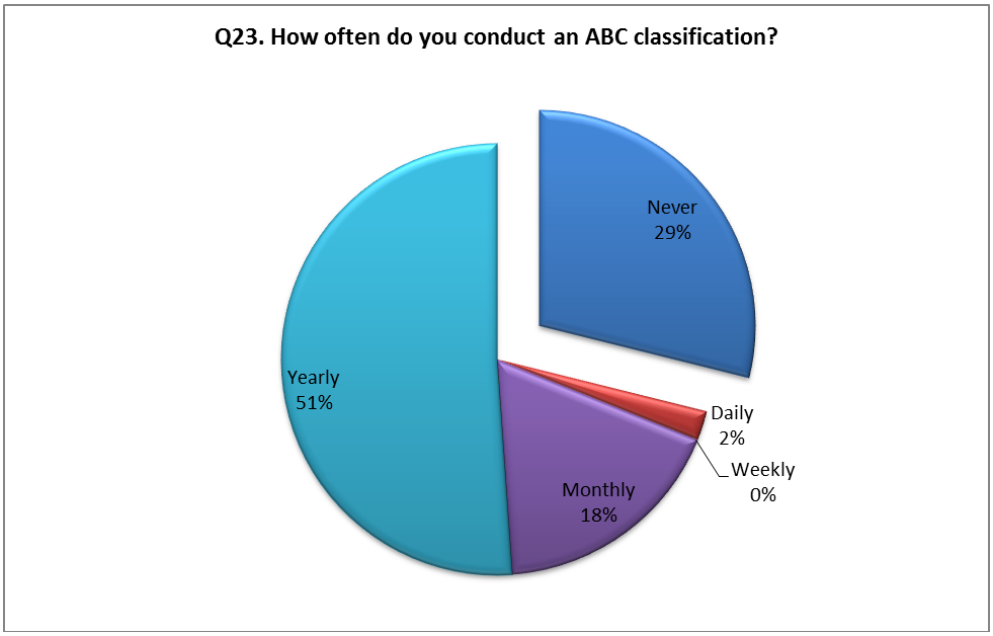

Figure 2.9 Frequency of performing ABC classification

In two separate questions, SC professionals were asked if they use ABC classification based on value and usage. Proportions of those who said they use, do not use, and in-between were 34.4%, 34.4%, and 31.2% for the value, respectively. While based on usage proportions were 39.4%, 30.4%, and 21.2%, respectively. Score median is 4 for both which is confirmed by the one-sample sign test, and obviously both distributions seem to be uniform, which is confirmed by one-way χ^2 tests. When asked if they share ABC classification data with physicians, just 16% said they do, and 71% do not share it. It seems to be much detail to share with physicians who might not have the time look at. The one-sample sign test and one-way χ^2 test gave p-values less than 0.05. When asked if ABC classification should be shared with physicians or not, 56% said it

should be. The score median was 5, and the one-sample sign test confirmed this with p-value of 0.04. Scoring distribution is uniformly distributed according to the one-way χ^2 with p-value 0.13.

When asked about their perceived potential impact of utilizing ABC classification on controlling PPIs, 44.4% said it does have potential in controlling PPIs, while 37.8% said it does not. The one-sample sign and one-way $\chi 2$ tests both gave p-values of 0.74 and 0.07, respectively. This indicates that the median score is actually 4 and results are uniformly distributed. The SC professionals seem to not have much trust in this practice as an effective way to control PPIs. A breakdown of the perceived potential impact by using ABC classification based on value and based on usage, sharing ABC classification data with physicians, and if the data should be shared or not showed is shown in Table 2.22 below. The χ^2 analysis shows a moderate association with utilizing ABC classification based on value and usage.

Table 2.22 Percieved potential impact of utilizing ABC classification on controlling PPIs by actual using it and data sharing

Characteristic	Categories	No Impact 1, 2, 3 n (%)	Neutral 4 n (%)	5, 6, 7 High Impact n (%)	Total	χ^2 Analysis	Gamma Analysis (If applicable)
The extent of utilizing ABC classification on PPIs based on value.	Not at all 1,2,3	7 (63.6)	2 (18.2)	2 (18.2)	11	χ^2 = 10.07 df=4, p= 0.04	γ = 0.62
	Nuetral 4	1 (10)	2 (20)	7 (70)	10	Cramer's V = 0.397	Z = 1.62
	Always 5,6,7	2 (18.2)	1 (9.1)	8 (72.7)	11	**Moderate Association**	**No Association**
	Total	10	5	17	32		
The extent of utilizing ABC classification on PPIs based on usage.	Not at all 1,2,3	8 (61.5)	1 (7.7)	4 (30.8)	13	χ^2 = 9.76 df=4, p= 0.04	γ = 0.56
	Nuetral 4	1 (14.3)	1 (14.3)	5 (71.4)	7	Cramer's V = 0.391	Z = 1.32
	Always 5,6,7	1 (8.3)	3 (25)	8 (66.7)	12	**Moderate Association**	**No Association**
	Total	10	5	17	32		
The extent of sharing ABC classification data with physicians.	Not at all 1,2,3	10 (45.5)	2 (9.1)	10 (45.5)	22	χ^2 = 6.21 df=4, p= 0.18	γ = 0.65
	Nuetral 4	0 (0)	1 (25)	3 (75)	4	Cramer's V = NA	Z = 1.41
	Always 5,6,7	0 (0)	1 (20)	4 (80)	5	**No Association**	**No Association**
	Total	10	4	17	31		
To what extent ABC classification data should be shared with physicians.	Not at all 1,2,3	6 (75)	1 (12.5)	1 (12.5)	8	χ^2 = 13.72 df=4, p= 0.01	γ = 0.78
	Nuetral 4	2 (33.3)	2 (33.3)	2 (33.3)	6	Cramer's V = 0.463	Z = 2.91
	Always 5,6,7	2 (11.1)	2 (11.1)	14 (77.8)	18	**Relatively Strong Association**	**Very strong association**
	Total	10	5	17	32		

Another very strong association with their opinion of sharing the data with physicians was recognized by the gamma analysis, as well as by the χ^2. Those who believe the data should be shared also believe in the potential of ABC classification as a good practice in controlling PPIs. Interestingly, 56% of them are vice presidents and 39% are directors, the original job titles percentages were 39% for vice president and 45% for directors. Believing in this practice from top level management will point out its effectiveness.

The fifth practice is cross-functional teams, as it is assumed to be utilized especially for the PPIs. When asked about utilizing it in their organizations, 71.7% of the SC professionals said it is utilized, while 17.4% said it is not. The score median was 6, and the one-sample sign test gave a p-value of 0.00 which confirms this result. Also the one-way χ^2 test gave a p-value of 0.00 indicating significance of the results. A $\chi 2$ analysis shown below in Table 2.23, indicates that utilizing cross-functional teams depends on years of experience and department's purchasing budget. Dependence on experience could be because respondents with low experience are actually not included in the process and consequently may not be aware of it. On the other hand, the higher the purchasing budget is, the more they utilize this practice, which is expected. This is due to the need for more structured and organization of selection's decisions, due to the sensitivity of small margins on the big scale of purchasing.

Table 2.23 Utilizing cross-functional teams by experience and purchasing budget

Characteristic	Categories	Not at all 1, 2, 3 n (%)	Neutral 4 n (%)	5, 6, 7 Always n (%)	Total	χ^2 Analysis	Gamma Analysis (If applicable)
Years of experience	< 2, 2 - 5, 6-10	0 (0)	3 (33.3)	6 (66.7)	9	χ^2 = 10.60 df=4, p= 0.03	γ = 0.25
	11-20	5 (35.7)	1 (7.1)	8 (57.1)	14	Cramer's V = 0.339	Z = 0.35
	> 20	3 (13)	1 (4.3)	19 (82.6)	23	**Moderate Association**	**No Association**
	Total	8	5	33	46		
Department's annual purchasing budget	<$5M	1 (11.1)	1 (11.1)	7 (77.8)	9	χ^2 = 15.50 df=6, p= 0.02	γ = 0.44
	$5M - <$20M	5 (55.6)	1 (11.1)	3 (33.3)	9	Cramer's V = 0.425	Z = 0.84
	$20M - <$50M	1 (25)	0 (0)	3 (75)	4		
	>$50M	0 (0)	2 (9.5)	19 (90.5)	21	**Relatively Strong Association**	**No Association**
	Total	7	4	32	43		

When asked if the procurement (supply chain) department is represented in the cross-functional team, 87.5% said they are highly represented, while12.5% said the representation is not significant. When they were asked if the physicians are represented, 68.3% said they are, while 31.7% said they are not effectively represented. A $\chi 2$ analysis showed that representing physicians in the cross-functional teams depends on the purchasing budget, results in Table 2.24. The strong association means that physicians are more represented in cross-functional teams within bigger organizations.

Table 2.24 Representing physicians in cross-fucntional teams by purchasing budget

Characteristic	Categories	Not at all 1, 2, 3 n (%)	Neutral 4 n (%)	5, 6, 7 Always n (%)	Total	χ^2 Analysis	Gamma Analysis (If applicable)
Department's annual purchasing budget	<$5M	2 (25)	4 (50)	2 (25)	8	χ^2 = 14.79 df=6, p= 0.02	γ = 0.74
	$5M - <$20M	1 (20)	2 (40)	2 (40)	5	Cramer's V = 0.441	Z = 2.42
	$20M - <$50M	0 (0)	0 (0)	4 (100)	4		
	>$50M	0 (0)	3 (14.3)	18 (85.7)	21	**Relatively Strong Association**	**Strong Association**
Total		3	9	26	38		

When asked whether they discuss PPIs in cross-functional team meetings or not, 75.6% said they do discuss PPIs while 12.2% said they rarely do. The score median was 6, and the one-sample sign test gave a p-value of 0.00 confirming the result. The one-way $\chi 2$ also gave a p-value of 0.00. A very strong association with purchasing budget was recognized by the γ analysis as shown in Table 2.25 below. Two points could be learned from this; the first is that PPIs are discussed within healthcare organizations which may permit negotiations over the selection process. Second point is that more focusing on PPIs is found in bigger healthcare organizations, this means that PPIs inevitably have high potential of savings and cross-functional team is an effective way of doing so.

Table 2.25 Discussing PPIs in cross-functional team meetings by purchasing budget

Characteristic	Categories	Not at all 1, 2, 3 n (%)	Neutral 4 n (%)	5, 6, 7 Always n (%)	Total	χ^2 Analysis	Gamma Analysis (If applicable)
Department's annual purchasing budget	<$5M	4 (50)	0 (0)	4 (50)	8	χ^2 = 23.22 df=6, p= 0.00	γ = 0.76
	$5M - <$20M	0 (0)	2 (40)	3 (60)	5	Cramer's V = 0.553	Z = 2.43
	$20M - <$50M	0 (0)	1 (25)	3 (75)	4		
	>$50M	0 (0)	1 (4.8)	20 (95.2)	21	**Relatively Strong Association**	**Very Strong Association**
	Total	4	4	30	38		

To validate this conclusion, they were asked about their perceived potential impact of utilizing cross-functional team meetings on controlling PPIs, 85% said it is effective practice while just 8.7% said it is not. Score median was 6, and both the one-sample sign and $\chi 2$ tests gave p-values of 0.00, indicating significant results. A very strong association was determined by the γ analysis. Those who actually utilized cross-functional teams in their organizations found it an effective practice in controlling PPIs and improving the selection process.

Table 2.26 Perceived potential impact of utilizing cross-functional teams on controlling PPIs by using it

Characteristic	Categories	No Impact 1, 2, 3 n (%)	Neutral 4 n (%)	5, 6, 7 High Impact n (%)	Total	χ^2 Analysis	Gamma Analysis (If applicable)
Utilizing cross-fucntional teams	Not at all 1,2,3	4 (50)	1 (12.5)	3 (37.5)	8	χ^2 = 33.56 df=4, p= 0.00	γ = 0.95
	Nuetral 4	0 (0)	2 (40)	3 (60)	5	Cramer's V = 0.604	Z = 7.38
	Always 5,6,7	0 (0)	0 (0)	33 (100)	33	**Strong Association**	**Very Strong Association**
	Total	4	3	39	46		

Results of the $\chi 2$ analysis, represented in Table 2.27, indicate the perceived potential impact of utilizing cross-functional teams on controlling PPIs depends on two of organization's characteristics, purchasing budget and organization's settings. Bigger organizations seem to be more receptive to this practice and consequently found it effective.

Table 2.27 Perceived potential impact of utilizing cross-functional teams on controlling PPIs by organization's characteristics

Characteristic	Categories	Not at all 1, 2, 3 n (%)	Neutral 4 n (%)	5, 6, 7 Always n (%)	Total	χ^2 Analysis	Gamma Analysis (If applicable)
Department's annual purchasing budget	<$5M	1 (11.1)	1 (11.1)	7 (77.8)	9	χ^2 = 15.40 df=6, p= 0.02	γ = 0.66
	$5M - <$20M	3 (33.3)	2 (22.2)	4 (44.4)	9	Cramer's V = 0.423	Z = 1.62
	$20M - <$50M	0 (0)	0 (0)	4 (100)	4		
	>$50M	0 (0)	0 (0)	21 (100)	21	**Relatively Strong Association**	**No association**
	Total	4	3	36	43		
Organization's setting?	National	0 (0)	0 (0)	9 (100)	9	χ^2 = 12.62 df=6, p= 0.05	
	Rural	3 (30)	1 (10)	6 (60)	10	Cramer's V = 0.397	
	Suburban	0 (0)	2 (15.4)	11 (84.6)	13		
	Urban	0 (0)	0 (0)	8 (100)	8	**Moderate Association**	
	Total	3	3	34	40		

The sixth and last practice investigated is the value analysis or process. When asked how aware they are of the value analysis process, all of the responses (100%) indicated that they are highly aware. This could be due to the versatile use of this process in healthcare organizations as well as other kind of organizations to assess the value of items and processes. When asked about the extent to which physicians are included in the value analysis process, 65.2% indicated that physicians are included in the process while 28.3% said they are not and remaining were in-between. The median score was 5, and the one-sample sign test confirmed this result with a p-value of 0.01 which provides statistical evidence that the median is greater than 4. The one-way χ^2 test gave a p-value of 0.04 which indicates significance of data. A χ^2 analysis was performed to determine if including the physicians in the value analysis process has any association with any of the characteristics.

The results, shown in Table 2.28, indicate the only association with department's annual purchasing budget, χ^2 determined it as relatively strong and γ confirmed the dependence with strong relationship. The healthcare organizations with more purchasing budgets seem to insist more on including physicians in the process. This could be due to the benefits they see from this process.

Table 2.28 Including physicians in the value analysis process by department's annual purchasing budget

Characteristic	Categories	Not at all 1, 2, 3 n (%)	Neutral 4 n (%)	5, 6, 7 Always n (%)	Total	χ^2 Analysis	Gamma Analysis (If applicable)
Department's annual purchasing budget	<$5M	6 (66.7)	0 (0)	3 (33.3)	9	χ^2 = 17.02 df=6, p= 0.01	γ = 0.71
	$5M - <$20M	4 (44.4)	1 (11.1)	4 (44.4)	9	Cramer's V = 0.445	Z = 2.41
	$20M - <$50M	0 (0)	0 (0)	4 (100)	4		
	>$50M	1 (4.8)	2 (9.5)	18 (85.7)	21	**Relatively Strong Association**	**Strong Association**
	Total	11	3	29	43		

One more piece of the puzzle is to learn about their perceived potential impact of utilizing value analysis on controlling PPIs. When asked this question, 89% indicated a high potential impact of this practice on controlling the PPIs, while just 6.7% disagreed. This result is expected due to the wide use and knowledge of this practice in all other sectors. No association was determined by the χ^2 analysis with characteristics. A χ^2 analysis was performed to determine if the perceived potential impact depends on whether physicians are included in the value analysis process. The results, shown in Table 2.29, indicate a moderate association was recognized by the χ^2 analysis but no association was determined by the γ analysis.

Table 2.29 Perceived potential impact of value analysis process on controlling PPIs by including physicians in the process

Characteristic	Categories	No Impact 1, 2, 3 n (%)	Neutral 4 n (%)	5, 6, 7 High Impact n (%)	Total	χ^2 Analysis	Gamma Analysis (If applicable)
Including physicians in the process of value analysis	Not at all 1,2,3	3 (23.1)	0 (0)	10 (76.9)	13	χ^2 = 14.23 df=4, p= 0.01	γ = 0.70
	Nuetral 4	0 (0)	1 (33.3)	2 (66.7)	3	Cramer's V = 0.398	Z = 1.47
	Always 5,6,7	0 (0)	1 (3.4)	28 (96.6)	29	**Moderate Association**	**No Association**
	Total	3	2	40	45		

Those who include their physicians in the value analysis process realize more the potential impact of this practice on controlling PPIs. The value analysis practice is the inspiration of another research where a decision making framework based on multi-criteria decision making techniques will be developed.

Last question within the practices' items was an open question which requested respondents to provide any additional practices they think are important but were not included in the survey. Here are what they provided after shortening text to meaningful names and removing redundant.

A summary of key hypotheses with the tests used and conclusions are summarized in Table 2.30 below.

Table 2.30 Summary of key hypotheses with tests used and the conclusions

Hypothesis	**Test Used**	**Conclusion**
Physicians are aware of the term PPI	One-Sign	Yes
Physician awareness of the term PPI depends on characteristics	Two-way $\chi 2$	No association
Physicians are more aware of the term than SC	Mann-Whitney U	No, SC are more aware
Physicians are not willing to use available non-preferred items	One-Sign	No, they are willing
Physicians willingness to use non-preferred items depends on characteristics	Two-way $\chi 2$	Yes, on years of experience
Physicians are permitted to order their preferred items	One-Sign	Yes
Physicians permission to order their preferred brands depends on characteristics	Two-way $\chi 2$	No association
Physicians who are aware of the PPI term, are more willing to use available items in stock	Two-way $\chi 2$	No association
Ordering permission affects physicians' willingness to use available items in stock	Two-way $\chi 2$	Yes, those who are not permitted are more willing to use available items in stock
Factors significance affecting physician preference	One-Sign, Kruskal-Wallis	"Item effectiveness" and "previous experience with the item" are the most important
Factors significance affecting physician preference depends on characteristics	Two-way $\chi 2$	Yes, on years of experience
Patient's preference is important to the physician when selecting the item	One-Sign	No, it is not important
Physicians are knowledgeable on how the organization make decision	One-Sign	No, they are not aware
Physicians have high ability to influence the decision to select an item	One-Sign	No, they are not highly able
physicians' ability to influence the organization's decision depends on characteristics	Two-way $\chi 2$	Yes, on years of experience
Physicians are aware of the items actual costs	One-Sign	They are neither aware nor not aware

Table 2.30 Summary of key hypotheses with tests used and the conclusions (Cont.)

Hypothesis	Test Used	Conclusion
Physicians willingness to substitute an equivalent item is less within the high cost surgeries	Kruskal-Wallis	No, they have the same willingness among all cost categories
SC professionals think the physicians preference is a major contributor to the SKU proliferation problem	One-sign, Kruskal-Wallis	Yes, it is affecting and significantly more than other factors
SC professionals believe that sharing item cost with physicians will have potential impact on controlling PPIs	One-Sign	Yes, it significantly has a potential impact on controlling PPIs
SC professionals perform spend analysis on their PPIs	One-Sign	Yes
Performing spend analysis on PPIs depends on characterizations	Two-way $\chi 2$	Yes, depends on department's annual purchasing budget
SC professionals perform spend analysis on their PPIs more than regular items	One-sign	Yes, they do it more on PPIs
SC professionals believe that performing spend analysis will have potential impact on controlling PPIs	One-Sign	Yes, it has potential impact
SC professionals are highly aware of the capitated pricing practice	One-sign	Yes, they are aware
SC professionals believe that performing capitated pricing will have potential impact on controlling PPIs	One-Sign	Yes, it has potential impact
SC professionals perceived potential impact of capitated pricing depends on the frequency of performing the practice	Two-way $\chi 2$	Yes, those who do it more frequently believe more in this practice as a good practice for managing PPIs
SC professionals are aware of the ABC classification practice	One-Sign	Yes, they are aware
SC professionals believe that performing ABC classification will have potential impact on controlling PPIs	One-Sign	No, it does not help with controlling PPIs, it is not a good practice for this purpose
SC professionals are aware of the value analysis practice	One-Sign	Yes, they are aware
SC professionals believe that performing value analysis will have potential impact on controlling PPIs	One-Sign	Yes, it helps controlling PPIs

2.5 Discussion

Physician preference items management aspects included in both, physicians and SC professionals surveys and summarized in this article included preference characterization, decision process, and practices that could have impact. Where appropriate, physicians' survey responses were segmented according to years of experience (<2, 2-5, 6-10, 11-20, >20),

organization's setting (rural, suburban, urban), employment type (hospital employed, contracted physician group, community physician), and compensation model (Per wRVU, percentage of net collections, percentage of practice, percentage of gross charges, per encounter, guaranteed base plus incentives). While SC survey responses were also segmented by years of experience (<2, 2-5, 6-10, 11-20, >20), organization's setting (rural, suburban, urban), job title (Executive, vice president, director), and annual purchasing budget (<$500k, $500k-$1M ...). $\chi 2$ analysis was performed to identify any patterns that exist in how both physicians and SC professionals are looking to the problem and driving factors.

In general, there is common awareness of the problem, but more within SC professionals. Awareness of the term PPI is higher within the SC; this indicates its effect on the SC performance and defines it as a SC term rather as a medical term. Physicians showed a high willingness to use available items in stock, which seemed to be higher for highly experienced physicians. Just to be willing to use available items in stock means they are willing to use standardized items and minimize the number of items used for the same purpose. Physicians' ability to use non-preferred items increases with their skills gained through experience. Organizations should focus on more experienced physicians to standardize items since they are more willing to use any brand due to their skills and experience. As 83% of physicians said they are sometimes permitted to order whatever they want, this confirms that PPIs is an issue. However, when limitation on what physicians are permitted to order takes place, they will be more willing to use available items.

Physicians also showed willingness (90%) to substitute an item from stock which is not their preferred brand but functionally equivalent. This result is consistent with the previous one, except that physicians became more willing to use another brand given it is functionally

equivalent. More experienced physicians are more willing to use another functionally equivalent brand. Even when they asked, 71% are very willing to permanently drop a brand and adopt another one. Healthcare organizations should focus on experienced physicians to adopt standardized items, and at the same time provide sufficient illustrations on items showing which are functionally equivalent.

The two factors that most affect physician's preference are *Items' effectiveness* and *previous experience.* Physicians will choose items that they have experience with, and which they think are more effective. Healthcare organization may want to invest more in training physicians on the items they would like to lean toward, and also provide brief evaluation of items effectiveness. Another aspect to consider is the item's cost, as physicians' knowledge with items' cost depends on experience, a more experienced physician may consider the item's cost significantly more important in his decisions than a lower experienced physician. Reasons that would cause physician switching to another brand are patient's related aspects followed by the ease of use. If a physician learned that this item is better for the patient's outcome, he/she will adopt it as expected. Also, if it is easier to use, the physician will adopt it.

Physicians do not consider patients' preference when selecting the right item. Interestingly, those who said patient's preference is *not important* indicated that manufacturer reputation is *important* when selecting the item. An explanation for this could be that physicians, who do not consider patient's preference, trust manufacturer reputation more since patients could be unaware of what is available.

Physicians are not totally knowledgeable about how the organization makes the decision. Around half of physicians are able to influence the decision of selection, and this depends on physicians' experience. More experienced physicians are more able to influence the decision, yet

they are more flexible to use available items. Healthcare organizations should focus on encouraging experienced physicians to standardize items and enhance this by incentive systems; the return of this system could be used to train low experienced physicians and clinical staff to do better jobs.

Total cost is the dominant factor in influencing the organizations' item selection decision according to physicians. They considered administration to make decisions based on cost, then patients' outcome and finally physicians' preference. Physicians may complain about the central decision by administrators on brands. This may cause physicians to feel excluded, which is a negative impression that should be changed. Including physicians in the decision process and appreciating their input always, having them in cross functional teams, actively participate in value analysis teams would have effective outcomes. It is not just about changing their attitude toward being valuable to the decision process, it will make them feel the pressure and appreciate more the effort done to select the best items that could create the balance between all stakeholders. SC professionals were asked the same question, they agreed with physicians on the patient's outcome as an important factor, however, they said physician preference is the second important factor and total cost came third. The result concluded from SC professionals input that patient outcome and physician preference were most important factors, is basically what was expected in this research. Since, no one disagreed that patient outcome is the first priority, it can be said that physicians' preference is the most important factor. Both physicians and SC professionals said that total cost and physician preference are two important factors to the organization decision; however, they indicated different rankings. The SC professionals indicated higher rankings for the physicians' preference than what physicians themselves said, and lower rankings on the total cost than what the physicians indicated.

Less than half were aware of the actual items' costs, which depends on physicians' experience. The SC professionals were asked the same question, all of them are highly aware of the items' actual costs. SC professionals are more aware than physicians as expected. Educating physicians about cost of items they use is thought to be beneficial in encouraging physicians to think more before requesting any item. On the other hand, physicians' willingness to substitute an item was expected to depend on the cost range of surgeries. In other words, a physician will stick to his/her choices when performing high cost surgeries. However, it was found that physicians' willingness to substitute an item does not depend on the cost range of surgeries physicians do.

Majority (93%) of physicians use items that can be classified as PPIs. Of the total amount of items used in healthcare organizations, 39.1% are considered PPIs.

SC professionals are highly aware of the term SKU proliferation. They indicated PPIs as the major cause of the SKU proliferation issue, while unpredictable schedules for needed items as second important and growing size came last. With physician preference being first cause of this problem, it is highly needed to improve the selection process to reduce number of items. In other research, factors affecting and considered in the PPI selection decision process by physicians and other stakeholders as well, are analyzed in detail. The purpose is to develop a decision framework to improve the item's selection process.

The main body of the SC survey was about practices that could help in managing PPIs. The first practice was sharing items' costs and total cost with physicians. Mostly, they share the items' costs with physicians but not total cost. Of total respondents, 92% think that sharing item cost has high potential impact on controlling PPIs, either they actually share it or not. For the

total cost, 72% think it would impact controlling PPIs. Since just 23% share total supply cost, healthcare organizations should start sharing total supply cost with physicians.

Second practice is spend analysis, where majority of SC indicated high awareness and utilizing of this practice on their PPIs. Utilizing spend analysis was found to depend on annual purchasing budget; the higher the budget, the more focus on spend analysis on PPIs. This is because of the potential savings in PPIs and noticeable effect when purchasing size is big. Of total respondents, 64% said they perform spend analysis on their PPIs more than regular items, while 21% are doing it the same frequency. Highly aware SC professionals are more likely to perform spend analysis practices on their PPIs, and if they do it on their PPIs, they will do it more than other standardized items. This means that SC professionals will realize the importance of this practice and its impact on managing PPIs as they learn more about it, and when they actually try it on their PPIs. 89% indicated that spend analysis has a high potential impact on managing PPIs. The higher the annual purchasing budget, the more they believe in the spend analysis practice potential impact on controlling PPIs. Those who perform spend analysis practice on PPIs more than other items, believe more in the practice potential impact, actually they will not do it more if they do not believe in it. It is highly recommended that healthcare organizations start educating their SC professionals about this practice and encourage them to apply it on their PPIs more frequently than regular items. Three quarters of SC professionals share spend analysis data with physicians. Analysis showed that those who share spend analysis data, see the potential impact of it on controlling PPIs. This is evidence that spend analysis data should be shared with physicians, which is confirmed by the 96% who said that data should be shared.

Third practice is capitated pricing, majority (91%) were aware of this practice. about 70% use it on their PPIs more than other items, while 21% use it the same frequency. Three quarters indicated high potential impact of this practice on controlling PPIs, while 17% were neutral. Higher awareness of this practice implies higher perceived potential impact on controlling PPIs, which comes from the understanding of its capabilities. A stronger association of capitated pricing perceived potential impact with its frequency of use was recognized, indicating that when using capitated pricing more, its impact will be more noticeable. It could be also vice versa, which means organizations do this practice more since they believe in its impact. Either way, it is recommended to adopt capitated practice as a good practice within healthcare organizations. Individual's spending is monitored by most of healthcare organizations, and those who do so indicated a higher potential impact of the capitated pricing. However, most of them do not compare individual spending to a budgeted amount. This could be due to difficulty in setting up a budget because of the healthcare service nature. Most healthcare organizations compare physicians to each other on their spending habits, and this was indicated more by higher management levels, meaning that they do so to watch physicians' performance. Physicians should pay more attention to their selections and wisely choose the most effective items.

The fourth practice was ABC classification, majority are highly aware of this practice, and more than 70% do it either daily, or weekly, or monthly or yearly. Either based on value or usage, ABC classification data is not shared with physicians by 71% of respondents. However, 56% said that it should be shared. In general, they were not sure of the potential impact for ABC classification on controlling PPIs. However, those who do the practice either based on value or usage, believe more in this practice. Vice presidents and directors seem to be the most enthusiastic for this practice as they believe ABC data should be shared with physicians, and also

they believe in this practice as an effective practice in controlling PPIs. This practice is seen by higher management level as an effective practice, and this could be because they are able to capture physicians' behavior when such data is shared with them.

Cross functional team is the fifth practice, and it is utilized by more than two thirds of healthcare organizations. The higher the purchasing budgets the more they utilize this practice. This is due to the need for more structured and organization of selection's decisions, due to the sensitivity of small margins on the big scale of purchasing. One third said that physicians are not represented in cross functional teams, and this actually depends on how big the organization is, with smaller organizations have less representation of physicians in their cross functional teams. More than three quarters discuss PPIs in the cross functional teams, and this percentage depends on purchasing budget. Bigger healthcare organizations adopt cross functional teams more than smaller organizations, and they also discuss PPIs more; this highlights the savings potential in PPIs. The majority indicated that this practice has high potential impact on controlling PPIs. Bigger organizations seem to be more receptive to this practice and consequently found it effective.

Value analysis is the sixth practice investigated. All were aware of this practice and indicated that just 65% of the physicians are included in the process. Healthcare organizations with higher purchasing budget effectively include physicians in this process. Almost all indicated that value analysis has high potential impact on controlling PPIs. Interestingly, those who included their physicians in the value analysis process, realize more the potential impact of this practice on controlling PPIs.

For future work and research, a distinction could be made between the tools and items that are used in treating patients, and the replacement devices that will be in use directly by the

patient after the treatment. Cutting tools are an example of the first group, and heart stent is an example of the second group. The reason for separating them in two groups is due to the difference in objectives for each; consequently the kind of questions asked should be tailored according the objective investigated. For instance, a device that will be used directly by the patient may be affected by the opinion of the patient, which means asking questions regarding this point. In this research, the objective was to have a comprehensive understanding on both PPIs categories.

Another future work is to redo the survey reflecting on common language with physicians and SC professionals. The survey could be improved by developing additional hypothesis learned from this one. We recognized that we are limited because of the sample size. This work could be considered as initial results that would indicate what a bigger sample would need to be in order to have improved confidence in the results.

One more work for future, is to investigate more on the recommended practices from this work. This could be done by working with hospitals to implement these practices and evaluate the effect on performance.

In a separate question (Q37), SC professionals were asked about any additional practices they think should be considered.

One of the practices recommended was to make teams for physicians led by physicians themselves to review clinical and cost data for specialty items. The purpose is to encourage physician to use an already contracted product or perhaps one other doctors are using rather than bringing in something a representative is marketing. Physicians will need to present clinical evidence to their peers on why they must use a certain item, which direct the process towards

reviewing clinical data and outcomes and stressing clinical acceptability rather than just a personal preference.

Another practice that was recommended was to limit sales representative access to surgical suites and their relationships with physicians. This direction actually helps in achieving the clinical evidence discussions mentioned above.

They also suggested using an incentive system to encourage implementing and continue using agreed upon items. One example is to put a portion of savings from using standard items into an extra educational fund, that is to provide education the staff would not otherwise have had access to, or research, or capital investment. Another example is to reward physicians financially for choosing vendors that increase contract compliance.

Another practice that was recommended is the integration of cost, quality, and outcomes in the value analysis process, to provide an analysis of patient impact and financial impact. Actually, this is a fundamental concept in the framework proposed in another research the authors are working on (Shbool and Rossetti 2016). The model captures all these elements mathematically and provides the necessary analysis of the different outcomes elements tradeoffs in terms of preferred selection value versus cost.

Actual usage of products at the point of use and integrating the information with clinical systems was also recommended. The idea is to get outcomes so that they can do a more thorough and evidence-based comparative-effectiveness analysis across similar products. This will also be used to understand impact on outcomes like (readmission rates, reimbursement for related procedures, infection rates, surgical times, etc.). The usage and clinical data will also be used in variation analysis by physicians to drive standardization. In this way, physicians' preference will

not be sufficient justification for utilizing products, and the performance of those who are getting better outcomes at lower costs will be the benchmark.

3 Chapter 3: Physician Preference Items – A Decision Making Framework

Abstract

Physicians' preference items contribute to 61% of total supply expenditure (Schneller and Smeltzer 2006). (Shbool and Rossetti 2016) found that 39.1% of total items in healthcare organization are PPIs. Stock keeping unit (SKU) proliferation is an issue for healthcare organizations, of which PPIs is a major contributor to the problem. Item's selection process is done based on value analysis at best, which (value analysis) is done through discussions by a cross functional team on the candidate items. This process is highly subjective. This work uses Multiple-objective decision analysis (MODA) to develop a mathematical structured framework for the PPIs selection decision process. This paper offers three contributions: characterization of the PPI selection problem by defining the criteria used in evaluating alternatives, implementing a multi-criteria decision making (MCDM) methodology to develop a framework for the decision that can be used in practice, and an illustration of the framework through a case study to evaluate the framework effectiveness.

3.1 Introduction

Effective and efficient selection of medical items and supplies within healthcare providers can lead to better management of inventory within the organization's supply chain, and reduced total cost. During the last decades, the healthcare sector has advanced enormously regarding treatment processes, technology, devices and medical items/supplies. However, this puts the supply chain of healthcare providers under pressure due to the overwhelming number of items. The focus of this research is on functionally equivalent items which are introduced by competitors. In the retail sector this is called stock keeping unit (SKU) proliferation and is caused by holding different brands for the same item. SKU proliferation can be defined as the increasing of the variety and the number of functionally equivalent items that are stocked by

inventory management systems in response to marketing, acquisitions, sales incentives, and lack of life cycle controls.

In the healthcare sector, SKU proliferation is a problem for the supply chain and might be attributed to many reasons of which physician preference items (PPIs) is the major contributor. PPIs are costly medical/surgical items, such as hip and knee implants, cardiac stents, mechanical devices…etc., that are selected/preferred by the physician to use for a specific patient and procedure/treatment. PPIs exist in most of treatment areas such as: orthopedics, cardiovascular, plastic surgery … etc., and within each area they are classified according to the purpose of use into further categories. In each category (same purpose) there are many items (brands) for the same item type, they are functionally equivalent but may come with different features since they are produced by different manufacturers. Some examples of PPIs are heart valves, orthopedic and cardiovascular implants. For instance, orthopedic implants can be classified into many categories according to use such as: Austin-Moore prosthesis (for fracture of the neck of femur), Baksi's prosthesis (for elbow replacement) … etc. (List of orthopedic implants 2014). Within each category, there are many items available in the market from different manufacturers.

It is difficult to reduce labor cost which is the largest expense in a typical hospital according to (Schoen, et al. 2010), so the focus has turned to the reduction of supplies, which represent the second largest expense (Moon 2004). A major portion of medical items and supplies in hospitals is actually in the form of PPIs (DeJohn 2005). According to (Chow and Heaver 1994), 40% of expenses in hospitals is due to supply chain activities, and according to (Schneller and Smeltzer 2006), PPIs make up to 61% of total supply expenditure.

Regularly stocked items are those adopted by the organization, stocked in the warehouse and ordered from suppliers on a regular basis without the need for a special approval from the

organization administration. These items can be managed with conventional inventory theory by using forecast models, traditional inventory policies, and optimization techniques. On the other hand, PPIs are often considered specialized items from a supply chain perspective. PPIs are more difficult to manage, and involve aspects beyond engineering, which can be attributed to factors affecting the selection process such as the physicians' preference.

Because PPIs may not be regularly stocked, a request by the physician should be placed to secure the item by materials management. From the perspective of this research, the problem mainly involves two kinds of decisions to be made based on some criteria. The first decision is, if a new item (technology) has been introduced, does the organization need to adopt it or not? The second decision is, for an existing item, is it better for the organization to not stock the item and replace it with another more efficient one based on its effect on the supply chain? In other words, should a regular item be used instead of a set of equivalent PPIs? For both decisions, the essential question is: Which item should be considered the standard one in a small set of items?

Currently, healthcare organizations collect information about items, then cross-functional teams consisting of clinicians, supply chain professionals, value analysis professionals, and healthcare administrators discuss the items and then decide which item to purchase. This process is called value analysis by some organizations. Value analysis teams meet and discussions about items will take place. One of the examples on how healthcare organizations are doing the value analysis is included in Appendix F.1: Value Analysis Example. When making a new item's request, this form requires the value analysis team members to score on four areas, namely: financial, quality, impact, and clinical evidence on a scale from 1 to 10 except for the impact, which is from 2 to 20. If an item scored a total of 25, it is rejected. This method seems to use similar concepts to what is proposed in this work, yet it is less rigorous and has major technical

drawbacks. It does not consider all criteria when evaluating items, it does not have the ability to show all items in one picture, it does not have the ability to re-evaluate existing items, and even more technical issues related to combining multiple criteria.

Due to the lack of quantitative evaluation of item's value versus its cost, decision makers will not see the consequences of their decision on supply chain performance and the organization's financial situation. This process is sub-optimal for two major reasons: first, criteria considered in the decision process are not clearly weighted, and second, no value-cost tradeoff is shown, consequently, decisions will be very subjective. For these reasons, a framework that considers putting this value analysis context within a more sound mathematical structure that captures criteria weights and the sensitivity of these weights is a contribution of this paper. Figure 3.1 below is a schematic view of how the MODA framework aligns with the value analysis.

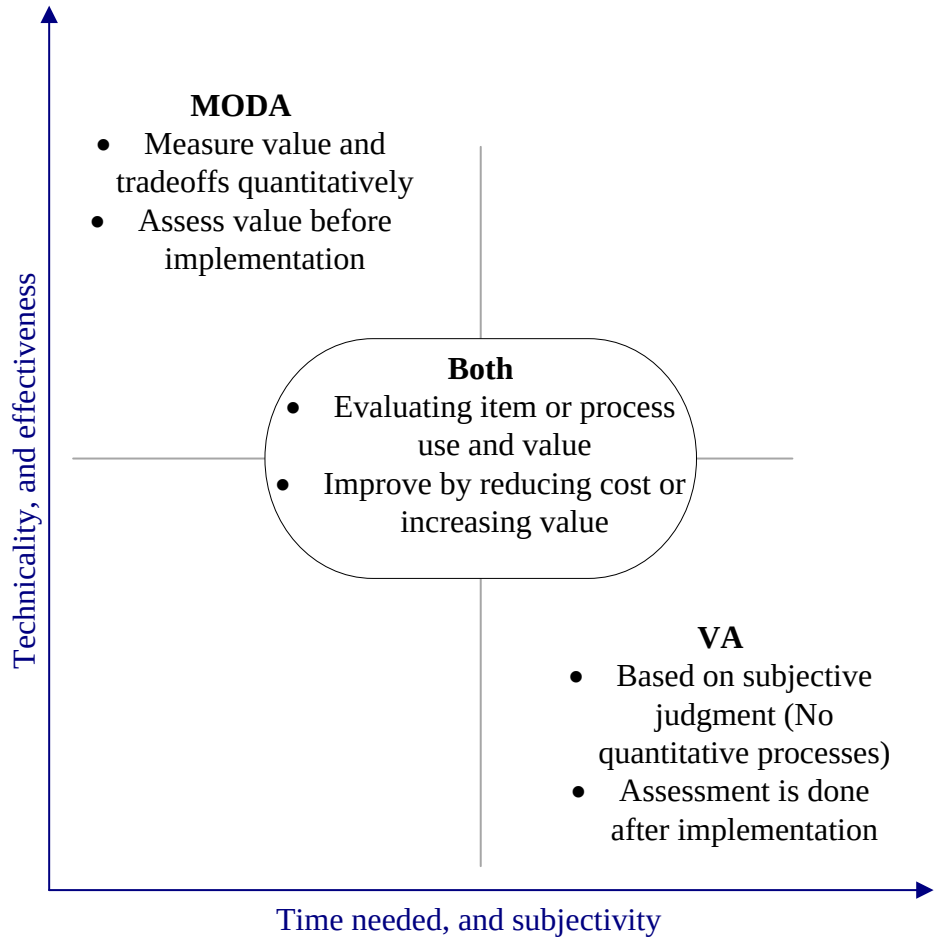

Figure 3.1 Value analysis and MODA relationship

This process involves stakeholders, criteria/factors, and alternatives to choose from. Hence, it can be seen as a group decision making process with multi-criteria. Multi-criteria decision making (MCDM) is a sub-discipline of operations research, it is defined as taking/judging an action or a choice based on two or more standards/criteria/factors, which mostly will be conflicting (Belton and Stewart 2003). Group decision making is challenging due to different perspectives and judgments by stakeholders. Decision making is based on trade-offs between different outcomes, where trade-offs are actually based on values (valuable things for the decision maker). The presence of different attributes that are not measurable/incommensurable is what makes MCDM essentially not easy to solve (Triantaphyllou, et al. 1998).

MCDM methodology adopted in this research was the multiple-objective decision analysis (MODA) with the purpose of building a framework for the PPI selection decision process. The MODA method is actually based on measurable value theory, which is discussed in (Dyer and Sarin 1979). Details of the procedure, such as swing weights and value function assessments, is based on the Simple Multi-attribute Rating Technique using Swings (SMARTS). Further details of the SMARTS procedure can be found in (Edwards and Barron 1994), and (Von Winterfeldt and Edwards 1986). The goal is to implement the framework on a selection process through a case study in a healthcare organization and evaluate the framework's effectiveness by the users themselves.

Due to the fact that the PPI problem is a healthcare related issue, which has not been structured yet, we consider two important issues before attempting to implement the MODA approach. The first critical issue is the nature of the problem. The second issue is the unavailability of a structured problem's definition. Being a health related problem actually implies the complicated relationship between all elements and overlap between stakeholders' desires. The nature of factors and stakeholders contributing to the selection process imposes difficulty to the problem and make it more challenging. Measuring physicians' preferences is a challenge, as well as how to combine all objectives into a meaningful indicator. Physicians' preference is difficult to measure, and to not satisfy it increases the risk of physicians leaving the organization or being less motivated. In this research, physician preference was expressed in terms of objectives considered by physicians when building their preference. Unavailability of the problem's characterization means that the criteria considered by all related stakeholders are not well defined. Eliciting criteria was the most time consuming stage in this research, and the most critical step in building the objectives structure.

According to (Triantaphyllou, et al. 1998), MCDM has three unique characteristics which are: presence of multiple qualitative and conflicting criteria, multi-dimensional criteria (different units of measurement), and the existence of different alternatives. The stakeholders generate conflicting objectives that should be considered. For example, supply chain professionals desire to minimize the number of different items, and to have regular stock managed at the lowest cost. On the other hand a physician's main objective is satisfying their preferences with highest effective items that are easier to use. See Appendix F.2: Stakeholders and Objectives Definitions for full list of stakeholders, their desires, objectives and definitions. This tradeoff between maximizing supply chain performance and maximizing preferences should be consolidated in some way taking into account factors affecting decisions and the consequences of those decisions. A good selection decision should be made to increase inventory utilization and maximize dollar value as well as to keep a high service level.

To proceed with this problem investigation, it is necessary first to understand three essential elements: How the selection process is being made and who is involved? What are the major factors affecting the selection process? How are these factors weighted for alternatives from the perspectives of stakeholders involved? These questions will be answered and explained in the methodology section.

The remaining sections of this article are organized as follows; section 3.2 contains literature review related to PPI and MCDM. Details of the methodology used in this work can be found in section 3.3, which explains the approach and the model developed qualitatively and quantitatively. The case study conducted is shown in section 3.4, which includes the process of scoring alternatives, analyzing the results, sensitivity analysis. The feedback on the framework

effectiveness from users is presented and analyzed in 3.5. Finally, conclusions are presented in section 3.6.

3.2 Literature Review

Very limited work has been done on the PPI topic and majority of it is in the form of non-technical reports, which present opinions and experiences of people in the field. The lack of modeling on this problem suggests the need for further investigation. It is stated by (Chow and Heaver 1994) that more than 40% of expenses in hospitals are attributed to supply chain activities. The same result was found later by (Nachtmann and Pohl 2009). Within supply chain costs, (DeJohn 2005) indicated that PPIs make-up a great deal of these costs, (Schneller and Smeltzer 2006) stated that PPIs make up to 61% of total supply expenditure. According to (Siddel 2012), one of the reasons for losses in hospitals is the PPIs, and this is an indication that PPIs is a problem for healthcare providers.

(Jebson and Sweat 2010) discussed factors causing PPIs, as well as factors that make physicians use a specific item (brand). Persistent pressure by implant vendors to use the newest technology, the approach of one treatment for one disease that followed by some medical doctors MDs, and the fact that MDs usually do not take into account financial matters of their hospitals are three factors that cause PPIs. Factors that make a physician prefers a specific brand are: how experienced a physician is with utilizing the item during residency training, the incentives a physician receives due to using a specific implant type, being a member in the design or trials team of that item, the good vendor-physician relationship, and finally availability of representatives as they add clinical educational value and expertise to routine and complex cases.

The authors are also currently working on another research to examine the PPI problem from a different perspective (Shbool and Rossetti 2016). They developed a deeper understanding of

the role that PPIs play within the healthcare supply chain. Two surveys were developed to gather information about the management process from two points of view, physicians and supply chain professionals. Surveys' results will help to understand the factors and significance of each in the selection process.

A bibliometric analysis on MCDA researches in healthcare done by (Diaby, Campbell and Goeree 2013) showed a steady increase in number of publications on MCDA in healthcare over the years 1965-2011. Three research topics were analyzed namely clinical, health systems, and methods, and all of them experienced the increase in research volume. However, no literature was found that has adopted MCDM methodology or implemented any decision analysis technique into the PPIs selection problem.

MCDM techniques have different capability with different features and characteristics. The use of a technique over another depends on the problems elements, and the result may not be an optimal choice, rather it improves the quality of the decision taken. A review of MCDM techniques and classification can be found in (Triantaphyllou, et al. 1998). A literature review performed by (Velasquez and Hester 2013) discussed common MCDM techniques, their applications, and strengths and weaknesses.

A very popular problem in the supply chain space is the evaluation and selection of suppliers. The selection of a supplier is a similar problem to the item selection problem; in that it has an objective of selecting a supplier based on some criteria. In addition, the decision is done by a group of decision makers who have input into the process from different perspectives. Many research efforts have been done on this problem, (Agarwal, et al. 2011) reviewed the most common techniques used in literature for this purpose. In more than 60 articles, they found that the most common methods are DEA, mathematical programming (linear programming, integer

linear programming, integer non-linear programming, goal programming, and multi-objective programming), AHP, CBR, ANP, fuzzy set theory, SMART, genetic algorithm, and criteria based decision making methods (ELECTREE and PROMETHEE), with DEA as the most prominent one. Following the sense of methods' combination mentioned above, many researchers proposed a decision framework for supplier selection based on a combination of two or more techniques. An integrated decision model was proposed by (Vijayvagy 2012) to select a supplier using a combination of AHP and TOPSIS. The model included 18 criteria set classified into 7 groups. A survey was distributed to 50 managers to capture their opinions about importance of selection criteria and suppliers performance. AHP was used to make a primary evaluation, and then TOPSIS was used to do a second round of evaluation. TOPSIS did not conclude with the same choice as AHP, and hence AHP was declared as a better method for supplier selection.

Decisions can be made either individually or by a group, and in both contexts the purpose is to make a decision, that minimizes the possibility of after-decision regret by being satisfied that the decision considered all factors properly (Belton and Stewart 2003). Group decision is more sophisticated than individual decision making; because it should tackle in addition to the level of conflict between criteria, the conflict between stakeholders in deciding which criteria are relevant, and to what extent it is important.

There is no right answer to the decision problem; decision is mainly built on subjectivity (Belton and Stewart 2003). Decision analysis is designed to help in managing subjectivity and integrating objectives with criteria into one frame to select/rank from available alternatives. Multi criteria decision making will not provide a cut point and objective decision which takes the decision making's pain out. MCDM will guide the decision process, and provide more

transparent decision through focusing on trade-offs of different objectives and result in a more informed decision. We should also differentiate between decision makers, who are responsible for making the decision, and the facilitators or analysts, who work to guide and assist the DM in making the most appropriate decision.

MODA ((C. W. Kirkwood 1997), (Keeney and Raiffa 1976), (Parnell, et al. 2013)) has been applied to applications in areas like military, see (Trainor, et al. 2007) and (Ewing Jr., Tarantino and Parnell 2006), and resulted a good quality decisions. MODA was chosen in this research due to many reasons of which that it is designed to be consistent with the five rules formulated by (Howard 2007). The framework consists of applying MODA on the PPI selection problem, performing a case study with users in a healthcare organization, and finally evaluating the framework effectiveness by the users.

The end result of the framework produces an assessment of the value of different alternatives versus cost for the assessed alternatives. This will facilitate the decision process by informing decision makers of the estimated value of their selection versus the cost tradeoffs. In other words, it is not about making a decision, rather the goal is to add a sustainable better process (framework) that can help making the selection decision many times. We believe this paper offers the following contributions:

- Characterization of the PPI selection problem by defining the criteria used in evaluating alternatives
- Providing a framework for implementing MCDM techniques on the PPI selection decision problem,
- Evaluating the decision framework effectiveness and applicability through a case study

- Putting the existing value analysis process in a structured mathematical sound process which has two advantages: measuring value and tradeoffs quantitatively, and assessing value before implementation

3.3 Methodology: MODA Implementation

The intended goal of this work is to offer a framework that can be used by value analysis teams to guide the decision process and add visibility to the decision process. Understanding this is important to PPIs assessment for two reasons. First, selected attributes must emerge from the value analysis context. Second, the methodology should support the decision makers' ability to increase the value of selected items' portfolio and interpret the results at any time. Thus our approach assessed the value of items versus cost independent of their current state (in stock, approved, new, etc.), which allows us to treat all items from the same point of view and giving each item the same chance of staying in use, phased out, or adopted.

The methodology (MODA) in this work implemented a nonmonetary value function (Approach 1A), which is found in (Parnell, et al. 2013) and (Keeney and Raiffa 1976). MODA enables the quantification of values of different candidate alternatives (items) based on the criteria considered when making the decision. Criteria like: Item's effectiveness, manufacturer's lead time, etc. While the specific model and framework was developed specifically for the PPIs selection decision problem, the methodology could be applied to other similar problems in healthcare. For alternatives involving multiple yet conflicting objectives, one of the most appropriate techniques to determine value and analyzing those alternatives is MODA.

We developed a value model using MODA, which provides logical, transparent, and an unbiased structure to assess each alternative with a single numerical value. The main 5 parts of the model are:

1. An objectives hierarchy (Value tree) that summarizes and organizes the objectives
2. Metrics (value measures) that quantify each objective
3. Range of each value measure, from worst performance point (acceptable or available) to best possible performance (ideal or achievable)
4. Value functions that define value return to scale levels of value measures
5. Swing weights that determine the relative value assessed from swinging on the full range of the different value measures

The process of developing the framework is presented in Figure 3.2 .

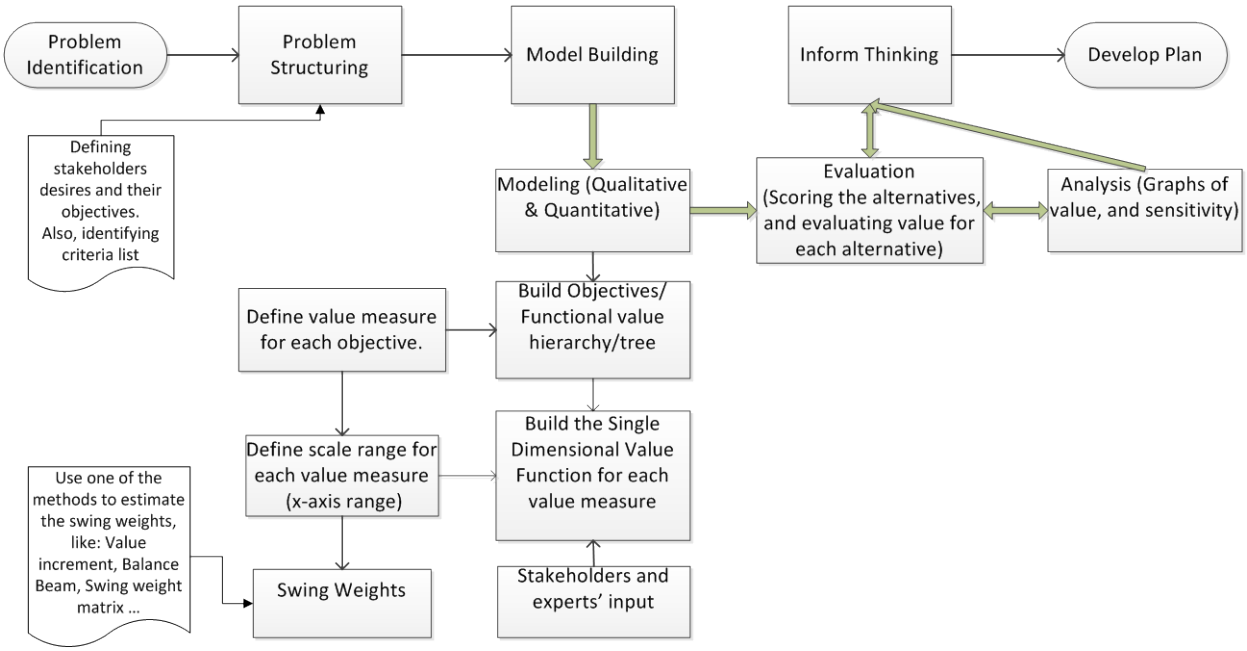

Figure 3.2 Process of MODA implementation

MODA can evaluate alternatives using any of several mathematical functions. The most commonly used and simplest model is the additive value function, which assumes mutual

preferential independence as well as that value scales and swing weights should be assessed for the value measures (C. W. Kirkwood 1997). Our work involved several key stages:

Qualitative PPI selection value model. We developed a qualitative PPI selection value model based on research from available literature and stakeholder analysis. The value model includes criteria related to all involved stakeholders organized in 5 major top level objectives. We interviewed professionals from three major different healthcare organizations in the area, and two other remote organizations either in person, or virtually to define the PPI value model. Feedback was also collected using computer based forms.

Quantitative PPI value model. The quantitative model was developed using the qualitative model to determine the value of a PPI.

Items selection analysis. Analysis of preferred items to select was done within the case study. This includes value versus cost chart, value components charts, and sensitivity analysis.

Supply chain professionals from the healthcare organizations participated as users of the model and also gave feedback on the model before and after using it. Physicians were key to the process; they contributed to the model development process by criticizing and fixing, adding, and removing items within the objectives hierarchy. They also provided valuable feedback on the model elements, and the framework evaluation. The authors played the major role in the modeling and analysis of the value model.

3.3.1 **The Qualitative Model**

Developing the PPI value model was accomplished by a number of steps: analysis of literature, conducting interviews of professionals in the field, analyzing stakeholders and their desires, translating these desires to objectives in a hierarchy value tree, and finally building the quantitative model using MODA which by itself is composed of 5 parts.

Literature was reviewed to initiate understanding of the problem. It was understood from available literature that the problem is not straightforward, it is still based on opinion, and the whole process is very subjective. This helped to conceptualize the model. Medical and PPI terminology were also reviewed to develop a common language with healthcare. This facilitated the communication with SC professionals and physicians.

Interviews with physicians and supply chain professionals were conducted and helped to develop understanding of the basic elements of the PPI value model. Insights from these interviews also helped in analyzing the stakeholders and their desires.

Stakeholder analysis was done to supplement the information reviewed from literature. We conducted stakeholders' interviews with three local healthcare organizations. Results from those interviews provided further insights that were not found in the scant literature. It helped to capture the desires and objectives of stakeholders. We listed the five main stakeholders (Physicians, Nurses, patients, supply chain professionals, and the organization itself), and then defined desires and objectives for each stakeholder, see Appendix F.2: Stakeholders and Objectives Definitions. Finally, the objectives hierarchy (also known as value hierarchy) was built for the PPI selection problem.

Table 3.1 demonstrates the PPI selection value qualitative model, which we define as objectives and sub-objectives. The first column contains the five first level objectives that support the overall objective of improving the control and effective use of PPI items within the healthcare supply chain. The second column shows sub-objectives under each of the five objectives. A pictorial representation of the qualitative value model is shown in Figure 3.3. The orange boxes indicate the first (top) level objectives; the light blue boxes indicate the sub-objectives, while the yellow boxes indicate the value measures. The cost objective was not

included in the value hierarchy for two main reasons. First, the context of this problem is healthcare, which makes it different in terms of objectives attainment and priority for value over the cost. Second, treating cost separately and showing the amount of value added per each unit cost is useful for the decision makers to evaluate the best choice, as well as for using such analysis in portfolio analysis.

Table 3.1 PPI selection value qualitative model

First Level Objectives	Sub-objectives	Value Measures	Type of scale
1. Maximize treatment effectiveness	1.1 Prefer items with higher efficacy (during trials)	Proportion of treatments that achieved the intended effect during ideal trials	Natural
	1.2 Prefer items with higher effectiveness (during actual use)	Proportion of treatments that achieved the intended effect during actual use	Natural
	1.3 Prefer items with lower Side effects/risks	Side effects type	Constructed
	1.4 Prefer items for which physicians have more experience using	Skill and experience	Constructed (Multidimensional)
	1.5 Prefer items that have more distinguishing/unique features	Amount of distinguishing features	Constructed
	1.6 Prefer items that are safer (Higher reliability and less issues during use)	Reliability	Natural
2. Improve patient's long term outcome	2.1 Prefer items that minimize patient's length of stay	Total # of days stayed	Natural
	2.2 Prefer items that maximize quality adjusted life years	Expected years*Quality of living (QALY)	Natural
	2.3 Prefer items that minimize infection rates	Infection percentage	Natural
	2.4 Prefer items that have longer expected working life	Expected item's working life	Constructed
3. Maximize clinicians satisfaction (Physicians and nurses)	3.1 Prefer items from manufacturers/suppliers that have higher ability to provide product support	Ability to solve problems	Constructed
	3.2 Prefer items from manufacturers that have higher willingness and ability to support product trials	Testability	Constructed
	3.3 Prefer items that have easier instructions for preparation and use	Instructions difficulty level	Constructed
	3.4 Prefer items that are actually easier to use	Usage difficulty level	Constructed
	3.5 Prefer items that minimize the time needed for additional training	Time needed	Constructed
	3.6 Prefer items that minimize the time needed for performing treatment	Relative time	Constructed

Table 3.1 PPI selection value qualitative model (Cont.)

First Level Objectives	Sub-objectives	Value Measures	Type of scale
4. Maximize Organizational benefits	4.1 Prefer items that maximize patient's acquisition	Acquired patients rate	Natural
	4.2 Prefer items that maximize the reimbursement associated with procedures	Reimbursement rate	Natural
	4.3 Prefer items that minimize readmission	Readmission rate	Natural
	4.4 Prefer items that maximize patient retention	Retention rate	Natural
	4.5 Prefer items that maximize attractiveness of profitable physicians	Attractiveness of profitable physicians	Constructed
	4.6 Prefer items that minimize the amount of associated medical lawsuits/claims	amount of lawsuits	Constructed
5. Maximize supply chain performance	5.1 Prefer items that are easier to handle and manage	Ease of handling	Constructed
	5.2 Prefer items that have more flexibility in specifying the minimum order quantity	Minimum order quantity allowed	Constructed
	5.3 Prefer items from manufacturers/suppliers that have higher ability to meet urgent delivery requirements	Ability of urgent delivery	Constructed
	5.4 Prefer items that have more consistent lead-time reliability	Lead-time coefficient of variation	Constructed

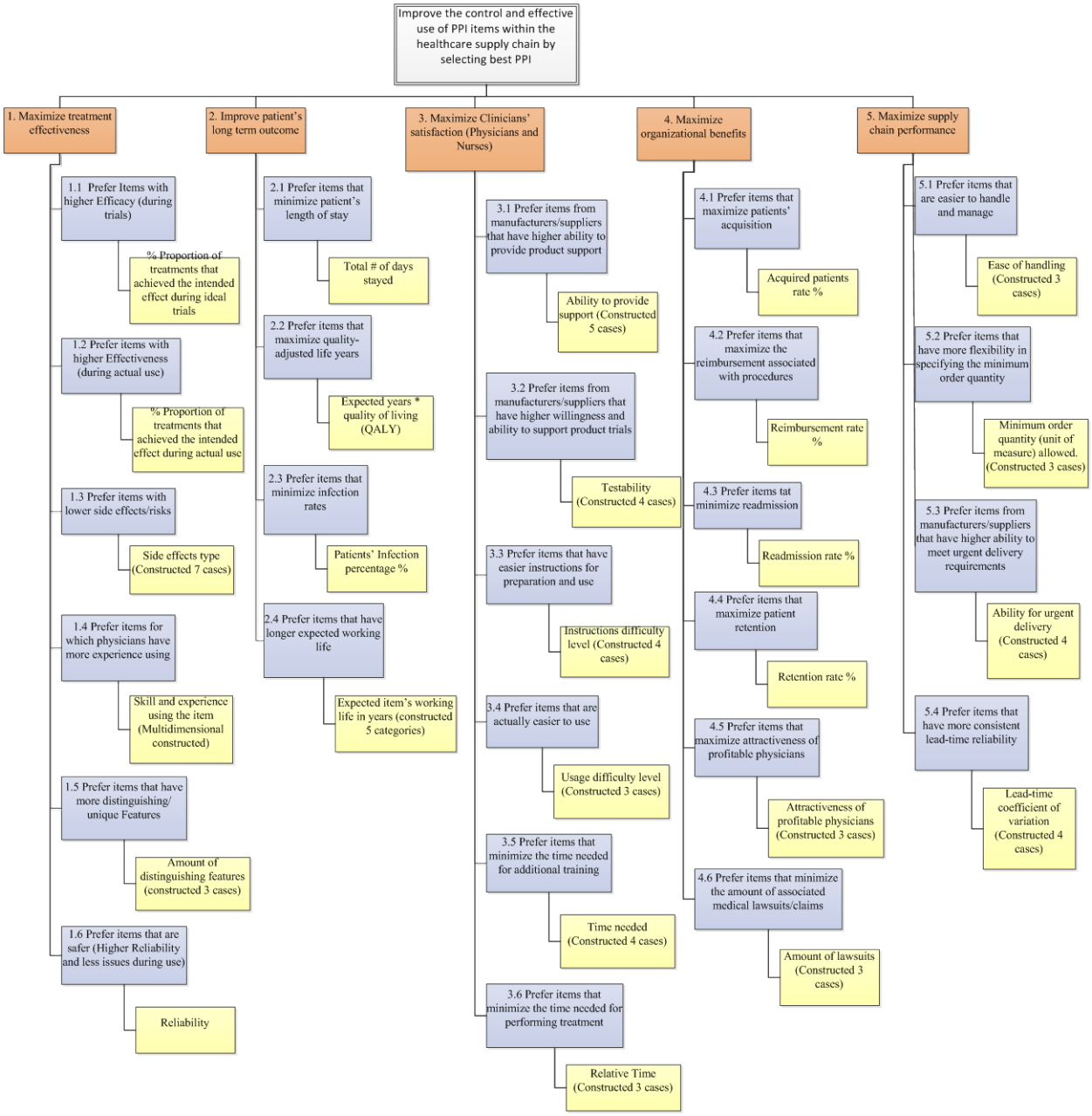

Figure 3.3 PPI objectives hierarchy

Initially, the objectives hierarchy included 36 sub-objectives, but was reduced to 27 after getting initial feedback from both the experts (physicians and SC professionals participated). We asked for their feedback on how they feel about the importance of these criteria to the context of

the PPI problem. Another round of meetings and feedback on the objectives hierarchy was conducted with physicians working in the area of item selection. This feedback was very important and deeper than the first round for two reasons. First, it is from physicians who are working with items selection and value analysis, which makes this the most accurate and valuable feedback due to their knowledge in all elements of the problem. Second, the feedback was done after an educational meeting was conducted to explain the MODA methodology itself, and provided them with all required information about the PPI model including hierarchy, definitions, and value measures scales. The feedback form used to give feedback on the definitions of objectives and value measures is included in Appendix F.3: Objectives and Value Measures Review. The result was removing 4 objectives, fixing definitions of few objectives and value measures, and finally adding 3 objectives leaving the tree with a total of 26 objectives.

The first objectives level is used to increase the hierarchy readability and traceability. Each of the first level objectives has a set of sub-objectives. The lower level objectives (sub-objectives) are directly measured, and also can be called attributes, criteria, etc. For each sub-objective, a value measure was assigned to assess how a PPI selection supports the sub-objective, and a value function was defined which quantifies the value of returns to scale on each value measure.

The preferential independence was inspected by making sure none of the criteria/sub-objectives has joint value function with any of the other criteria. This was assumed in this research since it is almost impossible to fully marginally measure all criteria with no effect on any of the rest. Overlap always exists, but there is a reason for not combining criteria together. For example, side effects and effectiveness have some overlap. However, side effects should not be a key factor in selecting an effective item for critical treatments, and can differentiate items

for non-critical treatments or similar items in terms of effectiveness. This allows differentiating between importance of effectiveness and side effects. For example, when the treatment is risky and crucial, both the physician and the patient do not care about side effects as much as they care about the patient's life! So, a low swing weight on side effects and high score on effectiveness can manage this possible dependence. When the treatment/item is not critical, close scores on treatment will allow differentiating the items based on side effects.

3.3.2 **The Quantitative Model**

After the qualitative model was developed, value measures were defined for all objectives, single-dimensional value functions were also specified to measure returns to scale. One of the value measures needed a two-dimensional value function to accommodate for the value dependence, and this is the physicians experience using the item. Weights were also assessed as described later. The required assumptions for the additive value model were also ensured to be satisfied.

Value Measures

A value measure/metric is “a quantitative scale that measures the value to the decision makers and stakeholders of the degree to which objectives are achieved” (Parnell, et al. 2013). Value measures specified for the PPI model objectives are shown in Figure 3.3 as the yellow boxes, and also in Table 3.1. Different levels (or scores) for each value measure were also defined to work as a rubric for the scores on the x-axis and the corresponding values on the value function. According to (C. W. Kirkwood 1997), value measures can be classified according to two dimensions: alignment with the objective either direct or proxy, and types of measures either natural or constructed, with both direct and natural being preferred from both dimensions. Of the

26 objectives in the PPI model, 10 were direct natural measures, where 16 were direct constructed with 15 being single-dimensional and 1 being a two-dimensional measure. The two-dimensional constructed scale was introduced to account for the interaction between physician's skill and years of experience in one value measure.

The value measures constructed scales must pass the clairvoyance test (C. W. Kirkwood 1997). The scales must be well defined and include all outcomes possible to satisfy this test's requirements. We defined the scales for the PPI model considering all possible outcomes; as subject matter experts we reviewed and approved/improved the scales and their definitions with physicians who are working in item selection. For the natural scales, the definitions are straightforward. An example of a natural measure is the item efficacy value measure "proportion of treatments that achieved the intended effect during ideal trials", which has levels of measure as % ranging from 20 to 100%. An example of a constructed one-dimensional value measure rubric is the item's distinguishing features value measure "amount of distinguishing features", for which we defined the score levels as shown in Table 3.2. The full list of value measures (natural and constructed) and their levels definitions are shown in Appendix F.4: Value Measures Scales.

Table 3.2 Item distinguishing features value measure

Prefer items that have more distinguishing/unique features	
Score	Definition
0	No distinguishing/unique features
1	Few extra features
2	Noticeable distinguishing/unique features

A Value Function for Each Value Measure

In this section, the value functions are described in terms of types and assessment. The mutual preferential independence assumption means that the preference order of a criterion does

not change with changes in the rank ordering of preferences of other criteria. In other words, the assessment of the value for an alternative on a specific value measure does not depend on any other value measure's assessment. If the criteria $\{X_1,\ X_2, \dots, X_n\}$ are mutually preferentially independent, the value function $v(x_1,\ x_2, \dots,\ x_n)$ is additive (for n>3) as proved by (Keeney and Raiffa 1976). We worked in this research to ensure that the value difference of a criterion is independent of the remaining criteria. Hence, the PPI value for a selection$v(x)$, can be captured with an additive measurable value function as

$$v(x) = \sum_{i=1}^{n} w_i v_i(x_i),$$

Where *x* is a vector of the set of value measures

$v(x)$ is the overall value of an alternative on all the set of value measures, *x*

i is an index of the value measure, and *n* is the total number of value measures

x_i is the alternative score, level on the *x-axis*, of the i^{th} value measure

$v_i(x_i)$ = is the corresponding value on the *y-axis* of the i^{th} value measure

w_i is the swing weight of the i^{th} value measure, and

$$\sum_{i=1}^{n} w_i = 1.$$

Value functions provide normalized unified scores on the y-axis (value of preference) corresponding to alternative scores on the x-axis (score levels on the measure scale) of the specific value measure. Each value measure has its own x-axis. Two methods were presented to assess value functions by (Keeney and Raiffa 1976) namely, Midvalue Splitting Technique and the Lock-Step Procedure, with the first being the most common in practice. Another two methods were presented by (C. W. Kirkwood 1997) and they are the piecewise linear function

and the exponential function. The basic concept behind the piecewise linear single dimensional value function is the relative value increment. That is, for the small set of possible evaluation measure scores, the relative value increments should be determined between each successive score.

When the value measure can take on an infinite number of different measure levels, the exponential function approach is followed. It was proposed by (Kirkwood and Sarin 1980) as an extension to the Midvalue Splitting Technique when criterion meet certain conditions. For an evaluation measure x, there are two cases for the preferences trend, either monotonically increasing or monotonically decreasing. When preferences are monotonically increasing (that is, higher score levels of xi are preferred to lower score levels), then the exponential single dimensional value function $v_i(x_i)$ is

$$v_i(x_i) = \begin{cases} \dfrac{1 - \exp[-(x_i - x_i^L)/\rho_i]}{1 - \exp[-(x_i^H - x_i^L)/\rho_i]}, & \rho \neq Infinity \\ \dfrac{x_i - x_i^L}{x_i^H - x_i^L}, & otherwise \end{cases}$$

where x_i^L and x_i^H are the lowest and highest score levels of the specific value measure xi, respectively, and ρ_i is the exponential value function constant. The shape of the function is determined by ρ_i where negative values result in convex functions, and positive values result in concave functions. A similar exponential value function can be specified for the monotonically decreasing preferences case. The value resulted $v_i(x_i)$ from the previous exponential function ranges between 0 and 1, and if another scale is needed, a leader appropriate factor should be used. The unknown in this equation is ρ_i which can be numerically determined.

Any of the above mentioned methods need significant amount of time from available experts in the healthcare area. This was a very difficult task due to the unavailability of experts from the

field who are willing to spend the required time in answering the amount of questions needed to produce value functions for the 26 measures. Consequently, another approach was needed which depends more on the researchers effort and minimize extra needed input from experts. The group voting procedure in (Parnell, et al. 2013, 197-198) was followed to propose the preliminary set of value functions. The procedure steps are

- Define the value measures and the *x-axis* carefully. This is critical step, as everything following depends on it.
- Decide about the units of value, that is the range of the unified normalized value on the *y-axis*. Most common ranges are 0 – 1, 0 – 10, and 0 – 100.
- Specify the range of each value measure; that is the range of score levels on the *x-axis*. This is important since it affects the shape of the value function as well as the swing weights.
- Assess the value functions using one of two techniques
    a. Assess the shape of the curve (convex, concave, S-shape … etc.) and then assess corresponding parameters, inflection points
    b. Assess points of value corresponding to scores on the *x-axis* and fit the curve
- Get the experts to agree on the shape of the value functions and the justification for the returns to scale

The value functions in this research were developed using this approach, and the authors did extensive research to build the single-dimensional value functions and provide rational for the proposed shapes and returns to scale. Expert's opinion was captured to either support our proposed functions, or to provide justification for another curve shape. Each value measure has its own x-axis. All measures have a unified scale from 0 to 100 on the y-axis for the value curves

representing the potential value added from the PPI. Value functions corresponding to all value measures and their rationale in this research are summarized in Table 3.3, followed by two examples on the logic behind the value function shape for the item efficacy and side effects.

Table 3.3 PPI Selection Single-Dimensional Value Functions

Value Measures	Min Acceptable Level	Ideal Level	Curve shape	Rational
Proportion of treatments that achieved the intended effect during ideal trials	20	100	Convex	Higher efficacy is more valuable
Proportion of treatments that achieved the intended effect during actual use	20	100	Convex	Higher effectiveness is more valuable
Side effects type	0	6	S-Curve	Low side effects is more desirable, and decrement in value is slow until side effects hit the red zone, the value drops quickly
Skill and experience	1	7	Linear	Each increment in experience is equally valuable
Amount of distinguishing features	0	2	Linear	Each increment is equally valuable
Reliability	0.6	1	S-Curve	Higher reliability is more desirable, but initial increase in more likely to be required, then the increase in value is slower
Total # of days stayed	0	5	Concave	Lower number of days is more desired
Expected years*Quality of living (QALY)	0.1	1	Convex	Higher QALY is more desirable and valuable
Infection percentage	0	100	Linear	Each decrement is equally valuable
Expected item's working life	1	5	Linear	Each increment is equally valuable
Ability to solve problems	1	5	Linear	Each increment is equally valuable
Testability	1	4	Concave	Initial increase is more likely to be desired
Instructions difficulty level	1	4	Convex	Easier instructions is more valuable
Usage difficulty level	1	3	Linear	Each increment is equally valuable
Time needed	1	4	Concave	Shorter time needed for additional training is more valuable
Relative time	1	3	Linear	Each decrement is equally valuable
Acquired patients rate	10	100	Linear	Each increment is equally valuable
Reimbursement rate	40	100	Linear	Each increment is equally valuable
Readmission rate	0	100	Linear	Each decrement is equally valuable
Retention rate	10	100	Linear	Each increment is equally valuable
Attractiveness of profitable physicians	1	3	Linear	Each increment is equally valuable
amount of lawsuits	1	3	Linear	Each decrement is equally valuable
Ease of handling	1	3	Linear	Each increment is equally valuable
Minimum order quantity allowed	1	3	Linear	Each increment is equally valuable
Ability of urgent delivery	1	4	Convex	Higher ability for urgent delivery is more valuable
Lead-time coefficient of variation	0	2	Linear	Each decrement is equally valuable

Item efficacy

- The definition of item's efficacy is: the extent to which an item/drug/medical device has the ability to produce its intended beneficial effect (or therapeutic effect) in expert hands and under ideal circumstances. During trials, the effectiveness of an item is captured as number of times it achieved the intended effect. Relative to the total number of trials, the efficacy will be measured as rate of success during laboratory tests.
- The range of any percentage is from 0 to 100, but the minimum acceptable is assumed as 20%, so the range of the "item efficacy" value measure would also be 20 – 100 as a %.
- The value function was assessed as exponentially increasing; see below.

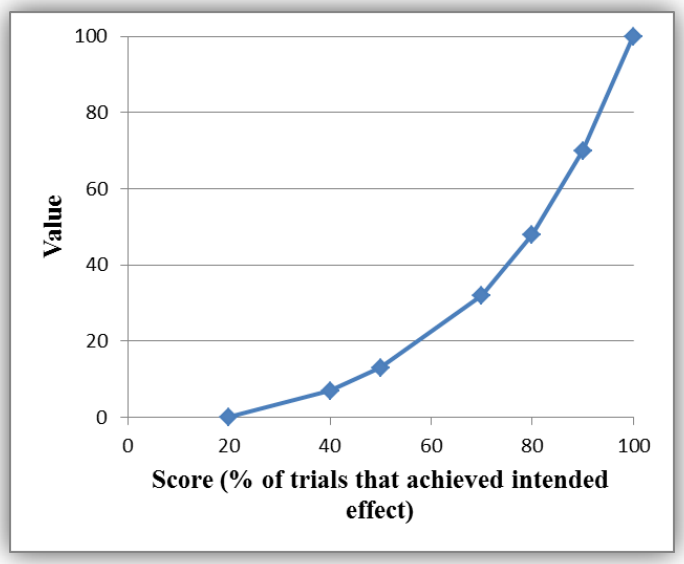

Figure 3.4 Item efficacy value function

- The justification for this shape is that the value added for each increment in efficacy is more desirable when moving up in the scale. Low scores will have less value

because an efficacy below a specific point is not wanted. After this deflection point, each increment in the score will have more value than the one before, or in other words a drop in the efficacy score will cost more (value) than a previous drop in efficacy to the left on the x-axis.

- Illustration: assume we have three points on the *x*-axis (efficacy score): x_1, x_2, x_3 where $x_1 < x_2 < x_3\ assume\ x_1 = 20,\ x_2 = 40, and\ x_3 = 50$. The corresponding *y-axis* values (value or return) are: $y_1 = 0, y_2 = 7, and\ y_3 = 13$, respectively. The two consecutive jumps in item efficacy will be $x_2 - x_1 = 20, and\ x_3 - x_2 = 10$ with the two corresponding value increments $y_2 - y_1 = 7\ and\ y_3 - y_2 = 6$, respectively. The value increment to scale increment ratio can be calculated as $R_{1-2} = \frac{y_2 - y_1}{x_2 - x_1} = \frac{7}{20} = 0.35$ and $R_{2-3} = \frac{y_3 - y_2}{x_3 - x_2} = \frac{6}{10} = 0.6$, then we can say that for this specific value function, $R_{2-3} > R_{1-2}$.

Side effects/risks

- The definition of side effects/risks is: *the possibility that an item/medical device could cause an* unwanted or unexpected negative effect ranging from minor (e.g. dry mouth) to serious (e.g. bleeding or heart attack). Observed problems in clinical trials are called “adverse events”; they might or might not be related to the item/medical device under study. Once that relationship is discovered, the problem is called “adverse effect” or as commonly known “side effects” (Medicine Safety and You 2011). When item has been used before, the total percentage of injury or death-related events over all events for the item is used to assess side effects/risks.

- There is not a natural measure for side effects. Thus, a constructed scale was initiated with 7 cases ranging from no side effects to serious with >60% death related events, see Table 3.4 for the side effects/risks value measure constructed scale definitions.

Table 3.4 Side effects/risks value measure constructed scale

Score	Definition	Value
0	No side effects	100
1	Minor side effects (Dry mouth, itching …)	95
2	Major injuries nonlife threatening	80
3	Serious life threatening (heart attack, internal bleeding…), % of death related events less than 20%	40
4	Serious life threatening (heart attack, internal bleeding…), % of death related events >20% & <40%	15
5	Serious life threatening (heart attack, internal bleeding…), % of death related events >40% & < 60%	5
6	Serious life threatening (heart attack, internal bleeding…), % of death related events >60%	0

- The value function was assessed as a decreasing s-curve, see Figure 3.5.

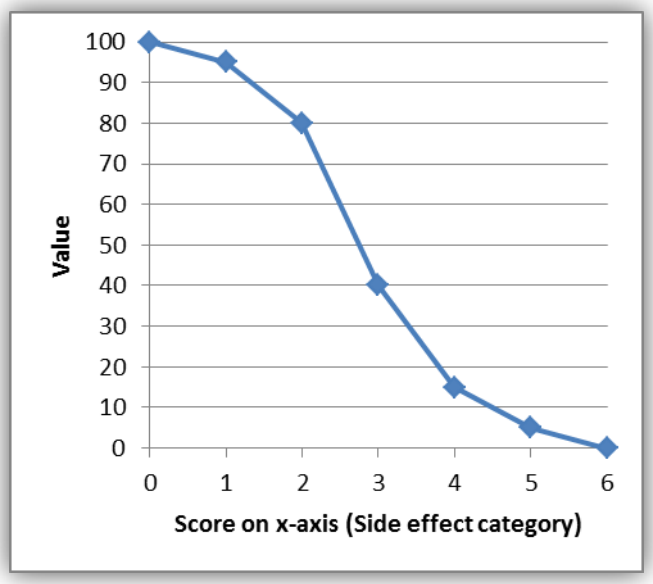

Figure 3.5 Side effects value function

- The justification for this is that a low side effect is more desirable, and the decrement in value is slow until the side effect hits the red zone, moving from case 2 to 3, the

value drops quickly. For life threatening side effects, the value is already very low, and the decrease progress becomes less significant. The value function is like 3 pieces together: concave, linear, and convex.

- Illustration: for the “no side effects” case which scored 0, the value is 100, this means it is the highest possible (and ideal at the same time) preferred scenario. However, in practice this is almost not achievable, so a near optimal case (score 1) was created and was assigned a value of 95. The next side effect case involves major injuries; but nonlife threatening, so the value assigned was 85. The next side effects case (score 3) represents a serious life threatening scenario, so a major drop in value is expected at this point due to the life threatening risk. Remaining cases are life threatening with higher risk expressed as death related events, so the value will continue to decrease; but with a lower rate than the rate of entering this red zone.

The model was implemented using a spreadsheet, and the calculations of alternative value were performed using a macro which passes the required scoring, and the value function list of values for both x and v(x) as input. The macro used was adopted from (C. W. Kirkwood 1997) which can be found in Appendix F.5: Excel Macros. It has two sub-functions, one uses a piecewise linear approximation, and the other one uses an exponential approximation. The piecewise linear function is used when the value measure has a small number of possible scoring levels. It uses linear equations to approximate the value.

The exponential approximation is used for monotonically increasing/decreasing preferences. For any given score level (x), the function will approximate the value preference using the equation shown previously. The low and high scores are known from the value measure scale

definition, and the parameter ρ should be assessed using a third point on the value, usually the mid-value such that v(x) = 0.5. There is no close form solution, it should be solved numerically. Using goal seek, ρ can also be estimated such that the value is 0.5 for the specific x.

Weights Assessment

Swing weights can be defined as the degree of desire assessed (value increment) by swinging the score on each value measure from its least preferred level to its most preferred level. Swing weights depend on importance and range of variation of the value measure; they represent the increment in value that is added from the alternative by enhancing the score on that evaluation measure from its least preferred level to its best level. Each value measure should be assigned a swing weight, which assesses the value added by the alternative when scoring high on that value measure. Sum of normalized swing weights should be 1.

Determination of swing weights is the last step in building the model, after which the model will be ready for scoring and evaluating the alternatives. The weights' assessment process is basically subjective, and to satisfactorily assess weights, both the decision makers' preferences (relative importance of the criterion/objective) and the range of the value measures should be considered. In general, it is difficult to reach a consensus on the weight assessment from a group of decision makers. There are many methods for assessing swing weights such as: Simple Multiattribute Rating Technique (SMART), Simple Multiattribute Rating Technique using Swings (SMARTS), Simple Multiattribute Rating Technique Exploiting Ranks (SMARTER), Analytical Hierarchy Process (AHP), and Value Increment. Another approach to assess weights which could be used with groups is the voting (ordinal then cardinal) (Parnell, et al. 2013).

In this research, the voting for groups (cardinal and ordinal) method described in Parnell et al. (2013) was used to determine the weights for the PPI model to illustrate the process. Once the range has been determined for each value measure, the voting for groups steps are:

1. Vote. (Have each individual order value measures based on the measures' importance and range.)
2. If the groups did not agree on the order, discuss the differences. Have the "outliers" explain their rationales.
3. Revote until the group come to a consensus on the order.
4. Have each person to spread 100 points over the measures following the group's ordinal ranking of the value measures.
5. Average the weights and normalize to range 0-1, the sum should be one.
6. Discuss if points assigned are significantly different. Have the "outliers" explain their rationales.
7. Redo steps 4–6 until the group come to a consensus.

For a real case study, the swing weights are to be determined using the value increment (C. W. Kirkwood 1997) method or swing weight matrix method (Parnell, et al. 2013). The swing weights also should be determined from the bottom to the top of the tree. In the illustrating example included in this work, voting was used to make it easy when explaining the methodology to the experts who participated in this process. Considering the first level of objectives shown in Figure 3.6, the voting approach was used to assess swing weights with professionals; results are shown in Table 3.5 below.

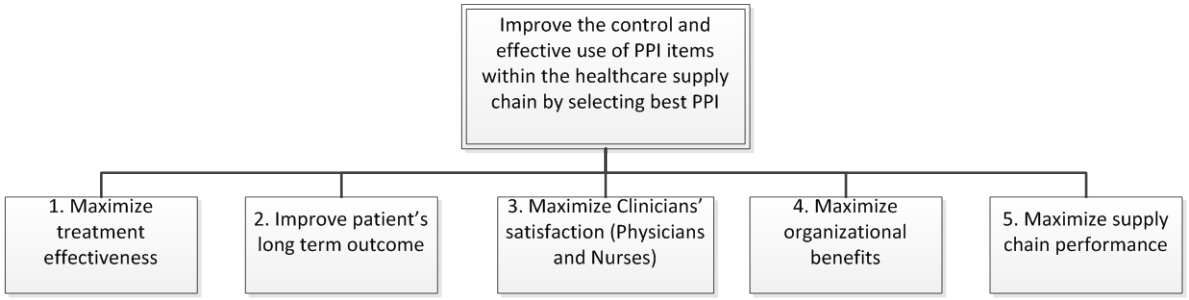

Figure 3.6 Top level objectives

Table 3.5 Top level objectives' swing weights

Order	First level objectives	Points (100)	Swing Weights
1	Treatment Effectiveness	22	0.22
2	Patient Long Term Outcome	22	0.22
3	Clinicians Satisfaction	20.9	0.209
4	Organizational Benefits	18.7	0.187
5	Supply Chain Performance	16.4	0.164

The swing weight for each of the top level objectives will be used to determine the subgroup contribution to the overall alternative value. Within each group of sub-objectives, swing weights should also be determined using the same procedure, and again the summation of the swing weights should be 1. For the first group "Treatment Effectiveness" shown in Figure 3.7 below, the resulting swing weights are shown in Table 3.6. Similarly, for the remaining 4 groups: "Patient long term outcome", "Clinicians' Satisfaction", "Organization Benefits", and "Supply Chain Performance", the swing weights results are shown in Table 3.7, Table 3.8, Table 3.9, and Table 3.10, respectively.

The normalized global swing weights can be calculated using the formula:

$$w_i = \frac{f_i}{\sum_{i=1}^{n} f_i}, \qquad \text{Where}$$

i = the i^{th} value measure,

n = total number of value measures,

f_i = swing weight assigned to a measure (in points)

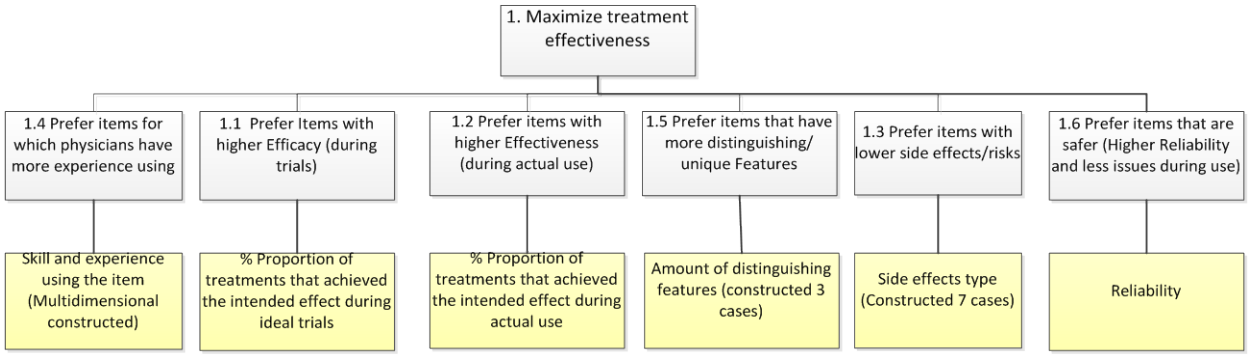

Figure 3.7 Treatment's effectiveness objectives group

Table 3.6 Treatment effectiveness objectives group swing weights

Rank	Treatment Effectiveness	Points	Swing Weights
1	Item Effectiveness	18.1	0.181
2	Item Safety (Reliability and issues during use)	18	0.18
3	Item Efficacy	17.1	0.171
4	Side effects/risks	17.1	0.171
5	Physician experience using the item	16.2	0.162
6	Item distinguishing features	13.5	0.135

Table 3.7 Patient long term outcome objectives group swing weights

Rank	Patient Long Term Outcome	Points	Swing Weights
1	Patient length of stay	26.9	0.269
2	Infection rates	26.9	0.269
3	Quality-adjusted life years	25.4	0.254
4	Item expected working life	20.8	0.208

Table 3.8 Clinicians' satisfaction objectives group swing weights

Rank	Clinicians Satisfaction	Points	Swing Weights
1	Supplier ability to support product trials	18.7	0.187
2	Time needed for additional training	17.7	0.177
3	Ease of instructions for preparation and use	16.7	0.167
4	Ease of actual Use of the item	16.7	0.167
5	Supplier ability to provide product support	15.6	0.156
6	Time needed for performing treatment	14.6	0.146

Table 3.9 Organizational benefits objectives group swing weights

Rank	Organizational Benefits	Points	Swing Weights
1	Readmission rates	19.6	0.196
2	Reimbursement rates associated with procedures	17.5	0.175
3	Amount of associated medical lawsuits/claims	17.5	0.175
4	Patient retention	15.5	0.155
5	Attractiveness of profitable physicians	15.5	0.155
6	Patient acquisition rate	14.4	0.144

Table 3.10 Supply chain performance objectives group swing weights

Rank	Supply Chain Performance	Points	Swing Weights
1	Flexibility of minimum order quantity	35	0.35
2	Suppliers' ability of urgent delivery	30	0.3
3	Ease of item handling and management	20	0.2
4	Lead-time reliability	15	0.15

The overall value for each alternative was calculated using the following double summation to account for the two objectives hierarchy structure for the PPI model.

$$\sum_{j=1}^{l}\sum_{i=1}^{n} w_{ij} v(x_i)$$

Where *j* is an index of the top level objectives, and *l* is the total number of top level objectives, which are five.

3.4 Case Study

3.4.1 Scoring the Alternatives

Four alternatives for a specific item were scored on the 26 value measures by the decision team, scores are shown in Table 3.11 below with a theoretical ideal alternative having maximum possible scores on all value measures for comparison and verification purposes.

Table 3.11 PPI Scores on Each Value Measure

Value Measures	Stent A	Stent B	Stent C	Stent D	Ideal
Proportion of treatments that achieved the intended effect during trials %	90	70	85	60	100
Proportion of treatments that achieved the intended effect during actual use %	95	80	80	55	100
Side effects type	1	2	2	1	0
Skill and experience using the item (Multidimensional constructed)	2	5	6	7	1
Amount of distinguishing features	2	0	2	1	2
Reliability	0.7	0.8	0.6	0.75	1
Total # of days stayed	1	2	3	4	0
(# of years*life quality)	0.8	0.7	0.5	0.7	1
Patients' infection %	10	40	30	70	0
Expected Working life years (categories scale)	1	2	3	4	5
Ability to solve problems	2	3	4	5	5
Product trials availability	1	2	4	3	5
Instructions difficulty level	2	3	1	4	4
Usage difficulty level	1	2	3	1	4
Time needed (non, short, medium, long)	2	3	1	4	4
Relative Time (low, medium, high	3	2	1	2	3
Acquired patients rate %	3	3	1	1	1
Reimbursement rate %	3	2	4	1	5
Readmission rate %	2	2	1	2	1
Retention rate %	50	75	80	75	100
Attractiveness of profitable physicians	80	90	60	85	100
Amount of lawsuits/claims	30	25	50	40	0
Ease of handling	90	85	70	80	100
Minimum order quantity	3	2	2	1	3
Ability for urgent delivery	3	3	2	2	1
lead-time coefficient of variation	2	2	3	2	1

Using the single-dimensional value functions previously built for the value measures and the scores given for each item, the single-dimensional value for each alternative item was calculated for each value measure. The value calculation for the ideal should always be 100, and this is used to verify mathematics as well as a guide to improvements of alternatives.

With all required information available, the quantitative measure of the total potential value for each item was calculated using the additive model. For each alternative item, the swing weight is multiplied by the value for each measure score, and total value is the sum across all value measures for each item. The scoring data was processed using a spreadsheet model to calculate the potential value for each alternative.

3.4.2 **Analyzing the Results**

A summary of alternatives scores on value measures and corresponding calculations including the single-dimensional values, swing weights, weighted values, and total values are summarized in Table 3.12. The total potential value versus cost is plotted and shown for all alternatives in Figure 3.8 below.

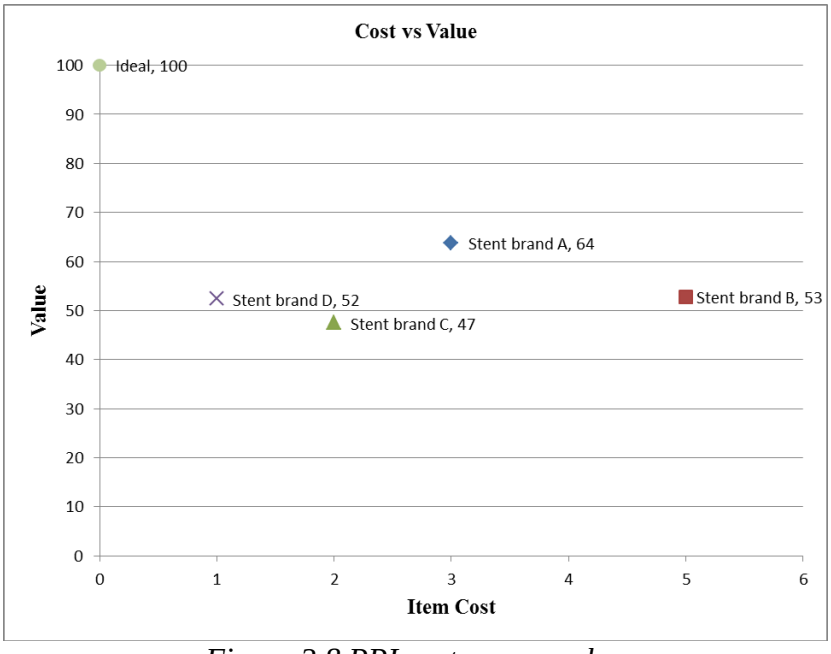

Figure 3.8 PPI cost versus value

Table 3.12 PPI Total Value Calculations

		Stent A			Stent B			Stent C			Stent D			Ideal		
Sub objective / Measure	Swing Weight (w_i)	Score (x_i)	Single-Dimensional Value $v_i(x_i)$	Value $w_i v_i(x_i)$	Score (x_i)	Single-Dimensional Value $v_i(x_i)$	Value $w_i v_i(x_i)$	Score (x_i)	Single-Dimensional Value $v_i(x_i)$	Value $w_i v_i(x_i)$	Score (x_i)	Single-Dimensional Value $v_i(x_i)$	Value $w_i v_i(x_i)$	Score (x_i)	Single-Dimensional Value $v_i(x_i)$	Value $w_i v_i(x_i)$
1.1	0.037	90	70	2.6	70	32	1.2	85	59	2.2	60	23	0.8	100	100	3.8
1.2	0.039	95	85	3.4	80	48	1.9	80	48	1.9	55	18	0.7	100	100	4.0
1.3	0.037	1	95	3.6	2	80	3.0	2	80	3.0	1	95	3.6	0	100	3.8
1.4	0.035	2	84	3.0	5	36	1.3	6	20	0.7	7	0	0.0	1	100	3.6
1.5	0.029	2	100	3.0	0	0	0.0	2	100	3.0	1	50	1.5	2	100	3.0
1.6	0.039	0.7	25	1.0	0.8	80	3.2	0.6	0	0.0	0.75	53	2.1	1	100	4.0
2.1	0.059	1	95	5.6	2	80	4.7	3	60	3.6	4	30	1.8	0	100	5.9
2.2	0.055	0.8	75	4.2	0.7	60	3.4	0.5	33	1.8	0.7	60	3.4	1	100	5.6
2.3	0.059	10	90	5.3	40	60	3.6	30	70	4.1	70	30	1.8	0	100	5.9
2.4	0.045	2	25	1.1	3	50	2.3	4	75	3.4	5	100	4.6	5	100	4.6
3.1	0.032	1	0	0.0	2	25	0.8	4	75	2.4	3	50	1.6	5	100	3.3
3.2	0.039	2	50	2.0	3	90	3.5	1	0	0.0	4	100	3.9	4	100	3.9
3.3	0.034	2	25	0.9	3	55	1.9	1	0	0.0	4	100	3.5	4	100	3.5
3.4	0.034	3	100	3.5	2	50	1.7	1	0	0.0	2	50	1.7	3	100	3.5
3.5	0.037	3	50	1.8	3	50	1.8	1	100	3.7	1	100	3.7	1	100	3.7
3.6	0.030	2	50	1.5	2	50	1.5	1	100	3.1	2	50	1.5	1	100	3.1

Table 3.12 PPI Total Value Calculations (Cont.)

		Stent A			Stent B			Stent C			Stent D			Ideal		
Sub objective / Measure	Swing Weight (w_i)	Score (x_i)	Single-Dimensional Value $v_i(x_i)$	Value $w_i v_i(x_i)$	Score (x_i)	Single-Dimensional Value $v_i(x_i)$	Value $w_i v_i(x_i)$	Score (x_i)	Single-Dimensional Value $v_i(x_i)$	Value $w_i v_i(x_i)$	Score (x_i)	Single-Dimensional Value $v_i(x_i)$	Value $w_i v_i(x_i)$	Score (x_i)	Single-Dimensional Value $v_i(x_i)$	Value $w_i v_i(x_i)$
4.1	0.026	50	44	1.2	75	71.5	1.9	80	77	2.1	75	72	1.9	100	100	2.7
4.2	0.032	80	66	2.2	90	83	2.7	60	33	1.1	85	75	2.4	100	100	3.3
4.3	0.036	30	70	2.6	25	75	2.7	50	50	1.8	40	60	2.2	0	100	3.7
4.4	0.029	90	88	2.6	85	82.5	2.4	70	66	1.9	80	77	2.2	100	100	2.9
4.5	0.029	3	100	2.9	2	50	1.4	2	50	1.4	1	0	0.0	3	100	2.9
4.6	0.032	3	0	0.0	3	0	0.0	2	50	1.6	2	50	1.6	1	100	3.3
5.1	0.032	2	50	1.6	2	50	1.6	3	100	3.3	2	50	1.6	3	100	3.3
5.2	0.057	3	100	5.7	2	50	2.9	1	0	0.0	2	50	2.9	3	100	5.7
5.3	0.049	3	50	2.5	2	25	1.2	1	0	0.0	2	25	1.2	4	100	4.9
5.4	0.024	2	0	0.0	2	0	0.0	1	50	1.2	2	0	0.0	0	100	2.5
	1.000	$V_{Item1} =$		63.7	$V_{Item2} =$		52.8	$V_{Item3} =$		47.5	$V_{Item4} =$		52.3	$V_{Ideal} =$		100.0

All sub-objectives in the PPI value tree are listed in the table by their heading number, which indicates the group's (first level objectives) number and the sub-objective's number in the list. Swing weights were also included for all value measures based on the sub-objectives level, in other words the weights were normalized based on the weight of the first level objectives. In addition, scores for each alternative on all value measures, the corresponding values, weighted values, and finally the total value were also calculated.

Value versus cost plot helps the decision makers to identify the dominant and dominated alternatives and to see the potential value for each alternative if selected for the cost needed. In Figure 3.8 it can be seen that stents A and D dominate the other two alternatives. Hence, stents B and C, the dominated alternatives, are not recommended since the organization will be paying more money for less value compared with one of the dominant alternatives. This stage helps eliminate weak alternatives, and from this point on, analysists will focus on analyzing the dominant alternatives and look further into them with the decision makers.

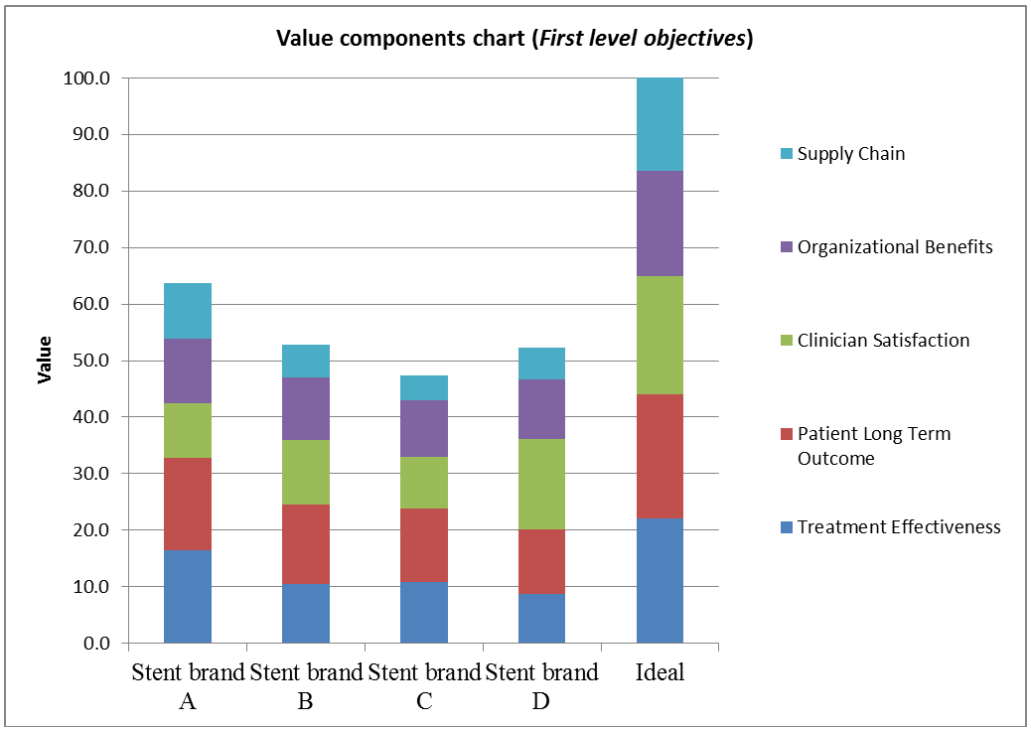

Figure 3.9 PPI total value components chart

Value component charts are used to show the contribution to total value for each value measure. Column stacked bar charts are used here to represent the value contribution for each alternative from each group of objectives (first level objectives) as whole, then another value component chart is shown for the sub-objectives in each group for further analysis. Figure 3.9 shows the PPI total value components chart, the ideal alternative is shown for reference. Identifying what alternatives are doing best on which measures helps analyze the alternatives and creating a better alternative. Obviously, stent A is doing best on the "Treatment Effectiveness" group. Value components charts for all alternatives on each group are shown in Figure 3.10, Figure 3.11, Figure 3.12, Figure 3.13, and Figure 3.14.

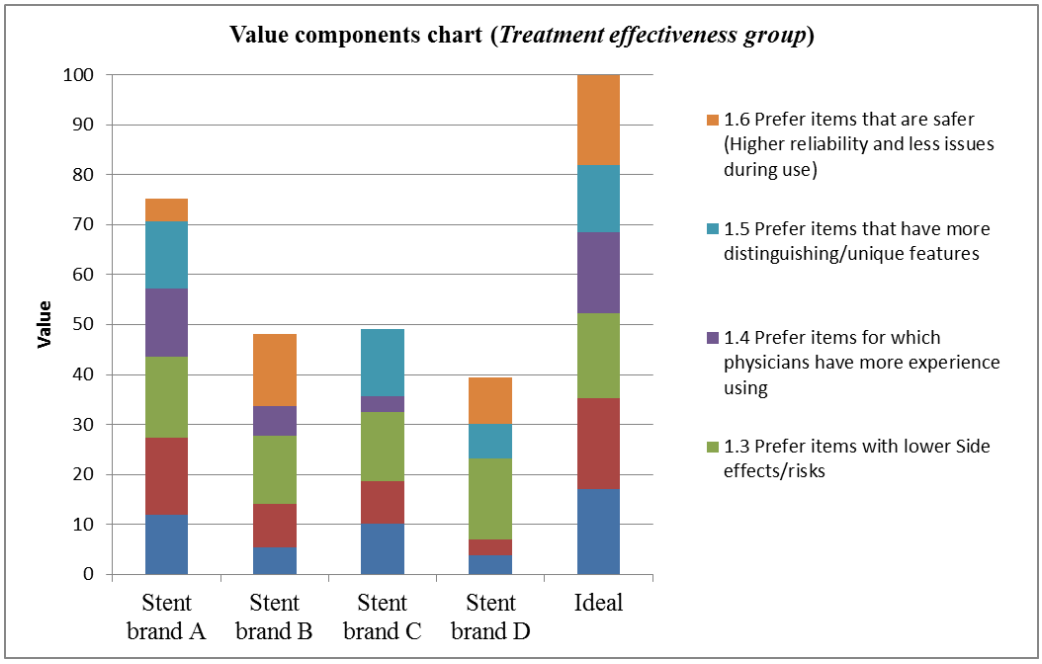

Figure 3.10 PPI "Treatment effectiveness" value components chart

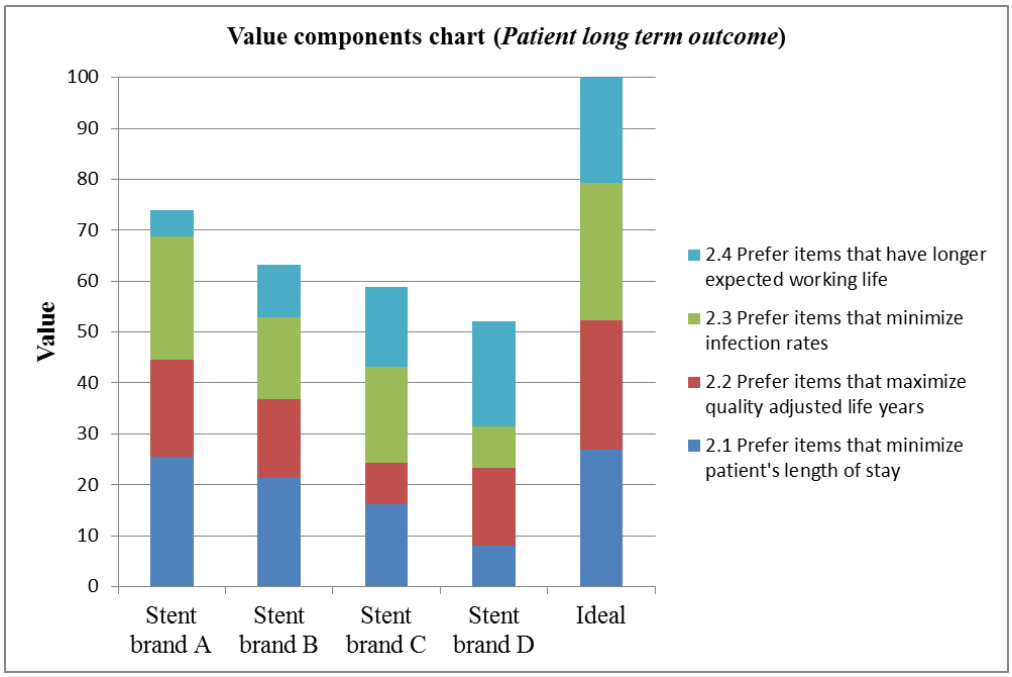

Figure 3.11 PPI "Patient long term outcome" value components chart

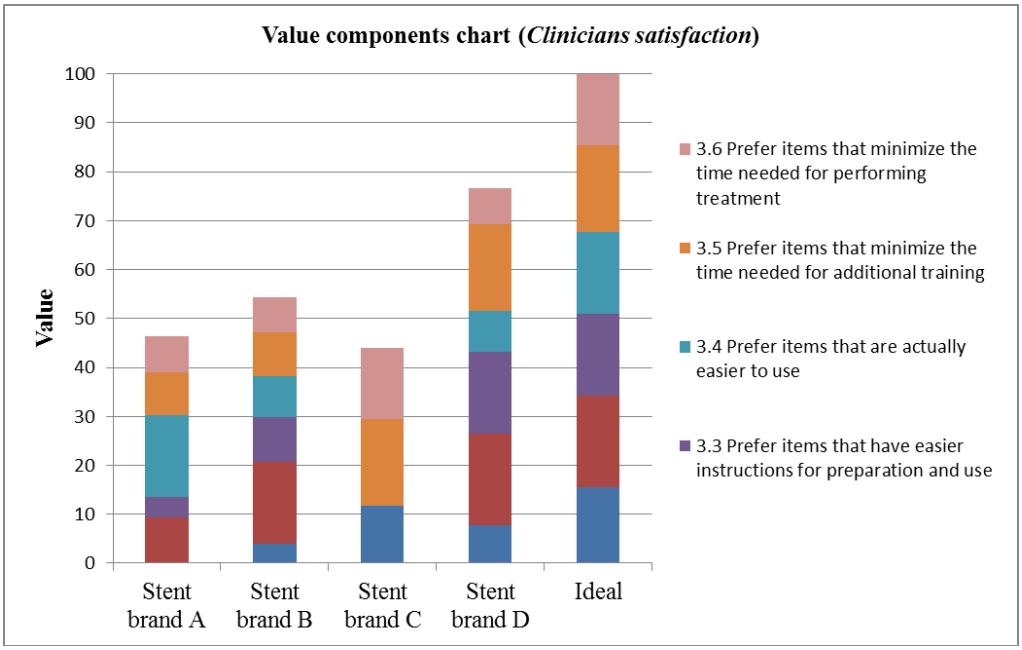

Figure 3.12 PPI "Clinicians satisfaction" value components chart

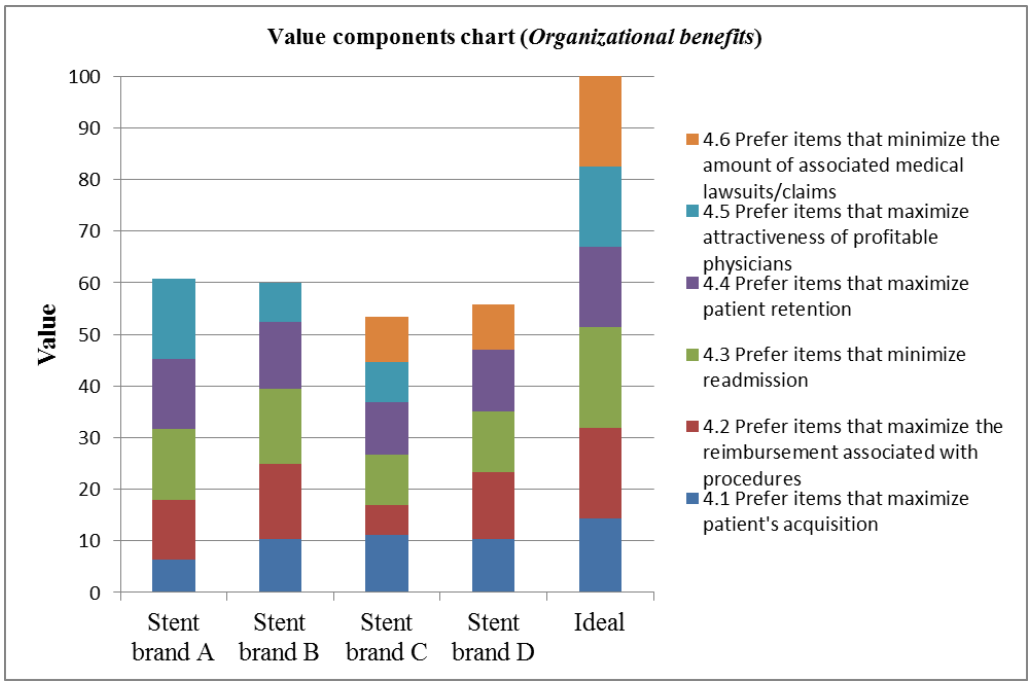

Figure 3.13 PPI "Organizational benefits" value components chart

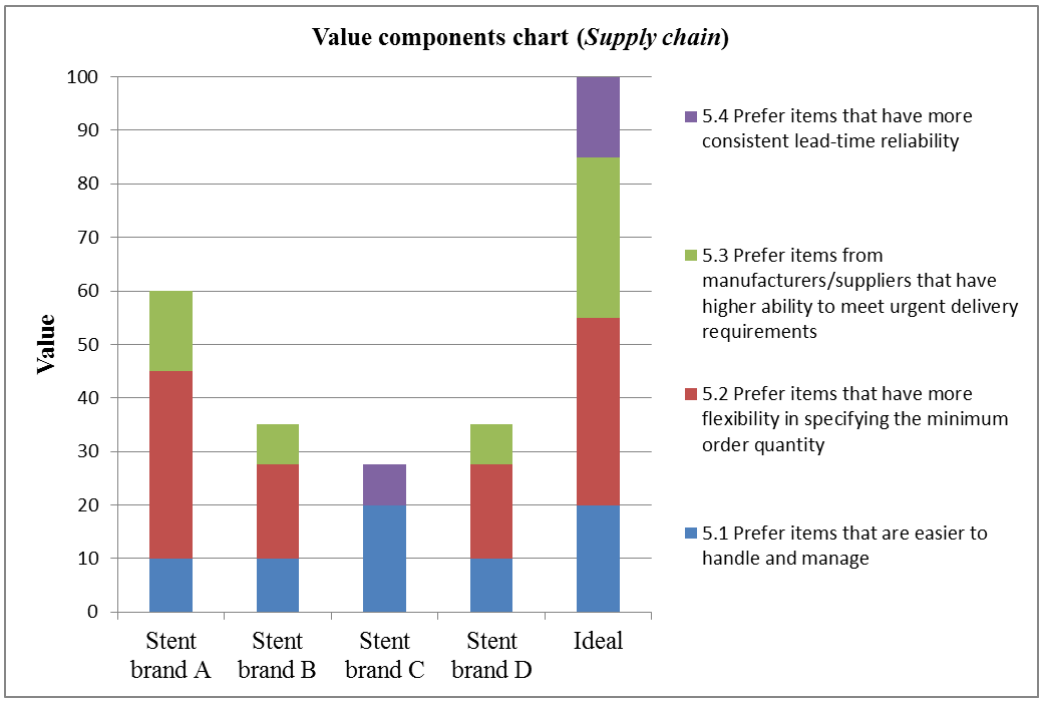

Figure 3.14 PPI "Supply chain performance" value components chart

Focusing on the two best alternatives, a visual representation of the components of the difference in value between the two non-dominant alternatives is called a waterfall charts. A

waterfall chart for the PPI case is shown below in Figure 3.15. Stent D is better than Stent A for the clinician satisfaction group of objectives. However, stent A is better than stent D on the remaining four objectives groups. For example, it is seen that stent A has a 7.75 point advantage over stent D in treatment effectiveness. If stent A can be improved on the clinician satisfaction measure, then it is a better alternative.

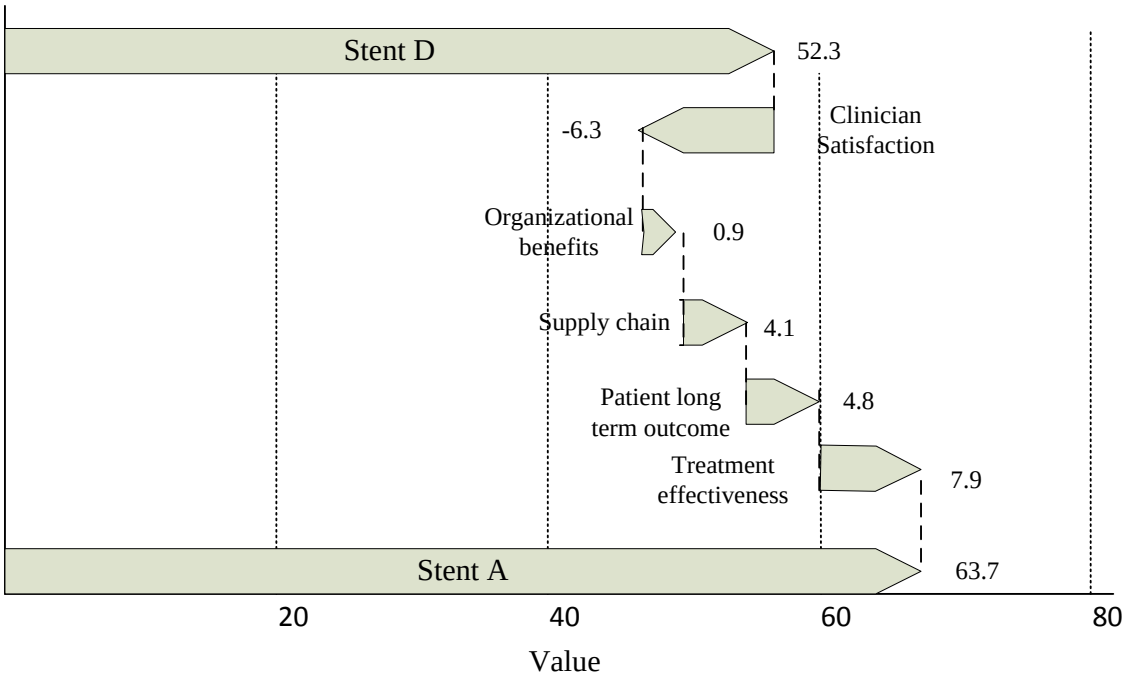

Figure 3.15 PPI waterfall chart

The best alternative can also be compared to the ideal in terms of value gaps. Value gaps are determined from the value components stacked bar charts, and are the delta between the two components. Value gaps help the analysts identifying potential areas for improving the alternative.

3.4.3 **Sensitivity Analysis**

Sensitivity analysis in MODA can be performed on any parameter such as swing weights, value curve shapes, and scores. The most common is the swing weights sensitivity. The

sensitivity was analyzed on the first objectives level, i.e. for each group as a whole, for example treatment effectiveness swing weight. When each swing weight of the five groups was varied, the remaining 4 swing weights were varied in the same proportion to ensure the swing weights sum to 1. The sensitivity analysis for the unnormalized swing weight assigned to treatment effectiveness is shown in Figure 3.16 below. The original swing weight assigned to the treatment effectiveness is 22, and varying it from 0 to 100 makes no difference on the best alternative, but when it is greater than 22, stent B becomes preferred in terms of value. Sensitivity of swing weights for the other groups "Patient long term outcome", "Clinicians' satisfaction", "Organizational benefits", and "Supply chain" are shown below in Figure 3.17, Figure 3.18, Figure 3.19, and Figure 3.20, respectively.

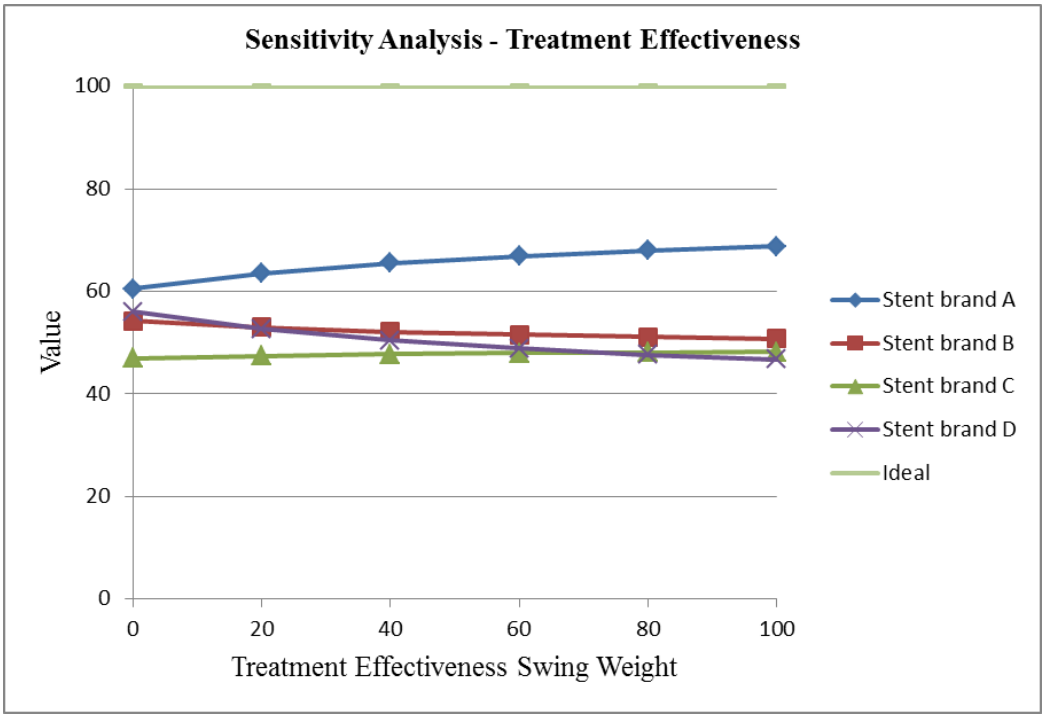

Figure 3.16 PPI sensitivity analysis for treatment effectiveness unnormalized swing weight

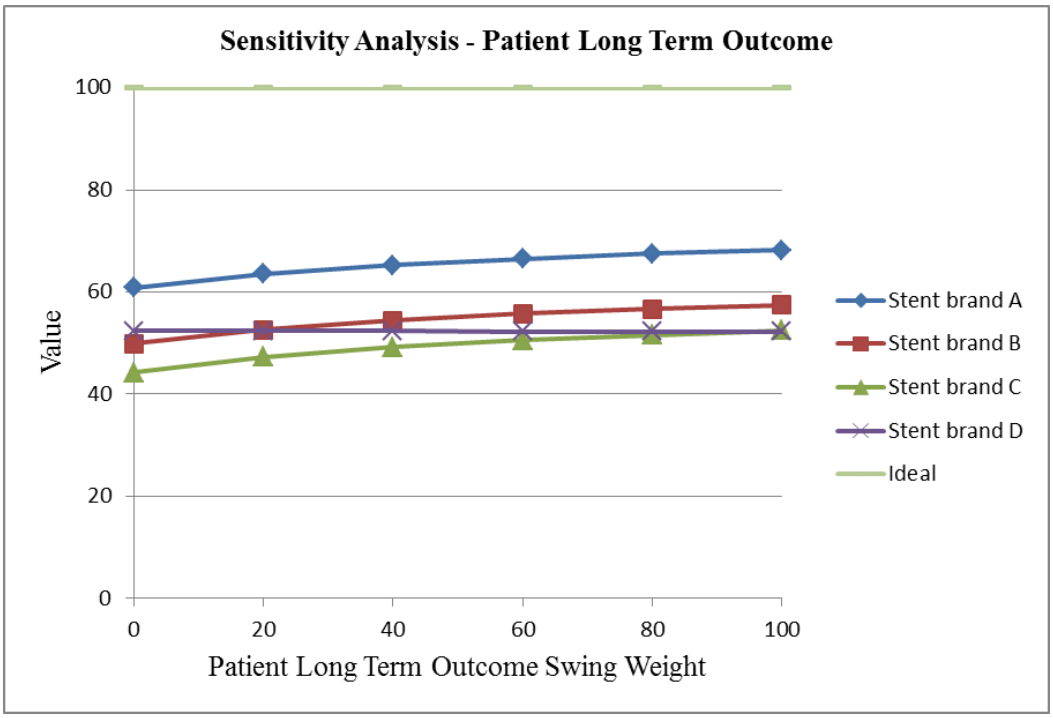

Figure 3.17 PPI sensitivity analysis for patient long term outcome unnormalized swing weight

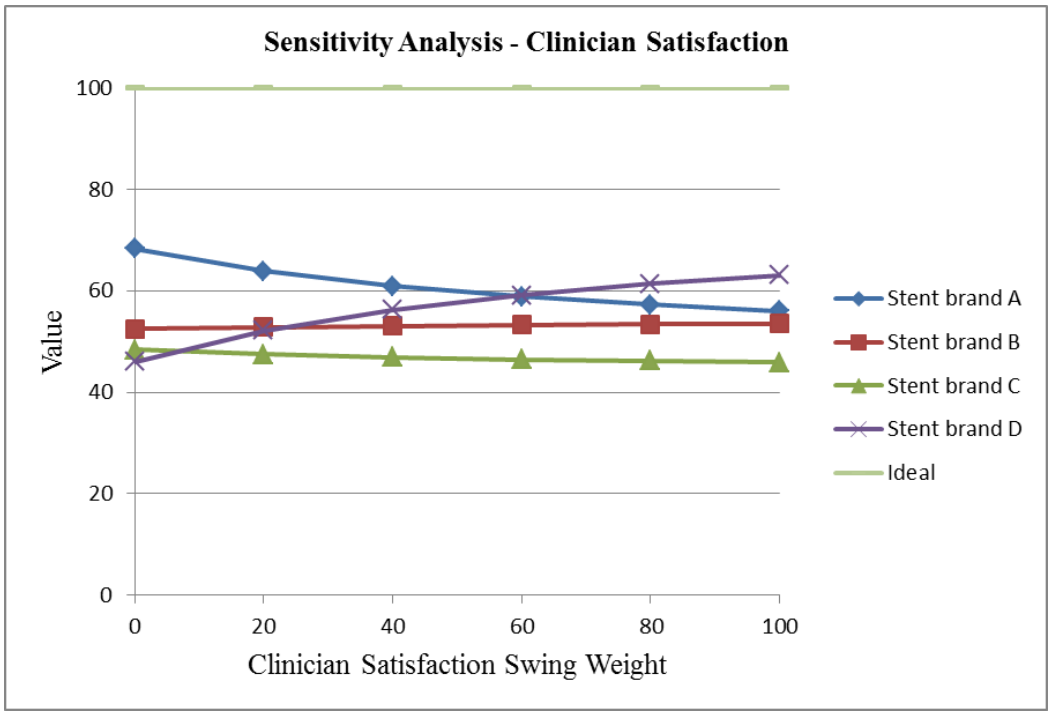

Figure 3.18 PPI sensitivity analysis for clinician satisfaction unnormalized swing weight

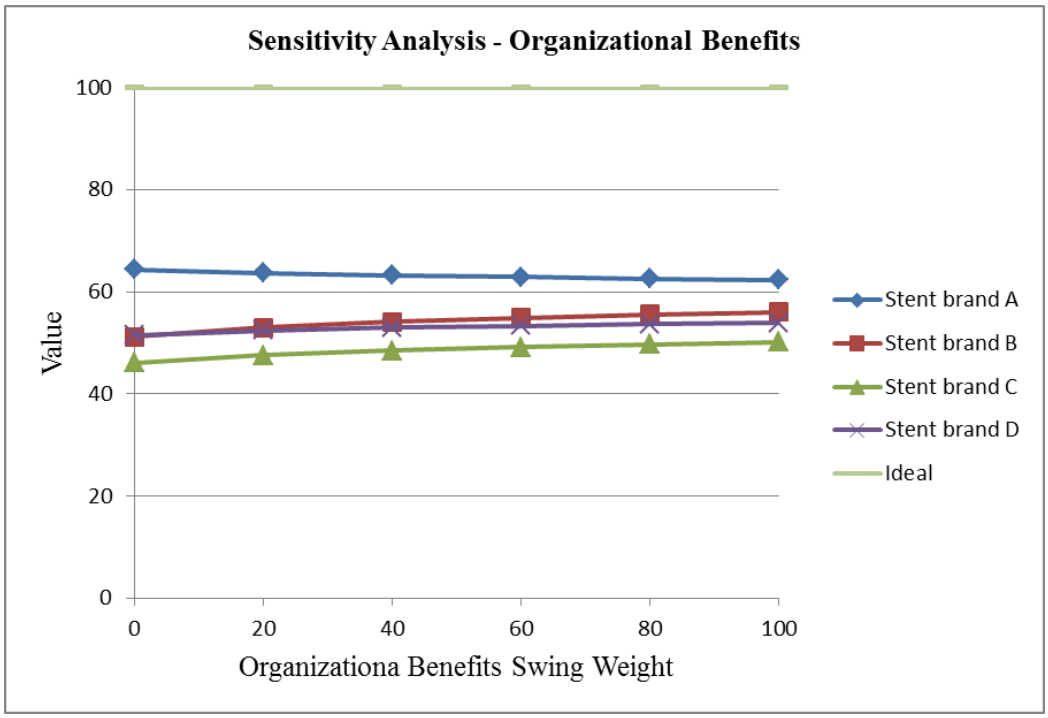

Figure 3.19 PPI sensitivity analysis for organizational benefits unnormalized swing weight

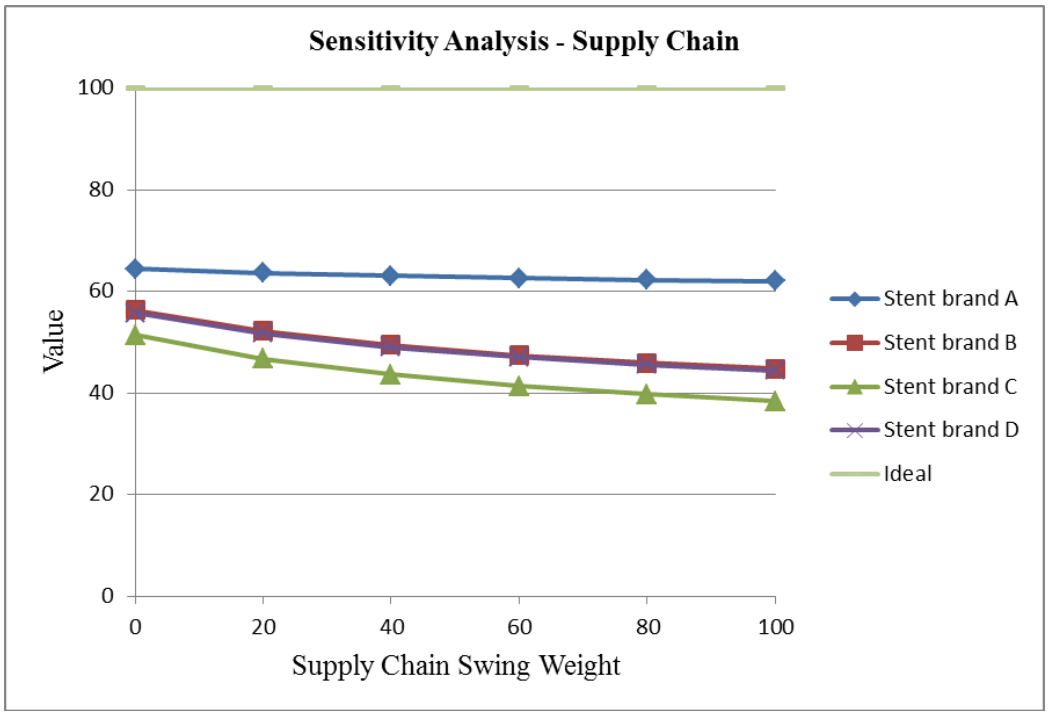

Figure 3.20 PPI sensitivity analysis for SC unnormalized swing weight

The sensitivity analysis for the unnormalized swing weight assigned to patient outcome is shown in Figure 3.17. It is obvious that the alternatives were not affected when changing the patient outcome swing weight. The same unresponsiveness to swing weight changing was for the organizational benefits Figure 3.19, and also for the SC performance as seen in Figure 3.20. However, the decision is sensitive to the clinician satisfaction swing weight as seen in Figure 3.18, such that for a swing weight greater than 50, stent D will become more valuable than stent A and consequently the dominant one since it is cheaper.

3.5 Feedback and Evaluation

Meetings, either actual or virtual, with experts on the PPI problem were carried out. The purpose was to explain the decision framework developed in this research including the methodology (MODA), as well as the PPI model elements. Four SC professionals and two physicians from 3 different organizations were interviewed.

Based on the discussion during the meetings, we can conclude that all participants were receptive to the process and thought it is valuable. A document summarizing the framework was prepared specifically for this education process and shared with the experts as well as all required elements of the PPI model. The goal after explaining the methodology was to conduct a case study on few real items, and then evaluate the framework in terms of many factors, which will be discussed later. However, due to lack of time, a real case study was not conducted, and a notional example on 4 heart stents was created by the researchers for illustration. Participant's initial reactions were captured during the meetings. In addition, participant evaluation of the framework and the process was collected through a feedback form that was sent to participants after showing the example with all results. The feedback form is included in Appendix F.6: Evaluation Feedback Questions.

The experts participated in giving input during the modeling process, education process, and all the way through to evaluating the framework. The experts are all working directly in the items selection process and value analysis process within their organizations. A special note is to be made about the two physicians who participated in this process; this is because of their knowledge and experience which make them best fit for the evaluation and an asset for developing the model. Two of the participants are physicians: a plastic surgeon and neurosurgeon, with each having more than 15 years of experience. Both are also leading value analysis programs in their organization, experienced in clinical and financial outcomes, standardizing quality of care, and facilitating physician engagement and the integration of value-driven decision making within healthcare delivery systems. Thus, they have valuable experience as clinicians and they bring experience in value-driven decision making.

It was possible to get evaluations from these two surgeons in addition to one SC professional at the time of writing this dissertation. All questions were asked on a scale of 1 to 5 Likert scale, where 1 means “I do not agree” and 5 means “I strongly agree”. The 15 questions were classified into 4 groups, namely: Degree the framework captures the PPI problem, time and ease of implementation, value added from this framework, if implementable in their companies. Average scorings on all items per group are shown in the bar chart in Figure 3.21.

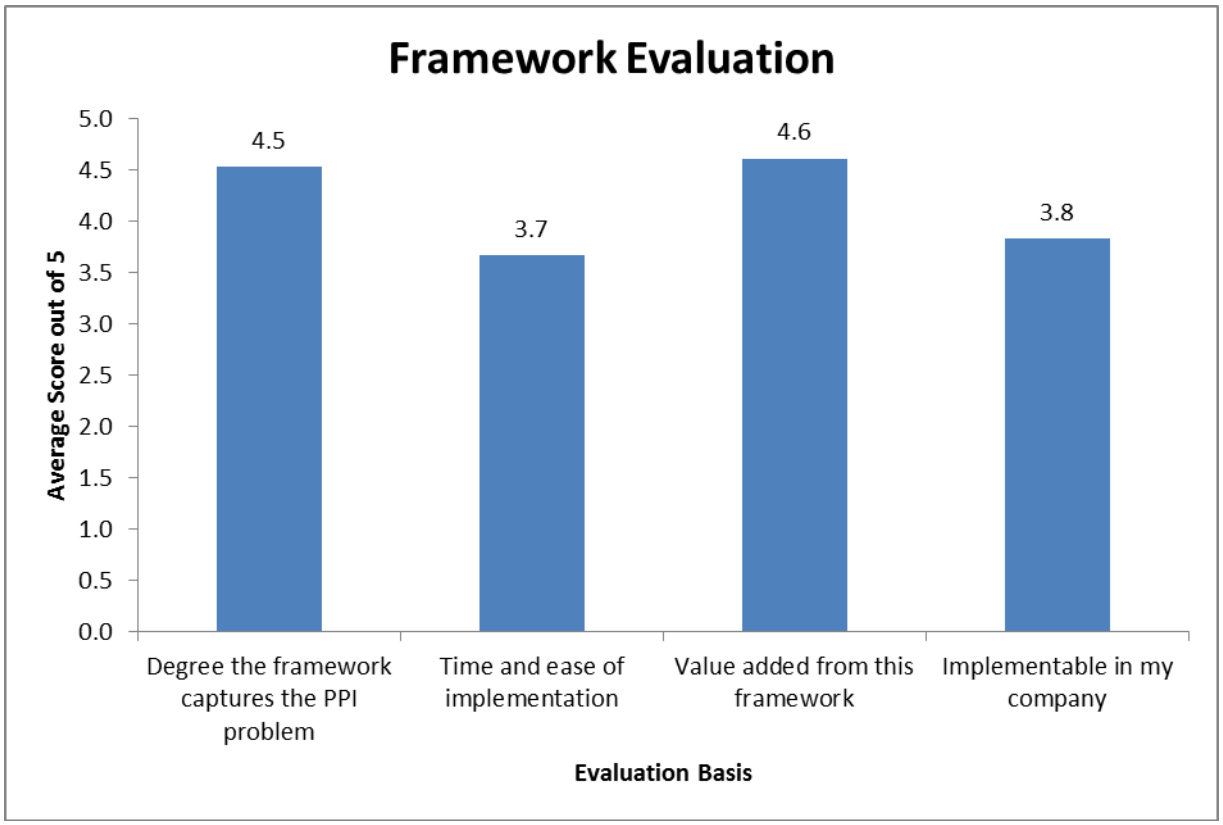

Figure 3.21 Framework evaluation feedback

The highest scores for the "degree the framework captures the PPI problems" and "value added from this framework". The first one is very important as it serves as a potential indicator for the value of the model; it satisfied the participants in terms of capturing the problem and all objectives for involved stakeholders. This is by itself is a contribution; as it can be stated now that the basic PPI model has been built in this research and it is available for any future and further work. All previous work and non-academic discussions about the PPI problem were based on opinions and pure subjectivity. This model provides a rigorous methodology for incorporating subjective and objective factors and makes discussion involving these factors more effective. In addition it is also rigorous and mathematically structured. The second evaluation item (Third bar on the chart) also supports the contributions made in this research. There is a high potential value added to the value analysis process by the framework. This should

encourage healthcare organizations to consider adopting this methodology in order to increase the efficiency of their items selection process as well as adding value to their value analysis process.

For the “Time and ease of implementation”, it is expected to have lower score; the model needs explanation and input is needed from stakeholders before any item value evaluation can take place. Items evaluation (scoring) itself requires input assessment on all of the 26 sub-objectives. With that being said, this will not be always the case, since organizations will learn with time, can customize the framework, and automate portions of the evaluation process. In the long run, it may be expected to be even easier than the pure discussions due to the fact that the framework more readily fosters the tracking and evaluation of decisions over time. For the last item “If they think it is implementable in their companies”, this is the nature for any new process. It is not easy to change and adopt new processes since people in general do not like to spend time learning new methods as well as the fear from the added layer of complexity. The last question in the evaluation feedback was an open question, and the following summarize the comments with minor changes to correct spelling and formatting.

The SC professional said “Even though this is a university setting and our Physicians are scientists, there has not been a culture in the past of adding scientific theory to the Value Analysis process. In the past, decisions have been made "assumedly" under the need of the patient and (typically) with very little scrutiny. Implementation (though not impossible) would be very difficult due to what would be seen as additional layers of complexity and more "bureaucratic hoops" to jump through. In many cases, if systems are deemed too cumbersome, Physicians complain, and find ways around the system.”

Physicians said “I think any tool that lends objectivity to the value analysis process is a welcome addition. Value analysis in practical terms often gets slowed down by indecision and lack of momentum.” Also “This tool can potentially improve that and simplify the decision making analysis.” Finally, “I appreciate the fact that the developers sought clinician input to ascertain which were the most important aspects to consider in the various categories. I felt the criteria they selected were extremely thorough and represented a comprehensive thought process in evaluating products.”

One final note to mention is a comment that was made through one of the meetings that the power of physicians’ contribution to the decision will outweigh other people’s opinion. This concern is actually one of the major reasons for using such a methodology because it systematically includes the perspective of all stakeholders. This type of analysis will enable value analysts to show the consequences of any decision in terms of added value versus cost. Visibility of decisions and traceability are two major characteristics for the big picture shown in the output.

3.6 Conclusions

SKU proliferation can decrease the supply chain performance of healthcare organizations for many reasons. First, proliferation causes additional administrative cost to handle multiple item types, vendors and purchase orders. Second, SKU proliferation decreases the ability of the organization to pursue order size discounts. Third, SKU proliferation decreases the ability the organization to negotiate price because of the need to meet physician preference. Fourth, SKU proliferation can cause additional shipping and handling of items in stock because more item types must be ordered. A very good reason for having fewer items to manage is the stock out issue. That is with more items to manage and less quantities needed; there is higher probability

of stock out for particular items, which translates to poor service to patients. This may also hurt the reimbursement rates.

The objective of the proposed framework is to add value to the current value analysis process by making more informative decisions to keep the highest value added items relative to cost. A magazine specifically devoted for value analysis and utilization management in healthcare is published quarterly (Yokl, et al. 2016). A review of the periodical indicated that much emphasis is being placed on this area for being a very critical practice in utilization management within healthcare. Articles also emphasize the need for adding software and more structured models to enhance and enrich the value analysis process. The mathematical modeling and structured MCDM methodology (MODA) used is expected to enhance the value analysis process.

A PPI selection model was proposed, and a MCDM decision framework was developed based on MODA. The model was reviewed, and evaluated in terms of effectiveness and value added to the current value analysis process. The evaluation feedback received from experts as summarized in the previous section, shows a very positive perspective about the framework and a high perceived potential regarding its effectiveness. An emphasis should be made here that this framework separates the cost from all other non-cost related qualities, which was found as interesting and useful by the healthcare organizations.

The framework is implemented via a tool that shows all of the calculations as well as outputs and sensitivity analysis. The framework was positively evaluated as a mathematical rigorous framework that enhances the objectivity of the decision process. Also, the process was seen as extremely thorough and comprehensive.

One of the contributions of this work is that we built the first comprehensive PPI model. Another contribution is that MODA has never been applied to this problem. This framework

improves the value analysis process and adds value to the context of items selection. This framework has the potential (with some improvements) to be used commercially across healthcare organizations.

Finally, in the following we discuss recommendations for future work. A difference between healthcare modeling and the modeling for other sectors is the need to address the ethical and criticality of this kind of service. Dealing with people and lives is definitely more sensitive than dealing with other sectors. Another difference is the complexity of the healthcare nature due to the many stakeholders involved, namely: patients, physicians, nurses, supply chain professionals, hospital's administration, and insurance companies. This actually creates a variety of tradeoffs and overlapping between desires and objectives.

A recommendation for healthcare organizations is to conduct value focused thinking (VFT) after analyzing the results and performing the sensitivity analysis; to improve the alternatives. This interactive process involves decision makers, stakeholders, experts, and decision analysists to look for alternatives that can create higher value. The VFT approach was created by (R. Keeney 1992). This framework should be reviewed frequently; to make sure weights as well as value functions represent the stakeholders' preferences.

As a future work, the authors are planning on applying a portfolio optimization modeling after the value versus cost analysis. The best value of selected items subjected to constraints like available budget and available space should be the focus of the optimization. Another work for the future is to develop a total cost of ownership (TCO) model for the PPI and to use it instead of the item's purchase price.

As a future work, PPIs may be categorized into 3 different groups namely: tools, replacement devices, and consumables and a framework may be developed for each category. The rationale behind this is because items in these categories differ in terms of objectives and swing weights.

A real case study is also planned to be conducted following this work. Also, models other than the additive may be applied and the framework performance investigated.

Another work for future is to investigate the reliability of the value measures and incorporate this parameter in the model. Uncertainty of the value measure estimation could be a distinguishing factor in the decision.

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Appendix A: Terms' Definitions

Physician preference items: costly medical/ surgical items, such as hip and knee implants, cardiac stents, mechanical devices…etc., that are selected by the physician to use for a specific patient and procedure, and they are not preferred by the healthcare management and still being selected by the physician

SKU Proliferation: The increasing of the variety and the number of functionally equivalent items that are stocked by inventory management systems in response to marketing, acquisitions, sales incentives, and lack of life cycle controls

Item: A specific brand from a specific manufacturer (stent A from supplier X.

Item type: The class of the item for which it belongs (e.g. heart stent)

Spend Analysis: is the process of analyzing expenditure data. The purpose of spend analysis is to find ways of reducing procurement costs, and monitoring compliance.

Capitated Pricing: A model established that allows healthcare providers to purchase medical products and devices from a variety of original equipment manufacturers (OEMs) at set levels based on the level of the product. For example there may be 3 levels: Standard, High, and Premium. Each OEM will establish their products that fall into each of these categories by a certain set of characteristics that make these products "equal" from a clinical effectiveness point of view. Then the healthcare provider will pay each OEM the same amount for any product in each level. For example: $3500 for all Standards, $5000 for all High, and $7500 for all Premiums. The capitated pricing model also allows for OEMs to produce a special or "niche" product that does not fall into these categories if they can prove the clinical reasoning"
http://wiki.answers.com/Q/What_is_capitated_pricing?#slide1

Appendix B: IRB Approval and Protocols

Appendix B.1: IRB Approval

Office of Research Compliance
Institutional Review Board

April 28, 2015

MEMORANDUM

TO:	Mohammad Shbool Edward Pohl Ashlea Milburn Christian Hofer Manuel Rossetti
FROM:	Ro Windwalker IRB Coordinator
RE:	PROJECT CONTINUATION
IRB Protocol #:	14-04-706
Protocol Title:	*Effect of Physician Preference Items (PPI) on the SKUs Proliferation in Healthcare*
Review Type:	☒ EXEMPT ☐ EXPEDITED ☐ FULL IRB
Previous Approval Period:	Start Date: 05/13/2014 Expiration Date: 05/12/2015
New Expiration Date:	05/12/2016

Your request to extend the referenced protocol has been approved by the IRB. If at the end of this period you wish to continue the project, you must submit a request using the form *Continuing Review for IRB Approved Projects*, prior to the expiration date. Failure to obtain approval for a continuation on or prior to this new expiration date will result in termination of the protocol and you will be required to submit a new protocol to the IRB before continuing the project. Data collected past the protocol expiration date may need to be eliminated from the dataset should you wish to publish. Only data collected under a currently approved protocol can be certified by the IRB for any purpose.

This protocol has been approved for 1,200 total participants. If you wish to make *any* modifications in the approved protocol, including enrolling more than this number, you must seek approval *prior to* implementing those changes. All modifications should be requested in writing (email is acceptable) and must provide sufficient detail to assess the impact of the change.

If you have questions or need any assistance from the IRB, please contact me at 109 MLKG Building, 5-2208, or irb@uark.edu.

109 MLKG ▪ 1 University of Arkansas ▪ Fayetteville, AR 72701-1201 ▪ (479) 575-2208 ▪ Fax (479) 575-6527 ▪ Email irb@uark.edu

Appendix B.2: Survey Protocol

IRB Project Number

UNIVERSITY OF ARKANSAS INSTITUTIONAL REVIEW BOARD
PROTOCOL FORM

The University Institutional Review Board recommends policies and monitors their implementation, on the use of human beings as subjects for physical, mental, and social experimentation, in and out of class. . . . Protocols for the use of human subjects in research and in class experiments, whether funded internally or externally, must be approved by the (IRB) or in accordance with IRB policies and procedures prior to the implementation of the human subject protocol. . . Violation of procedures and approved protocols can result in the loss of funding from the sponsoring agency or the University of Arkansas and may be interpreted as scientific misconduct. *(see Faculty Handbook)*

Supply the information requested in items 1-14 as appropriate. **Type** entries in the spaces provided using additional pages as needed. In accordance with college/departmental policy, submit the original **and** one copy of this completed protocol form and all attached materials to the appropriate Human Subjects Committee. In the absence of an IRB-authorized Human Subjects Committee, submit the original of this completed protocol form and all attached materials to the IRB, Attn: Compliance Officer, ADMN 210, 575-2208. Completed form and additional materials may be emailed to irb@uark.edu. The fully signed signature page may be scanned and submitted with the protocol, by FAX (575-3846) or via campus mail.

1. Title of Project: Effect of physician preference items (PPI) on the SKUs Proliferation in Healthcare

2. (Students **must** have a faculty member supervise the research. The faculty member must sign this form and all researchers and the faculty advisor should provide a campus phone number.)

	Name	Department	Email Address	Campus Phone
Principal Researcher	Mohammad Shbool	Industrial Engineering	mshbool@uark.edu	Fayetteville
Co-Researcher	Edward Pohl	Industrial Engineering	epohl@uark.edu	Fayetteville
Co-Researcher	Ashlea Milburn	Industrial Engineering	ashlea@uark.edu	Fayetteville
Co-Researcher	Christian Hofer	Sam Walton (Business)	chofer@walton.uark.edu	Fayetteville
Faculty Advisor	Dr. Manuel Rossetti	Industrial Engineering	rossetti@uark.edu	Fayetteville

3.Researcher(s) status. Check all that apply.

☒ Faculty ☐ Staff ☒ Graduate Student(s) ☐ Undergraduate Student(s)

4. Project type

☐ Faculty Research ☒ Thesis / Dissertation ☐ Class Project ☐ Independent Study / Educ. Spec. Project
☐ Staff Research ☐ M.A.T. Research ☐ Honors Project

5. Is the project receiving extramural funding? (Extramural funding is funding from an external research sponsor.)

☒ No ☐ Yes. Specify the source of funds

IRB Project Number

6. Brief description of the purpose of proposed research and all procedures involving people. Be specific. Use additional pages if needed. (**Do not** send thesis or dissertation proposals. Proposals for extramural funding must be submitted in full.)

Purpose of research: to investigate the issue of physician preference items and understand how organizations handle this matter. Then, to model the problem and evaluate the consequences of each decisions about any item and help the organization make the best decision

Procedures involving people: Physicians and supply chain professionals in healthcare will be asked to complete a web based survey. Phone calls or interviews might be conducted to collect more information about the subject.

7. Estimated **number of participants** (complete all that apply)

_____ Children under 14 _____ Children 14-17 _____ UA students (18yrs and older) _50_ Adult non-students

8. Anticipated dates for contact with participants:

First Contact May 30th, 2014 Last Contact April 30th, 2014

9. Informed Consent procedures: The following information must be included in any procedure: identification of researcher, institutional affiliation and contact information; identification of Compliance Officer and contact information; purpose of the research, expected duration of the subject's participation; description of procedures; risks and/or benefits; how confidentiality will be ensured; that participation is voluntary and that refusal to participate will involve no penalty or loss of benefits to which the subject is otherwise entitled. See *Policies and Procedures Governing Research with Human Subjects*, section 5.0 Requirements for Consent.

☐ Signed informed consent will be obtained. **Attach copy of form.**
☐ Modified informed consent will be obtained. **Attach copy of form.**
☒ Other method (e.g., implied consent). **Please explain on attached sheet.**
☐ Not applicable to this project. **Please explain on attached sheet.**

10. Confidentiality of Data: All data collected that can be associated with a subject/respondent must remain confidential. Describe the methods to be used to ensure the confidentiality of data obtained.

Completed surveys will be collected via the available UA web-survey system.
All responses by individuals will remain confidential. Individual participants will only be identified in the database with a pin number to eliminate the possibility of duplicate entries. Once the survey period is over, the linkages between the pin numbers and survey respondents will be eliminated. The responses will be analyzed and reported for physicians or supply chain professionals as a group, so individual names and that of their institution will never be associated with any particular findings.

11. Risks and/or Benefits:

Risks: Will participants in the research be exposed to more than minimal risk? ☐Yes ☒ **No** Minimal risk is defined as risks of harm not greater, considering probability and magnitude, than those ordinarily encountered in daily life or during the performance of routine physical or psychological examinations or tests. Describe any such risks or discomforts associated with the study and precautions that will be taken to minimize them.

There are no risks associated with filling out the survey.

Benefits: Other than the contribution of new knowledge, describe the benefits of this research.
The findings from this research will characterize the issue the PPI and its effects on the organizations performance and the supply chain efficiency.

12. Check all of the following that apply to the proposed research. Supply the requested information below or on attached sheets:

- ☐ A. Deception of or withholding information from participants. Justify the use of deception or the withholding of information. Describe the debriefing procedure: how and when will the subject be informed of the deception and/or the information withheld?
- ☐ B. Medical clearance necessary prior to participation. Describe the procedures and note the safety precautions to be taken.
- ☐ C. Samples (blood, tissue, etc.) from participants. Describe the procedures and note the safety precautions to be taken.
- ☐ D. Administration of substances (foods, drugs, etc.) to participants. Describe the procedures and note the safety precautions to be taken.
- ☐ E. Physical exercise or conditioning for subjects. Describe the procedures and note the safety precautions to be taken.
- ☐ F. Research involving children. How will informed consent from parents or legally authorized representatives as well as from subjects be obtained?
- ☐ G. Research involving pregnant women or fetuses. How will informed consent be obtained from both parents of the fetus?
- ☐ H. Research involving participants in institutions (cognitive impairments, prisoners, etc.). Specify agencies or institutions involved. Attach letters of approval. Letters must be on letterhead with original signature; electronic transmission is acceptable.
- ☐ I. Research approved by an IRB at another institution. Specify agencies or institutions involved. Attach letters of approval. Letters must be on letterhead with original signature; electronic transmission is acceptable.
- ☐ J. Research that must be approved by another institution or agency. Specify agencies or institutions involved. Attach letters of approval. Letters must be on letterhead with original signature; electronic transmission is acceptable.

13. Checklist for Attachments

The following are attached:
☐ Consent form (if applicable) or
☒ Letter to participants, written instructions, and/or script of oral protocols indicating clearly the information in item #9.
☐ Letter(s) of approval from cooperating institution(s) and/or other IRB approvals (if applicable)
☒ Data collection instruments

14. Signatures

I/we agree to provide the proper surveillance of this project to insure that the rights and welfare of the human subjects/respondents are protected. I/we will report any adverse reactions to the committee. Additions to or changes in research procedures after the project has been approved will be submitted to the committee for review. I/we agree to request renewal of approval for any project when subject/respondent contact continues more than one year.

Principal Researcher	[redacted] 4/15/2014	Date
Co-Researcher	[redacted] 4/16/2014	Date
Co-Researcher	[redacted] 4/30/14	Date
Co-Researcher	[redacted] 4/21/14	Date
Faculty Advisor	[redacted] 4/15/2014	Date

PROTOCOL APPROVAL FORM

(To be returned to IRB Program Manager with copy of completed protocol form and attachments)

Human Subjects Committee Use Only (In absence of IRB-authorized Human Subjects Committee, send protocol to IRB.)

Recommended Review Status

9 Human Subjects Committee can approve as exempt because this research fits in the following category of research as described in section 9.02 of the IRB policies and procedures **(Cite reasons for exempt status.)**:

Printed Name and
Signature of the HSC Chair _____ Date

****
**

9 Expedited Review by a designated member of the IRB because this research fits in the following category of research as described in section 9.03 of the IRB policies and procedures **(Cite reasons for expedited status.)**:

Printed Name and
Signature of the HSC Chair _____ Date

****
***

9 Requires Full Review by the IRB because this research fits in the following category of research as described in section 9.04 of the IRB policies and procedures **(Cite reasons for full status.)**:

Printed Name and
Signature of the HSC Chair _____ Date

IRB/RSCP Use Only

Project Number _____ Received RSCP

Sent to: _____ Date:

Final Status

9 Approved as **Exempt** under section 9.02 of the IRB Policies and Procedures **(Cite reasons for exemption.)**:

9 Approved as **Expedited** under Section 9.03 of the IRB Policies and Procedures because **(Cite reasons for expedited status.)**

Printed Name and
Signature: _____ _____ Date _____
IRB (for the Committee)

9 Approved by **Full** review under Section 9.04 of the IRB as meeting requirements of the IRB Policies and Procedures.

Printed Name and
Signature: _____ Date
IRB Chairperson

Appendix C: Surveys

Appendix C.1: Physicians' Survey

Effect of Physician Preference Items (PPI) on the SKUs Proliferation in Healthcare
Consent to Participate in a Research Study

Principal Researcher: Mohammad Shbool
Faculty Advisor: Dr. Manuel Rossetti

INVITATION TO PARTICIPATE

You are invited to participate in a research study about Physician Preference Items. You are being asked to participate in this study because you either a Physician or a Supply chain professional.

WHAT YOU SHOULD KNOW ABOUT THE RESEARCH STUDY

Who is the Principal Researcher?

Mohammad Shbool, PhD. Candidate,
(Contact information shown below)

Who is the Faculty Advisor?

Manuel Rossetti, Ph.D., P.E.
(Contact information shown below)

What is the purpose of this research study?

The purpose of this study is to develop a deeper understanding of the role that physician preference items play within the healthcare supply chain.

Who will participate in this study?

We are expecting to have at most 200 physicians participating in this survey, and a 1000 participants of supply chain professionals who work in the healthcare sector.

What am I being asked to do?

Your participation will require the following:
Answering questions in the questionnaire to the best of your knowledge.

What are the possible risks or discomforts?

There are no anticipated risks to participating.

What are the possible benefits of this study?

There are no anticipated benefits to the participant.

How long will the study last?

The survey should take between 10-15 minutes of your time

Will I receive compensation for my time and inconvenience if I choose to participate in this study?

No

Will I have to pay for anything?
No, there will be no cost associated with your participation.

What are the options if I do not want to be in the study?
If you do not want to be in this study, you may refuse to participate. Also, you may refuse to participate at any time during the study. My PhD degree will not be affected in any way if you refuse to participate.

How will my confidentiality be protected?
All information will be kept confidential to the extent allowed by applicable State and Federal law.
All responses by individuals will remain anonymous. Individual participants will only be identified in the database with a pin number to eliminate the possibility of duplicate entries. Once the survey period is over, the linkages between the pin numbers and survey respondents will be eliminated. No questions are presented that will allow for the identification of an individual respondent. Thus, the researchers will not be able to determine the identity of any respondents. The responses will be analyzed and reported for physicians or supply chain professionals as a group. Since individual responses are anonymous, individual names and that of their institution will never be associated with any particular findings.

Will I know the results of the study?
At the conclusion of the study you will have the right to request feedback about the results. You may contact the faculty advisor, Dr. Manuel Rossetti or Principal Researcher, Mohammad Shbool.

What do I do if I have questions about the research study?
You have the right to contact the Principal Researcher or Faculty Advisor as listed below for any concerns that you may have.

Mohammad Shbool, PhD. Candidate,
University of Arkansas
Department of Industrial Engineering
4207 Bell Engineering Center
Fayetteville, AR 72701
Phone:
email:
WWW:

Manuel Rossetti, Ph.D., P.E.
Professor and Associate Department Head
University of Arkansas
Department of Industrial Engineering
4207 Bell Engineering Center

Fayetteville, AR 72701
Phone: (479) 575-6756
Fax: (479) 575-8431
email: rossetti@uark.edu
WWW: www.uark.edu/~rossetti

You may also contact the University of Arkansas Research Compliance office listed below if you have questions about your rights as a participant, or to discuss any concerns about, or problems with the research.

Ro Windwalker, CIP
Institutional Review Board Coordinator
Research Compliance
University of Arkansas
210 Administration
Fayetteville, AR 72701-1201
479-575-2208
irb@uark.edu

I have read the above statement and have been able to ask questions and express concerns, which have been satisfactorily responded to by the investigator. I understand the purpose of the study as well as the potential benefits and risks that are involved. I understand that participation is voluntary. I understand that significant new findings developed during this research will be shared with the participant. I understand that my completion of the survey indicates that I agree for my responses to be used in this research. I have been presented a copy of the consent form.

Q1. How aware are you of the term “physician preference item?" (Definition of “Physician preference items”: costly medical/ surgical items, such as hip and knee implants, cardiac stents, mechanical devices…etc., that are selected/preferred by the physician to use for a specific patient and procedure.)

- ❍ Not aware 0
- ❍ 1
- ❍ 2
- ❍ 3
- ❍ 4
- ❍ 5
- ❍ Highly aware 6

Q2. How willing are you to use an available item in stock even if it is not your preferred brand?

- ❍ Not Willing 0
- ❍ 1
- ❍ 2
- ❍ 3
- ❍ 4
- ❍ 5
- ❍ Very Willing 6

Q3. If the item in stock is not your preferred brand, are you permitted to order whatever you want (your preferred brand)? (Brands are versions of an item and they are used for the same purpose, even though they might have different features)

- ❍ Yes
- ❍ No
- ❍ Sometimes

Q4. Please, rate the following factors according to their importance when you make an item selection decision. (Two factors can have the same rating if you think they are equivalent in importance.)

	Not Important 0	1	2	3	4	5	Very Important 6
Previous experience using the item	❍	❍	❍	❍	❍	❍	❍
The effectiveness of the item	❍	❍	❍	❍	❍	❍	❍
Reputation of this item's manufacturer	❍	❍	❍	❍	❍	❍	❍
Relationship with sales representative	❍	❍	❍	❍	❍	❍	❍
Knowledge of item cost	❍	❍	❍	❍	❍	❍	❍
Other (Please specify and rate)	❍	❍	❍	❍	❍	❍	❍

Q5. How knowledgeable are you about how the organization decides to select items?

- ❍ Not-knowledgeable 0
- ❍ 1
- ❍ 2
- ❍ 3
- ❍ 4
- ❍ 5
- ❍ Knowledgeable 6

Q6. Please rate your ability to influence the decision to stock and use an item

- ❍ Low 0
- ❍ 1
- ❍ 2
- ❍ 3
- ❍ 4
- ❍ 5
- ❍ High 6

Q7. Please, rate the following factors according to their importance in influencing your organization's decision to stock and use a specific item. (Two factors can have the same rating if you think they are equivalent in importance.)

	0	1	2	3	4	5	6
Physician's preference	❍	❍	❍	❍	❍	❍	❍
Total cost	❍	❍	❍	❍	❍	❍	❍
Patient outcome	❍	❍	❍	❍	❍	❍	❍
Manufacturer reputation	❍	❍	❍	❍	❍	❍	❍
Required storage space	❍	❍	❍	❍	❍	❍	❍
Administration decision	❍	❍	❍	❍	❍	❍	❍
Other (Please specify and rate)	❍	❍	❍	❍	❍	❍	❍

Q8. Given that you have a preference for a particular brand, how willing are you to substitute an item from stock that is functionally equivalent but comes from a different manufacturer or brand?

- ❍ Not Willing 0
- ❍ 1
- ❍ 2
- ❍ 3
- ❍ 4
- ❍ 5
- ❍ Very Willing 6

Q9. How willing are you to drop a brand and adopt another one?

- ❍ Not Willing 0
- ❍ 1
- ❍ 2
- ❍ 3
- ❍ 4
- ❍ 5
- ❍ Very Willing 6

Q10. What are the reasons that would make you switch to another brand? (Please rate the selected ones according to priority)

	0	1	2	3	4	5	6
Easier to use	❍	❍	❍	❍	❍	❍	❍
More features	❍	❍	❍	❍	❍	❍	❍
Being produced by a reputable manufacturer	❍	❍	❍	❍	❍	❍	❍
Safer for patient	❍	❍	❍	❍	❍	❍	❍
Cheaper	❍	❍	❍	❍	❍	❍	❍
Expected to give better results for the patient	❍	❍	❍	❍	❍	❍	❍
Other (List any other reason and rate it)	❍	❍	❍	❍	❍	❍	❍

Q11. Please rate your awareness of the actual costs of items that you are requesting or using on your patients.

- ❍ Not aware (No awareness of $ value) 0
- ❍ 1
- ❍ 2
- ❍ 3
- ❍ 4
- ❍ 5
- ❍ Highly aware (know the exact $ value) 6

Q12. When an item will be directly used on a patient, how important is the patient's preference to you in deciding which item to use?

- ❍ Not Important 0
- ❍ 1
- ❍ 2
- ❍ 3
- ❍ 4
- ❍ 5
- ❍ Very Important 6

Q13. What is the cost range of the procedures/surgeries/operations that you perform? (Check all categories that apply)

- ❑
- ❑ $1,000 - $5,000
- ❑ $5,001 - $10,000
- ❑ $10,001 - $20,000
- ❑ $20,001 - $50,000
- ❑ $50,001 - $100,000
- ❑ >$100,000

Answer If “Q13. What is the cost range of the procedures/surgeries/operations that you perform? (Check all categories that apply)” Selected Choice Is Not Empty”

Q14. In previous question, you were asked about the cost range of operations you perform, please rate your willingness to substitute an equivalent item when performing a procedure in each selected category).

	0	1	2	3	4	5	6
If What is the cost range of the procedures/surgeries/operations that you perform? (Check all appropriate categories, and at the same time, rate your willingness to substitute an equivalent item when ... < $1,000 Is Selected < $1,000	❍	❍	❍	❍	❍	❍	❍
If What is the cost range of the procedures/surgeries/operations that you perform? (Check all appropriate categories, and at the same time, rate your willingness to substitute an equivalent item when ... $1,000 - $5,000 Is Selected $1,000 - $5,000	❍	❍	❍	❍	❍	❍	❍
If What is the cost range of the procedures/surgeries/operations that you perform? (Check all appropriate categories, and at the same time, rate your willingness to substitute an equivalent item when ... $5,001 - $10,000 Is Selected $5,001 - $10,000	❍	❍	❍	❍	❍	❍	❍
If What is the cost range of the procedures/surgeries/operations that you perform? (Check all appropriate categories, and at the same time, rate your willingness to substitute an equivalent item when ...	❍	❍	❍	❍	❍	❍	❍

$10,001 - $20,000 Is Selected $10,001 - $20,000 If What is the cost range of the procedures/surgeries/operations that you perform? (Check all appropriate categories, and at the same time, rate your willingness to substitute an equivalent item when ... $20,001 - $50,000 Is Selected $20,001 - $50,000 If What is the cost range of the procedures/surgeries/operations that you perform? (Check all appropriate categories, and at the same time, rate your willingness to substitute an equivalent item when ... $50,001 - $100,000 Is Selected $50,001 - $100,000 If What is the cost range of the procedures/surgeries/operations that you perform? (Check all appropriate categories, and at the same time, rate your willingness to substitute an equivalent item when ... > $100,000 Is Selected > $100,000	❍	❍	❍	❍	❍	❍	❍

Answer If “Q3. If the item in stock is not your preferred brand, are you permitted to order whatever you want (your preferred brand)? (Brands are versions of an item and they are used for the same purpose, even though they might have different features)” No Is Not Selected

Q15. What percentage of the items that you utilize in your procedures, fall into the category of physician preference items (i.e. you are allowed to indicate your preference)?

- ❍ < %25
- ❍ 25% - 50%
- ❍ 51% - 75%
- ❍ >75%

Answer If “Q3. If the item in stock is not your preferred brand, are you permitted to order whatever you want (your preferred brand)? (Brands are versions of an item and they are used for the same purpose, even though they might have different features)” No Is Not Selected

Q16. How would you characterize the cost of the items for which you are able to specify your preference?

- ❍ Low
- ❍ Medium
- ❍ High

Q17. What is your specialization (cardiothoracic, orthopedic … etc.)

Q18. In which state do you work? (Used to determine if there is any difference attributed to location)

	AL	AK	…	…	WI	WY
State						

Q19. What type of healthcare provider is your organization? (Check all that apply)

- ❑ Academic Institution
- ❑ Acute Care Facility
- ❑ Assisted Living Facility
- ❑ Hospital/Medical Center
- ❑ Managed Care Organization
- ❑ Long-Term Care Facility
- ❑ Health System / Network (IDS / IDN)
- ❑ Military/VA/Government affiliated
- ❑ Rehabilitation Center
- ❑ Other _____

Q20. What best describe your compensation model?

- ❍ Per wRVU (per work relative value units)
- ❍ Percentage of net collections
- ❍ Percentage of practice "bottom line"
- ❍ percentage of gross charges
- ❍ Per encounter
- ❍ Guaranteed base plus incentive

Q21. Indicate the approximate size of your organization.

Number of beds								
Number of Employees								

Q22. How many years have you worked in the healthcare industry?

- ❍ < 2
- ❍ 2 - 5
- ❍ 6 - 10
- ❍ 11 - 20
- ❍ > 20

Q23. What is your gender?

- ❍ Male
- ❍ Female
- ❍ Prefer to not answer

Q24. What is your employment type?

- ❍ Hospital employed
- ❍ Contracted physician group
- ❍ Community physician
- ❍ Other _____

Q25. What is your provider organization's setting?

- ❍ National
- ❍ Rural
- ❍ Suburban
- ❍ Urban
- ❍ Other _____

Appendix C.2: Supply Chain Professionals' Survey

Effect of Physician Preference Items (PPI) on the SKUs Proliferation in Healthcare
Consent to Participate in a Research Study

Principal Researcher: Mohammad Shbool
Faculty Advisor: Dr. Manuel Rossetti

INVITATION TO PARTICIPATE

You are invited to participate in a research study about Physician Preference Items. You are being asked to participate in this study because you either a Physician or a Supply chain professional.

WHAT YOU SHOULD KNOW ABOUT THE RESEARCH STUDY

Who is the Principal Researcher?

Mohammad Shbool, PhD. Candidate,
(Contact information shown below)

Who is the Faculty Advisor?

Manuel Rossetti, Ph.D., P.E.
(Contact information shown below)

What is the purpose of this research study?

The purpose of this study is to develop a deeper understanding of the role that physician preference items play within the healthcare supply chain.

Who will participate in this study?

We are expecting to have at most 200 physicians participating in this survey, and a 1000 participants of supply chain professionals who work in the healthcare sector.

What am I being asked to do?

Your participation will require the following:
Answering questions in the questionnaire to the best of your knowledge.

What are the possible risks or discomforts?

There are no anticipated risks to participating.

What are the possible benefits of this study?

There are no anticipated benefits to the participant.

How long will the study last?

The survey should take between 10-15 minutes of your time

Will I receive compensation for my time and inconvenience if I choose to participate in this study?

No

Will I have to pay for anything?
No, there will be no cost associated with your participation.

What are the options if I do not want to be in the study?
If you do not want to be in this study, you may refuse to participate. Also, you may refuse to participate at any time during the study. My PhD degree will not be affected in any way if you refuse to participate.

How will my confidentiality be protected?
All information will be kept confidential to the extent allowed by applicable State and Federal law.
All responses by individuals will remain anonymous. Individual participants will only be identified in the database with a pin number to eliminate the possibility of duplicate entries. Once the survey period is over, the linkages between the pin numbers and survey respondents will be eliminated. No questions are presented that will allow for the identification of an individual respondent. Thus, the researchers will not be able to determine the identity of any respondents. The responses will be analyzed and reported for physicians or supply chain professionals as a group. Since individual responses are anonymous, individual names and that of their institution will never be associated with any particular findings.

Will I know the results of the study?
At the conclusion of the study you will have the right to request feedback about the results. You may contact the faculty advisor, Dr. Manuel Rossetti or Principal Researcher, Mohammad Shbool.

What do I do if I have questions about the research study?
You have the right to contact the Principal Researcher or Faculty Advisor as listed below for any concerns that you may have.

Mohammad Shbool, PhD. Candidate,
University of Arkansas
Department of Industrial Engineering
4207 Bell Engineering Center
Fayetteville, AR 72701
Phone:
email:
WWW:

Manuel Rossetti, Ph.D., P.E.
Professor and Associate Department Head
University of Arkansas
Department of Industrial Engineering
4207 Bell Engineering Center
Fayetteville, AR 72701

Phone: (479) 575-6756
Fax: (479) 575-8431
email: rossetti@uark.edu
WWW: www.uark.edu/~rossetti

You may also contact the University of Arkansas Research Compliance office listed below if you have questions about your rights as a participant, or to discuss any concerns about, or problems with the research.

Ro Windwalker, CIP
Institutional Review Board Coordinator
Research Compliance
University of Arkansas
210 Administration
Fayetteville, AR 72701-1201
479-575-2208
irb@uark.edu

I have read the above statement and have been able to ask questions and express concerns, which have been satisfactorily responded to by the investigator. I understand the purpose of the study as well as the potential benefits and risks that are involved. I understand that participation is voluntary. I understand that significant new findings developed during this research will be shared with the participant. I understand that my completion of the survey indicates that I agree for my responses to be used in this research. I have been presented a copy of the consent form.

Q1. How aware are you of the term "Stock keeping unit (SKU) proliferation?"

- ❍ Not aware 0
- ❍ 1
- ❍ 2
- ❍ 3
- ❍ 4
- ❍ 5
- ❍ Highly aware 6

Q2. What is a possible cause for the SKU proliferation problem? (Please rate following causes according to degree of effect). (Definition: SKU proliferation is the increasing of the variety and the number of functionally equivalent items that are stocked by inventory management systems in response to marketing, acquisitions, sales incentives, and lack of life cycle controls)

	0	1	2	3	4	5	6
Physician preference items	❍	❍	❍	❍	❍	❍	❍
Growing size with limited space	❍	❍	❍	❍	❍	❍	❍
Unpredicted schedules of needed items	❍	❍	❍	❍	❍	❍	❍
Other (Please specify and rate)	❍	❍	❍	❍	❍	❍	❍

Q3. How aware are you of the term “Physician preference items?” (Definition of “Physician preference items”: costly medical/ surgical items, such as hip and knee implants, cardiac stents, mechanical devices…etc., that are selected/preferred by the physician to use for a specific patient and procedure.)

❍ Not aware 0
❍ 1
❍ 2
❍ 3
❍ 4
❍ 5
❍ Highly aware 6

Q4. How aware are you of the cost of your ordered items?

❍ Not aware 0
❍ 1
❍ 2
❍ 3
❍ 4
❍ 5
❍ Highly aware 6

Q5. Please rate the following factors according to their importance in influencing your organization's decision to stock a specific item. (Two factors can have the same rating if you think they are equivalent in importance.)

	0	1	2	3	4	5	6
Physician's preference	❍	❍	❍	❍	❍	❍	❍
Total Cost	❍	❍	❍	❍	❍	❍	❍
Patient outcome	❍	❍	❍	❍	❍	❍	❍
Manufacturer reputation	❍	❍	❍	❍	❍	❍	❍
Required storage space	❍	❍	❍	❍	❍	❍	❍
Administration decision	❍	❍	❍	❍	❍	❍	❍
Other (Please specify and rate)	❍	❍	❍	❍	❍	❍	❍

Q6. To what extent are the following costs shared with the physicians?

	0	1	2	3	4	5	6
Item cost (Unit purchase price)	❍	❍	❍	❍	❍	❍	❍
Total supply cost (Ordering, holding, and handling)	❍	❍	❍	❍	❍	❍	❍

Q7. To what extent do you think sharing item cost can have a potential impact on managing your PPIs?

- ❍ No Impact 0
- ❍ 1
- ❍ 2
- ❍ 3
- ❍ 4
- ❍ 5
- ❍ High Impact 6

Q8. To what extent do you think sharing total supply cost can have a potential impact on managing your PPIs?

- ❍ No Impact0
- ❍ 1
- ❍ 2
- ❍ 3
- ❍ 4
- ❍ 5
- ❍ High Impact6

Q9. To what extent are you aware of spend analysis practices? (Spend analysis is the process of analyzing expenditure data. The purpose of spend analysis is to find ways of reducing procurement costs, and monitoring compliance.)

- ❍ Not aware0
- ❍ 1
- ❍ 2
- ❍ 3
- ❍ 4
- ❍ 5
- ❍ Highly aware6

Q10. To what extent do you perform spend analysis on your PPIs?

- ❍ Not at all0
- ❍ 1
- ❍ 2
- ❍ 3
- ❍ 4
- ❍ 5
- ❍ Always6

Answer If “Q10. To what extent do you perform spend analysis on your PPIs?” (Not at all) Is Not Selected

Q11. How often do you perform spend analysis on your PPIs relative to other items?

- More
- The Same
- Less

Q12. To what extent do you think spend analysis can have a potential impact on managing PPIs?

- No impact 0
- 1
- 2
- 3
- 4
- 5
- High potential impact 6

Answer If “Q10. To what extent do you perform spend analysis on your PPIs?” (Not at all) Is Not Selected

Q13. To what extent is spend analysis data shared with physicians?

- Not at all0
- 1
- 2
- 3
- 4
- 5
- Always6

Q14. To what extent do you think spend analysis data should be shared with physicians?

- Not at all 0
- 1
- 2
- 3
- 4
- 5
- Always 6

Q15. To what extent are you aware of capitated pricing practice? (“Capitated pricing is a model established that allows healthcare providers to purchase medical products and devices from a variety of original equipment manufacturers (OEMs) at set levels based on the level of the product. For example there may be 3 levels: Standard, High, and Premium. Each OEM will establish their products that fall into each of these categories by a certain set of characteristics that make these products “equal” from a clinical effectiveness point of view. Then the healthcare

provider will pay each OEM the same amount for any product in each level. For example: $3500 for all Standards, $5000 for all High, and $7500 for all Premiums. The capitated pricing model also allows for OEMs to produce a special or "niche" product that does not fall into these categories if they can prove the clinical reasoning" http://wiki.answers.com/Q/What_is_capitated_pricing?#slide1)

- Not aware0
- 1
- 2
- 3
- 4
- 5
- Highly aware6

Q16. Are you more likely to use capitated pricing on PPI items relative to other items?

- More
- The Same
- Less

Q17. Please rate the potential of utilizing capitated pricing on controlling PPIs in your organization.

- No Impact0
- 1
- 2
- 3
- 4
- 5
- High potential impact6

Q18. To what extent is the spending of individual physicians monitored and used when making decisions regarding PPIs?

- Not at all 0
- 1
- 2
- 3
- 4
- 5
- Always6

Q19. To what extent is physician spending compared to budgeted amounts?

- ❍ Not at all0
- ❍ 1
- ❍ 2
- ❍ 3
- ❍ 4
- ❍ 5
- ❍ Always6

Q20. To what extent are physicians compared to each other on their spending habits?

- ❍ Not at all 0
- ❍ 1
- ❍ 2
- ❍ 3
- ❍ 4
- ❍ 5
- ❍ Always 6

Q21. Please rate your perceived potential impact of utilizing price reduction methods on controlling PPIs in your organization

- ❍ No impact 0
- ❍ 1
- ❍ 2
- ❍ 3
- ❍ 4
- ❍ 5
- ❍ High potential impact 6

Q22. To what extent are you aware of ABC classification practices? (ABC classification is categorizing the inventory …. the process of analyzing/categorizing inventory according to value, usage amount, revenue generation … etc.)

- ❍ Not aware 0
- ❍ 1
- ❍ 2
- ❍ 3
- ❍ 4
- ❍ 5
- ❍ Highly aware 6

Q23. How often do you conduct an ABC classification?

- ❍ Never
- ❍ Daily
- ❍ Weekly
- ❍ Monthly
- ❍ Yearly

If Never Is Selected, Then Skip To "Q28. Please rate your perceived potential impact of utilizing ABC classification on controlling PPIs in your organization."

Q24. Please rate the extent to which you utilize ABC classification on your PPIs based on value.

- ❍ Not at all 0
- ❍ 1
- ❍ 2
- ❍ 3
- ❍ 4
- ❍ 5
- ❍ Always 6

Q25. Please rate the extent to which you utilize ABC classification on your PPIs based on usage.

- ❍ Not at all 0
- ❍ 1
- ❍ 2
- ❍ 3
- ❍ 4
- ❍ 5
- ❍ Always 6

Q26. To what extent is ABC classification data shared with physicians?

- ❍ Not at all 0
- ❍ 1
- ❍ 2
- ❍ 3
- ❍ 4
- ❍ 5
- ❍ Always 6

Q27. To what extent do you think ABC classification data should be shared with physicians?

- ❍ Never 0
- ❍ 1
- ❍ 2
- ❍ 3
- ❍ 4
- ❍ 5
- ❍ Always 6

Q28. Please rate your perceived potential impact of utilizing ABC classification on controlling PPIs in your organization.

- ❍ No impact 0
- ❍ 1
- ❍ 2
- ❍ 3
- ❍ 4
- ❍ 5
- ❍ High potential impact 6

Q29. To what extent are cross-functional teams utilized in your organization for managing supply chain operations involving PPIs. (Cross-functional teams are groups of employees involving a range of stakeholders that assist with analyzing and deciding on the approval of new item, approving any requested item to be purchased, looking for process improvements in PPI management, etc.)

- ❍ Not at all 0
- ❍ 1
- ❍ 2
- ❍ 3
- ❍ 4
- ❍ 5
- ❍ Always 6

If Not at all 0 Is Selected, Then Skip To “Q33. Please rate your perceived potential impact of utilizing cross functional team meetings on controlling PPIs in your organization.”

Q30. To what extent is the ordering/procurement (supply chain) department represented in cross-functional team meetings? (Meetings that involve discussion of approving new items, or approving requested items to be purchased. This is about items that are not regular, in other words PPIs)

- ❍ Not at all 0
- ❍ 1
- ❍ 2
- ❍ 3
- ❍ 4
- ❍ 5
- ❍ Always 6

Q31. To what extent are physicians represented in cross-functional team meetings?

- ❍ Not at all 0
- ❍ 1
- ❍ 2
- ❍ 3
- ❍ 4
- ❍ 5
- ❍ Always 6

Q32. To what extent do you discuss PPIs in cross-functional team meetings?

- ❍ Not at all 0
- ❍ 1
- ❍ 2
- ❍ 3
- ❍ 4
- ❍ 5
- ❍ Always 6

Q33. Please rate your perceived potential impact of utilizing cross functional team meetings on controlling PPIs in your organization.

- ❍ No impact 0
- ❍ 1
- ❍ 2
- ❍ 3
- ❍ 4
- ❍ 5
- ❍ High potential impact 6

Q34. To what extent are you aware of the value analysis practice/process? (Value analysis (VA) is the process of checking an item for its total cost of acquisition, maintenance, and usage over

its expected useful life and, if appropriate, to replace it with a more cost effective substitute. At the core of the VA process is the task to evaluate features in the item product that don't add a true value to the patient but incur cost to the healthcare provider and patient, and eliminate them.)

- ❍ Not aware 0
- ❍ 1
- ❍ 2
- ❍ 3
- ❍ 4
- ❍ 5
- ❍ Highly aware 6

Q35. To what extent are physicians included in the process of value analysis?

- ❍ Not at all 0
- ❍ 1
- ❍ 2
- ❍ 3
- ❍ 4
- ❍ 5
- ❍ Always 6

Q36. Please rate your perceived potential impact of utilizing value analysis on controlling PPIs in your organization.

- ❍ No impact 0
- ❍ 1
- ❍ 2
- ❍ 3
- ❍ 4
- ❍ 5
- ❍ High potential impact 6

Q37. Is there any other practice/activity that you think that if adopted might potentially impact managing the PPIs? Also fill in any other comments you want to include.

Q38. What type of healthcare provider is your organization? (Check all that apply)

- ❑ Academic Institution
- ❑ Acute Care Facility
- ❑ Assisted Living Facility
- ❑ Hospital/Medical Center
- ❑ Managed Care Organization
- ❑ Long-Term Care Facility
- ❑ Health System / Network (IDS / IDN)
- ❑ Military/VA/Government affiliated
- ❑ Rehabilitation Center
- ❑ Other _____

Q39. Indicate the approximate size of your organization.

Number of beds	
Revenue	
Approximate number of employees	
Percentage of spend on PPI items	

Q40. How many years have you worked in the healthcare supply chain industry?

- ❍
- ❍ 2 - 5
- ❍ 6 - 10
- ❍ 11 - 20
- ❍ >20

Q41. Which of the following best describes your job title?

- ❍ Executive (CEO, CFO, CIO, President)
- ❍ Vice president
- ❍ Director
- ❍ Manager
- ❍ Associate
- ❍ Technician
- ❍ Buyer/Purchasing Agent
- ❍ Other _____

Q42. What is your gender?

- ❍ Male
- ❍ Female
- ❍ Prefer to not answer

Q43. What is your department’s annual purchasing budget?

- ❍ >$500K
- ❍ $500K - $1M
- ❍ $1M - $4.9M
- ❍ $5M - $10M
- ❍ $10.1M - $19.9M
- ❍ $20M - $50M
- ❍ >$50M

Q44. What is your organization's setting?

- ❍ National
- ❍ Rural
- ❍ Suburban
- ❍ Urban
- ❍ Other _____

Appendix D: Statistical Tests

Chi-Square χ^2 test

Chi square is the only significance test available for data with both variables measured on the nominal scale (basically it was built for nominal data). However, data measured on the ordinal and interval scales, organized into categories and presented in a contingency table, can also be tested using chi square.

H_0: no difference exists among the categories of the variables (Independent/no association)

H_1: there is a difference (dependent/association between categories of the variables

$$\chi^2 = \sum \frac{(f_0 - f_e)^2}{f_e},$$

where

f_0 = the frequency obtained in each cell

f_e= the frequency expected in each cell under the assumption of no difference. $f_e \geq 5$

There are measures of association (association strength) that can be derived for nominal data directly from the calculated chi-square statistic. The most versatile of these measures is Cramer's V, for which the formula is as follows:

$$V = \sqrt{\frac{\chi^2}{n(M-1)}},$$

where

n = sample size

M = Minimum number of rows or columns

(No association) 0 < V < 1 (Strong association)

Gamma γ: adopted from (Rea and Parker 2005)

$$\gamma = \frac{\sum(f_i . \sum f_s) - \sum(f_i . \sum f_d)}{\sum(f_i . \sum f_s) + \sum(f_i . \sum f_d)}$$

Where

f_i = the frequency of any cell

f_s = the frequency of a cell ordered in the same direction from the subject cell (below and right to the f_i cell)

f_d = the frequency of a cell ordered in a different (or inverse) direction from the subject cell (below and left)

EXHIBIT 10.3. INTERPRETATION OF CALCULATED GAMMA.

Measure	Interpretation
0	No association
.01–.09	Negligible association
.10–.29	Low association
.30–.59	Moderate association
.60–.74	Strong association
.75–.99	Very strong association
1.00	Perfect association

→ A **positive** gamma is read from the upper left corner of the cross-tabulation to the right across the top and from the upper left corner down the rows. A **negative** gamma is read again from the upper left and again to the right across the top, but it is read from the bottom row to the top row (in contrast to the positive gamma).

→ The chi square serves as the test for the significance of Cramer's V, phi, and lambda, but the presence of ordinal or interval data used in the calculation of gamma permits the use of a more direct test of significance for the calculated gamma.

$$Z = \gamma \left(\sqrt{\frac{\sum(f_i . \sum f_s) - \sum(f_i . \sum f_d)}{n(1-\gamma^2)}} \right)$$

Is the Z score necessary for determining the significance of gamma.

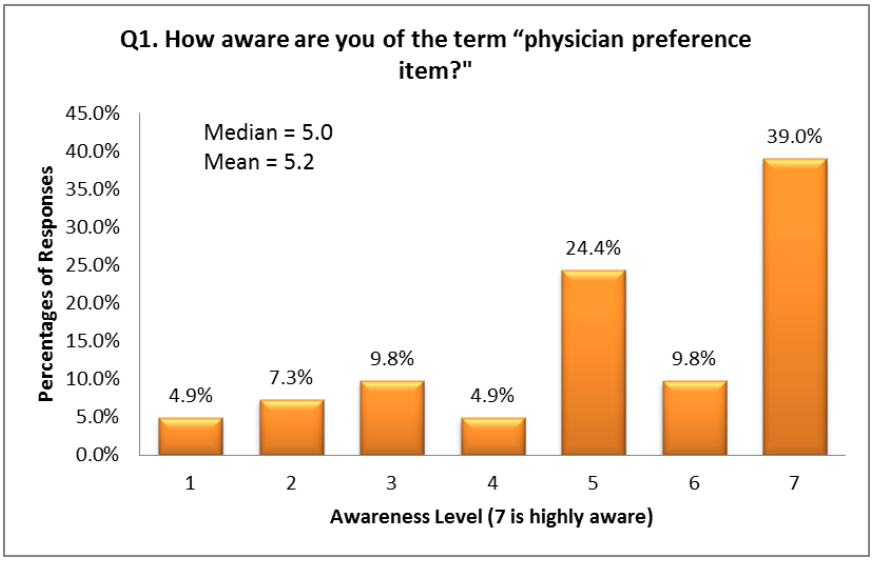
→ Inasmuch as gamma can be either positive or negative, the significance test for gamma's Z score is a two-tail test, with critical Z scores:

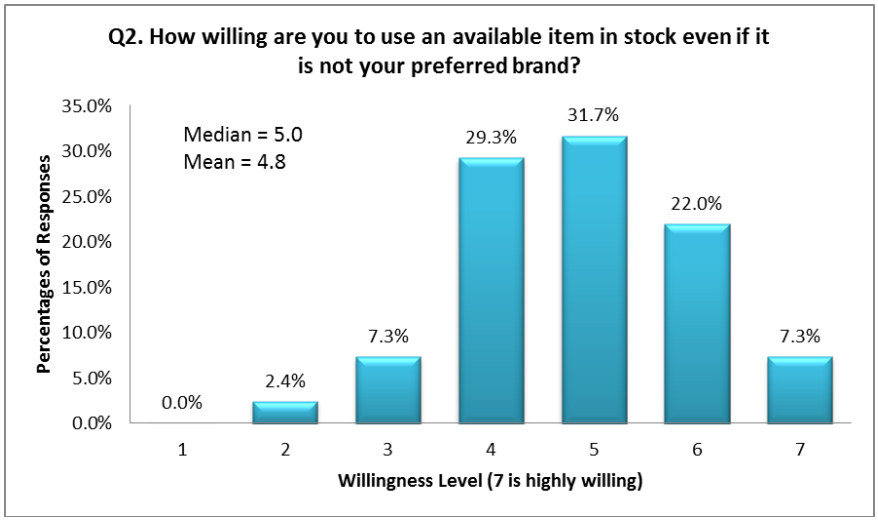
For 95% $Z_\alpha = Z_{0.05} = 1.96$ If $Z_\gamma > Z_\alpha$ ∴ significant relationship

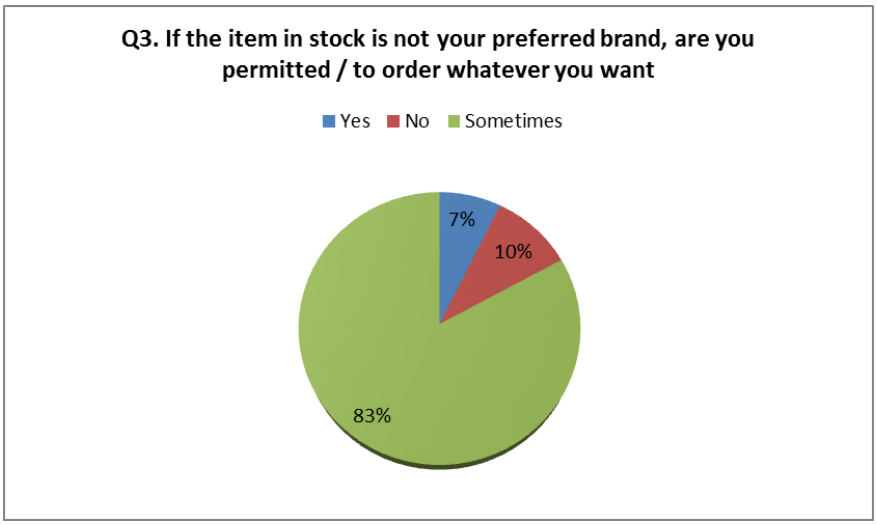
Appendix E: Surveys' Extra Results and Analysis

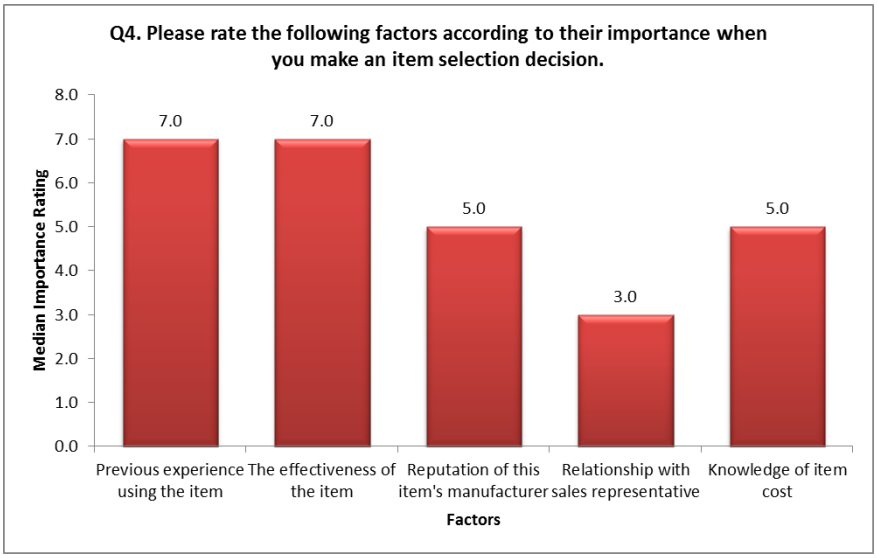
Appendix E.1: Physicians

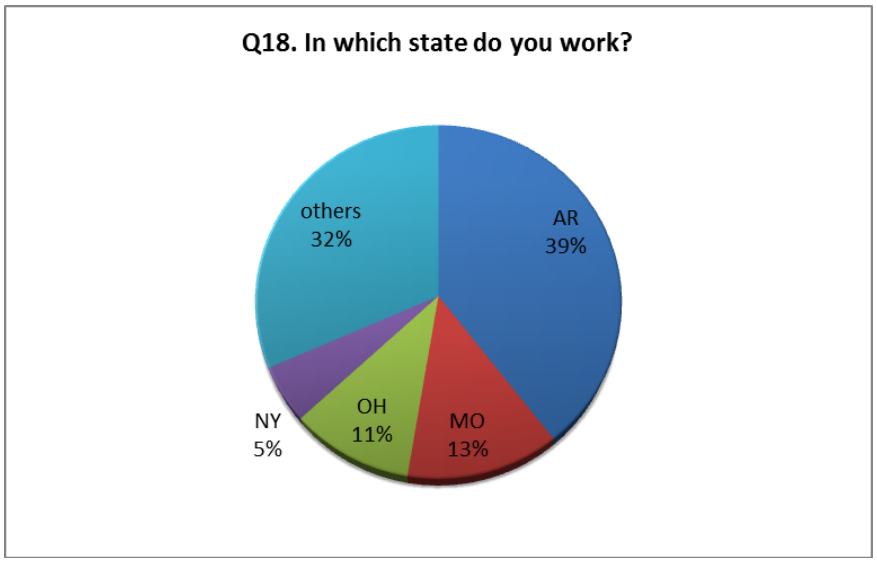
This will include results from both surveys that were not included in the writing body above.

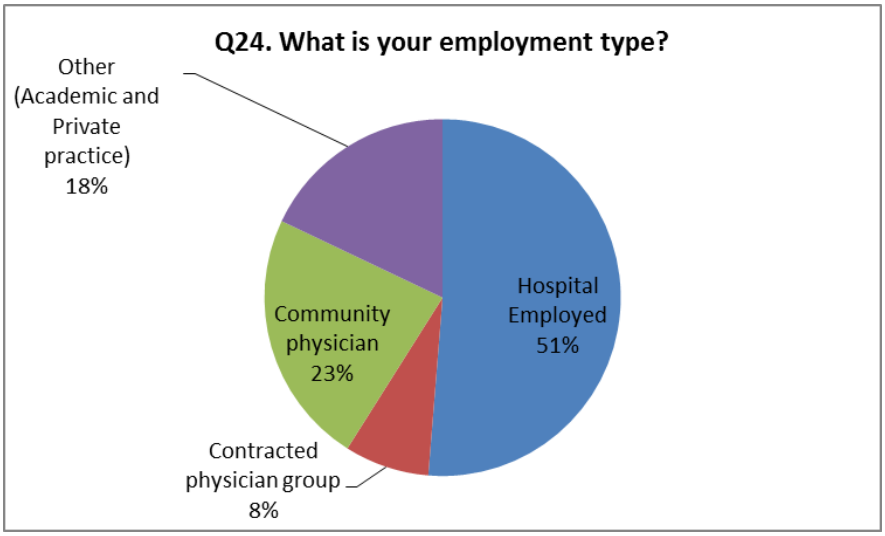





Q3. If the item in stock is not your preferred brand, are you permitted / to order whatever you want
Yes
No
Sometimes
7%
10%
83%


Q4. Please rate the following factors according to their importance when you make an item selection decision.
Median Importance Rating
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0.0
7.0
7.0
5.0
3.0
5.0
Previous experience using the item
The effectiveness of the item
Reputation of this item's manufacturer
Relationship with sales representative
Knowledge of item cost
Factors


Q18. In which state do you work?
others
32%
AR
39%
NY
5%
OH
11%
MO
13%


Q24. What is your employment type?
Other
(Academic and
Private
practice)
18%
Hospital
Employed
51%
Community
physician
23%
Contracted
physician group
8%

Mann-Whitney U - Awareness of PPI term - Physicians and SC							
Physicians	Supply chain		P Rank	SC Rank			
5	7		16.5	57.5		R_P	1249
7	7		57.5	57.5		R_{SC}	2579
2	7		4	57.5			
7	7		57.5	57.5		N_P	41
5	7		16.5	57.5		N_{SC}	46
7	7		57.5	57.5			
2	7		4	57.5		U_P	1498
4	7		10.5	57.5		U_{SC}	388
1	7		1.5	57.5			
6	7		24.5	57.5		U	388
5	6		16.5	24.5			
5	7		16.5	57.5		Z	-4.719233063
3	7		7.5	57.5		P	2.36735E-06
7	7		57.5	57.5			
5	7		16.5	57.5		Decision	**Reject**
4	7		10.5	57.5		There is a difference	
7	7		57.5	57.5			
7	7		57.5	57.5			
5	7		16.5	57.5			
6	7		24.5	57.5			
5	7		16.5	57.5			
2	7		4	57.5			
7	7		57.5	57.5			
7	7		57.5	57.5			
5	6		16.5	24.5			
1	7		1.5	57.5			
7	7		57.5	57.5			
7	7		57.5	57.5			
6	7		24.5	57.5			
7	7		57.5	57.5			
5	7		16.5	57.5			
5	7		16.5	57.5			
3	7		7.5	57.5			
7	7		57.5	57.5			
7	7		57.5	57.5			
7	7		57.5	57.5			
6	7		24.5	57.5			

7	7		57.5	57.5	
7	7		57.5	57.5	
3	7		7.5	57.5	
3	7		7.5	57.5	
	7			57.5	
	7			57.5	
	7			57.5	
	7			57.5	
	7			57.5	

Kruskal-Wallis Test: Q4 data versus Q4 Categories

```
Kruskal-Wallis Test on Q4 data

Q4 Categories                            N  Median  Ave Rank      Z
Knowledge of item cost                  41   5.000      96.6  -0.77
Previous experience using the item      41   7.000     142.0   4.70
Relationship with sales representative  41   3.000      39.3  -7.69
Reputation of this item's manufacturer  41   5.000      86.5  -2.00
The effectiveness of the item           41   7.000     150.7   5.76
Overall                                205             103.0

H = 95.14  DF = 4  P = 0.000
H = 100.15  DF = 4  P = 0.000  (adjusted for ties)
```

Kruskal-Wallis Test: Q7 data versus Q7 Text

```
243 cases were used
3 cases contained missing values


Kruskal-Wallis Test on Q7 data

Q7 Text                    N  Median  Ave Rank      Z
Administration Decision   40   6.000     129.4   0.73
Manufacturer Reputation   40   4.000      70.3  -5.09
Patient Outcome           41   6.000     160.6   3.86
Physician's preference    41   5.000     120.0  -0.20
Required storage Space    40   4.000      68.8  -5.23
Total Cost                41   6.000     180.5   5.84
Overall                  243             122.0

H = 85.80  DF = 5  P = 0.000
H = 88.79  DF = 5  P = 0.000  (adjusted for ties)
```

One-way ANOVA: Q7 data versus Q7 Text

```
Source    DF      SS     MS      F      P
Q7 Text    5  217.85  43.57  24.15  0.000
Error    237  427.62   1.80
Total    242  645.47

S = 1.343   R-Sq = 33.75%   R-Sq(adj) = 32.35%
```

```
Level                     N   Mean  StDev
Administration Decision  40  4.875  1.556
Manufacturer Reputation  40  3.500  1.340
Patient Outcome          41  5.512  1.705
Physician's preference   41  4.732  1.119
Required storage Space   40  3.475  1.261
Total Cost               41  6.024  0.935

                         Individual 95% CIs For Mean Based on
                         Pooled StDev
Level                    ---------+---------+---------+---------+
Administration Decision                (---*---)
Manufacturer Reputation  (---*---)
Patient Outcome                              (---*---)
Physician's preference                 (---*---)
Required storage Space   (---*---)
Total Cost                                       (---*---)
                         ---------+---------+---------+---------+
                                4.0       5.0       6.0       7.0

Pooled StDev = 1.343
```

Kruskal-Wallis Test: Q10 data versus Q10 categories

```
Kruskal-Wallis Test on Q10 data

Q10 categories                        N  Median  Ave Rank      Z
Better results                       41   7.000     176.2   5.20
Cheaper                              41   6.000      98.9  -2.42
Easier to use                        41   6.000     134.5   1.08
More features                        41   5.000     103.6  -1.96
Produced by reputable manufacturer   41   4.000      58.7  -6.39
Safer for patient                    41   7.000     169.1   4.50
Overall                             246              123.5

H = 82.45  DF = 5  P = 0.000
H = 89.08  DF = 5  P = 0.000  (adjusted for ties)
```

One-way ANOVA: Q10 data versus Q10 text

```
Source     DF      SS     MS      F      P
Q10 text    5  182.67  36.53  28.84  0.000
Error     240  304.00   1.27
Total     245  486.67

S = 1.125   R-Sq = 37.53%   R-Sq(adj) = 36.23%



Level                      N   Mean  StDev
Better results            41  6.659  0.530
Cheaper                   41  5.268  1.323
Easier to use             41  6.000  0.975
More features             41  5.366  1.318
Produced by reputable ma  41  4.146  1.590
Safer for patient         41  6.561  0.594

                          Individual 95% CIs For Mean Based on
```

```
                          Pooled StDev
Level                     --+---------+---------+---------+-------
Better results                                     (---*--)
Cheaper                                 (---*--)
Easier to use                                 (--*--)
More features                            (---*--)
Produced by reputable ma  (--*---)
Safer for patient                                (---*--)
                          --+---------+---------+---------+-------
                          4.0       5.0       6.0       7.0

Pooled StDev = 1.125
```

Kruskal-Wallis Test: Q14 Willingness to substitute item vs procedures cost ranges

```
Kruskal-Wallis Test on Q14

Cost Range        N   Median  Ave Rank      Z
<$1,000           15   5.000      30.8  -0.61
$1,000-$5,000     16   5.000      33.0  -0.11
$5,001-&10,000    15   5.000      35.3   0.41
$10,001-$20,000   10   5.500      36.0   0.46
$20,001-$50,000    7   6.000      37.0   0.51
$50,001-$100,000   3   4.000      23.8  -0.89
Overall  66              33.5

H = 1.60  DF = 5  P = 0.902
H = 1.69  DF = 5  P = 0.890  (adjusted for ties)
```

One-way ANOVA: Q14 Willingness to substitute item vs procedures cost ranges

```
Source  DF      SS    MS     F      P
Factor   5    1.99  0.40  0.19  0.966
Error   60  126.50  2.11
Total   65  128.48

S = 1.452   R-Sq = 1.55%   R-Sq(adj) = 0.00%


                        Individual 95% CIs For Mean Based on Pooled StDev
Level   N   Mean  StDev   +---------+---------+---------+---------
Q14_1  15  4.933  1.534              (------*-------)
Q14_2  16  5.188  1.328                 (------*------)
Q14_3  15  5.267  1.534                 (-------*------)
Q14_4  10  5.300  1.337                (--------*--------)
Q14_5   7  5.286  1.604                (----------*----------)
Q14_6   3  4.667  1.155    (----------------*---------------)
                          +---------+---------+---------+---------
                        3.0       4.0       5.0       6.0

Pooled StDev = 1.452
```

Appendix E.2: Supply Chain Professionals

Kruskal-Wallis Test: Q2 Data versus Q2 Text

```
Kruskal-Wallis Test on Q2 Data
```

```
Q2 Text                                    N  Median  Ave Rank      Z
Growing Size with limited space           46   4.000      41.6  -5.89
PPI                                       47   6.000     104.5   7.06
Unpredicted Schedules of needed items     47   5.000      64.7  -1.19
Overall                                  140              70.5

H = 57.34  DF = 2  P = 0.000
H = 59.73  DF = 2  P = 0.000  (adjusted for ties)
```

One-way ANOVA: Q2 Data versus Q2 Text

```
Source    DF      SS     MS      F      P
Q2 Text    2  136.68  68.34  45.26  0.000
Error    137  206.86   1.51
Total    139  343.54

S = 1.229   R-Sq = 39.79%   R-Sq(adj) = 38.91%



Level                 N   Mean  StDev
Growing Size         46  3.500  1.472
PPI                  47  5.915  0.952
Unpredicted Schedules  47  4.532  1.213

                      Individual 95% CIs For Mean Based on
                      Pooled StDev
Level                  -+---------+---------+---------+--------
Growing Size           (----*---)
PPI                                              (---*---)
Unpredicted Schedules              (----*---)
                       -+---------+---------+---------+--------
                      3.20      4.00      4.80      5.60

Pooled StDev = 1.229
```

Kruskal-Wallis Test: Q5 data versus Q5 Text

```
Kruskal-Wallis Test on Q5 data

Q5 Text                    N  Median  Ave Rank      Z
Administration Decision   47   3.000      77.4  -5.90
Manufacturer Reputation   47   4.000      93.0  -4.47
Patient Outcome           47   6.000     218.5   7.09
Physician's preference    47   6.000     186.9   4.18
Required storage Space    47   3.000      94.2  -4.36
Total Cost                47   6.000     179.0   3.46
Overall                  282             141.5

H = 127.94  DF = 5  P = 0.000
H = 131.95  DF = 5  P = 0.000  (adjusted for ties)
```

One-way ANOVA: Q5 data versus Q5 Text

```
Source    DF      SS     MS      F      P
Q5 Text    5  392.84  78.57  48.05  0.000
Error    276  451.32   1.64
Total    281  844.16
```

```
S = 1.279   R-Sq = 46.54%   R-Sq(adj) = 45.57%



Level                     N   Mean  StDev
Administration Decision  47  3.170  1.659
Manufacturer Reputation  47  3.617  1.407
Patient Outcome          47  6.213  0.858
Physician's preference   47  5.617  1.134
Required storage Space   47  3.638  1.495
Total Cost               47  5.489  0.906

                         Individual 95% CIs For Mean Based on
                         Pooled StDev
Level                    --+---------+---------+---------+-------
Administration Decision  (---*--)
Manufacturer Reputation      (---*---)
Patient Outcome                                      (---*---)
Physician's preference                          (---*---)
Required storage Space        (--*---)
Total Cost                                     (---*---)
                         --+---------+---------+---------+-------
                         3.0       4.0       5.0       6.0

Pooled StDev = 1.279
```

Kruskal-Wallis Test: Q17 by Q16

```
Kruskal-Wallis Test on C58

C57        N  Median  Ave Rank      Z
Less       4   4.000       9.5  -2.18
More      32   6.000      27.3   2.91
The same  10   4.500      16.9  -1.76
Overall   46              23.5

H = 9.35  DF = 2  P = 0.009
H = 9.91  DF = 2  P = 0.007  (adjusted for ties)

* NOTE * One or more small samples
```

One-way ANOVA: Q17 by Q16

```
Source  DF     SS    MS     F      P
C57      2  19.33  9.67  5.83  0.006
Error   43  71.27  1.66
Total   45  90.61

S = 1.287   R-Sq = 21.34%   R-Sq(adj) = 17.68%


                           Individual 95% CIs For Mean Based on
                           Pooled StDev
Level      N   Mean  StDev  --------+---------+---------+---------+-
Less       4  3.500  1.732  (------------*------------)
More      32  5.563  1.268                              (----*---)
The same  10  4.600  1.174                  (-------*-------)
                           --------+---------+---------+---------+-
                                 3.0       4.0       5.0       6.0
```

```
Pooled StDev = 1.287
```

Appendix F: Chapter's 3 Material

Appendix F.1: Value Analysis Example

Value Analysis Decision-Making Criteria Matrix for New Requests

Product: _____ VAT Member: _____

Please place "X" for each category. Blanks will be considered 0 points.

Category	Negative	Neutral	Positive
Financial: Compared with the cost of the current product, process, project or the cost of not implementing a change. Cost includes decreased product cost, inventory and/or increased reimbursement.	Increased cost 1 2 3 4	Cost neutral 5 6 7	Decreased cost 8 9 10
Quality: Relates to the quality of a proposed product compared with the current	Lower quality 1 2 3 4	Same quality 5 6 7	Higher quality 8 9 10
Impact: Relates to the impact the product has on clinical indicators such as length of stay, patient or employee safety, and mortality	Worse impact 2 4 6 8	Same impact 10 12 14	Better impact 16 18 20
Clinical evidence: Support of the product, process, or project	Inadequate evidence or lack of evidence 1 2 3 4	Evidence that supports and opposes, is limited, or is tentative in assumptions 5 6 7	Evidence and studies that are well constructed and supportive 8 9 10

Recommendations		
Not Recommended at this Time (< 25 points)	***Recommended Only if Funds Available (26-39 points)**	**Highly Recommended (40-50 points)**
	Indicates technology **might not** do one or more of the following: replace more costly existing technology, generate new "net" revenue, reduce clinical costs, generate new referrals, or improve quality of patient care	Indicates technology is **likely** to do one or more of the following: replace more costly existing technology, generate new "net" revenue, reduce clinical costs, generate new referrals, or improve quality of patient care.

- Allocations for VAT requests that score in the "Recommend only if funds are available" category will occur bi-annually (December and June).

Comments:

_____
_____
_____
_____
_____

Appendix F.2: Stakeholders and Objectives Definitions

Stakeholders

Identifying the stakeholders is an initial step in the value hierarchy tree structuring. This facilitates the definition of stakeholder objectives and the mapping of the objectives to measures, which defines the list of criteria. Fundamental objectives are objectives that we inherently care about and are included in the process. Means objectives indicate how fundamental are obtained.

In the medical items/devices selection process, stakeholders interested either directly or indirectly in the decision are: physicians, nurses, patients, hospital financial administrators, supply chain professionals, and vendors. Stakeholders will be involved from an inside point of view, i.e. of what is important for the healthcare organization when selecting the item. Decision makers are those who make the decision, while stakeholders are those who are interested in the decision or its results. In the following, objectives with their definitions are presented for each stakeholder, and measures for each objective as well in both list and hierarchy format.

1. Physicians desire to maximize treatment effectiveness by:
   1.1. Selecting items that have the best efficacy
   1.2. Selecting items that have the best effectiveness
   1.3. Selecting items that shorten required time for performing the treatment
   1.4. Selecting items that have the best safety/risk/side-effects record
   1.5. Selecting items that have distinguishing features that make it better than other items for the proposed usage
   1.6. Selecting items that they are good using due to skills they developed in practice (experience)

2. Physicians desire to maximize patient's outcome when using an item by:
   2.1. Selecting items that shorten patient's length of stay in the hospital
   2.2. Selecting items that maximize quality-adjusted life years
   2.3. Selecting items that have the best safety/risk/side-effects record
   2.4. Selecting items that have the lowest rates of infection
   2.5. Selecting items that have the best disposition

3. Physicians desire to maximize patient safety by:
   3.1. Selecting items that have the best reliability

3.2. Selecting items that have the best durability
3.3. Selecting items that have the best safety/risk/side-effects record
3.4. Selecting items that have the least amount of issues or problems during use

4. Physicians desire to maximize their satisfaction when using an item by:
   4.1. Selecting items that are supported by staff with high ability to solve problems
   4.2. Selecting items that are available for testing or trials by physicians for as long as possible
   4.3. Selecting items that are supported with updates from vendors concerning safety, issues, or best practices on regular basis
   4.4. Selecting items that have easy instructions for preparation and use
   4.5. Selecting items that are the easiest to use
   4.6. Selecting items that require the least amount time for additional training
   4.7. Selecting items that are expected to be available as long as possible

5. Patients desire to have their health problems cured to the best outcome possible by:
   5.1. Selecting items that maximize treatment effectiveness
   5.2. Selecting items that shorten required time for performing the treatment
   5.3. Selecting items that shorten patient's length of stay in the hospital
   5.4. Selecting items that maximize quality-adjusted life years
   5.5. Selecting items that have the best safety/risk/side-effects record
   5.6. Selecting items that have the lowest rates of infection
   5.7. Selecting items that have the best disposition
   5.8. Selecting items that have the longest expected working life
   5.9. Selecting items that satisfy their preferences

6. Nurses desire to reduce time spent on item management by:
   6.1. Selecting items that need less time and effort to prepare for treatments
   6.2. Selecting items that are easy to handle and manage in storage unit
7. Nurses desire to maximize patient safety by:
   7.1. Selecting items that have the least amount of issues or problems during use

8. Hospital administrators desire to maximize patients' satisfaction by:
   8.1. Selecting items that result in shortest possible length of stay
   8.2. Selecting items that satisfy patients preferences

9. Hospital administrators desire to maximize physicians' satisfaction by:
   9.1. Selecting items that are the easiest to use
   9.2. Selecting items that require the least amount time for additional training
   9.3. Selecting items that require the least amount time for performing the treatment
   9.4. Selecting items that are expected to be available as long as possible
   9.5. Selecting items that are available for testing or trials by physicians for as long as possible

10. Hospital administrators desire to minimize the liability associated with medical practice by:
    10.1. Selecting items that make the treatment safer
    10.2. Selecting items that have the least amount of associated medical lawsuits/claims

11. Hospital administrators desire to maximize market share by:
    11.1. Selecting items that increase patient acquisition
    11.2. Selecting items that increase reimbursement rates
    11.3. Selecting items that result in lower patient readmission rates
    11.4. Selecting items that increase patient retention
    11.5. Selecting items that ensure that profitable physicians want to practice at the hospital
    11.6. Selecting items that require the least amount time for performing the treatment
    11.7. Selecting items that have the longest expected working life

12. Hospital administrators desire to maximize nurses' satisfaction by
    12.1. Selecting items that require the least amount of time for additional training

13. Healthcare supply chain professionals desire to maximize SC performance by:
    13.1. Selecting items that have easy instructions for handling, need least amount of time for managing (loading, unloading, moving) and not easy to break
    13.2. Selecting items that have longest expected expiry possible
    13.3. Selecting items that are eligible for urgent delivery or from a vendor who offers urgent delivery
    13.4. Selecting items that can be provided with the lowest possible minimum order quantity
    13.5. Selecting items from vendors who provide most flexible payments' terms possible
    13.6. Selecting items that improve traceability
    13.7. Selecting items from vendors with reliable track records
    13.8. Selecting items that increase lead-time reliability
    13.9. Selecting items that are easiest to handle and manage by nurses in storage unit

Definitions

Purpose: the overall purpose or fundamental objective of the decision analysis process. In this research, the objective is to improve the control and effective use of PPI items within the healthcare supply chain.

Objectives: fundamental goals of related stakeholders

Criteria/value measures: the standards which determine degree of achieving the objectives of stakeholders. In other words, it is numerical representation of each objective; it measures the attainment of the objective.

Weights: relative importance of each criterion to the overall objective, sum of weights should be 1, also known as swing weights.

Value hierarchy tree: a pictorial structure presenting the value hierarchy.

Tree Levels

→*Purpose*: the overall goal/objective of the decision analysis process. In this research, the objective is to improve the control and effective use of PPI items within the healthcare supply chain.

→*Objectives:* fundamental goals of related stakeholders

→*Criteria/metrics*: the standards which determine degree of achieving the objectives of stakeholders. In other words, it is numerical representation of each objective; it measures the attainment of the objective.

Following are the objectives as main headings (**Bold**) followed by related criteria.

Treatment effectiveness: is how well the treatment attained its intended result

Item efficacy: The extent to which an item/drug/medical device has the ability to produce its intended beneficial effect (or therapeutic effect) in expert hands and under ideal circumstances (clinical trials or laboratory studies) see (Marley 2000) and (Efficacy 2015). This is a measure of the effectiveness but during trials, when the item is still tested. We prefer items with higher efficacy

Item effectiveness: The extent to which an item/drug/medical device achieves its intended effect in practice of medicine (during actual use in real life). In other words, the item can be evaluated when history of data becomes available through observational studies of real practice (Marley 2000). We prefer to choose an item that is more effective.

Side effects/Risks: the possibility that an item/medical device could cause an unwanted or unexpected negative effect ranging from minor (e.g. dry mouth) to serious (e.g. bleeding or heart attack). Observed problems in clinical trials are called "adverse events", they might or might not be related to the item/medical device under study. Once that relationship is discovered, the problem is called "adverse effect" or as commonly known "side effects" (Medicine Safety and You 2011). When item has been used before, it is the total percentage of injury or death-related events over all events for this item. This measure could be accompanied with an exponential value function where a high score (life threatening) will hugely inflate the effect on the score, and a low score (non-life threatening) will have less effect. Risk may be measured using historical data of cases. We prefer to choose the item with lowest side effects possible.

Item distinguishing features: the extent to which an item/device has extra special useful features that make this item different than others for the proposed usage. For example, an item could be lighter, coated …etc. we prefer an item with unique features.

Physician's experience using the item: physician's practical opinion of the item after using and observing the item in practice/events (experience aspects included are: how long the physician has been using this item, how professional/good/skilled he is in using this specific item). An item that the physician is more experienced in using is preferred.

Item's Safety: the extent to which the item is considered safe. Probability that the item/medical device perform its intended function safely under specified conditions throughout a specified time (expected life). Another definition by (Bajaria 2000) is "the measure of unanticipated interruptions during customer use." This includes issues and problems during use, which can be defined as: occurrences of issues/problems faced

when used the item from physician's experience standpoint. This is different than the ease of application since it could be easy to apply an item, yet a physician could have faced problems with the item like fracture, fatigue … etc. It is also different than the risk/side-effects of using the item, since risk is about consequences and complications of a problem. We prefer a safer item; one that is more reliable and give less issues during use.

Patient's Outcome: highly satisfied patients are those who had their health problems cured to the best outcome possible. The goal is to improve long term patient outcome, and consequently satisfaction. Mainly, patient outcome can be measured by:

Length of stay: is total number of days the patient needed from admission until discharging. It is a measure of patient's outcome.

Quality-adjusted life year: is a measure of patient's outcome which represents an assessment of both quality and quantity of life lived. A value measure for this criterion can be defined as the arithmetic product of life expectancy and a measure of the quality of the remaining life-years. It assumes that a year of life lived in perfect health is worth 1 QALY (1 Year of Life × 1 Utility value = 1 QALY) and that a year of life lived in a state of less than this perfect health is worth less than 1. See (Phillips and Thompson 2009)

Infection rates: percentage of infection of patients after procedures due to using specific item. When having more items, probability of infection will be higher.

Item's expected working life: the expected period of time the item/device will work effectively on the patient. It can be indicated as durability, which is: probability (ability) that an item will have a long continuous useful life relative to other similar items. A measure of durability is represented by the duration of item ownership. We prefer to choose an item that is expected to last longer

Clinicians' Satisfaction: the degree to which physicians and nurses are satisfied with items' choices.

Product support ability: existence of a trained team from the manufacturer/supplier and their ability to provide support and regular updates related to the item to the medical staff when using the item

Product trials: the extent to which the manufacturer/supplier allows healthcare organization to test the item before using it for as long as possible (using it for a grace period).

Easy of instructions for preparation: how easy and straightforward the instructions are for item's preparation and usage.

Ease of actual use of the item: Physician's opinion about the item's ease of application (actual use) from his experience standpoint.

Additional training time: extra training needed to learn about the new item. Basically the item is either an update to an existing one (for which the physician has previous training) , or similar to one that the physician has been already trained on.

Required time to do the treatment: if time required is less than that when using other similar items. This is specifically important for three main reasons: first is to avoid fatigue of

physicians who are doing the procedure, second is to avoid fatigue of the patient, and third is to lower infection rates by exposing the patient's internal tissues to the outside.

Organizational benefits:

Patient acquisition rate: rate of acquiring patients for healthcare services and treatments

Reimbursement rates: Expected reimbursement rates associated with procedures due to using this item

Patient readmission rate: is readmission of the patient after discharge due to follow-up needed, complications …etc.

Patient retention: measures the return rate for patients for new services

Profitable physicians: are physicians whom existence in the healthcare organization means more profit generation due to their good reputation (patients will come for them) and they are highly skilled in doing treatments and working with items such that they waste less, give better outcome, less time ... etc.

Medical Lawsuits/claims: lawsuits cases and claims raised by patients due to health problems consequences/death caused by malfunction in device/item or unexpected unwanted results.

Supply chain performance: effect of PPI selection on SC performance

Ease of handling and managing: effort and time needed to handle and manage the item in storage within the organization's supply chain.

Flexibility of minimum order quantity: ability of manufacturer/supplier to provide flexible order quantities (minimum possible unit of measure).

Ability of urgent delivery: the extent to which the manufacturer/supplier is willing/able of providing urgent delivery for this specific PPI

Lead-time reliability: minimum delivery lead-time, minimum lead-time variability, and minimum uncertainty in these measures. It is measured by the coefficient variation of the lead-time, (ratio of the standard deviation to the mean).

1. Physicians
    a. To maximize treatment effectiveness
        i. Maximize item's efficacy
        ii. Maximize item's effectiveness
        iii. Minimize required time for performing the treatment
        iv. Minimize side effects/risk (maximize safety)
        v. Maximize physician's experience using the item
        vi. Maximize item's performance due to the distinguishing features that the item has
    b. To maximize patient's outcome
        i. Minimize patient's length of stay
        ii. Maximize quality-adjusted life years
        iii. Minimize side effects/risk (maximize safety)
        iv. Minimize infection rates

v. Maximize disposition state

c. To maximize treatment safety
    i. Maximize reliability
    ii. Maximize durability
    iii. Minimize side effects/risk (maximize safety)
    iv. Minimize issues and problems during use

d. To maximize their satisfaction
    i. Maximize gaining of product support and problems' solving
    ii. Maximize testability of the item
    iii. Maximize availability of regular updates from vendor
    iv. Maximize ease of instructions for preparation and use
    v. Maximize ease of use
    vi. Minimize time needed for additional training
    vii. Maximize item's long term availability in market

2. Patients
    a. To maximize patient's outcome
        i. Minimize required length of stay
        ii. Minimize required time for performing the treatment
        iii. Maximize quality-adjusted life years
        iv. Minimize side effects/risk (maximize safety)
        v. Minimize infection rates
        vi. Maximize disposition state
        vii. Maximize expected item's working life
        viii. Maximize preference

3. Nurses
    a. To minimize time spent on items' management
        i. Minimize the time required in preparing items/tools for use in treatments
        ii. Maximize ease of handling and management in storage unit
        iii. Minimize time needed for additional training
    b. To maximize treatment safety
        i. Minimize issues and problems during use

4. Hospital administration
    a. To maximize patients' satisfaction
        i. Maximize patient's outcome
        ii. Minimize required length of stay
        iii. Maximize patients' preference satisfaction
    b. To maximize physicians' satisfaction
        i. Maximize ease of use
        ii. Minimize time needed for additional training
        iii. Minimize required time for performing the treatment
        iv. Maximize item's long term availability in market
        v. Maximize testability of the item

c. To minimize the liability associated with the use of items on procedures
    i. Minimize side effects/risk (maximize safety)
    ii. Minimize amount of associated medical lawsuits/claims

d. To Maximize expected market share
    i. Maximize patients acquisition
    ii. Maximize the reimbursement rates associated with procedures
    iii. Minimize readmission rates
    iv. Maximize patient retention
    v. Maximize attractiveness for profitable physicians
    vi. Minimize required time for performing the treatment

e. To maximize nurses' satisfaction
    i. Minimize the time required in preparing items/tools for use in treatments
    ii. Maximize ease of handling and management in storage unit
    iii. Minimize time needed for additional training

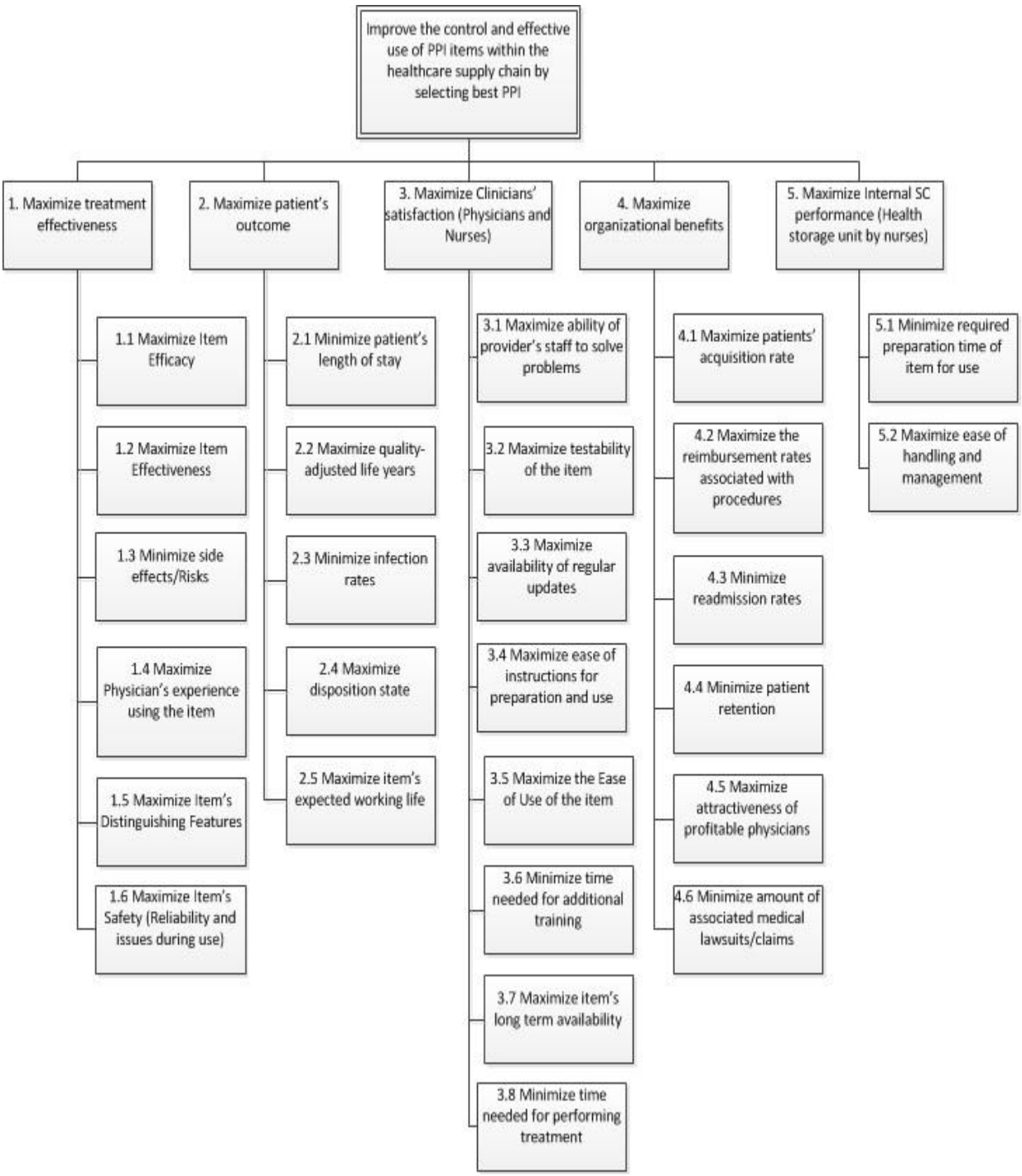
5. Supply chain professionals
    a. To maximize SC performance
        i. Maximize the ease of handling and managing
        ii. Maximize expiry
        iii. Maximize ability of urgent delivery
        iv. Maximize flexibility of minimum order quantity
        v. Maximize ability to have flexible payments' terms
        vi. Increase the traceability of the use of the item: does vendor provide ways to track the item?
        vii. Maximize vendor's good reputation
        viii. Maximize lead-time reliability: this includes delivery lead-time (time from placing the order until receiving shipment in SC), lead-time variability, on-time delivery (history on-time shipments).
        ix. Maximize ease of handling and management in storage unit

Appendix F.3: Objectives and Value Measures Review

PPI Objectives Hierarchy Input

The purpose of this feedback form is to capture your opinion regarding the definitions of the objectives and their sub-objectives, as well as the value measure's scale for each sub-objective. This is meant to be done after the presentation about the car example. Following to this page, you will be presented with the objectives hierarchy to visualize it (you will also be sent a copy via email). The complete list of definitions will also be sent to you in a separate document. We will need your input on 2 main things: definitions and the value measure scale. The first level of the tree includes the 5 objectives which we think are overall objectives. They also help organizing the lower level objectives (sub-objectives) into more meaningful groups which makes it easy to read the tree. For the first level, it is just about definition, do you agree or not. For all

sub-objectives, you will be asked few questions like, on a scale from 1 (I don't agree) to 5 (I extremely agree), please rate to what extent you agree to the definition. By agreement, we mean how much you think the definition captures the term. The more you feel the definition represents the objective, the higher you would rate it. If you have no idea about a particular objective, please leave that rating box blank. Next question is if you agree to the value measure (VM) Scale or not, on a scale from 1 (don't agree) to 5 (extremely agree), please rate to what extent you agree to the defined scale of the value measure. In case you need any clarification, please call Mohammad Shbool on 479-409-9957 or email: mshbool@uark.edu


Improve the control and effective use of PPI items within the healthcare supply chain by selecting best PPI
1. Maximize treatment effectiveness
2. Maximize patient's outcome
3. Maximize Clinicians' satisfaction (Physicians and Nurses)
4. Maximize organizational benefits
5. Maximize Internal SC performance (Health storage unit by nurses)
1.1 Maximize Item Efficacy
1.2 Maximize Item Effectiveness
1.3 Minimize side effects/Risks
1.4 Maximize Physician's experience using the item
1.5 Maximize Item's Distinguishing Features
1.6 Maximize Item's Safety (Reliability and issues during use)
2.1 Minimize patient's length of stay
2.2 Maximize quality-adjusted life years
2.3 Minimize infection rates
2.4 Maximize disposition state
2.5 Maximize item's expected working life
3.1 Maximize ability of provider's staff to solve problems
3.2 Maximize testability of the item
3.3 Maximize availability of regular updates
3.4 Maximize ease of instructions for preparation and use
3.5 Maximize the Ease of Use of the item
3.6 Minimize time needed for additional training
3.7 Maximize item's long term availability
3.8 Minimize time needed for performing treatment
4.1 Maximize patients' acquisition rate
4.2 Maximize the reimbursement rates associated with procedures
4.3 Minimize readmission rates
4.4 Minimize patient retention
4.5 Maximize attractiveness of profitable physicians
4.6 Minimize amount of associated medical lawsuits/claims
5.1 Minimize required preparation time of item for use
5.2 Maximize ease of handling and management

Q1 Does the first level of objectives in the hierarchy make sense to you? (1- No it does not make sense, 5-Yes it is good)

	1	2	3	4	5
Treatment effectiveness	❍	❍	❍	❍	❍
Patient outcome	❍	❍	❍	❍	❍
Clinician satisfaction	❍	❍	❍	❍	❍
Organizational benefits	❍	❍	❍	❍	❍
Internal supply chain performance	❍	❍	❍	❍	❍

Answer If Each sub-objective is accompanied with a value measure (metric), which defines how this objective's attainment will be measured. The definition is simply a rubric or scale that defines lowest, high... - 1 Is Selected Or Each sub-objective is accompanied with a value measure (metric), which defines how this objective's attainment will be measured. The definition is simply a rubric or scale that defines lowest, high... - 2 Is Selected

Q4 In the previous question, you scored less than 3 for some objectives, please explain why. (List the objective and any changes to the definition or just define it as you think it should be)

Q5 For the first objective (Treatment effectiveness), please rate to what extent you agree on the definition for each of its sub-objectives. (1- No it does not make sense, 5-Yes it is good).

	1	2	3	4	5
Item efficacy	❍	❍	❍	❍	❍
Item effectiveness	❍	❍	❍	❍	❍
Side effects/Risks	❍	❍	❍	❍	❍
Physician's experience using the item	❍	❍	❍	❍	❍
Item distinguishing features	❍	❍	❍	❍	❍
Item safety (Reliability)	❍	❍	❍	❍	❍

Q6 Each sub-objective is accompanied with a value measure (VM), which defines how this objective's attainment will be measured. The VM scale is simply a rubric that defines lowest, highest and some intermediate points of the possible score levels of the specific objective. (Note: the lowers level objectives "sub-objectives" are accompanied with value measures, while the first level is not). Referring to the "Treatment Effectiveness" group of sub-objectives, please rate to what extent you agree on the VMs scales provided in the document we sent to you.

	1	2	3	4	5
Item efficacy	❍	❍	❍	❍	❍
Item effectiveness	❍	❍	❍	❍	❍
Side effects/Risks	❍	❍	❍	❍	❍
Physician's experience using the item	❍	❍	❍	❍	❍
Item distinguishing features	❍	❍	❍	❍	❍
Item safety (Reliability)	❍	❍	❍	❍	❍

Answer If For the first objective (Treatment effectiveness), please rate to what extent you agree on the definition for each of its sub-objectives. (1- No it does not make sense, 5-Yes it is good). - 1 Is Selected Or For the first objective (Treatment effectiveness), please rate to what extent you agree on the definition for each of its sub-objectives. (1- No it does not make sense, 5-Yes it is good). - 2 Is Selected Or Each sub-objective is accompanied with a value measure (VM), which defines how this objective's attainment will be measured. The VM scale is simply a rubric that defines lowest, highest and some in... - 1 Is Selected Or Each sub-objective is accompanied with a value measure (VM), which defines how this objective's attainment will be measured. The VM scale is simply a rubric that defines lowest, highest and some in... - 2 Is Selected

Q7 In the previous questions, you scored less than 3 for some objectives, please explain why. (List the objective and any changes to the definition or the VM scale)

Q8 For the second objective (Patient Outcome), please rate to what extent you agree on the definition for each of its sub-objectives. (1- No it does not make sense, 5-Yes it is good).

	1	2	3	4	5
Patient length of stay	❍	❍	❍	❍	❍
Quality-adjusted life years	❍	❍	❍	❍	❍
Infection rates	❍	❍	❍	❍	❍
Disposition state	❍	❍	❍	❍	❍
Item's expected working life	❍	❍	❍	❍	❍

Q9 Referring to the "Patient Outcome" group of sub-objectives, please rate to what extent you agree on the VMs scales provided in the document we sent to you.

	1	2	3	4	5
Patient length of stay	❍	❍	❍	❍	❍
Quality-adjusted life years	❍	❍	❍	❍	❍
Infection rates	❍	❍	❍	❍	❍
Disposition state	❍	❍	❍	❍	❍
Item's expected working life	❍	❍	❍	❍	❍

Answer If For the second objective (Patient Outcome), please rate to what extent you agree on the definition for each of its sub-objectives. (1- No it does not make sense, 5-Yes it is good). - 1 Is Selected Or For the second objective (Patient Outcome), please rate to what extent you agree on the definition for each of its sub-objectives. (1- No it does not make sense, 5-Yes it is good). - 2 Is Selected Or We are still talking about the second group of sub-objectives, please rate to what extent you agree on the VMs scales provided in the document we sent to you. - 1 Is Selected Or We are still talking about the second group of sub-objectives, please rate to what extent you agree on the VMs scales provided in the document we sent to you. - 2 Is Selected

Q10 In the previous questions, you scored less than 3 for some objectives, please explain why. (List the objective and any changes to the definition or the VM scale)

Q11 For the third objective (Clinician Satisfaction), please rate to what extent you agree on the definition for each of its sub-objectives. (1- No it does not make sense, 5-Yes it is good).

	1	2	3	4	5
Ability of provider's staff to solve Problems	❍	❍	❍	❍	❍
Testability of the item	❍	❍	❍	❍	❍
Availability of regular updates	❍	❍	❍	❍	❍
Ease of instructions for preparation and use	❍	❍	❍	❍	❍
Ease of use of the item	❍	❍	❍	❍	❍
Time needed for additional training	❍	❍	❍	❍	❍
Item's long term availability	❍	❍	❍	❍	❍
Time needed for performing the treatment	❍	❍	❍	❍	❍

Q12 Referring to the "Clinician Satisfaction" group of sub-objectives, please rate to what extent you agree on the VMs scales provided in the document we sent to you.

	1	2	3	4	5
Ability of provider's staff to solve Problems	❍	❍	❍	❍	❍
Testability of the item	❍	❍	❍	❍	❍
Availability of regular updates	❍	❍	❍	❍	❍
Ease of instructions for preparation and use	❍	❍	❍	❍	❍
Ease of use of the item	❍	❍	❍	❍	❍
Time needed for additional training	❍	❍	❍	❍	❍
Item's long term availability	❍	❍	❍	❍	❍
Time needed for performing the treatment	❍	❍	❍	❍	❍

Answer If For the third objective (Clinician Satisfaction), please rate to what extent you agree on the definition for each of its sub-objectives. (1- No it does not make sense, 5-Yes it is good). - 1 Is Selected Or For the third objective (Clinician Satisfaction), please rate to what extent you agree on the definition for each of its sub-objectives. (1- No it does not make sense, 5-Yes it is good). - 2 Is Selected Or We are still talking about the third group of sub-objectives, please rate to what extent you agree on the VMs scales provided in the document we sent to you. - 1 Is Selected Or We are still talking about the third group of sub-objectives, please rate to what extent you agree on the VMs scales provided in the document we sent to you. - 2 Is Selected

Q13 In the previous questions, you scored less than 3 for some objectives, please explain why. (List the objective and any changes to the definition or the VM scale)

Q14 For the fourth objective (Organizational Benefits), please rate to what extent you agree on the definition for each of its sub-objectives. (1- No it does not make sense, 5-Yes it is good).

	1	2	3	4	5
Patient acquisition	❍	❍	❍	❍	❍
Reimbursement associated with procedures	❍	❍	❍	❍	❍
Readmission	❍	❍	❍	❍	❍
Patient retention	❍	❍	❍	❍	❍
Attractiveness of profitable physicians	❍	❍	❍	❍	❍
Amount of associated medical lawsuits/claims	❍	❍	❍	❍	❍

Q15 Referring to the "Organizational Benefits" group of sub-objectives, please rate to what extent you agree on the VMs scales provided in the document we sent to you.

	1	2	3	4	5
Patient acquisition	❍	❍	❍	❍	❍
Reimbursement associated with procedures	❍	❍	❍	❍	❍
Readmission	❍	❍	❍	❍	❍
Patient retention	❍	❍	❍	❍	❍
Attractiveness of profitable physicians	❍	❍	❍	❍	❍
Amount of associated medical lawsuits/claims	❍	❍	❍	❍	❍

Answer If For the fourth objective (Organizational Benefits), please rate to what extent you agree on the definition for each of its sub-objectives. (1- No it does not make sense, 5-Yes it is good). - 1 Is Selected Or For the fourth objective (Organizational Benefits), please rate to what extent you agree on the definition for each of its sub-objectives. (1- No it does not make sense, 5-Yes it is good). - 2 Is Selected Or We are still talking about the fourth group of sub-objectives, please rate to what extent you agree on the VMs scales provided in the document we sent to you. - 1 Is Selected Or We are still talking about the fourth group of sub-objectives, please rate to what extent you agree on the VMs scales provided in the document we sent to you. - 2 Is Selected

Q16 In the previous questions, you scored less than 3 for some objectives, please explain why. (List the objective and any changes to the definition or the VM scale)

Q17 For the fifth objective (Internal Supply Chain), please rate to what extent you agree on the definition for each of its sub-objectives. (1- No it does not make sense, 5-Yes it is good).

	1	2	3	4	5
Required preparation time of item by nurses	❍	❍	❍	❍	❍
Ease of handling and management by nurses	❍	❍	❍	❍	❍

Q18 Referring to the "Internal Supply Chain" group of sub-objectives, please rate to what extent you agree on the VMs scales provided in the document we sent to you.

	1	2	3	4	5
Required preparation time of item by nurses	❍	❍	❍	❍	❍
Ease of handling and management by nurses	❍	❍	❍	❍	❍

Answer if For the fifth objective (Internal Supply Chain), please rate to what extent you agree on the definition for each of its sub-objectives. (1- No it does not make sense, 5-Yes it is good). - 1 is selected Or For the fifth objective (Internal Supply Chain), please rate to what extent you

agree on the definition for each of its sub-objectives. (1- No it does not make sense, 5-Yes it is good). - 2 Is Selected Or We are still talking about the fifth group of sub-objectives, please rate to what extent you agree on the VMs scales provided in the document we sent to you. - 1 Is Selected Or We are still talking about the fifth group of sub-objectives, please rate to what extent you agree on the VMs scales provided in the document we sent to you. - 2 Is Selected
Q19 In the previous questions, you scored less than 3 for some objectives, please explain why. (List the objective and any changes to the definition or the VM scale)

Q20 Anything else you would like to say?

Appendix F.4: Value Measures Scales

The 10 Natural Value Measures	Score Levels (Scale)
Proportion of treatments that achieved the intended effect during ideal trials	% from 20 to 100
Proportion of treatments that achieved the intended effect during actual use	% from 20 to 100
Reliability	% from 0.6 to 1.0
Total # of days stayed	# of days from 0 to 5
Expected years*Quality of living (QALY)	QALY from 0.1 to 1.0
Infection percentage	% from 0 to 100
Acquired patients rate	% from 10 to 100
Reimbursement rate	% from 40 to 100
Readmission rate	% from 0 to 100
Retention rate	% from 10 to 100

Side effects/risks constructed scale (7-points scale)		
Score	Definition	Value
0	No side effects	100
1	Minor side effects (Dry mouth, itching …)	95
2	Major injuries nonlife threatening	80
3	Serious life threatening (heart attack, internal bleeding…), % of death related events less than 20%	40
4	Serious life threatening (heart attack, internal bleeding…), % of death related events >20% & <40%	15
5	Serious life threatening (heart attack, internal bleeding…), % of death related events >40% & < 60%	5
6	Serious life threatening (heart attack, internal bleeding…), % of death related events >60%	0

Physician's experience using the item Multidimensional constructed scale		
Score	Definition	Value
1	Highly skilled physician using the item/device, and experience >10 years	100
2	Highly skilled physician using the item/device, and experience >5 & <10 years	90
2	Medium skilled physician using the item/device, and experience >10 years	90
3	Highly skilled physician using the item/device, and experience <5 years	70
3	Medium skilled physician using the item/device, and experience >5 & <10 years	70
4	Low skilled physician using the item/device, and experience >10 years	60
5	Medium skilled physician using the item/device, and experience <5 years	40
6	Low skilled physician using the item/device, and experience >5 & <10 years	20
7	Low skilled physician using the item/device, and experience <5 years	0

Prefer items that have more distinguishing/unique features		
Score	Definition	Value
0	No distinguishing features	0
1	Few extra features	50
2	Noticeable distinguishing features	100

Expected Working life years (categories scale)		
Score	Definition	Value
1	<= 1 year	0
2	1-3 years	25
3	>3 & <6 years	50
4	6-10 years	75
5	>10 years	100

Maximize supplier ability to provide product support		
Score	Definition	Value
1	Not able at all	0
2	Able to solve description problems (like: missing information,	25
3	Ability to solve minor technical problems	50
4	Ability to solve major technical problems with a delay	75
5	Ability to solve major technical problems on the spot	100

Maximize supplier ability to support product trials		
Score	Definition	Value
1	Not testable	0
2	Limited time testability	50
3	Long time testability	90
4	Unlimited time testability	100

Prefer items that have easier instructions for preparation and use		
Score	Definition	Value
1	No instructions	0
2	Complicated instructions	25
3	Moderately easy instruction	55
4	Very easy instructions	100

Maximize the actual Ease of Use of the item		
Score	Definition	Value
1	Very difficult	0
2	Moderately difficult	50
3	Very easy	100

Minimize time needed for additional training		
Score	Definition	Value
1	No time needed	100
2	small amount of time relative to similar items	90
3	Moderate amount of time needed	50
4	Very long time needed	0

Minimize time needed for performing treatment		
Score	Definition	Value
1	Short time	100
2	Moderate time	50
3	Longer than other items	0

Maximize attractiveness of profitable physicians		
Score	Definition	Value
1	Low likely physicians in general will be attracted (i.e. the item is less preferred by physicians than other similar items, or the likelihood of physicians to come just because the healthcare provide is using this item, is low)	0
2	Moderately likely physicians in general will be attracted (i.e. the item is preferred by physicians as similar as similar items, or the likelihood of physicians to come just because the healthcare provide is using this item, is medium)	50
3	Highly likely physicians in general will be attracted (i.e. the item is more preferred by physicians than other similar items, or the likelihood of physicians to come just because the healthcare provide is using this item, is high)	100

Minimize amount of associated medical lawsuits/claims		
Score	Definition	Value
1	Low amount of lawsuits cases and claims	100
2	Medium amount of lawsuits cases and claims	50
3	High amount of lawsuits cases and claims	0

Prefer items that are easier to handle and manage		
Score	Definition	Value
1	Very difficult	0
2	Moderately difficult	50
3	Very easy	100

Maximize flexibility of minimum order quantity		
Score	Definition	Value
1	Not flexible, should order big quantity relative to the item type	0
2	flexible with minimum order quantity, but still there are limits	50
3	Very flexible, can order any quantity	100

Maximize suppliers' ability of urgent delivery		
Score	Definition	Value
1	Not at all	0
2	Sometimes able	25
3	Able with a considerable amount of time	50
4	Able to deliver whenever needed	100

Maximize lead-time reliability		
Score	Definition	Value
1	Not reliable, the lead-time is highly variable, the CV is big	0
2	Somewhat reliable, the lead-time is Intermediate variable	25
3	Good reliability, low lead-time variability	60
4	Highly reliable, lead-time reliability is almost 0	100

Appendix F.5: Excel Macros

```
Function ValuePL(x, Xi, Vi)
  i = 2
  Do While x > Xi(i)
    i = i + 1
  Loop
  ValuePL = Vi(i - 1) _
    + (Vi(i) - Vi(i - 1)) * (x - Xi(i - 1)) / (Xi(i) - Xi(i - 1))
End Function

Function ValueE(x, Low, High, Monotonicity, Rho)
```

```
    Select Case UCase(Monotonicity)
        Case "INCREASING"
            Difference = x - Low
        Case "DECREASING"
            Difference = High - x
    End Select
    If UCase(Rho) = "INFINITY" Then
        ValueE = Difference / (High - Low)
    Else
        ValueE = (1 - Exp(-Difference / Rho)) / (1 - Exp(-(High - Low) / Rho))
    End If
End Function
```

Notes:

- given an array of X values, Xi, and corresponding value array (Vi), ValuePL returns interpolated value
- Xi array must be monotonically increasing as i increases
- Given x, low and high scores of the value measure, and monotonicity (Increasing or Decreasing), ValueE returns normalized exponentially interpolated value
- Rho is the exponential constant. If Rho = infinity, the value curve becomes a straight-line
- This Excel macro is adopted from (C. W. Kirkwood 1997).

Appendix F.6: Evaluation Feedback Questions

Q1. The whole framework captures the PPI problem.

1 I don't agree 2 3 4 5 I strongly agree

Q2. The objectives and sub-objectives represent critical components in this decision area?

1 I don't agree 2 3 4 5 I strongly agree

Q3. This framework would improve the value analysis process.

1 I don't agree 2 3 4 5 I strongly agree

Q4. This framework would be easy to implement.

1 I don't agree 2 3 4 5 I strongly agree

Q5. The time needed to make a decision would be decreased/ improved.

1 I don't agree 2 3 4 5 I strongly agree

Q6. This framework would be implementable in my company.

1 I don't agree 2 3 4 5 I strongly agree

Q7. The quality of the decision should be improved.

1 I don't agree 2 3 4 5 I strongly agree

Q8. All aspects of the different stakeholders have been incorporated.

1 I don't agree 2 3 4 5 I strongly agree

Q9. The framework satisfactorily represents the multiple competing criteria within a PPI problem related to all stakeholders.

1 I don't agree 2 3 4 5 I strongly agree

Q10. It captures the importance of the objectives.

1 I don't agree 2 3 4 5 I strongly agree

Q11. Breaking the analysis out in the way would be beneficial.

1 I don't agree 2 3 4 5 I strongly agree

Q12. Understanding the sensitivity of swing weights would be important.

1 I don't agree 2 3 4 5 I strongly agree

Q13. This framework adds more visibility of the decision value and consequences

1 I don't agree 2 3 4 5 I strongly agree

Q14. This process (framework) educated me and made me think with more objectivity about the problem.

1 I don't agree 2 3 4 5 I strongly agree

Q15. Please, rate your perceived potential impact of implementing this decision framework on the PPI selection process.

1 I don't agree 2 3 4 5 I strongly agree

Q16. Anything else you would to say?