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Modeling of selection of supply sources for hospitals

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MODELING OF SELECTION OF SUPPLY SOURCES FOR HOSPITALS

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ABSTRACT

Most of the hospitals in the USA carry out their purchasing of supplies, including pharmaceuticals, through Group Purchasing Organizations (GPO). GPO is an organization, which aggregates procuring volumes of their member hospitals and negotiates low prices from manufacturers or vendors. According to 2013 statistics, 98% of hospitals in U.S. are purchasing their bulk health care products through GPOs, and it saves U.S. health care industry approximately $36 billion annually. Through these hospitals enjoy advantages by purchasing through their GPOs, there are some disadvantages such as paying membership fees to their GPOs, restricting the purchasing power of the hospitals outside their GPOs, making it more complicated to buy better or advanced products from new vendors. As various political and economic factors are forcing hospitals merge into large hospital associations, the concept of self-contracting or managing supplies directly, comes into the picture.

In this research, the concepts of healthcare supply chains with GPOs are described in detail. Purchasing systems under self- contracting are then discussed. Three possible options for the hospitals are then examined, namely, continuing current purchasing through their GPOs, direct purchasing from manufacturers (self –contracting), and finally, forming an association with other hospitals and purchasing through this association. The preferable options are discussed under the concepts of Game Theory. This research also examines the changes needed in the supply chain if any of the above new options is selected.

A regular supply-chain consists of Hospital, GPO, and vendor or manufacturer. As healthcare delivery systems are merging into one group or forming hospital associations, they have an additional option of carrying out their purchasing through these associations. In this work, it is assumed that the individual hospitals take their decisions based on total costs of supplies, and they chose the supplier by comparing the various options available. In this research, these questions are answered by following a game-theoretic model, by making some assumptions. Concepts of game theory such as Nash equilibrium, Mixed Strategy Nash Equilibrium (MSNE), etc. are discussed.

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CHAPTER 1: INTRODUCTION

The Healthcare system is a system in which many components interact and work resulting in delivering the best healthcare services to the patient. This system comprises of four major constituents, providers, facilities where the healthcare is provided, pharmaceuticals, and medical equipment operators. In the period of the contest, no industry can persist without considering much about cutting down expenses wherever feasible. The same is accurate for the healthcare industry, which is observing an apparent rise in cost in most of all its goods and services. The supply chain in this industry being a notable driver of price is, therefore, seizing all the recognition from industry stakeholders. The healthcare supply-chain concerns the flow of various product types and the cooperation of many stakeholders.

1.1 Introduction to healthcare supply chain:

The principal objective of the healthcare supply chain is to deliver commodities promptly, to meet the needs of providers. Based on their duties, stakeholders in the healthcare supply-chain can be classified into three major groups: producers, buyers, and providers. Supply-chain management in healthcare should guarantee total end-to-end distinctness of information among suppliers, producers, wholesalers and consumers.

1.2 Introduction to Group Purchasing Organization (GPO):

Group Purchasing Organizations have turned out to be exceptionally critical of the healthcare industry. The GPOs have for the most part get to be prevalent in healthcare services, training,

and government associations. The current health care industry is facing with the lot of pressure to chop down costs and intense competition among health care providers, which resulted in merging and attainments leading to a large size of suppliers. The most incessant reason given by health care providers to be partnered with a GPO is profitable contractual conditions. The current GPOs have changed the traditional strategy for acquiring products. The enormous pressure of bringing down the costs has for the most part been valuable to the end client, which for our situation is a client to a health care center.

A GPO is a formal and efficient organization that enables the alliance of procurements for many organizations (Nollet 2005). The subcontracting of procuring to GPOs has eased healthcare centers with an emphasis on their critical areas like giving proper healthcare. This has removed the load of buying operations, which many healthcare centers are facing formerly. According to recent statistics, 72% of the purchases are done through GPO contracts. According to the study conducted by Schneller (2009), these organizations save about 36 billion dollars every year for U.S. healthcare industry. By registering with these agencies, the providers are saving a lot of time and money by losing the burden of negotiating contracts and processing a lot of individual contracts. According to this study, some hospitals who are not proceeding through GPOs are spending a lot of money ($600,000 to $800,000) every year for operations and maintenance of staff, money that could be spent on appointing new doctors and staff and provide the best health services to their patients. Also, negotiating contracts they also assist their members by giving them extra services.

The primary function of group purchasing is to attain lower prices, safeguard price shield, and executing enhanced quality programs, reduced contracting costs and checking market situations regularly. Other than volume discounts, GPOs are helping health care members by delivering primary services such as supply chain management. They assist the health care providers by creating an online domain for their procurement use. They introduce new

technologies or existing technologies such as Barcoding to their members to manage their inventories. They also help them by suggesting any new medications, and educating them about new equipment. In addition, GPOs work with their client providers in making their supply chains more efficient by providing managerial insights into their operations. Schneller proposed that “product standardization” and “entering into GPO contracts” where the primary cost reducing strategies to be followed. While making a contract with a GPO, the health care member should evaluate the performance and quality of the suppliers as well as the GPOs purchasing power (Schneller 2000).

GPO ‘s from the Hospitals perspective:

- The agglomeration of purchasing power through GPOs have permitted clinics to bring down their procurement costs altogether.
- Hospitals administrators are not showing any interest in buying the required goods out of the GPO contract because they are in fear of losing manufacturers’ rebates as well as the portion of administrative fees, which is spent by the GPO.
- The hospitals are thinking in administrative expenses, so they always purchase through GPOs. This is why because GPOs can reduce the number of products and pharmaceuticals in the hospital formulary there by reducing the inventory costs.

GPOs from the Vendor's perspective:

Simply to say, if the vendor wants to increase their market share, they have to deal with the GPOs, as the contract duration is increasing and higher in purchasing volumes can be achieved.

1.3 Hospital Association:

All across America, hospitals are merging. Hospital officials who create the mergers believe that hospital consolidation enhances the efficiency, access and quality of care, and may reduce

costs as, in theory, the more care a hospital provides, the higher efficient and less costly it should become. For instance, when a smaller hospital merges with a larger hospital system, patients at the smaller hospital may obtain enough access to specialists and advanced therapeutic technologies, such as high-tech imaging methods and automated medical record systems. According to Harvard health publications, there were 95 mergers, acquisitions, and joint ventures between U.S. hospitals in the year 2014. Using the same concept of merging, but the consolidation of supplies between the hospitals as one of the alternatives of purchasing is employed in this thesis. The “Hospital Association” can also be stated as, hospitals are trying to form large associations to combine their resources and at the same time cut down their costs.

1.4 Objectives And Significance:

In this thesis, our fundamental goal is to look at three procurement models, concerning purchasing costs by two healthcare members. This study mainly involves in comparing the three scenarios featuring a healthcare organization procuring through its GPO, acquiring through self-sourcing (purchasing directly from manufacturers) and finally through a hybrid model, which involves in forming an association of hospitals and acquire required products. The items procured by the hospitals can be classified mainly into two types, surgical and pharmaceutical products and physician prescribed items. Physician prescribed products are not purchased in bulk, and these elements are excluded in this work. The items, which are bought in bulk, are considered and used for comparison. Apart from procurement costs, membership fees and administrative fees are also considered in analyzing the model. Our model analyzes the cost efficiency of all the scenarios basing on the situations and highlights the best possible solution.

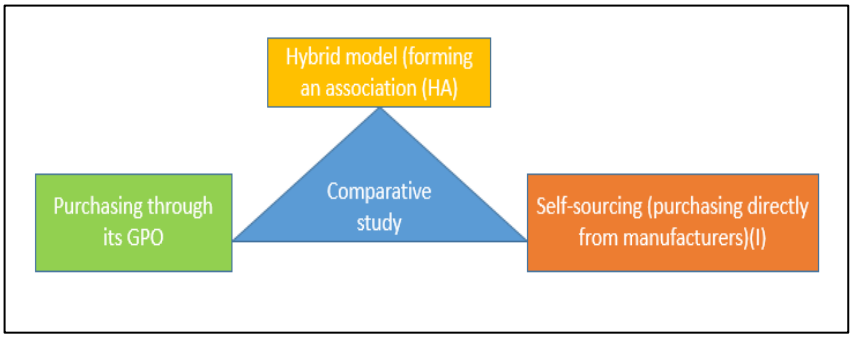


Figure 1.1: Procurement scenarios used for comparison

In this research, the comparison study is done using game theoretic models, in which the cost equations are considered as payoff points, and the detailed explanation is given in the procedure chapter.

Objective: The main objective is to find a preferable low cost option of purchasing for the hospitals using Game theory concepts.

Game Theory: “Game theory is the formal study of conflict and cooperation. Game theoretic concepts apply whenever the actions of several agents are interdependent. These agents may be individuals, groups, firms, or any combination of these. The concepts of game theory provide a language to formulate, structure, analyze, and understand strategic scenarios.” It is an essential tool that helps us to get to know about the situations in which there is a strategic cooperation among the decision makers. Decision makers frequently encounter a 'conflict-of-interest' situation, and each of them intends to get the best advantage out of it. This kind of circumstances arises in most areas. The concept of Best response is used to find the Nash equilibrium is used in this thesis, which gives the preferable option of purchasing.

1.4.1 Broader Impact Of The Research:

This research helps to identify whether cost savings can be achieved using a hybrid model or not. It will also determine the optimal or best preferable option for purchasing products basing on the scenarios stated in this research.

1.5 Organization Of Research:

The rest of the report is organized as follows: In section 2, the explanation about the earlier study on purchasing and on the game theory concepts is given; The working of GPOs and what facilitates the inclination towards the self contracting are discussed in section 3; The in detail explanation of Nash equilibrium and the models are developed in chapter 4 and 5 respectively. Finally, conclusions and future work are discussed in chapter 6

CHAPTER 2: LITERATURE REVIEW

Healthcare General Purchasing Organizations (GPOs) are major players in most of the healthcare organizations' supply chains. A Recent survey conducted by Burns and Lee in 2008, reviewed GPOs from their member's perspective. Based on 94% survey results, they reported that GPOs succeeded in lessening health care prices by dropping product costs, especially for commodity and pharmaceutical products.

Hu and Schwarz (2011) review some of the contentions about GPOs by a Hoteling design. The providers determine whether to establish a GPO while negotiating a price for the producers. They record that forming a GPO intensifies competition among manufacturers, thus reducing costs for healthcare members. They further illustrate that the presence of moderate off-contract rates is not an indication of anticompetitive course on the part of GPOs.

One of the most common concerns dealt in the current literature is about the ideal size of GPOs and the benefits which healthcare organizations gain by associating with a GPO. There is a general accord that connection with a GPO, in fact, results in cost savings. Member loyalty has a huge role to play in the success of a GPO and also the increase of member registration depends on it (Nollet, 2002). W. R. Doucette showed that the transparency in sharing of data among the members and the trust concerns shape the success of GPOs by generating a high member commitment (Doucette, 1997)

The significant portion of literature discusses costs, and the cost is saving privileges enjoyed by the healthcare organizations. Any health care center associated with a GPO benefit from three types of cost reductions: price, administrative expenses and utilization costs (Anderson 1998). The affiliation to a GPO can produce savings up to 10 to 15 percent, which is a direct cost saving (Hendrick 1997) and (Schneller 2000). The healthcare organizations can employ the savings generated in essential areas, which relate directly to the quality of health care.

Chapman (1998) suggested that the real profits in the healthcare savings arise from product standardization. However, certain types of purchases like products are suited for larger gains, and certain purchasing groups may enforce uniformity by forcing health care centers to use all the goods in the package (Nollet, 2005).

However, it is found that there has been a lack of work related to the comparison of procurement models through self-sourcing, national GPO sourcing, and through associations. Most of the earlier or present literature has identified economic and noneconomic costs associated with a GPO (Dobler, 1996; Anderson, 1998; Chapman, 1998, and Schneller, 2000), but there has been no direct comparison between three different procurement models. Also, most of the earlier research has just considered noneconomic costs like loss of independence of physicians and barrier to entry of innovative products (Zweig, 1998) and (Elhauge, 2002).

In this work the proposed methodology is the game theory, which is used to analyze the solution. Game theory is useful when other players in the system are also making decisions and each player's decision depends on the individual decisions taken by other players. Von Neumann and Morgenstern introduced the concept of Game Theory. Game theory has branched out to incorporate many other business methods, from optimal purchasing campaign strategies, war strategies, traditional auction tactics, and voting methods. For instance, pharmaceutical organizations probably face divisional issues on whether to advertise an item instantly and obtain a competitive advantage over competing firms, or delay the testing time of

the medication. Hu et al., (2011) applied game theory for analyzing the impact of GPOs on healthcare product supply chains. They used game theory concepts for checking whether contract administration fee affects the purchasing costs of the providers. They used the single product for analyses, but GPOs pricing frequently involves bundles of products. They considered two non-cooperative games, one that includes GPOs and another that does not, making an assumption that every player is aware of payoffs of other players. There is an enormous operation/supply chain management literature on contracting [Cachon (2003)], but not much research related to GPOs or other contracting mediators. Considering a monopoly producer that offers a "linear quantity discount" to competing retailers, Chen, and Roma (2011) distinguishes circumstances under which a GPO will form. In all these articles, the retailers' demands are price elastic, depending on the retail costs.

Another stream of study involves the distribution of some of the union gains back to its members, the balance of allocation, and the establishment of the association through a cooperative game framework. In particular, Schotanus et al. (2008) and Nagarajan et al. (2008) analyzed how a GPO can designate cost savings amongst its members. The following research further examines the stability of the GPO under various allocation rules. Also, there is a substantial amount of effort in the economics literature on the fair division of joint costs or excess (e.g., Moulin 1995, 1996; Friedman and Moulin 1999; Friedman 2004).

2.1 Development Of Group Purchasing Organizations (GPOs):

The Hospital Bureau of New York established the First GPO in 1910. Today, there are more than 600 GPOs in the United States, with about 98% of the care providing systems being members of GPOs. The overall savings for the members could go up to $866.4 billion (HSCA, 2014). The six largest PO's have more than 3000 members each.

The United States Congress has not kept any restriction on administration fees, but it appointed United States Department of Health and Human Services (HHS) to review and oversee whether the GPOs are exceeding their administrative costs more than 3%, as it exempted the GPOs from anti-federal kickback. Judging by the fee structure, it does help a GPO if it grows larger in size.

In 2002, the Senate developed a code of conduct for every GPO to subscribe to and follow correctly. Otherwise, they are imposed on severe charges. This growth in the number of GPOs ended in intense competition among the members in a volatile pricey market. GPOs could not expand by joining members as most of the organizations are already enrolled in one of the GPOs for purchasing their products (Nollet, 2002). To stay loose with the competition, GPOs began extending supplementary services, which promote the operational performance of a healthcare organization. These duties include supply chain management, ambulatory care, HR management, inventory management, etc.,

2.2 Applications Of Game Theory:

“These concepts are widely used in electrical engineering and computer science engineering from wireless networks to defense applications, from Internet security to Cybernetics, electricity marketing to image processing and coding, electromagnetic apparatus design to electrical vehicles, spectrum access to MIMO (Memory input and Memory output) systems, cognitive radio to target tracking, etc. For example, a survey of game-theoretic solutions applied to improve network security were listed and different game-theoretic solutions, together with their limitations, were discussed in Wireless networks are highly susceptible to jamming attacks, due to their broadcast nature”(IIE journal, 2016). Game theory provides powerful tools for modeling and analyzing such attacks. Effective playing strategy in information warfare was discussed in, where the game theory was used to study information warfare with mathematical models. A

game-theoretical approach was also used to optimize the design of the configuration of electromagnetic apparatuses (Anastasopoulos, 2012).

Of course, all of the players are involved in playing and attempting to modify the game. This is the second valuable supplement of the game theory framework: a focus on the entire player prospects, rather than only your company's perspective. Players must predict player actions and effects as the game is being played. This multidimensional aspect is essential for knowing who the opposition is and why?

For example, many hospital organizations focused principally on their hospital contestants rather than the competitors who were having a bigger influence on them—managed-care organizations. The insurers changed the players and the tactics to boost their value added to and derived from the game.

Finally, game theory presents the notion of changing the game by involving other players in cooperation and competition in a style that produces “win-win” rather than “win-lose” consequences. Health reformation generates many possibilities for hospitals, physicians, and insurers to associate together in this way. Game theory contributes the perfect form to test the strategic usefulness of these options and to design new fundamental relationships that “change the game” for the better

CHAPTER 3 – DESCRIPTION OF GROUP PURCHASING ORGANIZATIONS

A Group Purchasing Organization (GPO) is an organization, which facilitates supplies to its member healthcare providers. GPOs procurement strategy involves in better operational links with vendors resulting in shorter lead times and better efficiency, and this benefits the end customer with lower costs. GPOs also implement "joint purchasing programs" to clinicians and other healthcare bodies.

The domains where GPOs use their leverage in negotiating the prices are office facilities, dietary, laboratory, diagnostic imaging, pharmacy, IT, insurance, and maintenance (Burns, 2002). Aside from negotiating prices, a GPO works as a tool for price protection for its members as it operates as a connection among a large number of suppliers and the healthcare company.

In the past, GPOs granted their members the same regulated pricing irrespective of the quantity they acquired. This proved to be beneficial to the smaller members, and the bigger opponents felt that they had to bear the responsibility of subsidizing the smaller ones (Burns 2002). Nevertheless, the concept of “tiered pricing” (Burns 2002) has come into force recently, which links the pricing of goods to the quantities, the members’ purchase.

General services offered by GPOs:

- Other than volume discounts, GPOs are helping health care members by delivering primary services such are mentioned below. Managing an intricate system of procuring products in the health care industry.
- Offering e-commerce solutions for health care members for facilitating efficient procurement process.
- Helping the hospitals in managing their inventory by introducing the methods of Barcoding etc.
- The GPOs maintain their vendor networks by making proper dealings so that even vendor can enjoy the benefits. They ask for a dispensing fee of the products also.
- The GPOs educate the clinicians in the hospitals about the new products, and new machines entered into the market for easy usage.
- Quality check is the primary service given by GPO to the hospital, as they raise some enactment risks with some medicines and this process is considered crucial for the GPO. In addition to these, they also help hospital members in data analysis, supply chain management works, ambulatory care, allowing them to increase their staff, suggesting new medications, setting up proper fire aids in the hospital, improving their operations, etc.

3.1 Impact Of Purchasing Groups:

The purchasing groups act a critical role in the manipulation of the materials prices. The largest players in the market utilize their advantage with the supplier following in the wiping out of the smaller members who lack the negotiating ability. Due to the substantial market share by the prominent commanding members, entry of small members into the market becomes tight (Sethi 2006). It is acutely costly for a new competitor to obtain considerable market share since most

of the potential clients are affiliated with existing GPOs by various contractual agreements (Sethi 2006). The growth of larger purchasing groups may end up with a benefit to the current vendors as fewer quantity suppliers may fall out in an active price market although their product may be technologically excellent. This will concern the quality of products in the future.

3.2 Classification Of GPOs:

GPOs can be classified based on their membership, geographic scope, possession, and size (Burns 2002). When GPOs are classified based on ownership, they are listed as for-profit, non-profit and public GPOs (Burns 2002). The two largest for-profit GPOs are divisions of the two most important investors-owned hospital systems: HCA (Health Trust Purchasing Group) and Tenet (Buy Power) (Burns 2002). The three biggest nonprofit GPOs are hospital cooperatives like Novation, which is a group-purchasing arm for VHA/UHC (Burns 2002). The most massive public GPO is the VA. Healthcare organizations, which are a part of for-profit and the VA systems, are more committed to their group purchasing contracts. Healthcare organizations within the nonprofit alliances join their GPOs voluntarily (Burns 2002).

GPOs also vary in the type of membership. Some GPOs are bound to the larger healthcare companies where as some of them focus on smaller clients like ambulatory centers and practitioner's offices. Many GPOs try to focus on two types of the market to have a substantial presence (Burns 2002).

Many GPOs differ in their extent to cater to various markets. Some or rather smaller players concentrate on local healthcare organizations. This assists them to merge their resources and sometimes function properly in logistical operations than National players. Large GPOs focus on a National level. They have a better reach that is promoted by their economic muscle and quantities of purchases.

3.3 Services Offered By GPOs:

GPOs have progressed over the last few decades from basic claims managers to more complex administrations offering an extensive range of prescription drug controlling tools. Furthermore, offering their elementary services – Providing discounted contracts, claims handling, record protection, and reporting agendas – GPOs offer their clients a wide range of services together with the drug application review, disease supervision. GPOs also assist customers by forming their benefits configuration.

Some other core services listed out below other than providing huge rebates to the member hospitals, they are,

Formularies: GPOs use formularies (higher quantities) to negotiate high price discounts with manufacturers, established price-sharing stages to impact beneficiary consumption charges, and boost recipients to practice a mix of chosen or lower-price covered goods.

Rebates: GPOs negotiate with manufacturers for discounts on items designated for the formulary. Discount amounts are created by the contracts negotiated between the GPO and members and the GPO and producers. Typically, bonds are organized so that GPOs hold a portion of the discount in an altercation for increasing the formulary and negotiating with manufacturers.

Pharmacy Networks: These networks contain drug stores that have approved to dispense recommended drugs and provide pharmacy services to the members who are enrolled in the health plan. These networks can be comprehensive or constricted. These networks let GPOs reduce drug expenses by negotiating the compensation rate and administration fee with pharmacies.

Claims Settlement: All GPOs use an actual, “point-of-sale” scheme related to wholesale and mail-order pharmacies and delivery hubs. This procedure offers confirmation of coverage, formulary limitations, and drug contacts. This method also delivers prescription drug info. Back at the GPO data granary, where it can be used for modified reportage and “quality-focused” medical and interference agendas.

Quality-Focused Plans: GPOs improve programs that deliver disease controlling, agreement strategies, and other medical expertise endorsing the safe, cultivated use of prescription drugs. GPOs usually do not take physical control of recommended drugs when carrying out their core pharmacological running functions. Though, in their “mail-order” and “specialty-pharmacy” businesses, GPOs purchase medicines from retailers or manufacturers and distribute them directly to patients in a way analogous to other dispensaries.

3.4 Flow Of Products From Manufacturers To Hospital Members In The Supply Chain:

Manufacturers:

Manufacturers are the main players in this supply chain, as they are the source of the recommended drugs. Producers manage the particular distribution of medicines from manufacturing facilities to drug retailers, and in some cases, straight to “retail pharmacy chains”, “mail-order” and “specialty pharmacies”, hospice chains. Manufacturers may also dispense goods directly to government clients, which naturally obtain the significant price rebates. Wholesale suppliers are the producers’ largest procurers. Very few drugs are dispersed directly to users.

Wholesale suppliers:

Wholesale suppliers obtaining pharmaceutical goods from manufacturers and dispense them to a multiplicity of consumers, as well as pharmacies (retail and mail-order), clinics, and “long term

care” and other “medical facilities. Some retailers sell to an extensive variety of possible clients while others concentrate on auctions of particular goods or deals to specific types of clienteles.

Earlier, wholesalers restricted their actions to a traditional delivery function. They delivered the link between manufacturers and by warehousing products and managing inventory. While “traditional” distribution facilities continue the keystone of the business, the business has advanced a more inclusive list of services in reply to the growing marketplace. Today, retail distributors offer some focused services, including “specialty drug” circulation, repayment support, and “drug buyback” programs.

This merging has enforced the industry to transform its revenue model, developing its core dispersal, business into a less margin enterprise that generates income by maximizing “economies of scale”, generating corporeal productivities in the distribution system, and recognizing monetary efficiencies.

Pharmacies:

These are the closing players in the supply chain over drugs reach the customer/patient. Pharmacies acquire medicines from retailers, and infrequently straight from manufacturers, and then take bodily possession of goods. After acquiring pharmaceuticals, pharmacies undertake the charge for their nontoxic storage and providing to customers. Pharmacies also work as a necessary information relation among GPOs, drug manufacturers, and wholesale suppliers. Unlike, other segments of the “health care delivery system” in the U.S., the pharmaceutical supply chain is incredibly programmed, and efficiently all dues transactions are controlled electronically.

3.4.1 Negotiating Contracts:

According to the GPOs in our study, GPO contracting comprises of three stages: (1) issue "Requests for Proposals" (RFP) or requests for vendors to competitively tender for a contract, (2) evaluate proposals, and (3) negotiate and grant contracts.

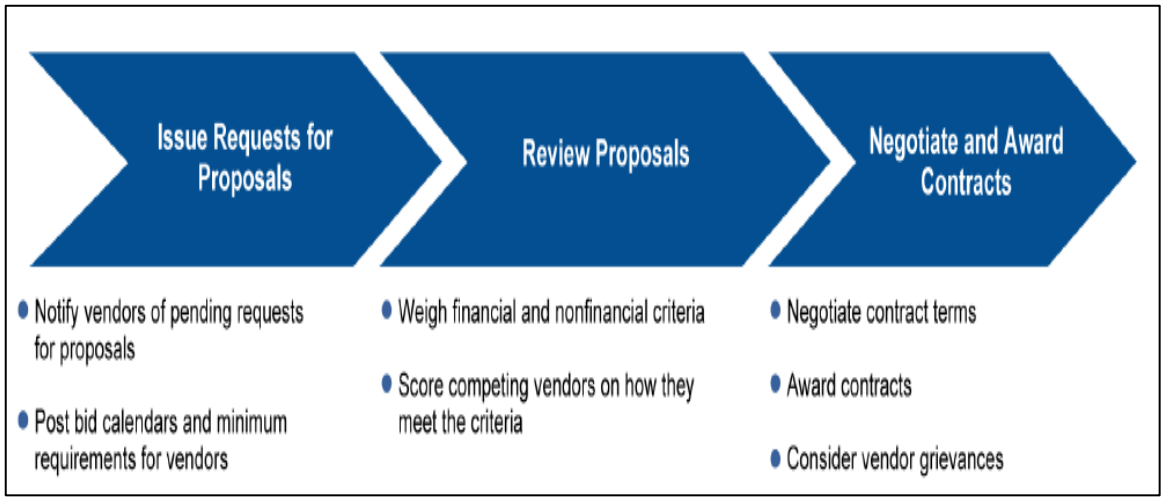


Figure 3.1: Stepwise procedure for negotiating contracts followed by GPOs

Source: GAO analysis of GPO- reported information

Issue RFPs: Issuing RFPs constitutes notifying vendors, and openly posting information such as tender calendars, minimum qualifications for suppliers, and standards that the GPOs will ponder when considering bidding proposals. All GPOs have posted on their websites information about the minimum qualifications that vendors must meet. For instance, one GPOs website says that suppliers must be the primary equipment manufacturer or exhibit a particular marketing, link with the goods involved in the RFP, among other elements. A sample RFP presented by a GPO says that during the competing bidding method, it will analyze a vendor's product inclinations, maintenance, and capacity to improve, as well as pricing and other economic factors. Sometimes "non-bid" contracts may be granted to suppliers that present a proprietary, copyright (Ed) or innovative commodity; if a small group of clients requests a local vendor contract.

The primary functions here are:

1. Notify vendors for pending requests for proposals
2. Post bid calendars and minimum qualifications for vendors.

Review proposals: All GPOs in our study reported considering various aspects of a supplier and product when evaluating proposals, including balancing financial and nonfinancial criteria, and then scoring bidding vendors to notify their contracting decisions. For example, one GPO detailed reviewing features such as a seller's capacity to provide sufficient stock to its clients, quality and safety of the commodities, the source of raw supplies, and bar code readability. The total amount set by GPO includes product quality, upfront cost, rebates, and expected administrative fee income.

Negotiate and award contracts: All GPOs in our study stated that the majority of the agreements they negotiate are either "dual-source" or "multi-source," suggesting that the majority of the goods traded through their contracts have more than one supplier available on the GPOs' contracts. The negotiation, for example, is taken as follows; a supplier might grant greater rebates to GPO consumers that acquire at least 80 percent of a particular group of goods from that producer. Loyalty requirements can also be layered, following in the opportunity for a client to commit to various percentages of purchasing quantity: the higher the percentage, the lower the cost.

Some of the key contracting strategies followed by GPOs is mentioned below.

Sole- Source Contracts: give one of many manufacturers of similar goods an independent right to sell an appropriate stock utilizing a GPO.

Commitment: which indicates that some percentage of purchase volume met by a provider member, when going through a GPO, which results in higher rebates. GPO can decide these commitment levels or a manufacturer based on mainly two factors such as manufacturing costs

for that product, negotiation by GPO. Here, the same rule follows, as higher the volume lowers the price. For an instance, a manufacturer provides 50% discount only for some goods when they purchase some 'H' quantity, and the provider member should buy the much (H) to avail that discount.

Bundling: This links particular products with discounts, this contracting helps both providers and manufacturers, but mainly advantageous to manufacturers as they are getting more sales. For example, A provider member wants to purchase some quantity of medicines through GPO, so the GPO includes some bundling products such as patient gowns, hats, cleaning liquids, etc. to obtain more discounts. So here the manufacturer will obtain more benefit as it is clearing its inventory. And the hospital members get benefits due to less cost charged for combining products.

GPOs would follow any of these contracting strategies, and this results in lessening the competition between the existing manufacturer and entrant manufacturer which makes the newcomer much harder to enter the market or can easily get them exit the market and causing more discouragement to the new arrivals.

3.4.2 GPO Fund Flow Model:

Originally devised in the 1960s, GPOs were formed as not-for-profit organizations financed solely by provider dues. Over time, for-profit GPOs developed, and by the 1980s, Congress approved GPOs to receive funding from suppliers, dispensers, and wholesalers, in addition to securing dues from the provider members. For GPOs, supplier payments turned out to be a far more productive means of funding the organization than provider based dues solely had been lessening the funding strain from provider members keen to see an additional reduction in contracting prices.

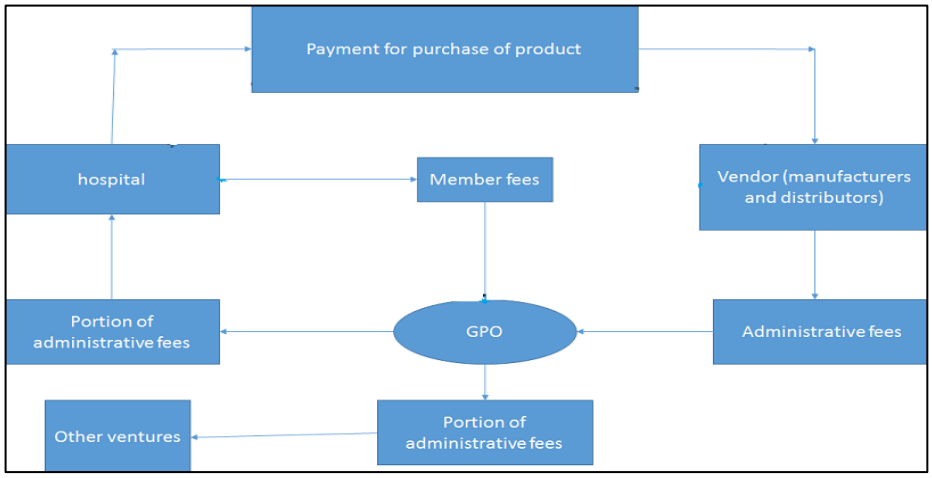


Figure 2.2: Payment Flow Model

Three types of payment negotiation are done between GPO and their sponsors and vendors.

- GPOs receive payment for the services they provide otherwise called member fees. (e.g.: disease management services etc.)
- GPOs assume some performance risk in their contracts they negotiate.
- GPOs also retain a portion of rebates they secure from vendors.

On the provider side, GPOs are financed by a blend of hospitals and health systems, some of which can have notable ownership stakes, both of whom frequently pay membership dues. Manufacturers, distributors, and vendors also pay administrative fees, which are usually calculated as a portion of contract value (typically about 3%).

Depending on the provider member's GPO contract value, owner hospitals and health systems can also gain returns usually equivalent to a percentage of entire fees secured (in the form of money or allowances). Therefore, GPOs have possibly contending incentives to not only achieve lower unit values for provider members but also enhance its members' total contract cost with suppliers.

3.4.3 GPO Product Flow Model:

The rebate flow happens between vendors (or manufacturers) and GPOs and from GPOs to hospitals. The product flow occurs between vendors to the customers or manufacturers to customers.

- The rebate flow happens between vendors (or manufacturers) and GPOs and from GPOs to hospitals.
- The product flow happens between vendors to the customers or manufacturers to customers. Third party logistics companies handle the shipping charges.
- GPOs do not take possession of products, but in some cases, they buy products from specialty care and mail- order pharmacies and dispense them directly to their customers like a normal vendor.

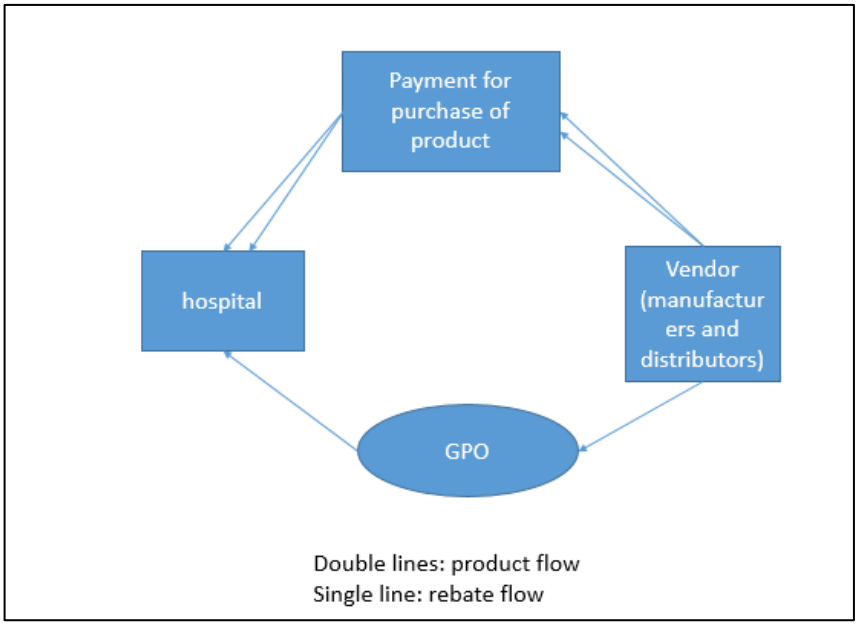


Figure 3.3: Product Flow

3.5 The Challenge Of Volume Involvements:

Contradictorily, one of the biggest challenges that the big national GPOs have in acquiring lower costs is a result of their size. As national GPO contracts can serve a huge share of a given supplier's business, many are reluctant to give their best rates to GPOs, particularly if they cannot make volume engagements. While GPOs negotiate contracted terms, hospitals are frequently not committed to obtaining at the volume levels charged in the contract. To help relieve these possible disincentives to pricing regulation, many GPOs have set so-called regional GPOs, which sums its bargaining power only within a circumstantial market or region. This smaller focus facilitates the local GPOs to:

- Enforce volume involvements since they have a greater capacity to predict volume requirements at a regional level and regulate within a lower association of members
- Increasingly leverage dual sourcing contracts that promote higher price contest between suppliers.

3.6 Vendor Funding:

Throughout the contracting process for goods and services, GPOs negotiate the installment of administrative fees by the seller to the GPO. In extension to utilizing these administrative fees to meet operating costs, GPOs may share a portion of the fees to their provider members or use them to fund other ventures, such as investing in other organizations. GPOs may also use administrative fees to subsidize supplementary services external to group purchasing for their clients, which can involve managing formulary, providing Fire aid services, assisting in supply chain metrics, benchmarking, quality assessment of the product, insurance services.

According to the survey done by "GAO" in 2012, it is reported that administrative fees received from vendors estimated for about 92 percent of their income (ranging from 83% to 98%). Also, according to the same survey, the other sources of revenue that include membership fees,

licensing fees, investment in their companies and another additional revenue is shown in below figure.

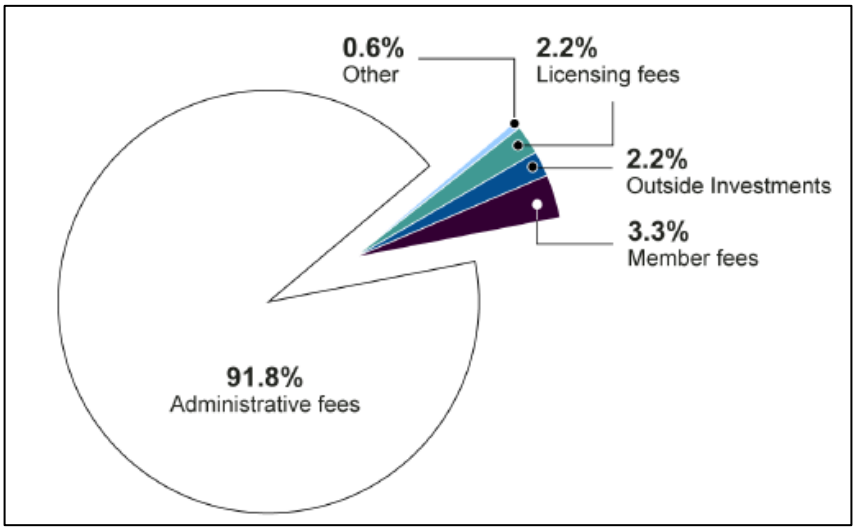


Figure 3.4: Revenue cycle for GPO

[Source: GAO analysis of GPO- reported information]

According to most of the critics, stated that the administrative fees which is collected by GPO is the main reason for high total contract costs. As if the contract costs increases, the administrative fees will increase which contributes the profit factor 'X' for GPOs. These critics argued that as the GPOs' compensation rises as prices rise, the GPOs have a limited influence to negotiate lower charges, even though their consumers would profit from lower rates. Hence, GPOs may assign greater importance on the administrative fees and other costs than the prices of commodities and services for their clients.

Some explained that provider members could change GPOs anytime if they are not satisfied with the rates that a GPO is negotiating. Some of the reviewers stated that hospitals change GPOs when they join with larger systems, but that there are notable expenses associated with the conversion. Notably, some asserted that GPO clients often receive pricing data from all

potential sources and then selectively choose goods and services they can get for the best prices.

3.7 Advantages And Disadvantages Of Group Purchasing Organizations:

GPOs bring benefits to its members and vendors comparatively. Vendors prefer to ensure business with huge customers but identify the value of attaining a significant number of minor consumers through one organized interface. Vendors are prepared to increase rebates and added service levels to the provider group to obtain a passage to their vast networks of customers. This enables vendors to lessen their vending cycle and beget a good progressing view into the market - greatly influencing stable production and supply chain management.

While some hospital members run as nonprofit organizations and some only for-profit organizations - so that the discount granted by vendors is crucial to the profitability of the hospital members. But vendors have a confined budget for rebates and developments, so anything that advances into allowances to gain market through the member hospitals is no longer accessible for commodity rebates and other promotions that would instantly benefit the members being served.

Other than volume discounts, GPOs are helping health care members by delivering primary services such as supply chain management; they assist the health care providers by creating an online domain for their procurement use. By introducing new technologies or existing technologies such as barcoding to manage their inventory. They also help hospital officials by suggesting the new medications and educating them about new equipment. They also help in their operations management.

Also, to these advantages, many critics oppose GPOs, and they mentioned the following,

- By removing or limiting purchasing decisions from the clinicians, restricting competition, thereby increasing the medical costs.
- They also raised a point on administrative fees, as GPOs are getting from the vendors who are used for covering their operating expenses, the contract prices are increased that results in the high amount of transactions.
- GPOs allow some hospitals to utilize the purchasing power provided by GPO up to 85% and can leave some percent to buy out of GPO contract. Some may forbid this entire buying product out of GPO contract.
- GPOs to maintain discipline among its member hospitals they follow two flow of actions, they are, they terminate institutions participation in that plan or withhold some incentive payments that are usually rebates from vendors.
- The main issue arises from the small manufacturers who find it difficult to get their products in the marketplace. The GPO wants alternative products to justify the small purchase.
- As the contracts are made for the longer duration (more than seven years) making the new vendors entering the market more problematic.

3.8 Statistics Of Group Purchasing Organizations:

1. There are roughly 600 active GPOs assisting hospital members in this country.
2. According to Healthcare supply chain association report, 90% to 95% of the hospitals national wide are doing purchasing through at least one GPO.
3. Roughly 73% of the hospital purchases are done via GPO contracts.
4. Cost savings approximately about $864.4 billion by 2022 can be done by GPOs to health care members according to the Hospital Supply Chain Association report, which is done by Dobson DaVanzo & Associates personnel.

5. According to New York Times Report, Congress has examined the GPO industry practices, such as whether the buying process is fair or not.
6. A large criticism is on Administrative fee, which is collected by GPOs [roughly about 2 to 3% of entire contract value], which is used for covering their operations and sometimes returning a portion of the total fees received by its hospital's members. The main criticism here is, to obtain more administrative fees; the GPOs are raising the total contracting costs, which in result increase in the prices, causing only little profits for the hospitals.

According to Healthcare Purchasing News, some of the largest GPOs are mentioned below, basing on Annual Purchasing Volume. [B*: Billions]

sl no.	GPO Name	2013 APV
1	MedAssets	$ 48.0 B
2	Novation LLC	$ 43.0 B
3	Premier Inc.	$ 43.0 B
4	Health Trust Purchasing Group	$ 21.2.0 B
5	Amerinet Inc.	$ 8.0 B
6	PDM Healthcare	$ 8.0 B
7	U.S. Department of Defense	$ 5.1.0 B
8	U.S. Department of Veterans Affairs	$ 5.0 B
9	Resource Optimization & Innovation	$ 817.2M

Table 3.1: Annual Purchasing Volume for Top 9 GPOs

Source: http://www.hpnonline.com/resources/GPOs.html

3.9 Introduction To Self-Contracting:

Over the times, it appears as if medical technology firms in the U.S. have had a love-hate association with national group purchasing organizations (GPOs). When a vendor achieves a contract position with a larger GPO, there's often a private celebration and press releases promoting the "victory." At the same time, many vendors question the value GPOs give and bitterly criticize about the administrative fees.

The vendors are not alone in their criticisms. Many other investors, counting the 'US Congress', have doubted the purpose, objectivity, and importance of GPOs. While GPOs unquestionably have had a prolonged and uncertain role in the healthcare supply chain, many other forces – such as hospital union, developing of the hospital supply chain, and transparency – are transforming the nature of purchasing and the prospect of buying. Some of the forces are mentioned below which are trending the way to self-contracting

Hospital consolidation: Hospitals and health systems proceed to merge, create joint ventures, and develop across the care continuum.

Developing of hospital supply chains: As hospitals mature in procurement abilities, expect a prominent focus on vendor-customer joint value formulation efforts, a reduction in many vendors, and a more diplomatic approach to sourcing.

Transparency to value: Many companies are working on presenting evidence-based data on the price and consequences associated with many complex supply items.

Self-contracting: Where a hospital purchases directly with the vendor, rather than buying through a group purchasing organization (GPO). It is accounting for an escalating proportion of hospital supply spend in the U.S. As hospitals merge, gain greater scale, and become qualified for longer-term results and prices. Many hospitals and health systems now have sufficient local

market potential to influence meaningfully suppliers' local income growth and therefore serve as a reliable contracting alternative to GPO contracts.

Many hospitals now have enough idea about the suppliers, their market share, etc. The hospitals can now move on to self-contracting (that is outside of GPO contracts). Keeping some physician prescribed items and some moderate prescribed items in the consideration, they have to follow some key steps

- They have to opt the efficient price discovery by engaging some decision makers to evaluate the correct volume and price.
- Should make contracts so that it should benefit both (the vendors and hospital) such as including some warehouse sharing concepts, and allowance of suppliers in critical discussions of inventory management and other supply chain perspective in the hospital.
- Proper information flow should be made about the required amount of volumes of commodities so that vendors should be well prepared.

3.9.1 The Inclination To Self-Contracting:

One of the GPOs principal functions had been to aggregate purchasing over thousands of hospitals to negotiate favorable terms with vendors. The aggregation strategy worked well with stocks that were less differentiated, nonclinical-preference items. Although GPOs have been fortunate at the aggregation of specialty items, most GPOs have been less successful with 'physician-prescribed items' (PPIs), outsourced assistances, and with the latest technologies.

According to the report given by researchers at Wharton hospitals, in 2005, 70.6% of purchases are done through GPO contracts. And it is declining significantly to 55.9% in 2014. It is believed that the remaining percentage of purchases are done via self-contracting. This doesn't imply GPOs will go off. With plentiful of supply goods to purchase, hospitals need GPOs to obtain an advantage in some cases – notably in commodity items.

Self-contracting should, however, be an essential means for hospitals to be more judicious in sourcing and customize contracts to meet their individual needs. It is also a moment to be more imperative about vendor relationships. Cooperating with select vendors has the potential to generate much more worth than simplistic price savings through GPO aggregation. Technology is a key operator of the inclination to hospital self-contracting. Although the right procurement supplies and facilities are critical, technology has and will accelerate the trend to self-contracting. New resolutions are helping hospitals achieve greater perceptibility to spend, enhance the power and effectiveness of procurement, and better control supply expenses. For example, Curvo, a new start-up, has an algorithm and fuzzy logic tool to facilitate hospital members to cross-reference promptly supply goods, conduct analyses, and conduct bid events for many sections. This substitutes, many highly error-prone and indefatigable spreadsheet-based tasks of cross-referencing and making reports.

For vendors, this hospital tendency to self-contracting should offer both risks and opportunities. Some of the risks and opportunities are mentioned below.

Relationship Management: Providers- Vendors relations can be established along the continuum from transactional to collaborate to the union. Vendors with an unaware key account system or poor key account approach may be forced into transactional relationships, and miss the chance to join in collaborative value-creating connections.

Price evaluation and Transparence: Price transparency will stimulate as technology carries out, spend analysis, cost comparisons, and competing for bidding events much simpler. With the tendency to self-contracting, there's a risk that vendors could conclude with undisciplined and disordered market pricing that will be found with unique transparency means.

Elevated Bid Frequency: If market rates are sinking for a supply level, it makes little sense for a provider member to stay locked into a 3 or 5-year contract. For those larger supply categories

under- pricing force or reaching the prime stage of the product lifecycle, at this juncture, the hospitals are trying to test the market and this enables self-contracting.

Unique Business Models: Self-contracting will start up new ways to contract vendors to meet the individual needs of the hospital. Self-contracting should open up more possibility to develop an alternative connection and business systems.

Rethink Administration Fees: In 2012, the five largest GPOs collected approximately $2.3 Billion in administrative fees. One of the important arguments for the presence of GPOs is the efficiency generated by both hospitals and vendors in the contracting method. With the tendency to self-contracting, vendors should re-assess how and why they pay administrative fees. Many vendors have outmoded practices and techniques for giving administrative fees to GPOs.

The variation in the hospital is contracting, and purchasing performance is an important trend to watch. For vendors, carefully piloting this change will be necessary. With over a hundred local buying organizations in the U.S., many developing hospital systems, and national GPOs, having a transparent pricing and contracting approach is a must for vendors that need to avoid margin decline, drained sales resources.

Since no individual GPO addresses all the different needs of its members or its vendors, hospitals still try to manage their contracts with the vendors. This trend, which is advancing in popularity, results about 40 percent of the rate, equating to a $50 billion spend yearly. Historically, this contracting strategy – known as “self-contracting” or “local-contracting” – has been far from ideal. Hospitals and vendors tend to lack sufficient access to data or to the means necessary to make the right choices. Without this insight, it has been tough for hospitals to assess the competitiveness of proposals from supply companies, ending in rebids and a lack of responsibility to signing the negotiated contract.

The blend of a lack of commitment and poor insight into pricing turned self-contracting into a tiresome ordeal. Hospitals had to plan voluminous RFPs but often demanded to rebid deals due to the ambiguity of competitive market pricing. Retailers were also cautious about the process since they had trouble in understanding actual and potential market share. Such were the limitations of self-contracting.

Some of the benefits of self-contracting:

- Freedom for hospitals to choose their supplier associates and selects relevant performance objectives.
- Flexibility to determine the length of the contract mutually accepted upon by both the hospital and the vendor.
- Access to data on possible pricing choices and how these possibilities relate to the overall business.
- Commitment, by enabling hospitals to understand the purchasing habits and practices that will drive to best pricing, and allow vendors to measure accurately, monitor, and control compliance.
- Efficiency in handling the contract complete lifecycle, covering a streamlined pricing request method and ongoing implementation and performance estimation.

All the hospital purchasing is done online in the current days. Clinicians' decisions are now considered as the primary source. All the estimation of costs, cost savings are shown in the online portal. The characteristic negotiation graphs are also mentioned. So the hospitals can purchase the commodities at the level where they can achieve more rebates. Here, the hospitals can choose the contract period. So the contract length has been deleted.

Some of the disadvantages of the self- contracting are, here as the hospitals are purchasing individually, so it is responsible for the government risk audits. It has to hold many workforces to

investigate regularly the prices and better optimizing the purchasing behavior. Any problems related to purchasing have put the burden on the hospital itself.

3.10 Hospital Associations:

Before proceeding into 'Hospital Associations', some of the advantages and disadvantages for manufacturers and hospitals, when the purchasing is not done through a GPO, are listed below. [+: Profit; - : Loss]

1. No membership fees (+ to hospitals)
2. No extra services (- to hospitals)
3. Managing supply chain of the hospital by its own (- to the hospital)
4. Negotiation (+/- to hospitals) ***
5. No administrative fees to manufacturers (++ to manufacturers)
6. Limited volumes (- to manufacturers)
7. Limited contracts (- to manufacturers)
8. Length of contract (++ to hospitals)

Bargaining power is the main issue here, basing on this the contracting efficiency depends on.

So, according to the above-listed points, there are some disadvantages that may cause high lifting of prices in the purchasing department of hospitals. By including a maximum number of benefits when buying is done through GPO as well as including the benefits when self-contracted, a new concept, i.e., 'Hospital Associations' is discussed in this research.

Hospital Associations can be stated as combining the purchasing power of several hospitals and purchasing is done through an association, which is similar to GPO, but all the hospitals handle its officials. So here, there will be no membership fees, which is an added advantage for the hospitals. The concept of self-contracting is also involved here as the profit factor in the association is not there, unlike GPOs, which is similar to self-contracting. So the purchasing is

done directly through manufacturers. Here, the hospital association for the benefit of the hospitals collects the administrative fee. Clear cost equation models of hospital association are given in the later chapters.

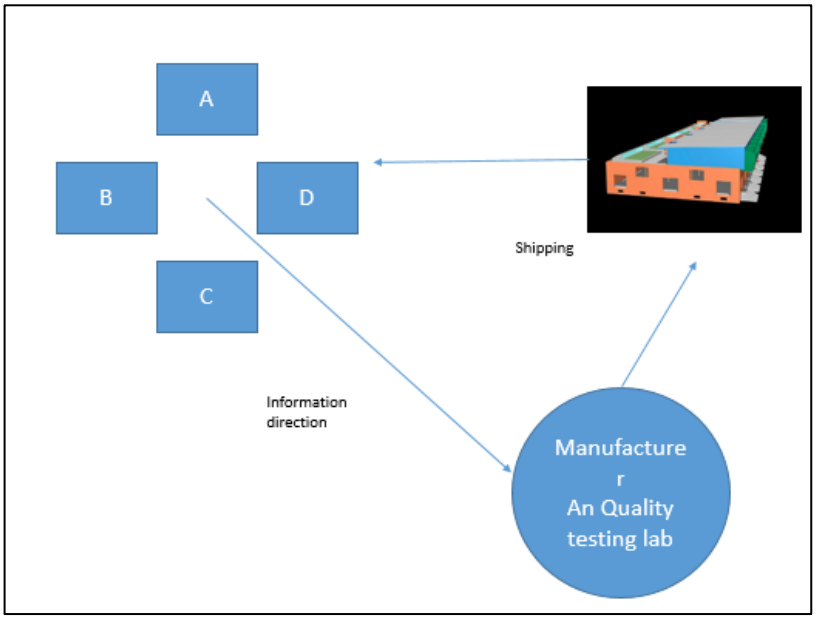


Figure 3.5: Hospital Association

Some of the advantages of the Hospital Association are listed below.

1. Collective Buying Power: Here, the purchasing volume is combined over several hospitals, which are members of an Association.
2. Warehousing sharing: Sharing of warehouses is the main advantage of this 'Hospital Association, which reduces the total costs of a product.
3. Employing OFFICIAL TEAM: the members of the hospital association to manage the whole team. So the total cost burden on every hospital is very less as managerial costs are shared.
4. Approaching for Bundled products: As the hospital members handle the association, there are no restrictions here, and they can approach the manufacturer for bundled products, which benefits the manufacturer too.

There are some other benefits such as physician choices for selection of products, the length of contracts, transportation fee, etc.

CHAPTER 4 – Introduction to GAME THEROY

4.1 Introduction To Game Theory:

"Game Theory is the formal study of conflict and cooperation. Game theoretic concepts apply whenever the actions of several agents are interdependent. These agents may be individuals, groups, firms, or any combination of these. The concept of game theory provides a language to formulate, structure, analyze, and understand strategic scenarios" [Ref: game theory PDF].

Game theory is a branch of applied mathematics that presents means for analyzing situations in which players make choices that are interdependent. This interdependence makes each player to consider the other player's likely decisions, in expressing his own. The game represents the optimal decisions of the players, who may have comparable, contrary, or mixed interests, and the consequences that may emerge from these decisions. Game theory has also been interpreted as a study of mathematical models of dispute and cooperation between smart and rational decision makers. While practical use of Game Theory can be observed throughout history, the credit of its discovery goes to John von Neumann and Oskar Morgenstern.

Important ingredients of a game:

- Players are managerial rulers in the game; a player can be an individual, group, organization or population.
- Strategies are the paths of action open to all the players in a game.

- Payoffs are the concluding returns to players, which are commonly said in terms that are accurately understood by each player of the game.

Game theory is an essential tool that helps us to get to know about the situations in which there is a strategic cooperation among the decision makers. Decision makers frequently encounter a 'conflict-of-interest' situation, and each of them intends to get the best advantage out of it. This kind of circumstances arises in most areas. Economics is the well-known application area for game theory. More precisely, buyer-seller relationships, firms' strategic decisions, government decisions, are some instances that can be modeled using game-theoretic tools. In addition to economics, so many areas like psychology, biology and many other use game theory concepts to analyze different situations.

4.2 Concept Of Nash Equilibrium:

Nash equilibrium is a major concept in the Game Theory and popularly used the technique of predicting the result of strategic interaction in the economics. A game consists of the following three elements: a set of actions available to each player, a set of players, and a payoff function for each player. The payoff functions describe each player's preference over work profiles, where a work profile is solely a program of actions, one for each player. 'Nash equilibrium' is also called as "strategic equilibrium", is a solution concept of a non-cooperative game involving two or more players, in which each player is assumed to know the equilibrium strategies of the other players, and no player has anything to gain by changing only his strategy" [Wikipedia].

"Payoff is a number, also called the utility, that reflects the desirability of an outcome for a player, for whatever reason. The expected payoff incorporates the player's attitude towards risk" [Turocy, 2003].

This theory can best be explained by looking at some examples. Consider a first game involving two players, each of whom has two possible actions, which are X and Y. If the players prefer

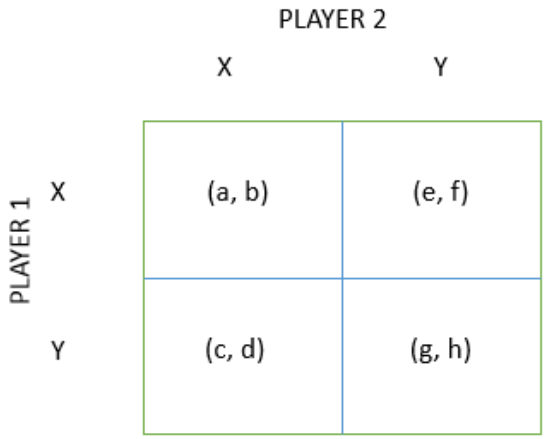
distinct actions, they each get a payoff of 0. If the two players choose X, they each get 2, and if the two players choose Y, they each get 1. This “coordination” game may be expressed as follows, where player 1 chooses a row, player 2 chooses a column, and the resulting payoffs are entered in parentheses, with the second element corresponding to player 2’s payoff.

The action profile (Y, Y) has been equilibrium, since a one-sided deviation to A by any one player would end up in a lower payoff for the deviating player. Similarly, the action profile (X, X) is also equilibrium [Shown in below figure].

		PLAYER 2	
		X	Y
PLAYER 1	X	(2,2)	(0,0)
	Y	(0,0)	(1,1)

Necessary Conditions for a payoff to be Nash Equilibrium:

Considering, the below game mentioned does not have payoff’s defined.



In order, for the payoff (X, X) to be a Nash equilibrium point, the following conditions must hold true.

1. a > or = c
2. b > or = f

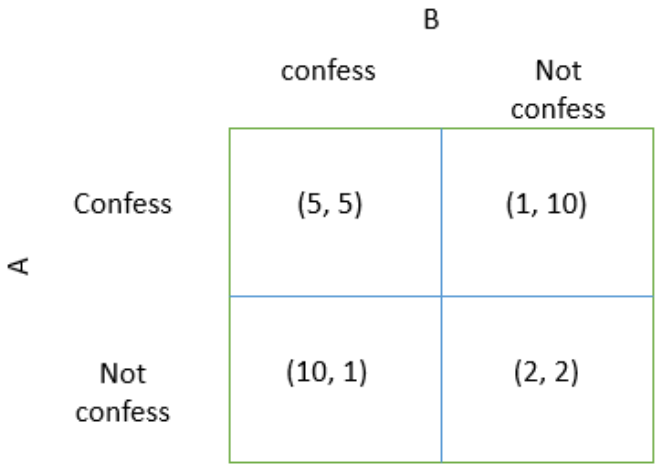
In order, for the payoff (X, X) to be equilibrium in dominant pure strategy, the following conditions must hold true. This payoff, which satisfies the conditions of Dominant Pure strategy, then the point is also considered as a Nash Equilibrium Point.

1. a > c
2. e > g
3. b > f
4. d > h

Prisoners Dilemma: There are two prisoners, A & B, who have been captured by the police for robbing a bank. But they don't have sufficient evidence to sentence them, but know that they committed the crime. They put the two players in separate rooms and interrogated by laying out the consequences listed below:

- If both players confess, they will each get 5 years in prison.
- If one player confesses and the other doesn't, the one who confessed will get 1 year in jail, and the other will spend 10 years in prison.
- If neither of players confesses, they will both get 2 years for another crime they were wanting to.

The payoffs are kept in a matrix,



Since A's strategies are entered in rows or the x-axis, his payoffs are posted first. The B's payoffs are entered second since his strategies are in columns. Confess and Not confess are the two main conditions here. Here, the moves are simultaneous, neither player knows what the other player opts. At first glimpse, it may appear that both players 'not confessing' is the sound choice since each hostage will only get 2 years, but that is not the case by following the rules of game theory.

Dominant Strategy: By viewing at each prisoner separately, we can find the dominant pure strategy. First looking at ‘A’, let B picks up the choice of confessing. Now the preferable choice for A should be selected. If A is not going to confess, then, he will get 10 years in prison, but if

he confesses, he will get a sentence for just 5 years. So, for A, the preferable choice is confessing. To show the best preferable option, the highlighted choice is kept in the matrix for a ready glimpse.

		B: confess	B: Not confess
A	Confess	(**5**, 5)	(1, 10)
	Not confess	(10, 1)	(2, 2)

Now let's imagine that B is not going to confess. If A confesses, he will get 1 year of prison, if he doesn't confess, he'll get 2 years. Again, the option of confessing is the preferable choice, no matter what B does. Here, confessing is dominating the choice of not confessing option in both the cases. By this, we can say a dominant pure strategy is followed. Highlighting the option of confessing here for A.

		B: confess	B: Not confess
A	Confess	(**5**, 5)	(**1**, 10)
	Not confess	(10, 1)	(2, 2)

Similarly, checking for player B. If A opts confessing, then B should check for its preferable option. Here, if B chooses not to confess, he may get 10 years in prison, but if he confesses, then he just gets 5 years of imprisonment. Confessing is the option best suitable for player B. Similarly; confessing is again the best option for player B even if player A is not confessing. By highlighting the choices in the matrix.

		B: confess	B: Not confess
A	Confess	(**5**, **5**)	(**1**, 10)
	Not confess	(10, **1**)	(2, 2)

Here, (confess, confess) are both highlighted. Since both players have the same dominant pure strategy, confess, they will both confess, and each will get 5 years in prison. This payoff point is in Nash Equilibrium. Here, if either of player deviates from confessing to not confessing, they will get 10 years in jail, which is not more good than getting 5 years in prison. The payoff box (2,2) that results from (Not Confess, Not Confess) is NOT a Nash Equilibrium since either player could confess (holding the other player constant) and get 1 year in prison instead of 2 years in jail.

CHAPTER 5- Development of Models

For the current study, a hospital group is considered. Within that group, two hospitals are of interest and are taken for decision modeling. These two hospitals, called H1 and H2 here, are close to each other geographically, and hence have the same population as their patient base. They may be competing, or they may be cooperating with each other and thinking of joining the same hospital association.

It is assumed that most of the hospitals in the area are purchasing through their GPOs. The inclination of purchasing through other sources is increasing among the hospitals. There is already a hospital association (HA) in the area, with 'n' members. The two hospitals H1 and H2 have to make decisions regarding their supplies individually, whether to continue in their current GPOs, or to go through the hospital association, or to work directly with manufacturers.

In the current situation, the two competing hospitals are trying to take their individual decisions at the same time, and keeping in view what the other hospital is going to decide. Hence the system is modeled as a game theory model.

All the related decisions are taken with the single criterion of total costs of the supplies. This is taken as the payoff function for the models.

Nomenclature Table:

Sl no.	Variable	Definition.
1	A	Total cost for managing work-force of Hospital Association (Operating costs for managing an association)
2	F_M	Provider's fixed contracting cost when purchasing from the manufacturer
3	F_G	H1's Fixed contracting cost per unit + membership fees when purchasing from its GPO
4	F'_G	H2's Fixed contracting cost per unit + membership fees when purchasing from its GPO
5	Q_J	Quantity required by each hospital
6	NH	Total number of hospitals planning to form a Hospital association
7	NG	Total number of members in a GPO
8	H1 and H2	Hospitals which are considered as the main players who are checking the best preferable option of purchasing
9	HA	Hospital Association
10	G	Group Purchasing Organization
11	I	Manufacturers
12	x_n	Total price of the contract for 'n' member hospitals
13	$i*x_n$	Total administrative fees collected by the hospital association from the manufacturers; where, i is the percentage (generally 2% to 3%)
14	Q1	Total Quantity required by n+2 hospitals
15	P(Q1)	Price for Q1 quantity (used as price set by manufacturers in the game problem)
16	Q1'	Summation of Quantity of all n hospitals and either H1 or H2 (also represented as n+1 hospitals)

17	P(Q1')	Price for Q1' quantity
18	P_G	H1's GPO per unit on-contract price
19	P'_G	H2's GPO per unit on-contract price
20	A"	Total manufacturing costs for a product
21	B	Minimum Possible costs
22	C	Varying Per unit costs with respective to volume
23	Z	Ware housing and transportation costs per hospital
24	H	Holding costs per unit per year
25	S	Ordering costs per order
26	q	Optimal order quantity
Sl no.	Symbols	Cost functions
1	π1	Total costs of the supplies when both H1 and H2 joins the association and purchasing through the association: (n+2 members)
2	π2	Total costs of the supplies when H1 or H2 join the association formed by 'n' hospitals and do the purchasing through it: (n+1 members)
3	π3	Total costs bared by H1 when it is purchasing its required quantity through its GPO
4	π4	Total costs bared by H2 when it is purchasing its required quantity through its GPO
5	π1'	Total costs, when Hospitals H1 and H2 form an association and do the purchasing
6	π2'	Total costs bared by either H1 or H2 do the purchasing directly through manufacturers

7	π3'	Same as π3
8	π4'	Same as π4
9	π5	Same as π1
10	π6	Same as π2
11	π7	Total costs, when H1 is purchasing directly from the manufacturer
12	π8	Total costs, when H2 is purchasing directly from the manufacturer
13	π5'	Same as π1'
14	π6'	Same as π2'
15	π7'	Same as π7
16	π8'	Same as π8

Table 5.1: Nomenclature Table

ASSUMPTIONS:

1. The n hospitals have not yet decided to continue purchasing through the group. They are waiting for the two hospitals H1 and H2 to join their group so that they can get more discounts than expected.
2. The hospitals H1 and H2 are trying to decide whether to proceed in Hospital Association (HA) or purchasing through GPOs (GP) or purchasing directly from manufacturers (I). All the variables and assumptions are mentioned in the nomenclature table.
3. It is assumed that the quantity required is same for all hospitals, including H1 and H2, Q_J.
4. The fixed contracting cost of the manufacturers is more than the fixed contracting cost of the GPO. That is $F_M > F_G$, as the two hospitals have different GPOs, and considering that $F_G' < F_G$; and similarly considering different manufacturers $F''_M \leq F_M' \leq F_M$ [where, F''_M

is the fixed contracting cost when purchasing through HA, and the remaining two are for hospitals H2 and H1 respectively.]

Scenario: Two hospitals (H1 and H2) are checking whether they can buy their supplies from their current registered GPOs (GP), or joining the single Hospital Association (HA) and buying from it, or purchasing directly from the manufacturers (I).

In this scenario, two cases are considered, depending on the values N_G and N_H, the sizes of the GPOs and association respectively, before they join it.

Three types of analysis are proposed in this research.

First is finding the preferable choice of purchasing in each of the case of scenario, with known costs.

Second one is proposing lemmas for each of the payoff, establishing conditions for a payoff to be a Nash Equilibrium point.

Lastly, finding the optimal total costs for each of the situations, and deriving the low cost option of purchasing for the hospital.

5.1.1 Case of Both GPOs and HA having n Members Each

Here, $N_G = N_H = n$, that is there are 'n' member hospitals in each GPO and in the HA.

The formulation of cost equations is done based on several factors. When both hospitals H1 and H2 join the HA, there will be (n+2) hospitals in the HA.

If a hospital joins the HA, the following costs need to be considered:

Administrative fees, managerial costs, product costs (price set by manufacturers), contracting costs (set by manufacturers), and holding and transportation costs.

Then for each of the two hospitals, in case of both joining HA,

- The managerial costs required for Hospital Association = [A/(n+2)]
- The fixed contracting costs when purchasing from manufacturer = [$F"_M$ / (n+2)]
- Product costs = [P(Q1)*Q1/(n+2)]

The price per unit quantity, P(Q1), is a function of Q1, the total quantity purchased by HA, which is equal to Q_J*(n+2).

- Administrative fee collected by the HA = [(i*(x_{n+2})/(n+2)]

The Hospital Association collects the administrative fee i*x_{n+2}, from manufacturers, which is a percentage of total contract value x_{n+2}.

Thus the total cost equation formulated here is represented as **π1**, which is given by

$$\boldsymbol{\pi 1} = Z + [A + F"_M + P(Q1)*Q1 - i(x_{n+2})]/(n+2) \quad (5.1)$$

Similarly, when only one of the hospitals of H1 and H2 joins the HA, then there will be (n+1) members in the HA. The total quantity purchased by HA is given by Q1' which is equal to Q_J* (n+1). The total costs for the single hospital, which joins the HA would be

$$\pi 2 = Z + [A + F"_M + P(Q1')*Q1' - i(x_{n+1})]/(n+1) \quad (5.2)$$

If the two hospitals remain in their respective GPOs, the related costs would include

Membership fees, Product costs (price set by GPO) and holding and transportation costs.

The other hospital, in this case, is purchasing through its registered GPO. The costs involved here, are the membership fee, which is collected by the GPO from the hospital, and is represented as F_G and the price per unit set by the GPO depends on the total number of quantities from its 'n' members, which is represented as P_G(Qn). The total amount which is paid to the GPO by the hospital is given by P_G (Qn) *Q_J. [Since Q_J is the quantity required by a hospital]. The total cost equations are given by,

$\pi 3: Z + F'_G + P'_G(Qn)*Qn/n$ (5.3)

$\pi 4: Z + F_G + P_G(Qn)*Q_J/n$ (5.4)

If the two hospitals purchase directly from the manufacturers, the related costs would be contracting costs (set by the manufacturer), product costs (price set by manufacturer) and holding and transportation costs.

The price per unit set by the manufacturer = $P(Q_J)$

The total costs which is given to the manufacturer by the hospital is given by $P(Q_J)Q_J$. [Since, Q_J is the quantity required by a hospital]. The total cost equations are given by,

$\Pi 5: Z + F'_M + P'(Q_J)Q_J$ (5.5)

$\Pi 6: Z + F_M + P(Q_J)Q_J$ (5.6)

The corresponding payoff matrix and the payoff equations π1, π2, π3, π4, π5, π6 are given in the figure 5.1

		H2		
		HA	GP	I
H1	HA	[Π1 , Π1]	[Π2 , Π3]	[Π2 , Π5]
	GP	[Π4 , Π2]	[Π4 , Π3]	[Π4 , Π5]
	I	[Π6 , Π2]	[Π6 , Π3]	[Π6 , Π5]

Figure 5.1 Matrix and Pay-off Functions for Case 5.1.1

5.1.1.1 Solution for Case 5.1.1, with Known Costs:

The concept of “Best Response” in the game theory is used as a principle procedure to find out if there exists a Nash Equilibrium Point (solution), for the above payoff matrix. The procedure is mentioned below:

1. Firstly, it is taken that H2 has chosen to go through the HA. Then, the H1 has the option of going through the HA, in which case its total cost would be Π1, or continue to go through its GPO, at a total cost of Π4, or purchasing directly from the manufacturers, at a total cost of Π6.

   1.1. The cost equations in comparison here are (5.1), (5.4), and (5.6).

   $\Pi 1 = Z + [A + F''_M + P(Q1)*Q1 - i*(x_{n+2})]/(n+2)$

   $\Pi 4 = Z + F_G + P_G(Qn)*Q_J$

   $\Pi 6: Z + F_M + P(Q_J)Q_J$

   In general, $P_G(Qn)*Q_J$ depends on upon the fixed contracting cost of manufacturers as well as price set by the manufacturers. A GPO ‘marks up’ this price by a profit factor of ‘X’, which is generally 1% to 2% of the total monetary value set by the manufacturer to obtain more income. In such a case,

   Π4 can be written as $(F_M + P_M(Qn)*Q_J + X) + F_G+Z$.

   Comparing the equations,

   As cited in the assumptions, the contracting costs set by the manufacturer when purchased through HA is F''_M which is less than the contracting costs when purchased through GPOs, i.e., F_M.

   $F''_M < F_M$.

Comparing the product costs, there is an extra profit factor 'X' and membership fees 'F_G' when purchased through GPOs which increases the total costs. These costs are not incurred when the purchasing is done through the HA, allowing for savings. Considering the rule, the higher the quantity, the lower the price per unit, higher the discounts, the quantity, when purchased directly from the manufacturers, would be less than the aggregated quantity when purchased from the other two alternatives. Therefore, the comparative relationship is given as,

$P(Q_J)Q_J > P_M(Qn*Q_J + X) + F_G > P(Q1)*Q1$

The managerial costs for HA, i.e., 'A' are totally covered by the administrative fees collected from the manufacturers by the HA. All the hospital members in HA share the remaining administrative fee. This shows that π1 has lower costs for purchasing in comparison to π4, π6 and thus π1 < π4< π6. Keeping '*' beside π1 in the game matrix to prove its dominance.

2. Likewise, if it is assumed that H2 is purchasing through its GPO, the hospital H1 now has the choice of purchasing through HA or purchasing via GPO or purchasing directly from the manufacturers.

   2.1. The equations for comparison here are π2, π4, and π6.

   $Π2 = Z + [A + F"_M + P(Q1')*Q1' – i*(x_{n+1})]/(n+1)$

   $Π4 = Z + F_G + P_G(Qn)*Q_J$

   $Π6 = Z + F_M + P(Q_J)Q_J$

   Following the explanation given to the previous case, purchasing via Hospital Association is the preferable option for H1, i.e., Π2 < Π4 < Π6, since the addition of membership fees and the profit factor X in the price which is set by the GPO [$P_G(Qn)$] is more than the price when purchased via Hospital Association (HA). The quantity versus

price rule is followed as mentioned above. Therefore, Π2 has dominance here in this comparison.

3. If H1 choses the purchasing option of HA, then H2 should choose between the Hospital Association and GPO and purchasing directly from manufacturers (I).

   3.1. The cost equations would be π1, π3 and π5.

   $\Pi 1 = Z + [A + F''_M + P(Q1)*Q1 - i*(x_{n+2})]/(n+2)$

   $\Pi 3 = Z + F'_G + P'_G(Qn)*Q_J$

   $\Pi 5 = Z + F'_M + P'(Q_J)Q_J$

   Following similar logic as given before; Π1< π3<π5. Hence the preferable option for H2 is purchasing through HA [Dominant strategy here is HA, i.e., for costs Π1].

4. Similarly, fixing the choice for H1 as GPO, the hospital H2 can choose between HA, GPO, and I. The cost equations here for comparison are

   4.1. $\Pi 2 = Z + [A + F''_M + P(Q1')*Q1' - i*(x_{n+1})]/(n+1)$.

   $\Pi 3 = Z + F'_G + P'_G(Qn)*Q_J$

   $\Pi 5 = Z + F'_M + P'(Q_J)Q_J$

   By following the above-mentioned explanation it can be shown that, Π2 < Π3 < Π5.

   Therefore, the preferable option of purchasing for H2 is through the HA.

5. When H1 chooses to purchase directly from the manufacturers, then H2 can make a choice between purchasing through GPO, purchasing via Hospital Association, and buying directly from the manufacturers. By following the same methodology mentioned above, purchasing via Hospital Association is a low-cost strategy when compared to other choices of purchasing. (HA: Dominant strategy).

The dominance matrix is shown in figure 5.2. Here, the payoff [HA,HA] satisfies the best response point.

		H2		
		HA	GP	I
H1	HA	[П1* , П1*]	[П2* , П3]	[П2* , П5]
	GP	[П4 , П2*]	[П4 , П3]	[П4 , П5]
	I	[П6 , П2*]	[П6 , П3]	[П6 , П5]

Figure 5.2: Dominance Matrix for payoff functions for Case 5.1.1

The conditions for a payoff to be Nash equilibrium are listed in Chapter 4. Here, the best response point [HA, HA] to be Nash equilibrium point, it should satisfy the conditions of dominant pure strategy. Here, the payoff is [П1, П1], the low-cost option is chosen as a preferable option.

П1 < П4< П6

П1 < П3< П5

П2 < П4< П6

П2 < П3< П5

This point is satisfying all the conditions of dominant pure strategy. Therefore, [П1, П1] is the Nash equilibrium point and the best strategy point for hospital H1 and H2.

5.1.1.2 Pay-Off Conditions for the existence of Nash Equilibrium

In section 5.1.1.1 certain assumptions were made regarding the cost structures and the resultant payoff functions were shown to have a Nash-Equilibrium point. In this section, the opposite path is taken, that is, it is assumed that the solution has a Nash-Equilibrium, and the related cost conditions for this equilibrium are derived from the four different combinations.

Assumptions: It is assumed that each of the two GPO has ‘N’ members, and the HA has 'n' members before the two hospitals make their decisions.

Lemma 1.1: It is assumed [HA, HA] to be a Nash Equilibrium point, which means both hospitals [H1 and H2] are choosing the purchasing option of going through the hospital association. Here the payoffs are [Π1, Π1]. The conditions below are derived as,

Π1 should be less than or equal to Π4 and Π4 should be less than or equal to Π6. The total cost equations are written below and are to be related to get one of the conditions, and Π1 should be less than or equal to Π3 which is less than or equal to Π5 to get the other condition.

Π1 ≤ Π4 ≤ Π6;

$$Z + [A + F_M + P(Q1)*Q1 - i*(x_{n+2})]/(n+2) \leq Z + F_G + P_G(Q_N)*Q_J \leq Z + F_M + P(Q_J)Q_J$$

Here, $i*(x_{n+2})$ is the administrative fees collected by the Hospital Association from the manufacturer, and it is generally 2% to 3% of the entire contract value. This term can be replaced by, $i* [F_M + P(Q1)*(Q_J)*(n+2)]$. On the RHS of the equation, F_G is the membership fees collected by the GPO from the member hospitals. It is generally about 1% to 2% of the entire contract value. This term can be replaced by $i"*(P_G(Q_N)*Q_J)$. Here, the contract cost, when purchased through the GPO, is denoted by $P_G(Q_N)*Q_J$, which depends on the fixed manufacturing cost set by the manufacturer (F_M), the price set by the manufacturer for the Quantity for N members which is denoted by $P(Q_N)$, and the profit factor “X” which is usually 1% to 2% of the total contract cost. So the term $P_G(Q_N)*Q_J$ can be replaced by $[F_M + P(Q_N)*Q_J + X]$. Therefore, the equation can be written with replaced forms as shown below,

$Z + [A + F_M + [P(Q1)*Q_J*(n+2)] - i* [F_M + P(Q1)*(Q_J)*(n+2)]\ ]/(n+2) \leq Z + i"*(\ [F_M + P(Q_N)*Q_J + X\ ]) + [F_M + P(Q_N)*Q_J + X] \leq Z + F_M + P(Q_J)Q_J$

By solving the above equation, (assuming i" = i)

$[(A + (F_M)(1-i))/\ [[(i+1)(F_M(Q_J+1) + Q_J* X)] + [Q_J*((i+1)* P(Q_N))\ - [(1-i)*(\ P(Q1))]]] - 2 \leq n.$ (5.7)

$[(A + (F_M)(1-i))/[(\ F_M+(Q_J*[P(Q_J)\ -(1-i)*(\ P(Q1))]))]] - 2 \leq n$ (5.8)

$[(i* F_M)/[P(Q_J)\ -\ (i+1)*[(P(Q_N)+X]]] \leq Q_J$ (5.9)

According to the quantity discount contract, the price per unit decreases when the quantity increases, which is shown in figure 5.3. [Where, P: Price; B: Minimum profit price]. The discounted price cannot go below the minimum profit price (B).

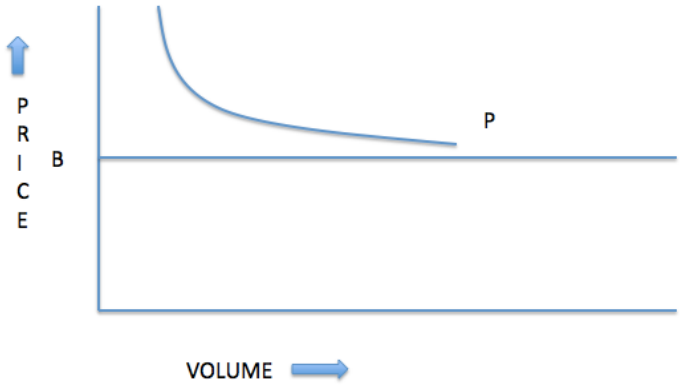


Figure 5.3: Volume versus Price curve

From the above graph it can be stated that, as volume increases, the price per unit decreases. The Volume versus Price curve can be expressed as an equation, which is given as,

$P(Q) = B + (P* (e^{-(s*Q)}))$

Here, s: the number of members and Q: the Quantity required by an individual hospital.

The terms P(Q1) and P(Q_N) can be replaced in the form of above stated equation. This results in,

⇨ P(Q1) = B + (P* ($e^{-((n+2)*QJ)}$) (5.10)

⇨ P(Q_N) = B + (P* ($e^{-(N*QJ)}$) (5.11)

⇨ P(Q_J) = B + (P* ($e^{-(QJ)}$) (5.12)

By substituting the equations eq. (5.10), eq. (5.11), and eq. (5.12) in the equations eq. (5.7), (5.8), (5.9);

⇨ [(A + (F_M)(1-i))/ [[(i+1)(F_M(Q_J+1) + Q_J* X)] + Q_J* [2iB + i*P*($e^{-((N+n+2)*QJ)}$ + P*[$e^{-(N*QJ)}$– $e^{-((n+2)*QJ)}$]] –2≤ n (5.13)

⇨ [(A + (F_M)(1-i))/[(F_M+(Q_J*[B + (P* ($e^{-(QJ)}$) - (1-i)* B + (P* ($e^{-((n+2)*QJ)}$))]))]] – 2≤ n (5.14)

⇨ [(i* F_M)/[[B + (P* ($e^{-(QJ)}$) - (i+1)*[(B + (P* ($e^{-((n+2)*QJ)}$) +X]]] ≤ Q_J (5.15)

⇨ These three conditions are to be followed in order the payoffs [Π1, Π1] to be in Nash equilibrium (Π1 < Π4< Π6). The other conditions are same but the terms differ, because the cost equation Π3 denotes a different GPO through which H2 purchases [Π1 ≤ Π3]. The final conditions are

⇨ [(A + (F_M)(1-i))/ [[(i+1)(F_M(Q_J+1) + Q_J* X')] + Q_J* [2iB + i*P*($e^{-((N+n+2)*QJ)}$ + P*[$e^{-(N*QJ)}$– $e^{-((n+2)*QJ)}$]] –2≤ n (5.16)

⇨ [(A + (F_M)(1-i))/[(F_M+(Q_J*[B + (P* ($e^{-(QJ)}$) - (1-i)* B + (P* ($e^{-((n+2)*QJ)}$))]))]] – 2≤ n (5.17)

⇨ [(i* F_M)/[[B + (P* ($e^{-(QJ)}$) - (i+1)*[(B + (P* ($e^{-((n+2)*QJ)}$) +X']]] ≤ Q_J (5.18)

- ⇨ In this equation the profit factor X' and the percentage of membership fees i' are different from the equation eq. (5.9). But assuming i' = i the resulting condition is derived. In order to be a best response point [Nash equilibrium point] the payoff [Π1, Π1] should satisfy all these six conditions.
- ⇨ From the lemmas, the conditions for a payoff to be a Nash equilibrium point are derived. These lemmas can be extended to other cases too. The conditions for 'n' (number of members in HA) are derived from these lemmas. When the value of 'n' (number of members in HA) reaches or exceeds the value of 'N' (number of members in GPO), then purchasing via HA attains more profits for the hospitals H1 and H2. But in general, the number of members in HA is less than the number of members in GPO [i.e., n<N].

5.1.1.3 Numerical Example

The situation is illustrated by a numerical example, with all the relevant numbers chosen hypothetically. In most of the cases, the number of members in GPO is more than the number of members in Hospital Association. Therefore, it is assumed there are 15 members in the hospital association and 30 members in GPO [including H1 and H2]. The quantity required is same for each hospital, that is Q_J =120,000 units.

The Fixed manufacturing costs F_M are basically the fixed manufacturer overhead costs, F_M = $15,000

Managerial costs for HA = A = $1,100,000

The percentage of administrative fees collected from the manufacturers by the Hospital Association is = i = 2%

Membership fee is collected by the GPOs from hospitals generally 1% to 2% of the entire contract value. It is assumed that membership fee for the GPO paid by the hospital H2 is 2% of the entire contract value and 1% for the GPO paid by the hospital H1.

The profit factor 'X' which is gained by GPO is about 1% to 2% of the total contract costs set by the manufacturer. Keeping X = 1%(total costs) for the GPO through which the hospital H1 is purchasing, and 2% (total costs) for the other GPO,

The base price or the minimum profit price is B = $150 / unit.

The selling price when purchased only one unit P = $700/unit.

Following the price per unit versus quantity curve [Fig. 5.3], the resulting is,

$P(Q) = B + P*(e^{-(Q_J *n")})$. If Q tends to infinity the price per unit will come closer to B.

Now, Assuming holding costs are same for each hospital, and hence ignoring the holding costs, and calculating the price per unit when purchased through HA, when both hospitals are purchasing through HA. i.e., π1.

$P(15) = 150 + 700*(e^{-(0.12*15)}) = \$265$ / unit. (Quantity in millions)

$\pi 1 = [A + F"_M + P(Q1)Q1 - i*(x_{n+2})]/(n+2) = [[1100000+15000(.98)]/15] + [0.98(265(120000))] = \$31238313.3 = \$31.23$ millions.

Similarly $\pi 2 = [A + F"_M + P(Q1)Q1 - i*(x_{n+1})]/(n+1)]$. Only one hospital joins the HA and other purchases through GPO. Therefore there are 14 members in HA.

$P(14) = 150 + 700*(e^{-(0.12*14)}) = \$280$ / unit.

Calculating for π2, we get = $33002313.3 = $33.0 millions.

Now calculating price per unit when the hospitals H2 and H1 purchase through their respective GPOs i.e., π3 and π4.

$P(Q_N) = B + P^*(e^{-(Q_J * N)})$

As mentioned in the above lemmas, we can replace the term $P(Q_N)Q_J$ with $[F''_M+P(Q_N)(Q_J)+X]$,

$P(Q_N) = 150 + 700 * (e^{-(.12*30)}) = \$170$ /unit.

Now $\pi 3 = F'_G + P(Q_N)Q_J$

$\pi 3 = 1.02(15000 + 170 (120000) + .02(15000 + 170*(120000))) = \$21239766 = \$21.2$ millions.

Similarly, $\pi 4$ is calculated, which is $= F_G + P(Q_N)Q_J$, by changing the values as mentioned in the start of the problem.

The resulting value for $\pi 4 = 1.01 (15000 + 170 (120000) + .01(15000 + 170*(120000))) = \$20825341.5 = \$20.8$ millions.

The payoffs $\pi 5$ and $\pi 6$ are computed, when H1 and H2 purchase individually from the manufacturers.

From the Volume versus Price curve (Fig. 5.3), [since, N=1]

- ⇨ $P(Q) = B + P^*(e^{-(Q_J)})$
- ⇨ $P(Q) = 150 + 700 * (e^{-(.12)}) = \$770.84$ /Unit.

Calculating the payoff $\pi 5$ which is equal to $\pi 6$,

$\pi 5 = \pi 6 = F'_M + P'(Q_J)Q_J = 15000 + 770.84(120000) = \$92.5$ millions.

Now the payoffs are calculated. The payoff matrix, with the payoffs given in millions of dollars, is given, for case 5.1.1 game, in figure 5.4

		H2		
		HA	GP	I
H1	HA	31.2, 31.2	[33,21.2*]	[33 , 92.5]
	GP	[20.8 *, 33]	[20.8* , 21.2*]	[20.8* , 92.5]
	I	[92.5, 33]	[92.5, 21.2*]	[92.5,92.5]

Figure 5.4: Payoff Matrix

Here, by following the best response procedure, the optimal or preferable point or the Nash equilibrium point is [GP,GP] and the payoffs are [20.8,21.2] for H1 and H2. This shows that, in general cases, the low cost option is purchasing via GPOs than purchasing via HA and purchasing individually from the manufacturers. The lemmas and the numerical examples can be done for all the other cases.

5.1.2 Case when there are no members in HA

Here, N_G = n and N_H= 0, that is there are 'n' member hospitals in each GPO, and there are no members in HA.

Here, the formulation of cost equations is done based on several factors. When both hospitals H1 and H2 merges (M) and work like a Hospital Association (HA), there will be just two hospitals in the HA.

If a hospital accepts to merge with another hospital, the following costs need to be weighed:

Administrative fees, managerial costs, product costs (price set by manufacturers), contracting costs (set by manufacturers), and holding and transportation costs. Then for each of the two hospitals, in case of both are merged (M),

- The managerial costs = [A/2]
- The fixed contracting costs when purchased from manufacturer = [$F"_M$ / 2]
- Product costs = [($P(2Q_J)*2Q_J$)/(2)]

The price per unit quantity, $P(2Q_J)$, is a function of $2Q_J$, the total quantity purchased by the two hospitals, which is equal to Q_J*2.

- Administrative fee collected by the hospitals when they are merged (M) = [($i*(x_2)$/2]

Hence the total cost equation formulated here is represented as π1', which is given by

$$\pi 1' = Z + [A + F"_M + (P(2Q_J)*Q_J) - i*(x_2)]/(2) \quad (5.19)$$

When one of the hospitals is purchasing through its registered GPO, there will be no merging of hospitals. In this instance, the other hospital would purchase directly from the manufacturer (I). The following costs need to be looked at:

Fixed contracting costs (set by the manufacturer), product costs (price set by the manufacturer), and the holding and transportation costs.

The total cost for the hospital would be $\pi 2' = Z + F"_M + P(Q_J)*Q_J$ (5.20)

If the two hospitals remain in their respective GPOs, the related costs would be:

Membership fees, Product costs (price set by GPO) and holding and transportation costs.

The costs involved here are the membership fee collected by the GPO from the hospital, which is denoted as F_G, and the price per unit set by the GPO depends on the total number of quantities from its 'n' members, which is represented as $P_G(Qn)$. The total amount which is paid

to the GPO by the hospital is given by $P_G(Qn)Q_J$. [Since Q_J is the quantity required by a hospital]. The total cost equations are given by,

$\pi 3: Z + F'_G + P'_G(Qn)*Qn/n$ (5.21)

$\pi 4: Z + F_G + P_G(Qn)*Qn/n$ (5.22)

If the two hospitals purchase directly from the manufacturers, the related costs would be:

Contracting costs (set by the manufacturer), product costs (price set by manufacturer) and holding and transportation costs.

The price per unit set by the manufacturer = $P(Q_J)$

The total costs paid to the manufacturer by the hospital is given by $P(Q_J)*Q_J$. [Since, Q_J is the quantity required by a hospital]. The total cost equations are given by,

$\Pi 5: Z + F'_M + P'(Q_J)*Q_J$ (5.5)

$\Pi 6: Z + F_M + P(Q_J)*Q_J$ (5.6)

The corresponding payoff matrix and the payoff equations π1', π2', π3, π4, π5, π6 are given in the figure 5.5

		H2		
		HA	GP	I
H1	HA	[Π1' , Π1']	[Π2' , Π3]	[Π2' , Π5]
	GP	[Π4 , Π2']	[Π4 , Π3]	[Π4 , Π5]
	I	[Π6 , Π2']	[Π6 , Π3]	[Π6 , Π5]

Figure 5.5: Matrix and Pay-off Functions for case 5.1.2

5.1.2.1 Solution for Case 5.1.2, with Known Costs:

The concept of "Best Response" in the game theory is employed as a principle procedure to find out if there exists a Nash Equilibrium Point (solution), for the above payoff matrix. The procedure is mentioned below.

1. If H2 chooses to purchase by merging with the H1, now, H1 should choose from merging with H2, purchasing via GPO, and purchasing directly from manufacturers.

   1.1. The payoffs here in comparison are,

   $\Pi 1' = Z + [A + F''_M + P(2Q_J)*2Q_J - i*(x_2)]/2$

   $\Pi 4 = Z + F_G + P_G(Qn)*Q_J$

   $\Pi 6: Z + F_M + P(Q_J)*Q_J$

   The comparison is performed between the prices $P(2Q_J)*2Q_J$,$P_G(Qn)*Q_J$ and $P(Q_J)Q_J$. As mentioned in assumptions, price is inversely proportional to the quantity, the total cost is $P_G(Qn)Q_J$, and even it has the profit factor X resulting in lesser value than $P(2Q_J)2Q_J$, i.e.,

$P_G(Qn)*Q_J < P(2Q_J)*2Q_J < P(Q_J)Q_J$ [since $Qn > 2Q_J > Q_J$], As a result, purchasing via GPO is chosen as the preferable option for H1 [Dominant strategy: GPO].

2. If H2 choose to purchase through GPO, then as there are no hospitals to merge, H1 should choose between purchasing directly from manufacturers (with fixed contracting cost as F_M''), GPO, and purchasing directly from manufacturers (F_M). The equations are given below.

   2.1. The cost equations are π2', π4 and Π6.

   $\Pi 2' = Z + F"_M + P(Q_J)*Q_J$

   $\Pi 4 = Z + F_G + P_G(Qn)*Q_J$

   $\Pi 6: Z + F_M + P(Q_J)*Q_J$

   The cost here is less when purchased via GPO as the combined volume, is higher (Qn) than Q_J and as per the rule: volume is inversely proportional to the cost is verified. So the option of purchasing through GPO is preferable than purchasing directly from manufacturers [Dominant strategy: GPO].

3. If H2 chooses to buy its supplies directly from the manufacturer, then H1 can choose among purchasing via HA, purchasing through its GPO and purchasing directly from the manufacturer.

   3.1. The payoff equations compared are,

   $\Pi 2' = Z + F"_M + P(Q_J)*Q_J$

   $\Pi 4 = Z + F_G + P_G(Qn)*Q_J$

   $\Pi 6: Z + F_M + P(Q_J)*Q_J$

   Similar to the above explanation, purchasing through GPO is preferable option than purchasing through other two alternatives.

4. Checking for the low-cost choice of purchasing for H2, when H1 chooses to purchase by merging with H2.

4.1. The payoff equations are π1',π3 and Π5.

$\Pi 1' = Z + [A + F''_M + P(2Q_J)*2Q_J - i*(x_2)]/ (2)$

$\Pi 3' = Z + F'_G + P'_G(Qn)*Q_J$

$\Pi 5 = Z + F'_M + P'(Q_J)Q_J$

By adopting the procedure stated above, Π3' is opted as the preferable choice of purchasing for H2. As, Π3'< Π1' < Π5 so H2 choosing the option of purchasing through its GPO than the other two choices. [Dominant strategy: GPO]

5. The preferable choice for H2 is purchasing via GPO when H1 opts purchasing through its GPO. The cost equations compared in this instance are Π2', Π3 and Π5. The outcome obtained is Π3 < Π2'< Π5 [Dominant strategy: GPO]. Same outcome is resulted when H1 chooses to purchase its supplies directly from the manufacturers.

The final dominance matrix here is shown in figure 5.6. Here, the payoff [GP, GP] is the best response point.

		H2		
		HA	GP	I
H1	HA	[Π1' , Π1']	[Π2' , Π3*]	[Π2' , Π5]
	GP	[Π4* , Π2']	[Π4* , Π3*]	[Π4* , Π5]
	I	[Π6 , Π2']	[Π6 , Π3*]	[Π6 , Π5]

Figure 5.6: Dominance Matrix for payoff functions for Case 5.1.2

The conditions for a payoff to be Nash equilibrium are listed in Chapter 4. Here, the best response point [GP, GP] to be a Nash equilibrium point should satisfy the conditions of dominant pure strategy. The payoff is [Π4, Π3], is chosen as the low-cost option of purchasing for H1 and H2 respectively.

Π4 < Π2'< Π6

Π3 < Π2'< Π5

Π4 < Π1'< Π6

Π3 < Π1'< Π5

This point is satisfying all the conditions of dominant pure strategy. Therefore, [Π4, Π3] is the Nash equilibrium point and the best strategy point for both hospitals H1 and H2.

5.3 Optimizing the order quantity:

So far, the total purchase costs have been considered without any consideration of order quantities and any determination of optimal quantities. In this section, optimal quantities and optimal total costs are taken up. The Optimal order quantity is determined in order to cut down the total costs. The concept of Economic Order quantity is used. The minimization of total costs is done for both the cases. The **main rule** followed here is: As the number of orders increases, the ordering costs increase and inventory (holding) costs decrease.

It is assumed the cost per order: S1< S2 < S3

Scenario: Two hospitals (H1 and H2) are checking whether they can buy their supplies from their current registered GPOs (GP), or joining the single Hospital Association (HA) and buying from it, or purchasing directly from the manufacturers (I).

Case 1.1: When $N_G=N_H=n$, the game model is given in the below figure;

		H2		
		HA	GP	I
H1	HA	[Π1 , Π1]	[Π2 , Π3]	[Π2 , Π5]
	GP	[Π4 , Π2]	[Π4 , Π3]	[Π4 , Π5]
	I	[Π6 , Π2]	[Π6 , Π3]	[Π6 , Π5]

The total cost equation generally can be written as,

Total Cost = Purchasing cost + ordering cost + Holding Cost

Considering, both Hospitals are going through HA, i.e.,

$\pi 1 = Z + [A + F''_M + P(Q1)*Q1 - i(x_{n+2})]/(n+2)$

The purchasing costs generally consist of fixed contracting costs (set by the manufacturers), product costs (price set by the manufacturers) and the managerial costs 'A'.

Purchasing costs for $\pi 1 = A+F''_M+P(Q1)*Q1]/(n+2)$ (5.23)

Ordering cost equation generally consists of, demand for each hospital (D), order size (q), and ordering costs (S).

The demand for each hospital in case of $\pi 1 = Q1/n+2$

The number of orders = $D/q = Q1/(q*(n+2))$,

Assuming ordering costs per order for $\pi 1$ is S1

Total ordering costs for π1 = the number of orders * annual ordering costs

= [[Q1/q(n+2)]*S1] (5.24)

Holding costs for π1 depends on average inventory level, which is determined by order size by 2 = q/2

Annual per unit holding costs = H

Annual holding cost is calculated by

= [(q/2)*H*P(Q1)] (5.25)

The total cost equation for π1 can be written as (summation of purchasing costs, ordering and holding costs)

Total Cost (TC) for π1 = [[A+F"$_M$+P(Q1)*Q1]/(n+2)] + [[Q1/q(n+2)]*S1] + [(q/2)*H*P(Q1)]

(5.26)

Here, optimizing the order quantity q:

The optimal order quantity is obtained at the point when the total cost is minimum.

Hence, minimizing the total costs,

$\frac{\partial TC}{\partial q} = 0$

= 0 – [Q1*S1/(n+2)]*[1/q^2] + + [[H*P(Q1)]/2]

That results as, optimal order quantity q* = sqrt ([2*Q1*S1]/[(n+2)* H*P(Q1)]) (5.27)

Substituting the value of q* in equation (5.26)

TC for $\pi 1$ = [[A+F"$_M$+P(Q1)Q1]/(n+2)] + [[Q1/(n+2) * sqrt ([2*Q1*S1]/[(n+2)*H*P(Q1)])]*S1] + [(sqrt ([2*Q1*S1]/[(n+2)*H*P(Q1)]) * H * P(Q1)/2] – [i(x_{n+2})/(n+2)]

The optimal value of the total costs is obtained for $\pi 1$, which is represented as $\pi 1_{opt.}$

$\pi 1_{opt.}$ = [(A+F"$_M$+P(Q1)*Q1) - i(x_{n+2})/(n+2)] + 2 [sqrt(Q1 * S1 * H * P(Q1)/(2*(n+2))] (5.28)

The optimal total costs for $\pi 2$ can be done in similar approach. The equation $\pi 2$ can be written as below,

$\pi 2$ = Z + [A + F"$_M$ + P(Q1')*Q1' – i(x_{n+1})]/(n+1)

The Purchasing costs for $\pi 2$ = A+F"$_M$+P(Q1')*Q1']/(n+1)

Ordering costs = [[Q1/q(n+1)]*S1] Here, annual ordering costs is S1

Holding costs for $\pi 2$ = [(q/2)*H*P(Q1)]

The total costs = A+F"$_M$+P(Q1')Q1']/(n+1) + [[Q1/q(n+1)]*S1] + [(q/2)*H*P(Q1)] (5.29)

The optimal order quantity q* = sqrt ([2*Q1'*S1]/[(n+1)* H*P(Q1')]) (5.30)

By substituting the equation (5.30) in eq. (5.29), the optimal total costs for $\Pi 2$ is obtained and it is represented as $\Pi 2_{opt.}$

$\Pi 2_{opt.}$ = [(A+F"$_M$+P(Q1')*Q1') - i(x_{n+1})/(n+1)] + 2 [sqrt(Q1' * S1 * H * P(Q1')/(2*(n+1))] (5.31)

Now, calculating the optimal costs for the equation for $\pi 3$, when H2 purchases through its registered GPO (GP) i.e., $\Pi 3$ = Z + F'$_G$ + P'$_G$(Qn)*Q_J

The total cost can be expressed as,

Total Cost = Purchasing cost + Ordering Cost + Holding Cost

The purchasing costs for Π3 comprises of product costs ($P'_G(Qn)*Q_J$) and membership fees collected from hospitals (F'_G). Hence,

Purchasing costs = $[F_G' + P_G'(Q_n)*Q_J]$

Ordering costs = $[(Q_J * S2/q)]$ (S2: cost per order)

Holding costs = $[(q/2) * H * P_G'(Q_n)]$ (H: per unit holding cost)

The total cost equation is written below,

$$TC = [F_G' + P_G'(Q_n)*Q_J] + [(q/2) * H * P_G'(Q_n)] + [(Q_J * S2/q)] \quad (5.32)$$

Finding the optimal order quantity which is determined by minimizing the total costs equation,

$$\frac{\partial \mathrm{TC}}{\partial q} = 0$$

This results in $q^* = \mathrm{sqrt}[(2^* QJ * S2)/(H * P_G'(Q_n))]$ (5.33)

Substituting this value in eq. (5.32), the optimal total costs for Π3 is obtained and is given by

$$\Pi 3_{opt.} = [F_G' + P_G'(Q_n)*Q_J] + [2 * \mathrm{sqrt}\,[(P_G'(Q_n) * Q_J * H * S2)/2]] \quad (5.34)$$

Similarly, deriving the optimal total costs equation for Π4

$$\Pi 4_{opt.} = F_G + P_G(Q_n)*Q_J] + [2 * \mathrm{sqrt}\,[(P_G(Q_n) * Q_J * H * S3)/2]] \quad (5.35)$$

Now for $\Pi 5_{opt.}$, which is the total optimal cost when hospital H2 is purchasing directly from manufacturer,

$\Pi 5 = Z + F'_M + P'(Q_J)Q_J$

The purchasing costs for Π5 comprises of fixed contracting costs set by the manufacturer and the price set by the manufacturer = $F'_M+P(Q_J)*Q_J$

The ordering costs = $(Q_J/q)*S2$ (here, the cost per order is assumed as S2)

The holding costs per unit are assumed to be same for all cases = H.

Holding costs = $[(q/2) *H *P(Q_J)]$ the total cost equation for Π5 is written as

Total costs = $F'_M+P(QJ)QJ + (QJ/q)S2 + [(q/2) *H *P(Q_J)]$ (5.36)

The optimal order quantity is obtained by minimizing the total cost equation,

which results in $q^* = sqrt [(2*Q_J*S2)/(H*P(Q_J))]$ (5.37)

Substituting in (5.36), the equation is written as,

$\Pi 5_{opt.} = [F'_M + P_M'(Q_J)*Q_J] + 2 * [sqrt [(P_M'(Q_J) * Q_J * H * S2)/2]]$ (5.38)

Similarly, formulating the optimal costs, when H1 is purchasing directly from the manufacturer,

$\Pi 6_{opt.} = F_M + P_M(Q_J)*Q_J] + 2 * [sqrt [(P_M(Q_J) * Q_J * H * S3)/2]]$ (5.39)

The concept of “Best Response” in the Game theory is employed as principle procedure to find out the Nash Equilibrium Point (solution). The procedure is mentioned below

1. If H2 chooses to purchase its supplies by joining the Hospital Association (HA), then H1 should opt the low preferable cost choice of purchasing between HA, GPO and I (individually).
   1.1. The total optimal cost equations are,

$\Pi 1_{opt.} = [(A+F"_M+P(Q1)Q1) - i(x_{n+2})/(n+2)] + 2\ [sqrt(Q1 * S1 * H * P(Q1)/(2*(n+2))]$

$\Pi 4_{opt.} = [F_G + P_G(Qn)Q_J] + [2 * sqrt\ [(P_G(Qn) * Q_J * H * S3)/2]]$

$\Pi 6_{opt.} = [F_M + P_M(Q_J)Q_J] + 2 * [sqrt\ [(P_M(Q_J) * Q_J * H * S3)/2]]$

Here, from above minimization procedure, the optimized equations are deduced. Comparing the terms $[(A+F"_M+P(Q1)Q1) - i(x_{n+2})/(n+2)]$ from $\Pi 1_{opt.}$, $[F_G + P_G(Qn)Q_J]$ from $\Pi 4_{opt.}$, and $[F_M + P_M(Q_J)Q_J]$ from $\Pi 6_{opt.}$; The price set by the GPO comprises of fixed contracting costs set by the manufacturers, the price set by the manufacturers and some profit factor X. The term $P_G(Qn)Q_J$ can be superseded by $[F_M + P(Qn)Q_J + X]$. The addition of profit factor 'X' and membership fee 'F_G' to the product costs adds more value to the total costs when purchased through GPO. But when the purchase of supplies is done through HA, there is no profit factor, however, there are other extra costs, which add value to the product costs. The administrative fees collected from manufacturers are utilized to cover the managerial expenses and add more services to the hospitals. When the goods are purchased directly from manufacturers, the price $P_M(Q_J)Q_J$ borne by the hospital will be more than the prices when purchased through other two choices. Hence, $[(A+F"_M+P(Q1)Q1) - i(x_{n+2})/(n+2)] < [F_G + P_G(Qn)Q_J] < [F_M + P_M(Q_J)Q_J]$. Now comparing the terms 2 [sqrt(Q1 * S1 * H * P(Q1)/(2*(n+2))] from Π1opt. , [2 * sqrt [($P_G(Qn) * Q_J * H * S3)/2]]$ from $\Pi 4_{opt.}$, and $2 * [sqrt\ [(P_M(Q_J) * Q_J * H * S3)/2]]$ from $\Pi 6_{opt.}$. Here, when comparing the costs P(Q1), $P_G(Qn)$ and $P_M(Q_J)$, as discussed earlier, purchasing via HA is less expensive than purchasing via GPO. According to the rule as number of orders increases, the ordering costs increase and inventory costs decreases. Since the cost per order, S1 is less than S3, it shows that $\pi 1_{opt.}$ is a low-cost way of purchasing for the hospital [Dominant strategy: HA] .

2. If H2 chooses the option purchasing through GPO, then H1 can choose the low cost option between the HA, GPO, and I.

2.1. The optimized cost equations are $\pi 2_{opt.}$ $\pi 4_{opt.}$., $\pi 6_{opt.}$

$\Pi 2_{opt.} = [(A+F"_M+P(Q1')Q1') - i(x_{n+1})/(n+1)] + 2\ [sqrt(Q1' * S1 * H * P(Q1')/(2*(n+1))]$

$\Pi 4_{opt.} = F_G + P_G(Qn)Q_J] + [2 * sqrt\ [(P_G(Qn) * Q_J * H * S3)/2]]$

$\Pi 6_{opt.} = [F_M + P_M(Q_J)Q_J] + 2 * [sqrt\ [(P_M(Q_J) * Q_J * H * S3)/2]]$

Similar to the above explanation, the comparison of costs P(Q1') Q1', $P_G(Qn)Q_J$, and $P_M(Q_J)Q_J$ is made. It can be stated that $\pi 2_{opt.}$ [Purchasing the supplies through the HA] is a preferable low-cost option rather than purchasing through its GPO or purchasing directly from the manufacturers [Dominant strategy: HA].

3. If H2 chooses the option of purchasing directly from the manufacturers then H1 can choose the low cost option between HA, GPO, and I (individual).

   3.1. The optimized cost equations are $\pi 2_{opt.}$, $\pi 4_{opt.}$., $\pi 6_{opt.}$

   $\Pi 2_{opt.} = [(A+F"_M+P(Q1')Q1') - i(x_{n+1})/(n+1)] + 2\ [sqrt(Q1' * S1 * H * P(Q1')/(2*(n+1))]$

   $\Pi 4_{opt.} = F_G + P_G(Qn)Q_J] + [2 * sqrt\ [(P_G(Qn) * Q_J * H * S3)/2]]$

   $\Pi 6_{opt.} = [F_M + P_M(Q_J)Q_J] + 2 * [sqrt\ [(P_M(Q_J) * Q_J * H * S3)/2]]$

By adopting the same strategies, $\pi 2_{opt.}$ [Purchasing through HA] is chosen as preferable choice of purchasing the commodities [Dominant strategy: HA].

4. The dominant strategies for other conditions are determined by following the procedure as mentioned above.
   - The preferable option of purchasing for H2 is HA when H1 opts for HA. [Dominant strategy: HA]
   - When H1 chooses the option of purchasing through its GPO, then the preferable option for H2 is purchasing its supplies through HA to gain more profits. [Dominant strategy: HA]

- When H1 chooses the option of purchasing directly from manufacturers, then the preferable option for H2 is purchasing via. HA. [Dominant strategy: HA]

The final best response point is [HA, HA], and this point is satisfying all conditions required of dominant pure strategy to be a Nash equilibrium point.

Case 1.2: Here, N_H=0, and that means hospitals H1 and H2 are checking to see whether they should combine their purchasing power (or merging or HA) or purchase through their respective GPOs (GP) and N_G = n.

		H2		
		HA	GP	I
H1	HA	[Π1' , Π1']	[Π2' , Π3]	[Π2' , Π5]
	GP	[Π4 , Π2']	[Π4 , Π3]	[Π4 , Π5]
	I	[Π6 , Π2']	[Π6 , Π3]	[Π6 , Π5]

Now writing the equation for Π1',

$\Pi 1' = Z + [A + F''_M + P(2Q_J)*2Q_J - i*(x_2)]/ (2)$

The total cost equation can be expressed as,

Total cost = Purchasing cost + Ordering cost + Holding cost

Here, the purchasing costs for Π1' = $[[A+F''_M+P(2Q_J)2Q_J]/(2)]$; since only two hospitals are trying to merge the total quantity would be $2Q_J$

The ordering costs = [[Q_J/q]*S1]. Here, the cost per order is S1.

The holding cost per unit is considered same = H

The holding costs for Π1' = [(q/2)*H*P(2Q_J)] The total costs equation is mentioned as shown in eq. (5.41)

TC = [[A+F"$_M$+P(2Q_J)2Q_J]/(2)] + [[Q_J/q]*S1] + [(q/2)*H*P(2Q_J)] (5.40)

Minimizing the total cost equation, results in optimal order quantity q*

$$\frac{\partial TC}{\partial q} = 0$$

= 0 – [(S1 * Q_J)/q^2] + [(H * P(2Q_J))/2] = 0

q* = sqrt [(2 * S1 * Q_J)/(H * P(2Q_J))] (5.41)

Substituting the eq. (5.41) in eq. (5.40) the final equation is,

Π1'$_{opt.}$ = [[A+F"$_M$+P(2Q_J)2Q_J]/(2)] + 2 * sqrt[(Q_J * S1 * H * P(2Q_J))/2] (5.42)

Deriving the equation for total optimal costs for Π2', that is either H1 or H2 is choosing the purchasing option of going through GPO (GP) and other hospital is purchasing directly from the manufacturers.

Π2' = Z + F"$_M$ + P(Q_J)*Q_J

The purchasing costs for Π2' = F"$_M$+P(QJ)QJ

The ordering costs = (QJ/q)S1 (here, the cost per order is assumed as S1)

The holding costs per unit are assumed to be same for all cases = H.

Holding costs = [(q/2) *H *P(Q_J)] the total cost equation for Π2' is written as

$TC = F''_M + P(Q_J)Q_J + (Q_J/q)S1 + [(q/2) * H * P(Q_J)]$ (5.43)

Minimizing the total cost results in optimal order quantity,

$$\frac{\partial TC}{\partial q} = 0$$

$0 = 0 – [(Q_J * S1)/q^2] + [(H*P(Q_J))/2]$

$q^* = sqrt [(2*Q_J*S1)/(H*P(Q_J))]$ (5.44)

Substituting in eq. (5.43), the equation is written as,

$\Pi 2'_{opt.} = F''_M + P(Q_J)Q_J + sqrt[(Q_J * S1 * H * P(Q_J))/2]$ (5.45)

$\Pi 3'_{opt.}$ and $\Pi 4'_{opt.}$ are same as $\Pi 3_{opt.}$ and $\Pi 4_{opt.}$ respectively, since the hospitals are purchasing through their current registered GPOs.

When hospitals H1 and H2 are purchasing their products directly from the manufacturers, the optimal total cost equations are written as,

$\Pi 5_{opt.} = [F'_M + P_M'(Q_J)Q_J] + 2 * [sqrt [(P_M'(Q_J) * Q_J * H * S2)/2]]$ [When H2 purchases directly from the manufacturers]

$\Pi 6_{opt.} = F_M + P_M(Q_J)Q_J] + 2 * [sqrt [(P_M(Q_J) * Q_J * H * S3)/2]]$ [When H1 purchases directly from the manufacturers]

By deriving the optimized equations, it can be found if the Nash equilibrium point exists or. By following the rules as mentioned above, it can be shown that the preferable point is [GP, GP] and the payoff [$\Pi 3'_{opt.}$, $\Pi 4'_{opt.}$], satisfying the conditions of Nash Equilibrium.

CHAPTER 6 – CONCLUSIONS AND FUTURE WORK

As addressed earlier, this study has mainly three contributions. In the first segment of the model, the goal was to determine the affordable option of purchasing for the hospitals H1 and H2, among the three choices; joining a Hospital Association (hospital society), buying through group purchasing organizations, and purchasing directly from the manufacturers. Based on this, a scenario is drawn, which includes two cases. The preferable option of purchasing is determined in every case, and for each case, a game theoretic model is created with the total cost equations as the payoffs. By adopting the procedure of best response, the Nash equilibrium point or the preferable point of purchasing is determined. Quantity discount contracts are used in the entire model; therefore the main rule here is, as the volume increases, the price per unit decreases.

- When $N_H = N_G = n$, Here, the preferable option of purchasing for both the hospitals is purchasing via Hospital Association.
- Similarly, When $N_H = 0$ and $N_G = n$, then the low cost option for H1 and H2 is purchasing through its own registered GPO.

The proof of payoffs satisfying the conditions of Nash equilibrium is done for each case.

Purchasing individually (I) might be the best choice only when the healthcare member wants to purchase very limited quantity such as physician prescribed medicines, some big operation

equipment's, operational tools etc., and the entire price of the contract mainly depends on the negotiating capacity of each healthcare organization, and the volume of purchase.

Different Lemmas are proposed in the second aspect of the model. Generally, the members in GPO will be more than the members in Hospital Association; this is because multiple healthcare organizations, which are in the close proximity geographically, combine their resources. Here, initially the assumption is made about the optimal point or the Nash equilibrium point, and the conditions are drawn for that payoff, in order to satisfy the rules of Nash equilibrium. Each lemma gives the conditions in relation to the number of members in the hospital association 'n' and the quantity (Q_J) ordered by each of the hospital.

The third aspect of the model is similar to the first aspect, but the main difference is purchasing is done based on an optimal order quantity. The main reason to implement this model is to avoid high inventory costs and to maintain correct demand relationship with the seller with a view to attain higher profits in the entire supply chain. The primary comparison is done between the quantity ordered, and the ordering costs versus inventory or holding costs. The best response points for each case are derived.

6.1 Future Work:

- Need to collect the real-time data about a Hospital Association and should perform analysis.
- In the current model, the contract that is used for all the cases is the volume discount contract. Using other type of contracts such as sole –source contracts, buy-back contracts, can further extend this model.
- We can extend the entire work, using a stochastic game, by varying the demands and costs in all the procurement models.

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