Optimizing Inventory Management Cost: Case of Simap

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Abstract

Inventory management is an important phase of total quality control. The surgical instruments manufacturing industry is one of the export-oriented sectors in Pakistan; there is a need to improve its business operations. This study focuses on comparison of eight techniques for the inventory management; data for 12 months was curated in 2017, from 75 firms operating in Sialkot. Statistical analysis was conducted to compare the following eight inventory management techniques: Lot for Lot, Wagner-Whitin, Least Unit Cost, Least Total Cost, Silver-Meal, Economic Order Quantity, Periodic Order Quantity, and Part Period Balancing. The Lot for Lot, Least Unit Cost, Least Total Cost, Silver-Meal, and Wagner-Whiten, were found better than Economic Order Quantity, Periodic Order Quantity, and Part Period Balancing; Periodic Order Quantity is better than Economic Order Quantity which in turn is better than Part Period Balancing. One must keep in mind that statistical out-performance of one technique against the other should not consume the decision-makers, rather the decision should also include the practicality of the business operation.

Keywords: Inventory-management; surgical manufacturing; total quality control; business operation; supply chain.
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Introduction

Inventory management is an important factor for maximizing the profits of a firm; firms with higher profit volumes are able to acquire predominant market share in the long run. It is because of the presence of global supply chain and the importance of inventory management in determining the firms’ performance that the overall idea of Total Quality Management (TQM) remains incomplete without optimizing the inventory management practices. Although the ideas of Supply Chain Management (SCM) and Total Quality Management (TQM) have different origins; nevertheless, both converge to the ultimatum of enhancing the organizational competitiveness by meeting customer satisfaction goals. The idea of efficient SCM and TQM enables the firms in developing countries to help their countries in strategizing for the achievement of the Sustainable Development Goals; indicator 8a, 9.3, 9.5, 9b, 16.3, and 17.11 are aligned with the global supply chains for the developing countries (ILO, c1996-2019). In this backdrop, inventory management should be considered important by the firms working in Pakistan.

According to Kotler (2002), inventory management is a process that encompasses all the activities that are involved in development and management of inventory levels for the raw materials, semi-finished materials, and finished good; this ensures timely availability of adequate supplies while Deveshwar and Dhawal (2013) emphasized the need to minimize the costs of excess or under stocks. The history of inventory management is as old as the early ages, buying and selling has always taken place in one form or the other; nonetheless, the Industrial Revolution and the rapid diffusion of technology in businesses, has enabled the stakeholders to maintain and analyze longitudinal data necessary for adopting cost-efficient strategies. Although there is no paucity of literature on advanced inventory management techniques; however, there is a need to present simple inventory management techniques to small scale firms because they lack the skillset and motivation to understand complex techniques. It must be kept in mind that adoption of innovative inventory management techniques relies upon adoption of technology for digital integration in all the business functions both within and outside the organization; nevertheless, small scale firms are hesitant towards this adoption. Prause (2019) analyzed the determinants of adoption of the Industry 4.0 technology by using data of 38 manufacturing companies working in Japan; it was found that small and medium-sized firms are late in adopting the Industry 4.0. Small and medium-sized firm are unable to evaluate the long-term gains from adoption of advanced information and communication technologies (ICT) (Lu et al. 2019). Given this backdrop, this study is two-pronged i.e., it aims to achieve following two goals: evaluate the optimum inventory management technique and educate the small and medium size surgical firms that there are simple techniques available whose calculations can be done in Microsoft Excel; it has been discussed by Fadhil and Fadhil (2011), that small and medium-sized firms prefer to adopt ICT only if it requires use of simple software, such as Microsoft Excel. Since the optimality check of the techniques discussed in this study, can be checked in Microsoft Excel, firms can recoup the optimality of the techniques; optimality check may be applied at the end.
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of each calendar year or whenever the underlying assumptions of the adopted technique, are violated.

An optimum inventory policy strategizes about the best time to order the input(s) from the supplier(s), and the magnitude of the order, this ensures a cost-efficient mechanism of input into finished products; such a policy circumvents the inventory costs that the firm may face due to physical storage capacity, deterioration of stock or obsolescence, incidence of theft, and hiring of manpower for managing the inventory in terms of receiving, unpacking and inspecting the lots (Muller 2003). The benefits of optimizing the inventory management practices are unequivocally promising because ignoring this important aspect in the supply chain can cause delay disutility i.e., the disutility of the demander when the supplier is unable to deliver the product in time; the delay disutility is directly related to the valuation of the order i.e., larger the order more is the intensity of disutility faced by the demander, in case of the supplier’s inability to deliver the order (Chen and Shi 2019). Inventory management is crucial for all suppliers (Muller 2003); nevertheless, its importance is even more inevitable for small-scale firms that face constraints of a diminutive cash flow, lack of resources for technological innovations that can modernize the supply chain, and an intractable lead time (Atnafu, and Balda 2018).

Optimum inventory management ensures better quality of products which in turn establishes a brand image and a sustainable customers base (Lane and Richey 2006; Sung et al. 2010; Banerjee 2016). Inventory management is even more important for the surgical instrument manufacturing firms because these firms serve the demands of a life-saving sector i.e., the health sector; if these firms are able to adopt optimum inventory management techniques, then they can focus more on the quality of products. Many international surgical brands have outsourced manufacturing units to Pakistan (Nazir and Mahmood 2018), Pakistani artisans are appreciated worldwide; nonetheless, it is unfortunate that the surgical sector of the country has failed to develop international brands (Khan 2016). The fact that annually, on average, the surgical industry produces more than 170 million pieces (Khan 2016), alludes towards the export potential of this industry; nevertheless, the surgical industry of Pakistan has merely reduced to a vendor for the international brands that decide to outsource their manufacturing operations, in Pakistan (Barlow 2016; Nazir and Mahmood 2018). In an overly competitive world, no industry can survive without adopting efficient processes in all the phases of production and supply-chain; the position of the surgical sector of Pakistan will be challenged from competition from Mexico and China, both these countries are advantaged in terms of an abundant supply of cheap labor, and innovative technologies required to optimize the production phases (Gerefi 2009).
Research Problem

To evaluate the optimum inventory management technique for the surgical manufacturing firms in the Sialkot region of Pakistan.

Significance of research

According to the Lancet Commission on Global Surgery, approximately 17 million people lose their lives each year, due to lack of timely surgical care (Meara and Greenberg 2015). The surgical manufacturing industry of Pakistan has fulfilled the global demands for surgical instruments in the global value chain; nevertheless, the recent years have witnessed a significant slowdown due to increased competition from new entrants in the market, production inefficiencies, and suboptimal human capital resources (Hamrick and Bamber 2019). The significance of this research is that it can enable the surgical equipment manufacturing industry to obtain a dominant share in the global market of surgical equipment. By using data from the surgical manufacturing firms working in Sialkot, this study provides a factual profiling of the inventory management practices in these firms. This study compares following lot-sizing techniques: Lot for Lot, Wagner-Whitin, Least Unit Cost, Least Total Cost, Silver-Meal, Economic Order Quantity, Periodic Order Quantity, and Part Period Balancing, to unveil the appropriate lot-sizing techniques for the surgical equipment manufacturing companies of Sialkot region. Some researchers have compared some of the aforementioned inventory management techniques, however, they used hypothetical data on demand patterns; some examples are Wemmerlöv, (1982); Veral and LaForge (1985); Dellaert and Jeunet, (2003); Ho and Ireland (2012).

There has been evidence that in Pakistan, the demanders of health sector products suffer due to inability of suppliers to deliver the products in time, for instance, Atif et al. (2019) conducted a qualitative enquiry of the factors responsible for medicines shortage in Pakistan, they concluded that one of the key avenues that require improvement, are inventory management system, regulations of manufacturers, and price control. This study attempts to fill the void in the literature, although researchers have investigated the determinants of productivity (Chaudhry 2011; Ikram et al. 2016); nonetheless, there is a dearth of studies that compared a wide variety of inventory management techniques to propose an optimum course of action for the supply chain. This study shall enable the surgical equipment’s manufacturing firms to choose the optimum inventory management technique to maximize their profits. Given the fact that technology adoption in the supply chain is limited by barriers, such as technical incapability, unwillingness for technology adoption, human & capital resources, cybercrimes, lack of uniform tagging standard followed by the RFID companies, and government’s legal regulations, limit the possibilities of RFID adoption, human assisted inventory management techniques should be a point of discussion for the firms in Pakistan.
Literature Review

The Surgical Instruments Manufacturers Association of Pakistan (SIMAP)

The surgical instruments manufacturing firms work under the umbrella of the Surgical Instruments Manufacturers Association of Pakistan (SIMAP) which was established in 1950; nevertheless, the history of these firms is set under the British colonial era in the Indo-Pak subcontinent. The number of firms registered with SIMAP is 3900 while 1.5 million workers are engaged in these firms, meeting national, and international demand. Researchers have analyzed the determinants of penetration in foreign country, productivity, and agglomeration economics for the cluster of surgical equipment’s manufacturing firms working in Sialkot. Ikram, et al. (2016) analyzed the technical efficiency of small and medium sized enterprises working in the surgical instruments cluster of Sialkot; by employing the Cobb-Douglas production function, and stochastic frontier analysis, it was established that this cluster is functioning in technically inefficient manner, and it is experiencing constant returns to scale. One of the determinants of this discouraging scenario, is the supply-side inefficiencies; proper supply of intermediate inputs is crucial to the performance of this sector (Ikram et al. 2016). Pakistan exports surgical instruments to different countries; major trading partners are given in Table 1 (TrendEconomy 2020). The top five global exporters of surgical instruments are the European Union, the USA, China, Switzerland, and Mexico; the percentage share in different categories ranges from 80 to 90 percent (Hamrick and Bamber 2019). Pakistan had an advantage of cheap labor and the historical background of exports during World War II; nonetheless, these factors are now less relevant because of the entry of many competitors in this field. Pakistan has recently experienced that its surgical instruments exports are plateauing (Hamrick and Bamber 2019). Pakistan needs to explore more potential markets for the exports of surgical instruments; these efforts include a need for efficient inventory management practices.

Table 1: Existing Markets for the Surgical Industries of Pakistan

| Country                | Percentage Share in Exports of Pakistan Surgical Manufacturing Industry |
|------------------------|--------------------------------------------------------------------------------|
| USA                    | 27% (99 million US$)                                                          |
| Germany                | 15% (54 million US$)                                                          |
| United Kingdom         | 8.27% (29 million US$)                                                         |
| China                  | 6.07% (22 million US$)                                                         |
| France                 | 3.45% (12.5 million US$)                                                       |
| United Arab Emirates   | 3.39% (12.2 million US$)                                                       |
| Japan                  | 2.52% (9.15 million US$)                                                       |
| Australia              | 2.15% (7.81 million US$)                                                       |
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| Country     | Percentage | Revenue ($US) |
|-------------|------------|---------------|
| Brazil      | 2.15%      | 7.79 million  |
| Italy       | 2.06%      | 7.46 million  |
| Germany     | 15%        | 54 million    |

Source: Trend Economy (2020). https://trendeconomy.com/data/h2/Pakistan/9018

Chaudhry (2011) analyzed the choice of contracting institutions for the purchase of inputs by the surgical equipment manufacturing firms in Sialkot. It was observed that these firms have access to a multiplicity of suppliers; nevertheless, almost fifty percent of the sampled firms would not give a chance to a new supplier even if it is offering lowest price. Firms were more willing to opt for a new supplier, if it was introduced through their business network (Chaudhry 2011). Akhtar (2012) analyzed the scope of surgical instruments business in Japan; by using a qualitative research approach Akhtar (2012) used interviews and questionnaires to derive an idea about the penetration of surgical manufacturing firms of Pakistan, in Japan. By using data from interviews and questionnaires conducted for the key informants in the surgical manufacturing firms of Pakistan, and the surgical and dental associations in Japan, it was established that non-financial factors impede the penetration of Pakistan’s surgical sector in Japan, such as the language-barrier, political, social, and legal obstacles.

A brief structure of the surgical industry of Pakistan is given in Table 2.

Table 2: Summary of Structure of the Surgical Industry of Pakistan

| Type of Firms * | No. of Firms | Annual Revenue Range | Employees  |
|-----------------|--------------|----------------------|------------|
| Large Scale     | 20           | 60 to 100 million    | 250 to 400 |
| Medium Scale    | 50           | 10 to 60 million     | 100 to 250 |
| Small Scale     | 150          | 1 to 10 million      | 30 to 50   |

* On the basis of sales turnover.

Source: Export Promotion Bureau and Punjab Board of Investment and Trade https://www.google.com/url?sa=t&rct=j&q=&esrc=s&source=web&cd=&cad=rja&uact=8&ved=2ahUKEwiFxOFmPbr KwAhXN-wKHSqIA7gQFIAegQIaxAD&url=http%3A%2F%2Ftrtapakistan.org%2Fwp-content%2Fuploads%2F2013%2F10%2FPF10%2FPFPharmaceuticals.pdf&usg=AOvVaw3a-bOQOXBz3LS6aqOVQ8

Controllable Factors for Lot-Sizing Techniques

Firms need to minimize their total production cost, this includes strategies to reduce the variable costs which includes improving the inventory management techniques (Stadtler 2007; Goerler and Voß 2016; Gören, and Tunali 2018). The inventory management cost comprises different dimensions, which includes cost of raw material, holding cost for that raw material, and the ordering cost for the raw material (Mathur 2007) — the firms working in the surgical sector of Pakistan rely on imported raw material. While the cost of raw
material depends upon the negotiation, and the quality of the material, the ordering cost and the holding cost of the raw material can be controlled at firm level by adopting optimum lot-sizing technique, such as Lot for Lot (LL), Wagner-Whitin (WW), Least Unit Cost (LUC), Least Total Cost (LTC), Silver-Meal (SM), Economic Order Quantity (EOQ), Periodic Order Quantity (POQ), and Part Period Balancing (PPB).

**The Global Market for Surgical Equipment**

With an increase in the prevalence of diseases requiring operative surgeries, such as cardiovascular diseases, neurological disorders, and urological issues; this has increased global demand for surgical instruments. In 2016, the global surgical equipment market was valued at USD 10.5 million, it is expected to double by 2025; moreover, the surgical equipment market is expected to grow at a compound annual growth rate of almost eight percent (Grand View Research 2017). North America dominated the global surgical equipment market, mainly due to the availability of advanced surgical tools, and expert surgeons (Grand View Research 2017). Pakistan major trading partners that receive exports of surgical equipment are the USA, Germany, Mexico, the UK, and France (Cluster Development Initiative c2017). Realizing the importance of the exports-oriented sector, the Government of Pakistan, announced exemption of sales tax on raw materials for leather, textiles, surgical goods, and sports goods (State Bank of Pakistan 2018). In the financial year 2018, a health growth was observed in the exports of medical & surgical instruments; nonetheless, the exports potential is much higher, there is a need for brand development, adoption of universal quality standards & certification is required, and the industry needs to streamline internal conflicts (TDAP, n.d.). Brand personality is an important determinant of customers’ loyalty (Lane and Richey 2006; Sung, et al. 2010; Banerjee 2016); universal certifications & authentication are crucial in the context of branding and market share of a product (Starr and Brodie 2016; Banerji 2016). Many international surgical brands have outsourced manufacturing units to Pakistan (Nazir and Mahmood 2018), Pakistani artisans are appreciated worldwide; nonetheless, it is unfortunate that the surgical sector of the country has failed to develop international brands (Khan 2016). The fact that annually, on average, the surgical industry produces more than 170 million pieces (Khan 2016), alludes towards the export potential of this industry; nevertheless, the surgical industry of Pakistan has merely reduced to a vendor for the international brands that decide to outsource their manufacturing operations, in Pakistan (Barlow 2016; Nazir and Mahmood 2018). In an overly competitive world, no industry can survive without adopting efficient processes in all the phases of production and supply-chain; the position of the surgical sector of Pakistan will be challenged from competition from Mexico and China, both these countries are advantaged in terms of an abundant supply of cheap labor, and innovative technologies required to optimize the production phases (Gerefi 2009).
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International Best Practices in the Health Sector’s Supply Chain

Kumar et al. (2008) investigated the supply chain of medical supplies in Singapore; proposed a framework for costs reduction through process reengineering that is based on the idea of warehouse’s centralization and controlling the non-production goods. Uthayakumar, and Priyan (2013) analyzed the inventory management practices of a hospital and a pharmaceutical company; they proposed an integrated model with continuous review of the supply chain by incorporating permissible payment delays, variable lead time, customer service level, and constraints on space availability. While the developed countries are adopting advanced inventory management technology, Pakistan’s surgical sector is still not adopting optimum human assisted solutions for inventory management. Sands et al. (2009) have patented a system for optimizing the supply chain of medical assets that is based on tagging of products through Radio Frequency Identification (RFID). Mall and Mishra (2015) conducted an inquiry of the potential of RFID as an inventory management tool, it was concluded that adoption of RFID is promising; nevertheless, the barriers of technical incapability, unwillingness for technology adoption, human & capital resources, cybercrimes, lack of uniform tagging standard followed by the RFID companies, and government’s legal regulations, limit the possibilities of RFID adoption.

Different Lot Sizing Techniques

Wagner Whitin Algorithm

The WW Algorithm was proposed by Harvey M. Wagner, and Thomson M. Whitin in 1958 (Wagner and Whitin 1958); it has been used extensively by researchers to analyze the inventory management practices (Evans 1985; Richter and Sombrutzki 2000; Chowdhury et al. 2016; Baki and Azab 2018; Hanafizadeh et al. 2019).

By using WW algorithm, firms can control the inventory cost, and setup cost; meeting the demand for the known periods. One of the merits of this algorithm, is its possible use, even if the holding costs, and setups are not constant across different periods. (Wagner and Whitin 1958). The formula for this algorithm is given in equation (1) below:

\[ Z_{ce} = S + h \sum_{i=c}^{e} (Q_{ce} - Q_{ci}), \quad 1 \leq c \leq e \leq N \]  

(1)

where:

- \( Z_{ce} \) = Total cost of periods from period \( c \) to \( e \),
- \( S \) = Setup cost,
Holding cost for the periods,

\[ h \sum_{i=e}^{c} (Q_{ce} - Q_{ci}) = \text{Holding cost for the periods}, \]

\[ Q_{ce} = \text{Total demand from period } c \text{ to } e, \]

\[ f_e = \text{Min} (Z_{ce} + f_{c-1}) = \text{Minimum possible cost from period } 1 \text{ to } e. \]

**Economic Order Quantity Algorithm**

The EOQ algorithm was proposed by Ford W. Harris in 1913; R. H. Wilson, who applied it extensively, is often given credit for elaborating this algorithm (Harris 1913; Wilson 1934). Many researchers have discussed the uses of the EOQ inventory management technique (Covert and Philip 1973; Schwaller 1988; Jawad et al. 2015; Perera et al. 2017). EOQ is used to control total ordering, and holding cost of inventory. This model works on certain assumptions, they are as follows: uniform, and known demand, fixed cost of items, and fixed cost of ordering, or holding inventory. To use EOQ, one must know demand rate, how much it costs to place an order, and how much it costs to hold that in inventory. EOQ also assumes that lead time is zero; time interval in placing and receiving order is zero, so delivery or manufacturing of products is instantaneous. EOQ accounts for three types of costs i.e., cost of the units, cost of holding units in inventory, and the fixed order cost i.e., cost of placing, and receiving an order, it also includes the cost of manufacturing setup. EOQ’s goal is to select the order-quantity that minimizes the average inventory-management cost, and time.

Formula for EOQ is given in equation (2) below:

\[ Q^* = \sqrt{\frac{2DS}{H}}. \]  
\[ (2) \]

After finding optimum quantity i.e., EOQ, this value is incorporated in equation (3), to calculate the annual cost.

\[ \text{Total Cost} = C^* \frac{D}{Q} + h^* \frac{Q}{2}. \]  
\[ (3) \]

where,

\[ Q^* = \text{Quantity}, \ D = \text{Annual Demand rate}, \ H = \text{Holding cost}, \text{ and } C = \text{Setup Cost}. \]
Silver Meal Technique

Silver and Meal (1973) introduced the algorithm of the SM for inventory management, to determine the production quantities to meet the requirement of operations at a minimal cost. It requires determining the average cost per period; yields an approximate solution for continuous time varying demand patterns; instead of finding the lot sizes that minimize the total ordering and inventory holding costs up to the time horizon, it determines each lot size sequentially, one at a time, by finding the minimum of the total inventory cost per unit time (Omar and Deris 2001). The SM model has following assumptions: Inventory schedule is required for calculations, demand rate is known, setup cost is fixed, and a known carrying inventory cost. In this technique, we add the holding cost and setup cost of the periods, and then divide the resultant value by the total number of periods, as we add periods the cost per period decreases; we stop adding periods until the cost per period starts to increase. We set the lot size where the period cost was least and start the process again from the next period; continue to repeat the process until lots of all defined period’s demand is made (Tersine 1994).

Least Unit Cost (Lu)

The LU a dynamic technique for lot-sizing; aims at achieving the minimal, per unit cost. (Tibeen-Lembke, and Rogers 2002). Many researchers have used the LU technique for inventory management (Benton 1991; Hariga 1994; Goyal and Giri 2003; Samak-Kulkarni and Rajhans 2013). The LU is similar to the SM; nevertheless, it relies on cumulative holding cost, and the cumulative setup cost to divide the result with the cumulative demand for the reference period (Tersine 1994). As successive periods are added, the cost per unit decreases; addition of periods ceases as the cost per unit starts increasing. Then an optimum lot size is determined for which the unit cost is least; then the process starts again for the next reference period, continue to repeat the process until demand for lots of all reference periods is made. The LU model is parsimonious as compared to the other inventory management techniques; nevertheless, the computations are dependent on the information about the predicted demand patterns for future, therefore, it relies on the quality of estimation procedure for the predicted demand. In addition to this demerit, LU has another consideration that it is a univariate method, it is only effective in minimizing the cost of a particular lot; the costs may differ from period to period so, the overall cost can be higher.

Part Period Balancing (PPB)

The PPB is a dynamic approach designed to balance the setup cost and the holding cost. (Dematteis 1968); balances these costs for the periods with known demand patterns. This technique uses the known demand information of the next period; balances the setup, and holding cost. The PPB computes the ratio of setup cost to holding cost; this ratio is known as Economic Part Period. Successive periods are added to calculate holding cost, or part periods; when the holding costs or part period becomes approximately equal to Economic Part Period,
addition of periods is stopped. This iterative procedure is continued till the end of the total periods. (Heizer et al. 2008).

Lot for Lot (LL)

The LL is also termed as Discrete Order Quantity algorithm; it is a stochastic algorithm, used when the net-requirement on a particular day determine the quantity to be ordered. This technique generates a greater volume of orders as compared to the fixed lot-sizing algorithms. Due to its temporal decisions, LL computes relatively smaller quantities per order; consequently, tapering the inventory investment; its use is suited for expensive items, or for those whose demand occurs intermittently. Many researchers have discussed the applications of the LL algorithm, such as Gosrani and Kolekar (2007), Heizer and Render (2008), Bhagoria (2010), and Malakooti (2013).

Research Methodology

Sample Composition, and Sample Design

The rationale behind concentrating on the Sialkot region is consequent upon the fact this region is the hub of the surgical sector in Pakistan (Deutsche Gesellschaft für Internationale Zusammenarbeit 2017). We conducted a survey of 75 surgical firms working in Sialkot; monthly data of one year was obtained against each firm’s demand and inventory management costs. The population consists of 3900 firms; our sample is roughly 2% of the total population. While the sample size is relatively small; however, this is because this study was carried on without any funding from a third party. Line transect sampling was used to recruit 75 surgical firms working in Sialkot.

Research Instrument

A semi-structured questionnaire consisting of three questions i.e., ordering cost of one order for raw material, holding cost of per unit of raw material, and the third one is related to the demand of the raw material of the last 12 months. The questionnaire is framed to achieve following research objective: to unveil optimum lot-sizing technique to minimize inventory management cost.

Statistical Tests

We applied Mann-Whitney non-parametric test, for equality medians across different lot-sizing techniques i.e., Lot for Lot, Wagner-Whitin (WW), Least Unit Cost (LUC), Least Total Cost (LTC), Silver-Meal (SM), Economic Order Quantity (EOQ), Periodic Order Quantity (POQ), and Part Period Balancing (PPB).
The hypotheses for the Mann-Whitney test is given below:

\[ H_0: \Omega_{LL} = \Omega_{WW} = \Omega_{LUC} = \Omega_{LTC} = \Omega_{SM} = \Omega_{EOQ} = \Omega_{POQ} = \Omega_{PBP} \]

\[ H_1: \text{at least one of the median is different}. \]

where,

\[ \Omega_k = \text{Median of the } k^{th} \text{ technique } k = \text{LL,WW,LUC,LTC,SM,EOQ,POQ,PBP}. \]

Next, we applied Classical Linear Regression Model (CLRM) to check whether the expected cost is lesser for techniques whose sample median was lesser; sample medians for LL, LUC, LTC, SM, and WW was lesser than the EOQ, POQ, and PPB. Given this scenario, we proceeded with the CLRM. The CLRM was applied to predict the cost as a function of the inventory management technique. From here on, LL, LUC, LTC, SM, and WW, are called Set-A, and EOQ, POQ, and PPB, are called Set-B.

**Results**

The significance value of the Mann-Whitney test came out to be zero; therefore, the null of equal median was rejected. This means that the median cost for different techniques is different; to comment on the optimality we banked on the CLRM. According to the CLRM results, given in Table-1, there appears to be a significant difference between techniques in Set-A, and Set-B. The linear model is Expected Cost= 6992-3072(D); D= 1 for Set-A, and 0 for Set-B. This implies that the cost of techniques in Set-A is 3072 units lesser than cost of techniques in Set-B.

**Table 3. Regression results for Set-A vs Set-B**

| Source                          | Coefficient | Significance Value |
|---------------------------------|-------------|--------------------|
| Constant                        | 6992        | 0.00               |
| Dummy Variable for Technique    | -3072       | 0.00               |

To comment on the magnitude of the average cost, we applied Post-Hoc test; results are given in Table-2. It can be observed that in population data, the inventory management algorithm-LL is expected to be 2505.5 units lesser than EOQ, LL is expected to be 1873.3 units lesser than POQ, LL is expected to be 4838.5 units lesser than PPB. EOQ is expected to be 2333 units lesser than PPB, POQ is expected to be 2965.2 units lesser than PPB, LTC is expected to be 4838.5 units lesser than PPB, SM is expected to be 4838.5 units lesser than PPB, and the WW is expected to be 4838.5 units lesser than the PPB. Figure (1) represents a quick comparison of the eight algorithms for inventory management. From Figure (1), it is evident that the WW, SM, LTC, and LUC outperform all the other algorithms, POQ is better than EOQ which in turn is better than PPB. The 95% confidence intervals for each cost can
be interpreted as follows: there is a 95% likelihood that LL margin of outperformance of LL over EOQ is between [2190.4, 2820.6].

**Table 4**: Post-Hoc analysis of the eight inventory management algorithms

| (I) Technique | (J) Technique | Mean Difference (I-J) | 95% Confidence Interval |
|---------------|---------------|-----------------------|-------------------------|
|               |               | Lower Bound           | Upper Bound             |
| LL            | EOQ           | -2505.5*              | -2820.6                | -2190.4                |
|               | POQ           | -1873.3*              | -2188.3                | -1558.1                |
|               | PPB           | -4838.5*              | -5153.6                | -4523.4                |
| EOQ           | POQ           | 632*                  | 317.1                  | 947.30                 |
|               | LUC           | 2505.50*              | 2190.4                 | 2820.6                 |
|               | LTC           | 2505.50*              | 2190.4                 | 2820.6                 |
|               | SM            | 2505.50*              | 2190.4                 | 2820.6                 |
|               | PPB           | -2333*                | -2648.1                | -2017.9                |
|               | WW            | 2505.50*              | 2190.4                 | 2820.6                 |
| POQ           | LUC           | 1873.20*              | 1558.1                 | 2188.3                 |
|               | LTC           | 1873.20*              | 1558.1                 | 2188.3                 |
|               | SM            | 1873.20*              | 1558.1                 | 2188.3                 |
|               | PPB           | -2965.2*              | -3280.3                | -2650.1                |
|               | WW            | 1873.20*              | 1558.1                 | 2188.3                 |
| LTC           | PPB           | -4838.5*              | -5153.6                | -4523.4                |
| SM            | PPB           | -4838.5*              | -5153.6                | -4523.4                |
| PPB           | WW            | 4838.50*              | 4523.4                 | 5153.6                 |

* implies, significant at 1%.

**Fig 1**: Post-Hoc analysis of inventory management cost for the eight algorithms.
Discussion

This study attempted to offer solution for inventory management practices for the surgical industry of Pakistan. It must be kept in mind that inventory management is only one dimension of the total quality control process, later dimension aims at optimizing the overall quality metrics by monitoring the volume and quality of output, while the former enables businesses to nip the problems affecting the quality control in terms of demand and supply decisions. Optimizing the inventory management process ensures that the demand & supply forecasts are estimated accurately; this includes decision about the product replenishment. This study has analyzed the inventory management practices of the surgical industry of Pakistan; this industry is crucial in terms of the designing the SDG Industry Matrix; which is a framework for businesses to create value for themselves, and the society (United Nations Global Compact 2015). In this context, one must understand the nexus between the value-addition for society, and the pyramid of human motivation purported by Maslow (1943), and O’Connor and Yballe (2007); it is less likely that businesses that are not cost-efficient, adopt the SDG Industry Matrix to achieve the Sustainable Development Goals.

Based on the regression findings, if businesses were to choose between Set-A (i.e., LL, LUC, LTC, SM, and WW) with Set-B (EOQ, POQ, and PPB), then any technique in Set-A is an optimum choice; however, a choice within Set-A should not be merely dependent upon the statistical significance depicted in Figure (1), and Table (2). One must keep in mind that statistical outperformance of one technique against the other should not douse the decision-makers, rather the decision should also include the practicality of the business operation. For instance, LL is proven to be less costly than POQ, EOQ, and PPB; nevertheless, LL algorithm, which is designed for intermittent demand patterns, can badly affect the brand-image, a supplier who fails to deliver goods at the time of demand loses the clients’ trust. Similarly, due to just-in-time nature of the LL technique, it can seriously get affected by unpredictable natural, and economic shocks, if these shocks stop the supply of inputs, then production process can halt.

Avenues for Future Research

Future studies can focus on explaining the determinants of adoption of inventory management techniques; analyze the characteristics of the firms that adopt a particular technique, for instance, whether younger firms adopt part period balancing technique, or experienced ones do so. Another dimension for future work can be to explore the impact of demand side and supply side shocks; are there any techniques that outperform others in presence of such shocks. Behavioral experts may research upon the personality dynamics of firm’s ownership and its link with the choice of the inventory management techniques; risk averse decision takers shall behave different than the risk lovers.

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