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Process Optimization of Engineering Work Request in an Offshore Environment

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Abstract: The survival of multinational corporations today and in the future is premised on their competitive edge in effectively deploying modern optimization tools in providing utility and services to clients. This research studies the applications of process optimization in the valve procurement life cycle of the engineering unit of an offshore corporation. A forensic audit into the operations of this multi-disciplinary corporation with varied processes targeted at achieving optimization goals reveals cases of inefficiencies in personnel utilization and cost management. These show up in duplication of personnel effort and inefficient cost burdens. Employing the excellent tools within the lean six sigma framework, analysis of the manufacturers and cost combinations were carried out on 9,145 valves procured between January 2017 and January 2020. The results indicate huge cost variations of over 50% of valve mean price of similar valve types and sizes with resulting loss of cost-saving opportunities for the period under consideration. Process inefficiencies were established, such as unnecessary duplication of the process step of contacting the valve original manufacturer for a quote, inadequate rigour in price negotiation, and unnecessary features requested during valve specification. The outcome of this study corrects these inefficiencies, improves opportunities, and makes recommendations such as the need for all manufacturer engagements to be multi-party that involves the end-user, supply chain group, and approvers to eliminate re-work and checkmate opportunities for racketeering. These establish cost-effectiveness and resource efficiency in the system.

Keywords: process, process optimization, engineering, work request, offshore environment.

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1. Introduction

While the majority of existing research is focused on general, not strategic elements of asset management (Schraven et al., 2015; Konstantakos et al., 2019), there has recently been a substantial amount of interest in research on strategic asset management in both academia and business (Konstantakos et al., 2019; El-Akruti et al., 2018; Schraven et al., 2015; Komonen et al., 2012). Physical asset management is not new to a variety of asset-intensive industries (such as aviation, commercial real estate, and other public infrastructures), and was originally intended to maximize the value of asset portfolios throughout their life cycle (Bulita, 1994), also known as terotechnology (White, 1975). Physical asset management, on the other hand, did not require any specific degree or professional skills, and numerous techniques, such as maintenance, logistics, and engineering, were emerging. The mounting demands from the external environment, as well as the concerns of many stakeholders, were unaddressed by such an approach. The rising complexity of technological nature across a wide variety of businesses and organizations necessitated asset management as a recognized subject

(Hastings, 2015). As a result, asset management has gained a lot of traction.

Process optimization has gained recognition and application in a diverse industry in recent years. Due to growing competition, businesses are obliged to make quick decisions, which from time to time are tailored towards creating solutions that will enhance performance and business sustainability. For rapid growth, business activities across any industry require the use of structure optimization techniques. Optimization is a mathematical approach for finding the extrema of a function with or without constraints; it seeks the combination of inputs to yield the best or most desired output (Ibidapo-Obe and Asaolu, 2006). Process optimization is a vital domain within process systems engineering (PSE). It is actively adopted in the development, decision-making, and subsequent development of processes. It points toward maximization of the process performance while at the same time decreasing the processing costs. Numerous mathematical programming methods are used in process optimization, such as mixed-integer non-linear programming, multi-objective optimization, and Monte-Carlo-based algorithms. Joint optimization has recently been adopted in the maintenance and spare parts inventory policy for a two-component system (Zhang et al., 2018; Karabağ et al., 2020; Zheng et al., 2021; Zhang et al., 2022).

Most of the aforementioned approaches have shown beneficial advantages since they provide a quantitative framework to justify safety influences, as well as support superior decision making, thereby contributing to cost-savings in engineering projects (Kelley, 2010). The remarkable strides accomplished in the field of management of engineering systems have exposed researchers and business practitioners to several optimization techniques that are cost-effective and yield significant performance improvement. The world today continues to grow in complexity, and new frontiers in business process improvement are emerging for improving performance standards. Global corporations are formed, and success in today's world demands an ever-increasing simplification of the complex and standardization of the routine. This study examines the engineering unit of an offshore corporation in Nigeria. A case in point is the valve procurement, design, manufacturing, and supply cycle.

Process optimization is a challenging task due to several uncertainties present in organizational systems, which are connected to technological issues, operational circumstances as well as economic-related factors. These complications may lead to uncertainties in the predictions of fundamental performance measures. Between January 2017 and January 2020, 9145 valves were procured by the offshore company. An analysis of the manufacturers and cost combinations indicates huge cost variations over 50% of the valve mean price. These inconsistencies are a result of inefficiencies in the existing process. Thus, the offshore corporation lost cost-saving opportunities of over $ 6 million during the period under consideration.

This study aims to properly assess the type and magnitude of inefficiencies in the company valve procurement activity and explore process optimization tools geared towards their resolution. To actualize this aim, the following objectives have to be met: cut down both man-hour wastage due to non-value-adding tasks and duplication of effort; eliminate processes that introduce unnecessary cost burden with resulting cost ineffectiveness; implement a process improvement capable of controlling variation in valve unit costs to not exceed 30% of valve mean price.

This paper has been arranged in the following pattern: firstly, a review of the valve life cycle, including a detailed process flowchart analysis to reveal cost optimization opportunities, followed by the application of lean sigma principles to capture optimization.

2. Process Optimisation

Optimization is used to control the most suitable value of variables under given circumstances. The major aim of using optimization techniques is to evaluate the maximum or minimum value of a function contingent on the criteria established. According to Schneider and Erney (2008) and Shinde and Kajale (2012), due to necessities imposed in the design of the mechanical parts, implementation and use of the designed products require optimization methods. Process Engineering encompasses the utilization of multiple tools and approaches from systems modeling, mathematics, and computer science. Process engineering undertakings can be categorized into process design, process control, process operations, supporting tools, process economics, and process data analytics (Ignacio & Arthur, 2006). Some of the optimization approaches include topological optimization, topographical optimization, free size optimizations, and shape optimizations.

Several experts in the field of technology have indicated that a key dissimilarity between the technological design procedure and the engineering design practice is analysis and optimization (Hailey et al., 2005; Wang et al., 2018). The optimization phase of the engineering design procedure is a systematic approach using design constrictions and criteria to enable the designer to locate the optimal solution. One of the simplest descriptions for optimization is doing the most with the least possible costs (Gomez et al., 2006). According to Lockhart and Johnson (1996), optimization is the procedure of finding the most effective or promising value or circumstance. Any optimization project aims to accomplish the "optimal or best" design relative to a set of prioritized criteria or constraints. These comprise maximizing influences such as efficiency, strength, reliability, longevity, efficacy, and utilization (Merrill et al., 2007). Engineers optimize when forced to recognize a few suitable design resolutions and then decide which one best meets the necessity of the client.

A couple of works have been carried out to address asset utilization and performance of organizations operating complex processes. Womack et al. (1990) used pull systems, statistical process control (SPC), an emphasis on the prompt resolution of quality concerns, the development of multiskilled personnel, and the usage of worker teams are all examples of typical lean manufacturing best practices. Palmberg (2009) adopted complex adaptive systems (CAS) to develop metaphors for managing organizational processes. His model incorporates a metaphor for an organization as a system, as well as management components and methodologies as it contributes to the continuing debate over managing organizations as CAS. This study examines practice as activity and proposes a framework for considering organizations as networks of activity systems. The method is used in a case study of a high-tech corporation. Key organizational conflicts are identified, and a comparative analysis of three strategy development teams is given. Sterman (2000) offers the following tools for solving problems: causal loop diagrams, stocks and flows, and accumulation.

Edgar et al. (2001) add the following tools to the problem-solving toolbox: Process maps, flow charts, cause, and effect (fishbone) diagrams, process decision program charts, and matrix diagrams. While these tools present the necessary framework for an overall approach, Pyzdek (2003) explores the six sigma approaches that include the “Improve” phase directly related to processing optimization. He explores the entire sigma framework that can only prove successful where the structured approach of the Define-Measure-Analyze-Improve-and-Control (DMAIC) cycle is applied in a disciplined and intelligent manner.

However, Poe and Mokhatab (2016) explained that process optimization is one of the best ways for technically adept organizations operating complex processes to achieve the best asset utilization and performance. The systems thinking approach to process optimization ensures the dynamics of complex interacting systems are modeled in a structured manner that allows for fruitful analysis.

While the six-sigma approach is targeted at reducing process variation, eliminating defects, and improving consistency, the lean manufacturing approach targets eliminating wastes, simplifying processes, and increasing efficiency and speed. Lean six sigma is the blended process improvement methodology defined by the Chevron Corporation as the structured application of both quality and statistical tools to gain process knowledge to make the output metrics safer, better, faster, and lower cost; that methodology is employed to realize tangible business value by systematically improving existing processes. Lean six sigma presents a methodology that ensures we do the right things that add repeatable and reproducible value to processes and systems.

3. Methodology

This study has adopted the lean six sigma methodology which entails the structured application of the internationally recognized DMAIC roadmap (Ramadan, 2022; iSixSigma-Editorial). The aspects reviewed and tools utilized in executing the study are detailed as follows.

3.1. Define Phase

The description of the output of the defined phase has largely formed the content of the first section of this paper. At this phase, the following steps were undertaken: determination of key process, variables and key output to be improved utilizing the input-process-output (IPO) chart, determination of customers affected by the process problem utilizing the supplier’s inputs processes output, customers (SIPOC) chart, interview of key customers to validate problem definition, delineation of scope and limitations of study and prioritization of opportunities utilizing the Pareto Chart (Brown and Mellott, 2016). Gantt chart (Wilson, 2002) for the study progress tracking with defined milestones is shown in Fig. 1 and 2. The charts depict the major inputs and outputs, as well as the required controls and crucial enablers of a system life cycle that is utilized in systems analysis. They define business processes using words rather than code or mathematical formulae to describe each component. In the case of Fig. 1, seven (7) inputs give rise to one output (i.e value unit cost) through the valve replacement and procurement enabler; while eight (8) give an output in the form of the supplier quote in Fig. 2. Four (4) enablers are used in the latter case, with the proposed customers being the National Petroleum Investment Management Services (*NAPIMS*) and the maintenance group.

To progress to a specific problem definition and goal articulation, this study reviewed all 9145 valves procured by the offshore corporation from January 2017 to January 2020. A summary of the valve types procured is given in Table 1.

To identify the distribution of quantity by valve types procured and by the cost of valve types procured, Pareto charts were conducted as shown in Fig. 3 and 4 respectively. According to the Pareto principle, a small number of contributors account for the majority of the influence in any collection of objects that contribute to a common effect.

Following the Pareto principle, it is obvious that optimum optimization will be achieved by concentrating on the top 20% of valve procurements. A review of valve procurements concerning overall value and quantity revealed over 50% of valves procured was the ball valve type. Consequently, we concentrated our review and analysis on the procurement of ball-type valves.

Drilling into ball valves, it was necessary to further determine what valve sizes were most procured in terms of quantity and value. The Pareto chart for the distribution by the quantity of ball valve sizes procured and by the cost of ball valve sizes procured were also conducted (see Fig. 5 and 6). Following the Pareto principle, the following valve sizes were consequently removed from the analysis: 14-inch ball valves, 16-inch ball valves, 18-inch ball valves, and 20-inch ball valves.

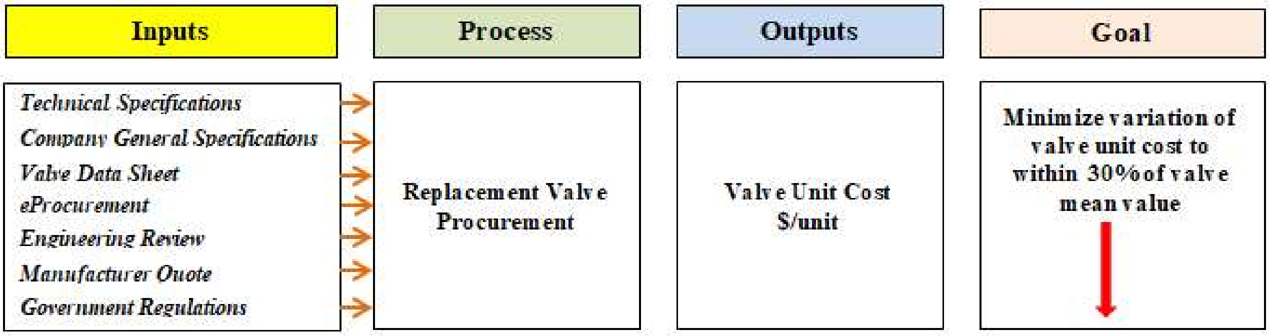

Fig. 1. Input-Process-Output (IPO) chart

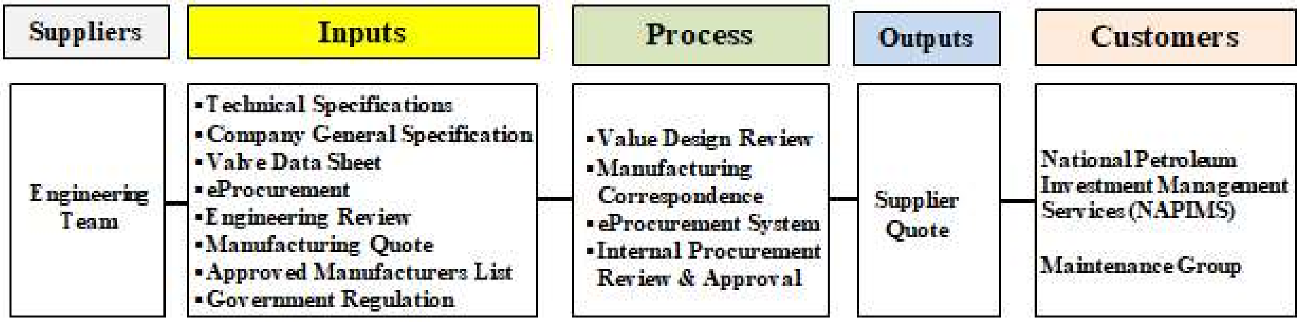

Fig. 2. Suppliers Inputs Processes Output Customers (SIPOC) chart

Table 1. Summary of valve types procured

Category	Quantity Procured	Cumulative Quantity	Cumulative Percentage	Valve Cost	Cumulative Cost	Cumulative Percentage
Ball Valves	4826	4826	53%	$14,896,395.06	$14,896,395.06	51%
Gate Valves	1071	5897	64%	$4,721,014.44	$19,617,409.50	67%
Plug Valves	1014	6911	76%	$2,391,935.76	$22,009,345.26	75%
Control Valves	851	7762	85%	$1,969,352.81	$23,978,698.07	81%
Check Valves	428	8190	90%	$1,890,601.79	$25,869,299.86	88%
Globe Valves	377	8567	94%	$1,846,089.25	$27,715,389.11	94%
Needle Valves	349	8916	97%	$1,635,221.72	$29,350,610.83	100%
Butterfly Valves	229	9145	100%	$104,364.51	$29,454,975.34	100%

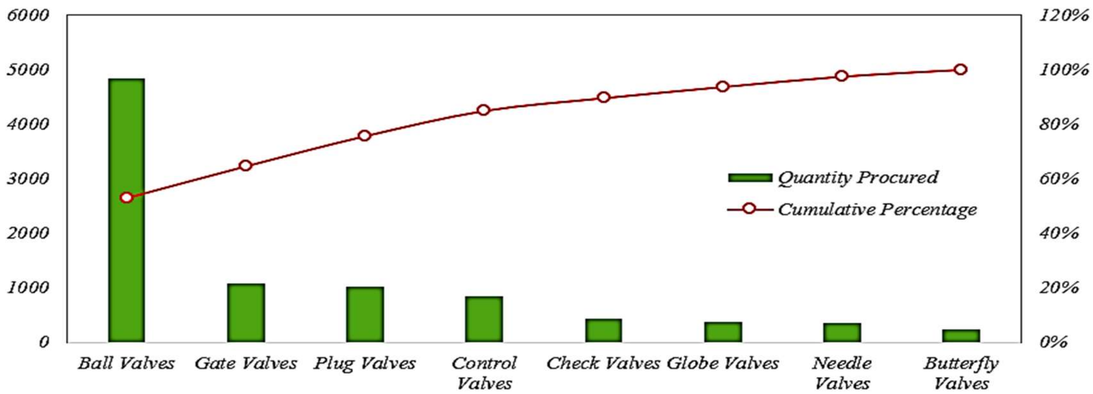

Fig. 3. Pareto chart for the distribution by quantity of valve types procured between 2017 and 2020

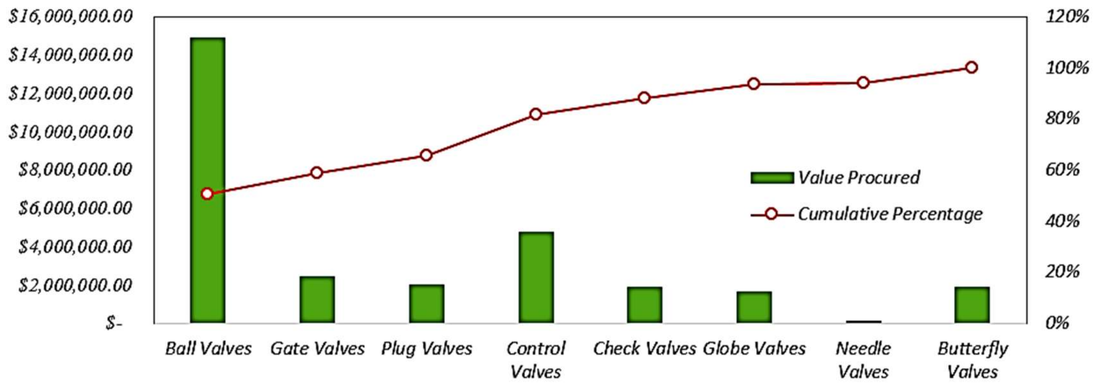

Fig. 4. Pareto chart for the distribution by cost of valve types procured between 2017 and 2020

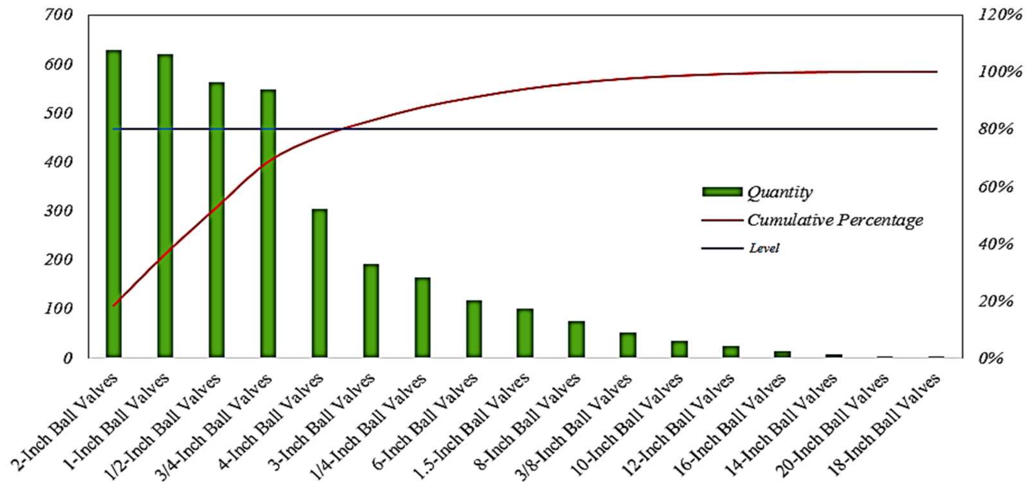

Fig. 5. Pareto chart for the distribution by quantity of ball valve sizes procured between 2017 and 2020

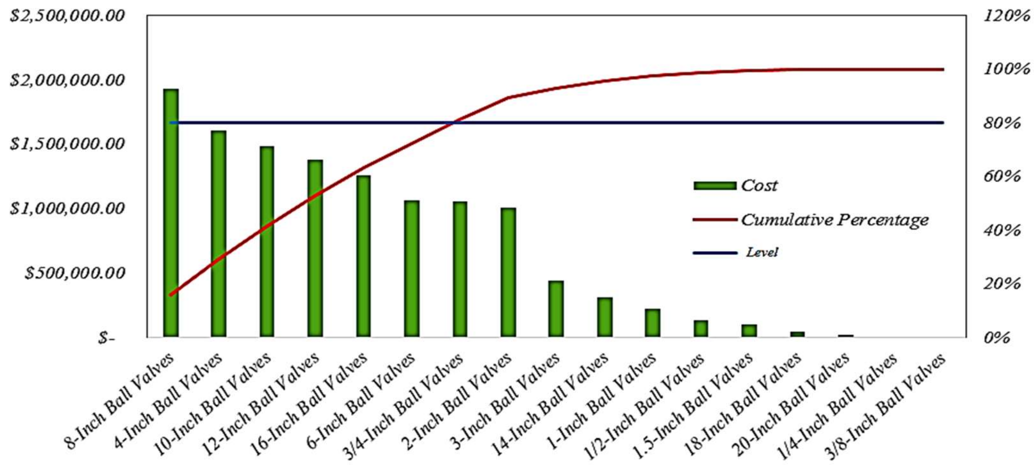

Fig. 6. Pareto chart for the distribution by cost of ball valve sizes procured between 2017 and 2020

3.2. Measure Phase

During the measure phase, the researchers requested for valve procurement data from the Supply Chain Management (SCM) department. The goal of this phase was to address the following: determine the current state of the valve procurement process, process the available data to enable further analysis, determine current process capability utilizing the Microsoft Excel statistical process control add-in and determine, in a broad manner, the current cost of poor quality.

The tools available from the lean six-sigma toolbox at this stage were as follows: process flowchart, histograms, and normal distribution curves. The cost variation measurements for different types of valves are shown in Fig. 7 – 10 with normal distribution curves. The figures depict an increase in the mean value cost as the size of the valve increases, giving a rise in the standard deviation of the distribution.

3.3. Analyse Phase

Here, we focused on the determination of wastes apparent in the process, review of observed cost variations and influencing factors and review of sources of the problem, and identification of root causes. We took out the value-added analysis and root cause analysis utilizing the why tree from the lean six sigma toolbox to accomplish the goals of this phase.

The process flowchart was drawn up with the aid of the SIPOC chart initially documented. This was expanded to show the relationships and interdependencies between various parties in Fig. 11. The process flowchart reveals that the engineering team and supply chain management team are key stakeholders of the process, and key decision loops are integrated into the process with specific decision outcomes. The results of this analysis form the discussion in the next section.

4. Analysis of Results and Discussion

Having established cost variations of significant magnitudes utilizing statistical tools, we turned over to the analysis tools available within the lean six sigma framework.

4.1. Value Added Analysis

The researchers analyzed every step of the process flowchart to delineate steps between the value-adding step, business value-adding step, and non-value-adding step (i.e. waste). The target of the value-added analysis is to ensure business non-value-adding steps are identified and optimized as much as possible and the non-value-adding steps are sufficiently reduced or eliminated. The value-adding steps were determined as those steps that met all three criteria such as: important to the customer in the way he would be willing to pay for it if he had to, the step is done right the first time, and not a re-work step, and the step transforms the item toward completion.

This analysis was performed by assessing what steps met the above criteria as the determined inputs were transformed into the determined output. Table 2 is the summary table for the outcome of this analysis. The process flowchart provided was modified to show the business value-adding steps circled and the non-value-adding steps crossed.

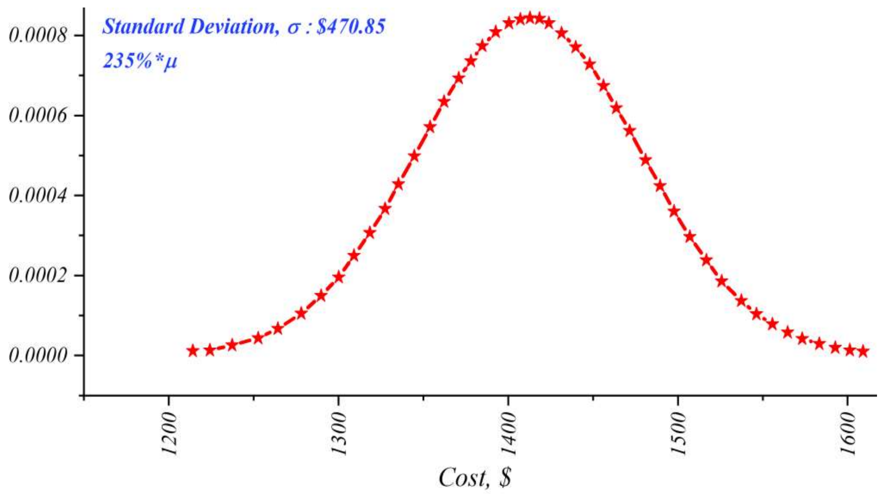

Fig. 7. Cost variation measurements – 1/2-inch ball valves

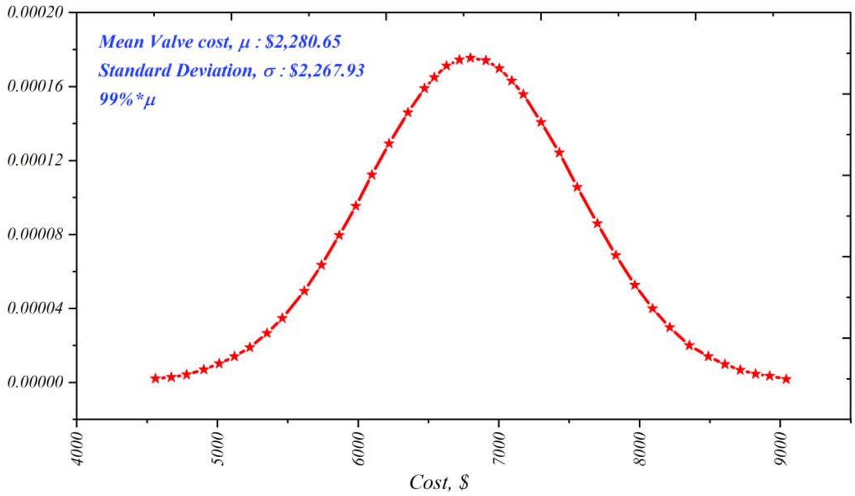

Fig. 8. Cost variation measurements – 3-inch ball valves

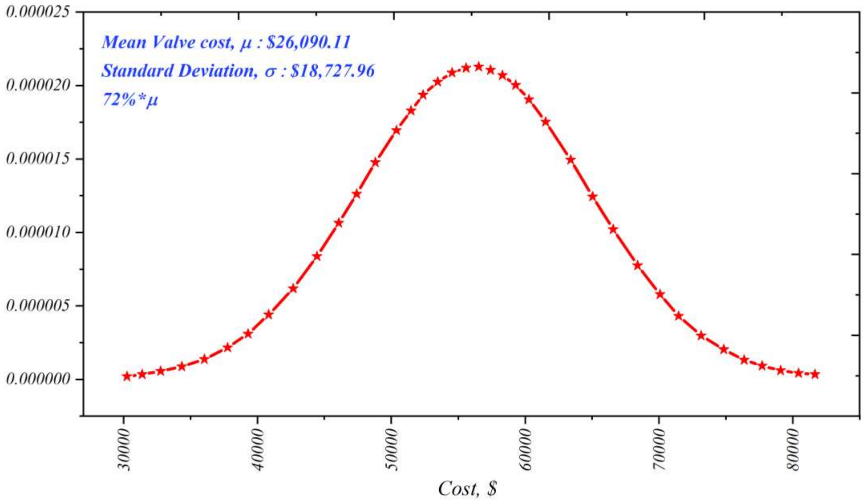

Fig. 9. Cost variation measurements – 6-inch ball valves

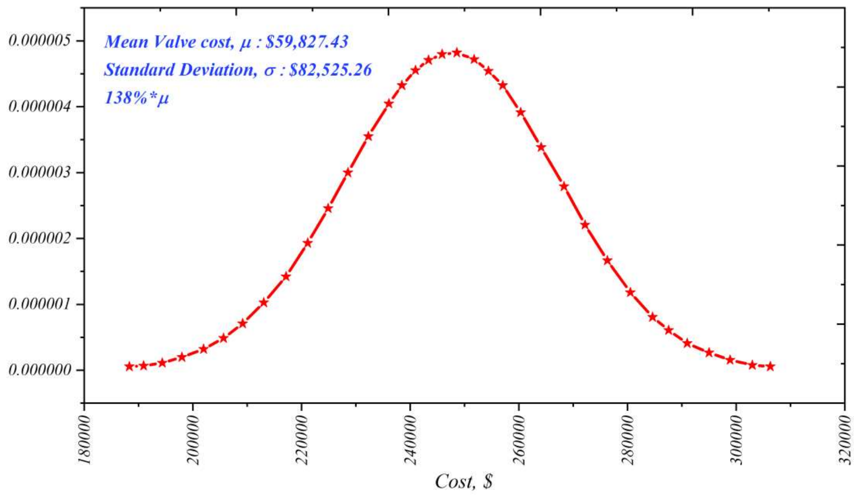

Fig. 10. Cost variation measurements – 12-inch ball valves

Table 2. Value added analysis result

Category	Number of Steps	Percentage Value Adding Steps
Value Adding Steps	10	
Business Value Adding Steps	4	59%
Non-value adding step (waste)	3	(Timing not considered)
Total	17	

The above activities truly transform the customer's request for valve replacement into a valve order and eventual valve delivery. Although the above activity does not directly value-adding to the process itself, it is a necessary step for the business to ensure proper cost control and maximum warehouse inventory utilization. With non-value-adding steps identified, to avoid the negative impact of process upset in the event these steps are outrightly eliminated.

4.2. Root Cause Analysis Utilizing the Why Tree

With the value-added analysis, we established the wastes in the process and recommendations for improvement. Subsequently, we turned attention to the cost variations themselves, and utilizing the Why Tree, drilled down to all potential causes with the end goal of resolving those causes within the control of the corporation. The six sigma 6M method for cause and effect analysis was the reference for the following analysis: machines, methods, materials, manpower, measurements, and mother nature.

The following process inefficiencies were established: a review of valve procurement data established unit cost variation within valves of the same time and size above 50% above the mean unit cost in all cases, and cost variation over 200% was recorded, unnecessary duplication of the process step of contacting valve original manufacturer for a quote by both the engineering team (end-user) and supply chain management team was identified. This step had an associated waste: wait time for valve original manufacturer response. These were obtained from a value-added analysis. Inadequate rigour in price negotiation was established and two root causes were identified viz; inadequate price benchmarking resulting from the unavailability of benchmark data and racketeering resulting from inadequate checks and balances. Increased valve cost was also determined to result from unnecessary features requested during valve specification, in turn resulting from inadequate processes in place to ensure optimum valve selection.

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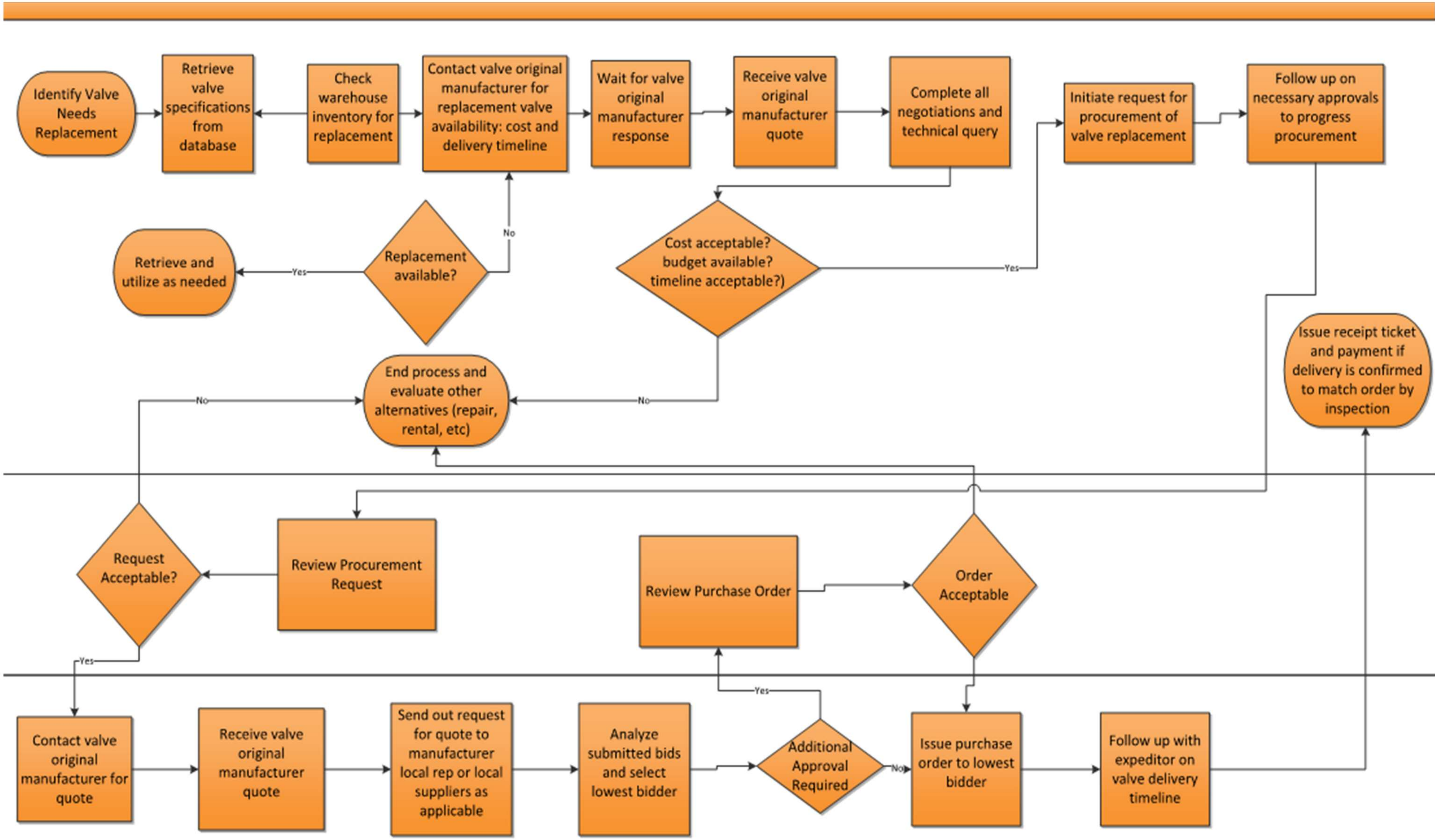

Fig. 11. Process flowchart

The outcome of the process optimization study yielded the following improvement opportunities/ recommendations: all manufacturer engagements must be multi-party (involving the end-user, supply chain group and approvers) to eliminate re-work and checkmate opportunities for racketeering; issuing all valve specifications must be preceded by review of equivalent specifications and alternate manufacturers per the approved manufacturer list; Equivalent specifications and alternate manufacturers to be included as inputs to the supply chain management group to minimize wait time for manufacturer response in cases where there are multiple manufacturers or multiple valve specification options; all manufacturer engagements must be multi-party (end-user, supply chain group and approvers) to reduce opportunities for racketeering; benchmark valve cost data to be created to serve as basis of manufacturer quote negotiation; equivalent specifications and alternate manufacturers to be included in inputs to the supply chain management group to minimize wait time for manufacturer response in cases where there are multiple manufacturers or multiple valve specification options.

5. Conclusion

The study set out to review the valve procurement process as a component of the engineering workflow and provide optimization opportunities. Utilizing the tools of the lean six sigma methodologies, process inefficiencies were identified, and improvement options were indicated. Optimization methods and processes have been deployed in the case study to streamline wastes and costs of valve procurement.

The study is not constrained on thoughts to lean six sigma principles only, but also to the other well-developed methodologies such as systems thinking, logistics and supply chain management, mathematical programming, and decision and risk analysis. Continuous process improvement is imperative in today's business world for continued comparative advantage and competitiveness. Rapid growth in the fields of energy, and technology, among other frontiers, forces a cost-effectiveness culture in global corporations. This study contributes significantly to the literature from the fact that the outcomes of this study are firmly aligned with these trending needs of the industry. While valve procurement is the target of this study, the general principles apply to the Bureau of Public Enterprises, and similar establishments saddled with processes with significant cost impact.

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