Lean Purchasing of MRO Supplies in a Philippine Coal-Fired Power Plant: A Portfolio Thinking Approach

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Abstract

Coal-fired power plants (CFPPs) are capital intensive that continuous operation is a must to recover investments while consistently supplying power and electricity to franchise areas mandated by the government. Though maintenance, repair and operations (MRO) supplies and services play a vital role in ensuring the company's assets perform properly, not much importance is placed in the management of MRO inventory. With multiple MRO line items required for operational continuity, an adaptive ordering, purchasing and inventory control platform will be of utmost importance beyond knowing how many MRO SKUs exist, supplier lead times to fulfill MRO replenishment orders, and depletion rate of MRO-related inventory in order to alleviate the varied problems, including the pandemic disruption, on the presently strained MRO supply chain of CFPPs. This study employed a lens of change in this regard, with focus on addressing recurring MRO-related operation stoppages, outdated Min-Max policy and centralized procurement processes among other recurring MRO inventory management issues of a Philippine-based CFPP. This was approached with the adoption of Portfolio Thinking as a procurement strategy and Lean MRO Purchasing as a buying platform model that can be emulated by engineering and utility firms with massive mechanical and electrical systems.

Keywords
Coal-Fired Power Plant, MRO supplies and services, Portfolio Thinking, Lean MRO Purchasing

1. Introduction

Coal-fired power plants (CFPPs) generate 38% of the world's electricity, more than any other power source, and are predominantly used in developing countries (World Coal Association, 2015). The Philippines currently has 50 coal-fired power plants, twenty-four (24) of which form the grid in its biggest island of Luzon and the rest are found in the Visayas-Mindanao grid (Department of Energy, 2020). Considered as one of Asia's fastest growing economies and with a population increasing at an annual rate of 2.3%, it is faced with the challenge of increasing energy demand which currently has averaged 55.7 Million Tons Coal Equivalent (Kessels & Baruya, 2013, March). This poses the challenges of ensuring continuity of operations, maximization of efficiency, capacity additions with new plants, and incorporating sustainability in the overall performance of CFPPs.

For existing power plants, management focus is placed on operational cost-efficiencies, asset management, ecological responsibility and financial sustainability. Literature is extant on capital or fixed asset management and only a handful of studies, if none, focused on inventory management of CFPPs. Fixed asset management tracks the equipment and supplies that a company uses internally to run the business and not for sale, while inventory management tracks the stock that comes in and goes out of a company's stores and warehouses. Asset management also deals with ensuring asset value and availability. But inventory management focuses on the flow of items a company sells or parts it uses to make goods. One of the goals of inventory management is to find the right balance of stock to satisfy customer

demand or, in a power plant environment, supply production lines. In other words, inventory management and asset management both track a company's property and greatly helps in improving the profitability of a firm (Jenkins, 2020).

Maintenance, Repair, and Operating (MRO) Supplies are part of inventory and are treated usually as line items kept in stock for the purpose of upkeep, repair and maintenance of the facility, machines & equipment, production line and capital asset used in the value creating process that generate sales. Traditionally, MRO comprises only 10% of the usage value of the total inventory of a firm but make up for 50% of the number of stock items due to the wide variety of items ranging from cleaning implements to office supplies, from maintenance parts to industrial equipment, and from consumables to technical components. Its importance is underscored, at times, that a stock out of an item critical to a process or an unscheduled machine repair will mean long downtimes, if not plant shutdown (Murray, 2019).

With the sheer number of MRO line items that have to be monitored for replenishment orders, the min-max method of inventory control is applied as one of the earliest automated stock replenishment methods under an enterprise resource planning (ERP) operating environment which most power plants have today. The "Min" value represents a stock level that triggers a reorder and the "Max" value represents a new targeted stock level following the reorder. The difference between the Max and the Min is frequently interpreted as the Economic Order Quantity (Vermorel, 2014). The appeal of the min-max approach rests on its extreme simplicity of implementation and on the assumption that demand is steady and constant. The automatic replenishment ordering method is so basic that it does not capture the idiosyncrasy of the following: timing or season that a supplier produces the required component of the plant; the lumpy demand of some items that may have no requirement at one point and may have a huge quantity needed at another point in time compared; supply chain variability of most MRO items; and the need for ordering a group of items at a certain time and at times with a single supplier or multiple suppliers that are dispersed geographically among other multi-item constraints. Also, manual intervention is necessary to respond to variability in replenishment time (Renard, 2006, September).

This paper attempts to address the drawbacks of the min-max method since it is geared towards simplicity rather than correctness and a case study on a Philippine-based CFPP is chosen to apply a more appropriate MRO inventory control platform, specifically for MRO items, which was made a focus of the study. With the pandemic disruption and the need to address the increasing repairs & maintenance (R&M) load of said 5-year old power plant, it is aptly of great interest to seek new ways of managing MRO inventory and ultimately move away from the min-max method to a path destined to improve MRO replenishment in an adaptive manner for the long term.

The disruptions caused by the coronavirus pandemic brought to fore supply chain weaknesses in the Philippines (Navarro, as cited by Almonte, 2020) significantly impeding the flow of goods across the supply network, with the supply capacity to satisfy the surging demand became insufficient due to travel bans, limited work force, lack of raw materials, and other bottlenecks choking the production and movement of goods (Bunyag, 2020). The coal-fired power plant under study, with the sheer number of its MRO line items and the increasing R&M needs, becomes highly vulnerable to stock outs that will lead to costly operational stoppages and monetary losses. These repercussions highlighted, first the fallibility of the Min/Max inventory approach with respect to the complex nature of MRO supply chain and second, the need of management to put in place a long-term strategy for MRO replenishment, being a critical factor in ensuring continuity of the power plant operations.

In this regard, there is a need to craft a better MRO procurement platform to adapt to the new normal and a more appropriate purchasing program to adapt to the power plant's nature of R&M requirements and MRO replenishment orders. Literature is extant in the use of Portfolio Thinking and Lean MRO to improve cost-effectiveness and fulfillment responsiveness mostly for manufacturing environments but few studies focused on MRO concerns of power plants, operations cost-efficiencies of which were mostly emphasized then.

In a September 1983 Harvard Business Review issue, Peter Kraljic stated, "Purchasing Must Become Supply Management" which was considered then as the bedrock of Portfolio Thinking. An approach usually taken in financing in order to manage investment options for growth and value maximization, portfolio thinking in MRO inventory refers to making procurement decisions on a higher classification level rather than on individual line item, considering the wide and varied assortment of MRO SKUs. This makes it more strategic than operational and one that approaches the MRO issues holistically in view of the overall objective of operations continuity and cost-effectiveness (Mironov, 2015).

Lean MRO enables MROs to eliminate nonproductive or unnecessary tasks from their process-event critical paths, improve maintenance team performance, increase the yield of scheduled maintenance actions, and increase supply chain effectiveness (Nagalla, 2014). This approach is anchored on the Toyota principle of eliminating non-value adding wasteful activities for a smooth flow of materials and supplies at the pull of the customer, employing tools and techniques to design, organize, and manage operations, support functions, suppliers, and customers (Mercer, 2005).

Combining portfolio thinking and lean MRO as an adaptive ordering and inventory platform would be the main discussion in addressing not only the MRO procurement strategy need of the coal-fired power plant but also the need to solve its frequent MRO line item stock outs that led to significant operational stoppages and huge monetary losses.

The power plant under study has 14,031 MRO line items that comprised 83.8% of the company's inventory. In the year 2020, the CFPP encountered 29% MRO stock out, including 426 items, which resulted in eight (8) major operational stoppages and opportunity losses of Php62.6M or US$1.3M. Insufficient MRO inventory, planning shortcomings and unreliable supply sources contributed to poor plant performance, hence a holistic and strategic view of MRO inventory management needed to be in place in the light of the new normal and the need to ensure cost-effective and continuous power plant operations.

As such, the study aimed at achieving the following objectives:

1. To assess the current MRO inventory policy and buying practices of the company in relation to the firm's operating priorities and supply ecosystem;
2. To determine the root causes of the MRO-related operations issues and significant factors that can be addressed by portfolio analysis and lean purchasing; and
3. To provide a strategy framework to implement an improved MRO inventory platform to eliminate MRO stock outs, overstocking and line item failures.

2. Methodology

The CFPP chosen as a unit of analysis is located in Misamis Oriental province in the southernmost part of the Philippines and is a 5-year old US$625M power plant supplying 405MW to the Mindanao power grid.

A problem-solving approach was taken to look into the root causes of MRO stock outs and to identify the areas of improvement using the SIPOC view of the supply chain to include the upstream chain players which are considered important in developing a strategic solution to the MRO concern. A process mapping of the internal supply chain of the CFPP was conducted to determine the delays and bottlenecks of the re-ordering, purchasing and supplier delivery processes that significantly contributed to the problem.

Root cause finding and inventory control tools of pareto analysis, cause-and-effect or fishbone analysis, swim lane diagram, portfolio analysis for new inventory classifications, strategy matrix using Kraljix method, and cost-benefit analysis were employed in coming up with the detailed factors for consideration as shown in the conceptual framework below that served as the logic of the study:

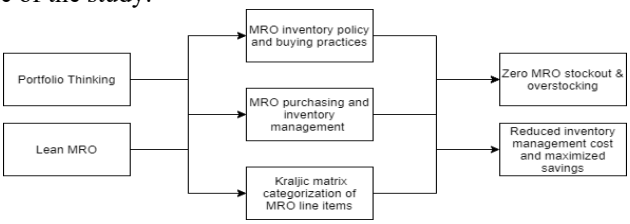


Figure 1: Conceptual Framework

The above framework is anchored on the marriage of portfolio thinking and Lean MRO which provide a better platform of implementing inventory management strategy and procurement tactics to eliminate stockouts and overstocking which consequently will reduce inventory management costs and maximize opportunities to save.

In summary, the overall aim of the study was to come up with a new MRO item classification based on the portfolio analysis and the Pareto results and a lean MRO purchasing approach that requires a procurement strategy from which lean tactics would be developed. This would be accomplished with a case study of a CFPP with actual losses arising from MRO-related problems of stock outs, long supplier delivery lead times, poor planning without real time information, and an adaptive look-ahead approach to respond to the many changes in both the operational demands and supply chain environment.

3. Results and Discussion

The existing MRO inventory classification shown in Table 1 and stock inventory performance analysis shown in Table 2 based on metrics such as stock turnover, average inventory and inventory write-off were the bases in assessing the adequacy of planned stock levels versus actual demand/usage and in categorizing the purchasing transactions vis-à-vis MRO classifications of low-to-high value or local-to-imported or off-the-shelf to customized items with corresponding lead times and sources of supply.

Table 1. Items to parts usage rate.

Item	Grade	Criteria
Number	High	More than 10
	Medium	Between 2 and 10
	Low	Only one
Redundancies	High	No redundancy
	Medium	Simple redundancy
	Low	Multiple redundancy

Table 2. Items to maintenance parts holding costs.

Item	Grade	Criteria
Space required cost	High	More than 3 standard locations per unit
	Medium	Up to 2-3 standard locations per unit
	Low	No more than 1 standard location per unit
Inventory service cost	High	More than 30% unit-price
	Medium	Between 30% and 5% unit-price
	Low	Less than 5% unit-price
Inventory risk cost	High	Obsolesce or deteriorate easily
	Medium	Obsolesce or deteriorate a little
	Low	No obsolescence or deterioration

This approach in the categorization and classification of MRO items according to the criteria indicated above identified the current reference for different classification and types of inventories, safety stocks and selective inventory control items, on which the Min-Max method was based and used from the very start of CFPP operations. This came to the attention of management which required a drastic and innovative approach of MRO supply management to eliminate the actual 29% MRO stock out rate. To provide a holistic solution to said stock out problem the SIPOC diagram below (Figure 2) was deemed as the overarching of this study:

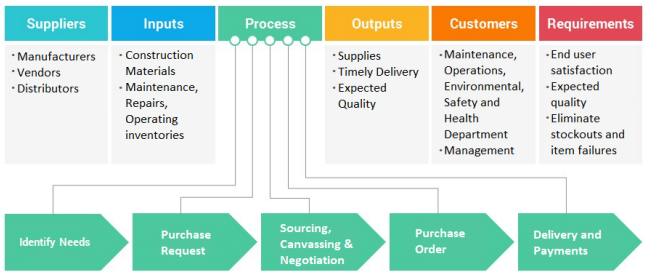


Figure 2: SIPOC Diagram for CFPP MRO Supply

The coal-fired power plant's purchasing process involved a requisition as a trigger in MRO ordering based on the traditional Min/Max method that set minimum inventory and a maximum inventory quantities for each MRO item. The requisition is issued when the inventory count reached the minimum level and a corresponding purchase order is prepared after verification of specifications and canvassing from accredited suppliers and is then placed after CEO approval after endorsement from the Accounting group. The following procurement process flow chart and swimlane diagram provided a reference in a close scrutiny of the major activities that significantly contributed to the problem,

such as but not limited to delays and bottlenecks from requisition preparation thru negotiation and the approval of the purchase order up to the receipt of supplier delivery and payment. The process where SCM encounter issues and challenges are identified in the swimlane diagram below and discussed the major causes and proposed solution of the bottleneck.

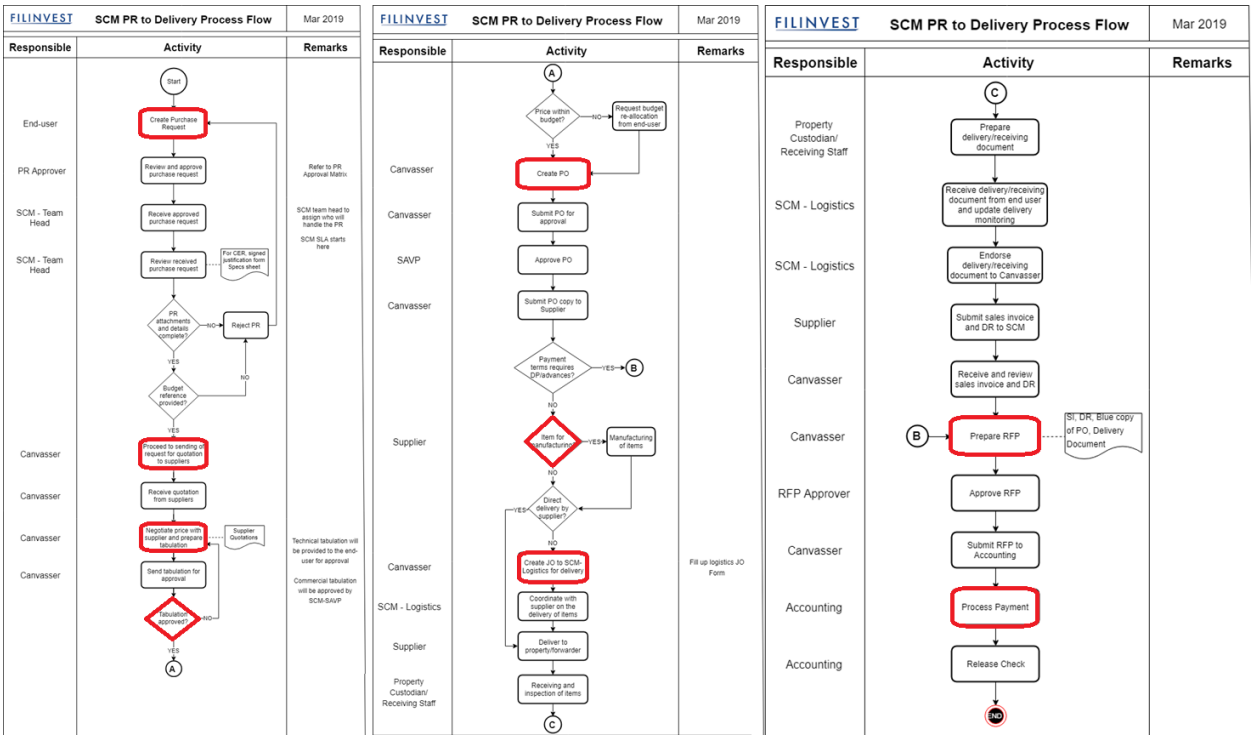
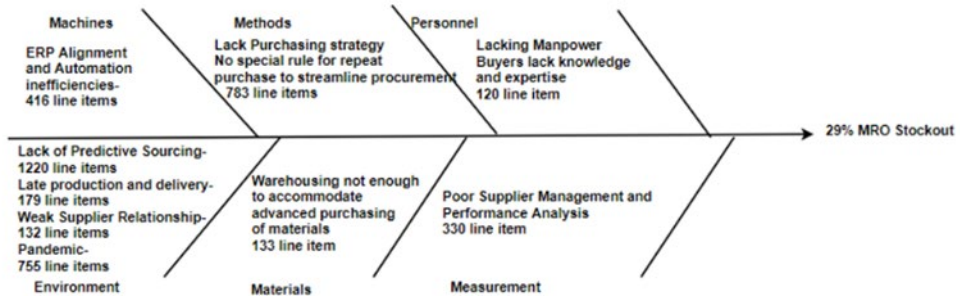


Figure 3: Coal-Fired Power Plant Procurement Swimlane Diagram

A root cause analysis yielded the Fishbone diagrams for the 29% MRO stock out rate and the 426 line item failure problems (shown in Figures 4) and the following causes were highlighted: ERP and Automation Inefficiencies; Lack of Purchasing Strategy; Inadequate Manpower and Predictive Sourcing; Poor Warehouse Management; and Poor Supplier Management and Supplier Performance Analysis.



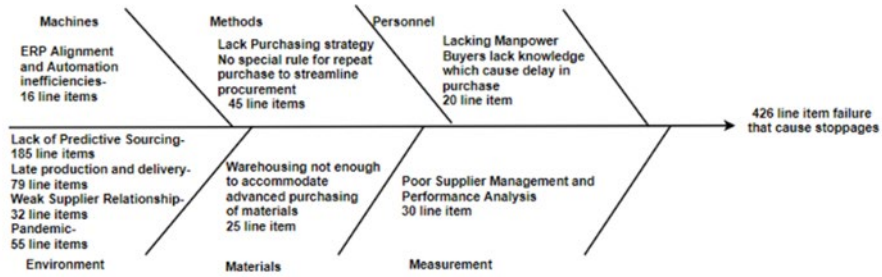


Figure 4: Fishbone Diagrams for the CFPP stock out and MRO line item failure

Alternative courses of action were then generated to directly address the root cause above and a summary is tabulated accordingly below (Table 3).

Table 3: Tabulated summary of major causes and proposed solutions

Major Causes	Proposed Solutions
A **Safety stock level that is too low** to cover the risk profile of an item	**Proper and accurate Forecasting by using Predictive and Prescriptive Analytics with collaboration with Operations and Management** A correctly designed Inventory Management System calculates the recommended order quantity from the arithmetic result of key inputs such as the forecast, lead time, planned replenishment cycle, and safety stock. For this reason, while the buyer may have a useful perspective of the requirements, the buyer is not the person who should be deciding how much to order.
Late delivery by a supplier. You ordered enough, but your supplier did not deliver when expected or only delivered part of your order.	
Using the wrong lead time. A supplier lead time that is shorter than the time it takes for the supplier to deliver will result in the delivery arriving later than planned. The consequence of this is that the re-order level will be too low	
Under ordering – result of a poor ordering system and poor decision making. Many businesses decide how much to order at the point of ordering.	**Consider Advancements In Technology To Improve The Supply Chain** Implement a system and other technology that streamlines the supply chain and improves communication and value to the customer. To drive further value, look for technology providers in the logistics and supply chain space who can integrate these systems together
Poor Supplier Management which is reason not to be prioritized, and encounter items with quality issues and not given favorable price	**Strengthening of Supplier Relationship** Supply chains rely on strong relationships with suppliers, manufacturers, logistics and other third parties. Although the governance of that relationship will be captured in contracts and service level agreements, excellent day-to-day relationship management will increase goodwill and help you resolve issues. Clarity and communication through the supply chain will help supply chain managers and other organizations like suppliers and end users.
The **supplier is refusing to deliver** due to a credit hold on your account from non-payment on your behalf.	**Fix payment Issues** Replacing traditional process and practices such as long routing of documents for checking and for signature.

The above proposals to the major root causes, though general in nature, would be more meaningful in MRO supply management by revisiting the current MRO Item Classification in order to get a basis for putting in a portfolio thinking approach that would certainly result to a set of more appropriate tactical procurement and purchasing tactic considering the nature of the items per classification and the annual inventory value (see Table 4 below) consistent with the above proposed solution solutions.

Table 4: MRO Item, Class, Description, Count and Cost

MRO Class	Description	MRO Count	MRO Cost
CNT	Construction	172	17797118.03
EIC	Electrical Consumables	3	7692.857143
ELC	Electrical	1188	105794345.9
ESH	Environmental, Safety, and Health	568	24741332.2
HSE	Health Safety Equipment	5	1755.178586

IAC	Instrumentation & Controls	561	70207343.25
ICT	Information, Communication, and Technology	303	48087925.76
LAB	Laboratory	1420	19960136.82
MCH	Mechanical	4571	185892922
OFC	Office	3789	80309461.3
OMP	Operations-Main Plant	602	22697695.88
PHK	Pantry and Housekeeping	642	1498150.859
VEH	Vehicle	207	15122526.41

In line with the review of item classifications, the portfolio thinking approach would require a new typology of item classifications according the importance of MRO item usage relative to CFPP operations continuity and to the sourcing, procurement and purchasing nature of the MRO items which embodied the concept of portfolio management, that is, a proactive approach, and not a requisition-based purchasing process in the replenishment planning of MRO line items that will require a new grouping or classification of items considering the strategic dimensions of business value and supply market complexities. The following chart (Figure 5) summarizes the new classification approach:

Figure 5: Typology of New MRO Classifications Using Portfolio Thinking

To populate the types of items into the new MRO Item Classification above, a Pareto analysis (see Figure 6) was conducted to determine the grouping items according to value, which is one of the strategic dimensions of the new MRO classification using Portfolio thinking approach together with the nature of sourcing, procurement and purchasing of the different MRO items in each group.

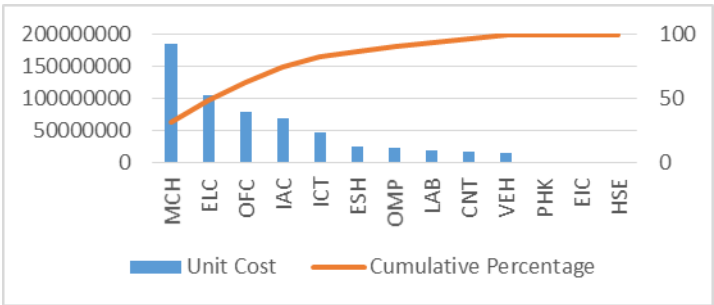


Figure 6: Pareto Diagram of MRO Item Classes

Based on the above, a re-classification of the MRO Item Classes was done with the following results (Table 5):

Table 5: New MRO Classification Table

MRO Class	MRO Count	MRO Cost	Cost	Space Required	Portfolio Matrix
CNT	172	17797118.03	Low	Low	NON CRITICAL
EIC	3	7692.857143	Low	Low	NON CRITICAL
ELC	1188	105794345.9	High	High	STRATEGIC
ESH	568	24741332.2	Medium	Medium	LEVERAGE
HSE	5	1755.178586	Low	Low	NON CRITICAL
IAC	561	70207343.25	High	High	STRATEGIC
ICT	303	48087925.76	High	Low	NON CRITICAL
LAB	1420	19960136.82	High	High	LEVERAGE
MCH	4571	185892922	High	High	STRATEGIC
OFC	3789	80309461.3	Low	Low	NON CRITICAL
OMP	602	22697695.88	High	High	BOTTLENECK
PHK	642	1498150.859	Low	Low	NON CRITICAL
VEH	207	15122526.41	Low	Low	NON CRITICAL

The MRO Classification Table, with cost and space required, helped in identifying and assigning the different MRO Item Classes to each of the new MRO portfolio groups as shown in the new MRO Portfolio Matrix (Table 6) below. Also included in the matrix are the different procurement strategies and lean purchasing approaches that prescribed the corresponding tactical actions per MRO Item Class in every portfolio grouping.

Table 6: MRO Portfolio Matrix with MRO Item Class and Corresponding Strategy, Tactics and Actions

Leverage Items		Strategic Items	
MRO: ESH LAB	**Strategy:** Promote competitive bidding to maximize returns by taking advantage of market cycles and trends and increasing number of qualified suppliers. **Tactics:** Purchase Agreement Stocking **Actions:** Use industry standards in specification and pricing Purchase directly for the hazardous and indirectly for non hazardous with sufficient lead time	**MRO:** ELC IAC MCH	**Strategy:** Form partnership with key suppliers and increase their role in the supply chain process to ensure production quality and supply continuity. Develop a streamlined procurement process in-house to ensure automatic replenishment of strategic items. **Tactics:** Supply Agreement Plant Inspection-OEM 1-3 years Purchase Plan **Actions:** Negotiation & Factory visit Secure stocks and avoid production lead time Purchase directly from manufacturing Predictive Ordering & Maintenance

Non-Critical Items		Bottleneck Items	
MRO: CNT EIC HSE ICT OFC PHK VEH	**Strategy:** Reduce procurement and inventory effort while simplifying the acquisition process of the products. Introduce alternative method of payment and allow stockless procurement. **Tactics:** Standardization Consignment, Credit Line **Actions:** Streamline PR-PO Process Establish buying schedule (monthly, quarterly, yearly) Purchase within the area (distributors/ trader)	**MRO:** OMP	**Strategy:** Increase number of suppliers or establish an in-house development capacity for bottleneck items to avoid slowing down the supply chain process. **Tactics:** Fabrication Find alternative since item is mostly phased out Widen specification **Actions:** Sourcing Purchase directly from manufacturing

A cost-benefit analysis was made in case of a scenario with a MRO stock out or line item failure in any of the bottleneck or strategic portfolio items that can cause the power plant a 7.825M stock out penalty loss, computed as an actual average opportunity loss based on the problem statement earlier mentioned. Results showed that the investment cost can easily be recovered as shown in Table 7 below.

Table 7: Tabulated Summary of Cost–Benefit Analysis

	Investment in Portfolio Implementation (in Pesos)	**Areas of Improvement Addressed by the MRO Portfolio Matrix**
Training & Education	P 200,000	Lean Purchasing and Negotiation for Purchasing Strategy Execution
Additional Personnel	P 780,000	Warehouse Management and Lack of Inventory Management Personnel
Application Software Support	P 600, 000	ERP and Purchasing Support; Automation for Predictive Sourcing
Increase in Safety Stock	P1,200,000	Re-start of the Inventory Management System and initiation of the Portfolio approach leading to Supplier Performance Management
Total	**P 2.780,000 (total investment)**	**P7,825,000 (average stock out cost saving)**

From an operational standpoint, the benefits of using portfolio thinking far outweigh the costs of implementation with the elimination of risks associated with and the ensuing problems from the Min/Max method.

4. Conclusion

The main goal of this study to come up with an adaptive purchasing and inventory strategy to avoid MRO stock outs, overstocking and line item failures was met and addressed concerns on the effects of the pandemic. The analysis done on combining the Lean MRO and Portfolio Thinking approach helped in appropriately classifying the MRO items, ultimately leading to a solid portfolio thinking MRO sourcing framework that will allow the Philippine coal-fired

power plant company to properly allocate its limited resources on MRO procurement according to the nature of items given the business value of MRO Items and the complex nature of the supply market. This practice with a supply chain thinking approach involving suppliers and engaging in lean purchasing programs complementing the company's procurement strategy are expected to yield overall long term gains.

Results of the study helped simplify the complex interplay and eliminate the MRO stockouts including line item failures. By applying these Lean principles to procurement and purchasing processes, businesses will experience multiple benefits throughout the supply chain. The discussion and results suggested that a portfolio approach would be the most effective of eliminating MRO stockout.

The study pointed out that Portfolio Thinking is relevant because there is no one approach or strategy that applies to all purchasing situation. Each have different tactics and process especially in terms of approval matrix, process flow, ERP and automation and Agreements, Standardization and Partnership. After identifying each portfolio group, non-value adding process steps in purchasing can be eliminated and building supplier relationships can be built by utilizing lean tools and employing the procurement strategy of portfolio thinking in the coal-fired power plant company.

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Biographies

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Marvin I. Noroña is currently a faculty member at the Mapua University School of Industrial Engineering & Engineering Management and School of Graduate Studies. He earned his BSIE and MBA degrees from University of the Philippines and is completing his dissertation for a Doctor in Business Administration degree at the De La Salle University. Apart from research and teaching, he is into management consulting and training in the areas of sustainability, supply & operations management, production & service systems improvement, strategic planning and management, lean six sigma, and design thinking.