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Using TRIZ to Improve the Procurement Process of Spare Parts in the Taiwan Navy

Chia-Nan Wang ^{1,2,*} , Ming-Hsun Lin ^{1,*}, Chung-Jen Huang ^{1,*}, Ching-Chiu Huang ^{1,3} and Ruei-Yuan Liao ⁴

¹ Department of Industrial Engineering and Management, National Kaohsiung University of Applied Sciences, Kaohsiung 80778, Taiwan; wakeup1129@pchome.com.tw

² Department of Industrial Engineering and Management, Fortune Institute of Technology, Kaohsiung 83158, Taiwan

³ Naval Maintenance and Repair Command Acquisition Management Unit, Navy, Kaohsiung 81346, Taiwan

⁴ Institute of Human Resource Management, National Sun Yat-sen University, Kaohsiung 80424, Taiwan; n954050002@student.nsysu.edu.tw

* Correspondence: cn.wang@kuas.edu.tw (C.-N.W.); newlife711365@gmail.com (M.-H.L.); cjhuang@gm.kuas.edu.tw (C.-J.H.); Tel.: +886-7-381-4526 (C.-N.W.)

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Abstract: The Naval Maintenance and Repair Command Acquisition Management Unit (NMRC-AMU) of the Taiwan Navy suffered from poor stock control of spare parts and inadequate modification of requested items and manufacturer/part codes during recent years. Therefore, the purpose of this study is to investigate core categorization, coordination, and procurement (CCP) problems, to formulate feasible solutions and then to improve the CCP performances of spare parts in NMRC-AMU. The Teoriya Resheniya Izobreatatelskih Zadatch (TRIZ) method was applied to solve this issue. A problem hierarchy analysis (PHA) was first used to identify the core problems. Then, the 40 principles were used to determine the ideal improvement solution and formulate a solution strategy that simultaneously simplified CCP processed and enhanced the correctness of procurement tasks, thereby elevating CCP efficiency, supporting the Taiwan Navy repair missions, and satisfying fleet maintenance and servicing demands. The results indicated that total 6925 requests for coordination and procurement were submitted. Of these requests, 4366 requests had been completed (with total 102 cases), and the CCP efficiency is 63.0%. After improvement by this study, a total of 4529 items were submitted and 3592 executed items were completed (with a total of 172 cases), and the CCP efficiency is 79.3%. The improvement percentage of the CCP efficiency and completed cases are 30.6% and 68.6%, respectively. The performances are good and the TRIZ could be applied for other military forces.

Keywords: TRIZ; procurement; efficiency; categorization; supply chain

1. Introduction

The stability and foreign affairs of various countries in the Asia-Pacific region have been severely affected by the increasing disputes over the sovereignty of several islands in the South China Sea and the East China Sea, in addition to the conflict between North Korea and South Korea. Among which, the Senkaku Islands dispute and the territorial disputes in the South China Sea pose the greatest threat to Taiwan's national security. Therefore, the Taiwan Navy should allocate an adequate budget for upgrading its defenses, strengthening its offshore patrol capability, enhancing combat readiness training, and acquiring new weapons and equipment to ensure national security and sovereignty.

China shows no intention of renouncing the use of military force against Taiwan. Although cross-strait tension has alleviated in recent years, China has steadily increased its defense budget

annually, facilitating an exponential growth in military development and weapons/equipment research. Therefore, the Chinese military deterrence strategy poses an immense threat to Taiwan's national security.

The proper functioning of a navy fleet hinges on maintenance and servicing. This is particularly true for the Taiwan Navy, in which navy fleet have been in service for over two decades. Spare parts for outdated equipment are often difficult to acquire because of discontinuation or manufacturer relocation. The fleet and equipment still need to sustain operations and maintenance for national security issues. The sustainable operations for parts procurement and maintenance are extremely important for the navy. However, procurement processes are often inefficient because of poor stock control of spare parts, failure to modify part names and codes adequately, and erroneous manufacturer/part codes. The categorization, coordination, and procurement (CCP) processes of the Taiwan Navy are long and tedious and often hinder the acquisition efficiency of spare parts. Therefore, to improve and to establish sustainable regulations are necessary for sustainability for Navy maintenance. The coordination and procurement efficiencies of spare parts directly affect the conditions of navy fleet and relevant equipment. Improving the existent CCP processes and the accuracy of procurement operations can enviably facilitate the coordination and procurement of spare parts and, by extension, significantly accelerate the sustainable maintenance for acquisition of spare parts. Procurement activities directly reflect government ability and image. The military should manage these sensitive, complex, and professional activities effectively to achieve defense requirements by using minimal resources.

There are already successful CCP experiences and participation of the private sector [1]. However, none of studies put attention on CCP of the navy. Currently, the Taiwan Navy primarily acquires spare parts through military procurement, overseas procurement, and domestic procurement. The purpose of the present study was to identify the core problems in the domestic coordination and procurement approach adopted by the Naval Maintenance and Repair Command Acquisition Management Unit (NMRC-AMU) by using a Teoriya Resheniya Izobreatatelskih Zadatch (TRIZ) contradiction matrix. Subsequently, 39 parameters and 40 principles were used to identify the ideal solutions or approach to improve the CCP processes, correctness of procurement tasks, and acquisition efficiency of spare parts, thereby effectively supporting Taiwan Navy repair missions and fulfilling fleet maintenance and servicing demands.

The rest of this paper is organized as follows: Section 2 includes a literature review about the CCP. Section 3 details the applied methodology of this study. Section 4 mentions the case study and results analysis. Section 5 offers conclusions and suggests future research directions.

2. Literature Review

To accurately review the regulations on procurement of military goods [2] proposed by the Ministry of National Defense (MOND) in 1995, and relevant material requirements, integrate professional and military repair capabilities, and establish a suitable spare parts inventory, the military endeavors to clarify job specifications, fulfill requirement reviews, plan the acquisition of spare parts in advance, punctually attain the goals proposed in annual plans, and reduce unplanned maintenance and repair tasks. In addition, the military is actively establishing various management information systems to facilitate the coordination and procurement of spare parts by using a limited budget, thereby achieving its goals of supporting annual combat exercises and training missions and improving resource allocation efficiency [3].

According to the regulations on procurement of military goods [2] announced by the MOND in 1995, independent repairing and manufacturing, intermediate maintenance, regular maintenance, and shipyard repair plans should be formulated on the basis of the recent two dry-dock shipyard repair sessions of each ship. Repair workshops are responsible for establishing the operating cycles for their docks to facilitate maintenance and repair. The workshops should also plan their maintenance

schedules in accordance with the different maintenance work periods stipulated in the maintenance planning system [4]. The procedures are presented below.

1. The NMRC shall collate a list of spare parts, recruit relevant professional personnel, confirm the requirements of various departments, and ensure the integrity of the technical documents 26 months prior to the target year. The NMRC shall share the review outcomes with relevant departments for department review, revision, and confirmation, thereby ensuring that the departments complete annual reviews in accordance with the annual plan.
2. The NMRC shall convene various preliminary and secondary review units to participate in a joint review 24–25 months prior to the target year to review the revised requirements of the various departments. Final requirements are confirmed according to the review outcomes, serving as a basis for subsequent acquisition operations.
3. The NMRC shall review the inventory management of existing stock and organize spare part categorization and procurement in accordance with the outcomes of the joint review 22 months prior to the target year.

Preliminary review units shall verify the requirement review outcomes and resource consumption conditions of their departments in the previous year to determine the support and usage rates of resources, as well as the rate of which required resources were unprepared or unavailable. This facilitates identifying related problems, analyzing strategic actions, and conducting acquisition operations in the following year three months prior to the target year.

Most and most researchers put attend on procurement process to improve performances of supply chain. Wang et al. [4] provided an integrated approach for selecting green logistics providers. This completely integrative methodology has the potential to provide the best decision-making strategies for finding suitable collaborative partners who are able to meet the sustainability requirements in most economic and environmental areas. A quantitative evaluation method [5] was provided to measure the green degree for the Chinese government for different products of the same use function with an indicator system established, which includes fundamental indicators, general indicators, and leading indicators. It shows that the green extent evaluation system can help classify the different products by evaluating their environmental performance, including structure and connection technology, selection of materials and marks, prolonged use, hazardous substances, energy consumption, recyclability rate, etc., and price, so that it can help to choose the greener products. Xue et al. [6] introduced an agent-based modeling approach to evaluate cluster supply chains. They used the approach to explore the service charging policy problem in collaborative procurement. Iftekhar and Tisdell provided a performance in multiple unit combinatorial fishery quota auctions [7]. This article explored the role of market information and learning in multiple unit combinatorial markets for fishing quotas. Combinatorial auctions allowed trading of packages quotas of spare parts procurement. Cruz and Marques [1] proposed that an effective allocation of the risks is the base for the well-functioning procurement processes, and for the success of the ‘landlord’ model. Based on several Portuguese concession contracts, this paper addresses the issue of risk-sharing agreements. Simões and Marques [8] focused on the congestion influence of European seaports. They used Data Envelopment Analysis (DEA) to determine this congestion inefficiency. The results show considerable signs of congestion in some European seaports.

According to the Provisions on Procurement of Military Organs announced by the MOND in 2003, procurement tasks can be categorized into three stages: plan submission; tendering and contracting; and compliance, verification, and settlement [9]. The process of military procurement of the Taiwan Navy is similar to that proposed by Robinson, who mentioned that procurement begins with the internal review of mission requirements (technical specification verification, accounting and auditing, and monitoring) and collection of supplier information [10]. The outcomes are then used to formulate a procurement plan and strategy. However, military procurement projects often involve various political, diplomatic, economic, livelihood-related, and policy-related problems, which have often

delayed the acquisition of resources. Therefore, the tasks and processes of military procurement are generally more complicated than those of private firms. Liao et al. provided a web-based architecture for implementing electronic procurement in military organizations [11]. The design of a relational database is introduced and system implementation is presented. The efficiency and benefits of the proposed system are discussed. However, few studies have spent effort to improve the process of military procurement.

3. Approaches

3.1. TRIZ Introduction

Teoriya Resheniya Izobreatatelskih Zadatch (TRIZ) was developed by Altshuller, who was a Russian engineer and inventor, in 1946 [12]. TRIZ was started from the 1950s, and Altshuller studied over 200,000 patents and summarized the data, creating 40 invention principles to be the basic concept of TRIZ. TRIZ is a systematic creativity process which transfers a specific problem to a generic framework, then summarizes a generic solution from patents, and translates back to the specific solution [13]. TRIZ has provided several methods, which are including: problem hierarchy analysis (PHA), substance-field (Su-Field) analysis, resources, trends of evolution, 40 inventive principles, ideal final result, and so on. These methods provide a wide application in decision support [14].

A problem hierarchy analysis was first used to identify the core problems. Then, the 40 principles were used to determine the ideal improvement solution or approach and formulate a solution strategy that simultaneously simplified CCP processed and enhanced the correctness of procurement tasks, thereby elevating CCP efficiency, supporting Taiwan Navy repair missions, and satisfying fleet maintenance and servicing demands.

3.2. Problem Hierarchy Analysis

For problem exploring, the PHA is a powerful tool. Figure 1 demonstrates the structure of the PHA [13]. The first step is to consider the broader requirement, and the second step is to narrower the detail problem. Applying the PHA can solve several important points, such as business opportunities, training minds and eyes, and finding better points to tackle a problem. PHA helps us to identify the best points to handle. What we see as the original problems sometimes are not the best points to solve. We should discover the true problems behind the original problems.

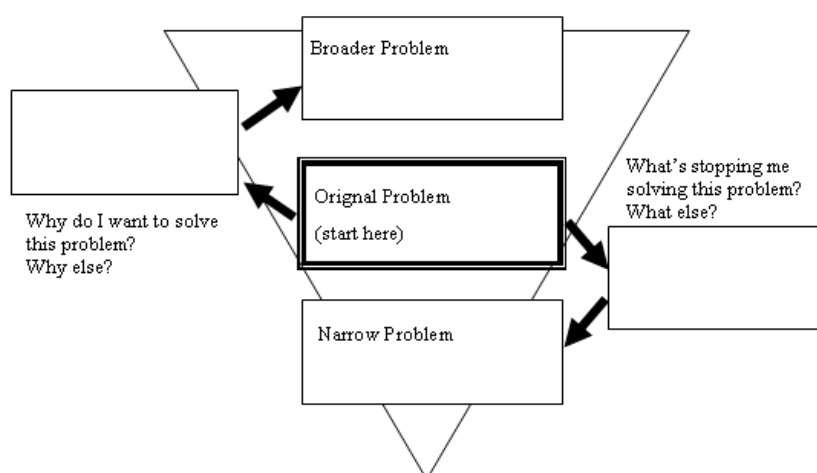


Figure 1. Problem hierarchy analysis [13].

3.3. Forty Principles

The working procedure in this study is primarily comprised of collecting the information of proceeding ship building industry data, and also collecting all related documents, as this study

draft action plan referenced. Then, after confirming the subject and proceeding industrial analysis, the procedure of this study is shown in Figure 1.

The 40 inventive principles are summarized by over 200,000 patents. This is the basic concept of TRIZ, the most accessible tool to solve contradictions. There are two categories of contradictions in TRIZ, technical contradictions, and physical contradictions [15]. The physical contradiction is a system with one parameter two opposite characteristics, such as large and small, and long and short [12]. The separation strategies are used for solved these issues. A technical contradiction is when we improve one engineering parameter of the system, in which at least one parameter will become worse, such as cost versus quality and brightness versus energy consumption. The 40 principles are used to solve the technical contradictions.

Normally, TRIZ solves problems by a two-dimensional contradiction matrix. The row of matrix depicts what is preventing things or what is getting worse, while the column expresses what we want to improve or what is getting better [16]. Consider the example in Table 1 for how to design a car: how can we consume less gasoline and carry a larger volume? Two contradiction parameters are found. “Weight of moving object” (column 1) becomes worse, and then “volume of moving object” (row 7) becomes better. The matrix numbers shown the most popular principles are #2 (extraction), #26 (copying), #29 (pneumatic and hydraulics), and #40 (composite materials). Begin with principle #2, which means taking something unnecessary out of the system to decrease the net weight and increase the volume. After checking, this study found that #26 and #29 could not be applicable. Regarding #40, it is possible to use composite materials with higher strength to reduce the weight of the car.

Table 1. Contradiction matrix of the car example.

Improving Feature \ Worsening Feature	Weight of Moving Object: 1	Productivity: 39
Weight of moving object: 1		35, 3, 24, 37
Volume of moving object: 7	2, 26, 29, 40	10, 6, 2, 34
Productivity: 39	35, 26, 24, 37	

4. Case Study and Results Analysis

4.1. Current State

All the data of the case study comes from NMRC-AMU of the Taiwan Navy. This is a real AMU project to improve the efficiency of CCP. The deputy director of CCP also participated in this case. This study is a focus on CCP of the navy. The suppliers need to pass strict verification before bidding for military business. The suppliers of parts for the navy are almost the same every year. Therefore, the number of bidders could have a small impact for this CCP process. However, the procedures could have a large impact on efficiency. Currently, the navy largely acquires spare parts through military procurement, overseas procurement, and domestic procurement. Project managers typically employ the following five-step coordination process to procure spare parts (Figure 2):

1. Departments submit a requisition for the coordination and procurement of spare parts: The requesting department formulates an annual acquisition plan on the basis of the stock level determined by the stock preparation system. The plan should clarify the requirements of the three maintenance levels, and procurement orders should be submitted to available suppliers or sources. Review of material requirements for military procurement and foreign commercial procurement plans should be completed 22 months prior to the target year. Unplanned procurement plans should also be arranged each quarter to meet the specific needs of individual departments.
2. Military officials are guided to submit their requisition to relevant project managers: The NMRC collates all acquisition requests 26 months prior to the target year, appoints dedicated personnel to each request, and reviews the integrity of the requests submitted by each department. The review outcomes are returned to the requesting departments for review, revision, and confirmation.

- The NMRC also establishes a timeframe in which the material preparation departments are required to complete annual request reviews.
3. Project managers reference the manufacturer/part codes in their requisition against the Navy Stock Control and Procurement System (SCPS): A balance should be maintained between demand, request, and consumption. The demand for spare parts should be cross-referenced with the information on the SCPS. Procurement may commence once the request is approved. The entire procurement process should be entered into the system to manage the timeliness of the procurement.
 4. SCPS-verified parts are issued a procurement project number. Projects are then posted online to attract bidders. The bids are analyzed, categorized, and approved for subsequent procurement tasks and processes: planned acquisition and unplanned recurrent acquisition demands should be submitted 22 months prior to the target year. The procurement volume is calculated once the demands are approved through cross-referencing with the stock information listed on the SCPS, and procurement plans are formulated and submitted to the procurement department for tender listing and procurement 18 months prior to the target year.
 5. SCPS-rejected parts are collated into a list and returned to the original requesting department for review: Planned acquisition and unplanned recurrent acquisition demands should be submitted 22 months prior to the target year. Items, inventory, and volume are cross-referenced with the information on the SCPS. Rejection lists are formulated and returned to the requesting departments for review.

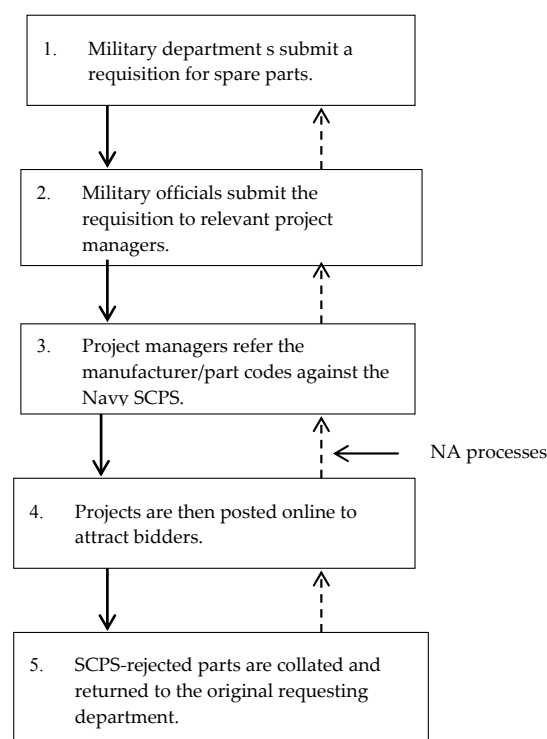


Figure 2. Improving the categorization procedures for the procurement of spare parts.

To analyze the research problem, this study adopted the problem hierarchy analysis (PHA) [13]. The problem was expanded, narrowed, and repeatedly analyzed to formulate an efficiency flowchart for the coordination and procurement of spare parts. The flowchart was then used to analyze demand and process descriptions (see Figure 3).

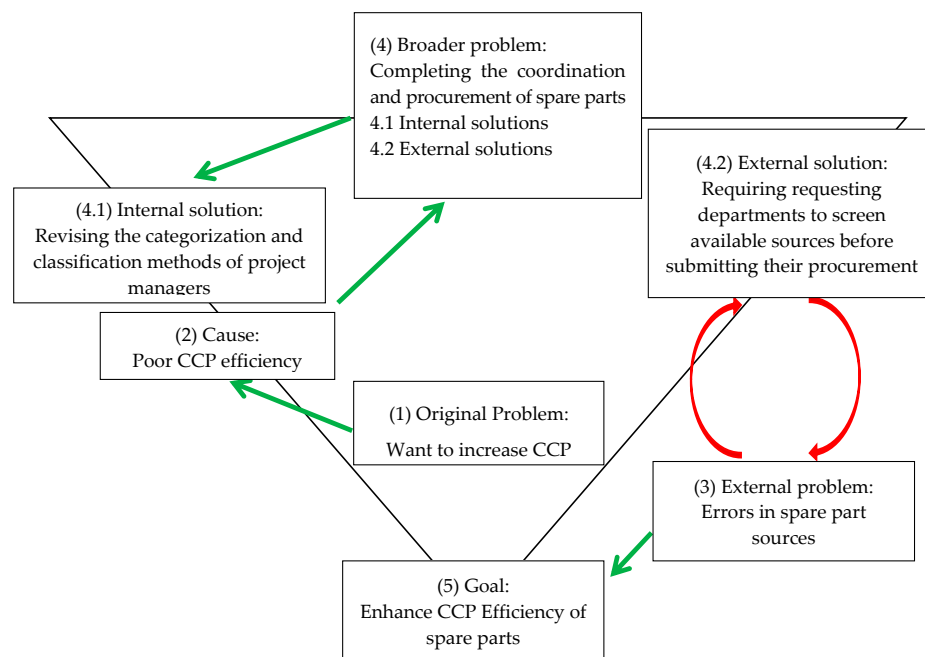


Figure 3. The problem hierarchy analysis of NMRC-AMU procurement.

The TRIZ problem hierarchy analysis of Figure 3 was adopted to elucidate the following aspects of the navy CCP process:

1. The original problem: The proper functioning of the navy fleet are focused on maintenance and servicing and the adequate supply of spare parts. Therefore, the primary problem is enhancing the CCP efficiency of spare parts.
2. Cause: Poor CCP efficiency of spare parts by requesting departments. A large number of cases were not completed before.
3. External problem: Errors in spare part sources and manufacturer and part code. The data should be examined and reviewed before processing.
4. Broader problem: Completing the coordination and procurement of spare parts.
 - 4.1 Internal Solutions: Revising the categorization and classification methods of project management.
 - 4.2 External solutions: Requiring requesting departments to examine available sources and manufacturer/part codes independently before submitting their coordination and procurement items.
5. Goal: Enhance CCP efficiency of spare parts

The results of this study revealed that revising the categorization and classification methods adopted by project managers and requiring requesting departments to screen sources and manufacturer/part codes independently before submitting their coordination and procurement items enhanced the CCP efficiency of spare parts. Therefore, project managers should verify the sources for military spare parts, compare the information of the spare parts with those in the system, notify discrepancies in information in accordance with relevant regulations, and modify the price of procurement item when necessary. In addition, requesting departments should ensure that the requested items conform to the scope of the acquisition plan before submitting their requests for coordination and procurement, as well as verify whether the material numbers, part numbers, orders, and unit prices match those entered into the system. Enhancing the accuracy of formulating and reviewing procurement projects improves the CCP efficiency of spare parts. Inaccurate procurement projects may cause bidders to raise questions during the tendering process, deferring the original

schedule of the project and affecting the punctuality of spare parts acquisition. Moreover, project managers' business analysis abilities and knowledge toward the materials in demand should be fostered to improve CCP efficiency.

4.2. Application of 40 Principles

The TRIZ 40 principles [13] method was adopted in this study to identify the causes of the related problems. Irrelevant combinations were eliminated to identify (1) parameters and principles that improve the categorization speed (#9) without affecting project formation accuracy (#29); (2) those that enable #9 without affecting project completion accuracy (#28); (3) those that reduce project formulation time (#25) without affecting project manufacturability (#32); (4) those that improve productivity (#39) without affecting #29; and (5) those that enable #39 without affecting #29. A contradiction matrix was created for the five solutions, namely, (#29; #9), (#29; #39), (#32; #25), (#28; #9), and (#28; #39), as tabulated in Table 2.

Table 2. The contradiction matrix.

Improving Feature \ Worsening Feature	Speed: 9	Unnecessary Time Expenditure: 25	Productivity: 39
Formation Accuracy: 29	10, 28, 32, 25		28, 32, 1, 24
Manufacturability: 32		35, 28, 34, 4	
Measurement Accuracy: 28	18, 10, 32, 1		1, 10, 34, 28

In the evaluation stage, the suggested principles obtained from the contradiction matrix were cross-referenced with the actual approaches to analyze the feasibility of the suggested principles. After inappropriate approaches were eliminated, the segmentation principle (#1), prior action principle (#10), mediator principle (#24), and color change principle (#32) were adopted to enhance the CCP efficiency of spare parts.

Segmentation Principle: The target is divided into several independent parts. Specifically, the requested parts are categorized and assigned to project managers according to the characteristics of the requesting departments or items. The requests of departments operating similar vessels or requiring similar parts can be consolidated for review. Moreover, subcategorizing spare part categories facilitates price negotiations and quotes, reduces categorization failure due to the lack of bidders, and enhances categorization efficiency.

Prior Action Principle: Useful effects are imposed on, or necessary changes are made to the target (all or partially) in advance. In accordance with the navy's Regulations for Material Acquisition, requesting departments should select the sources for acquisition and establish manufacturer/part codes in advance to enhance the accuracy of the categorization data, ensure the integrity of categorization data and conditions, and avoid delays stemming from bidder doubts.

Mediator Principle: An intermediary is added to a target or system. Once a mission is successfully executed, the intermediary can be easily eliminated. During the formulation of procurement projects, the stock levels in the system should be verified first. When discrepancies occur, requests should be returned to the requesting department for clarification. However, this process delays categorization processes. Requesting departments can compare their inventory management information with the data in the system during review to individually screen each categorization criterion. This process enables the requesting departments to revise system information immediately (saving at least three working days for the revision of stock management information). It also prevents delays stemming from bidder doubts after categorization approval but before opening tender (saving at least three days on procurement operations and seven days on tendering).

Color Change Principle: The color of the target is changed. Colored markers can be used to highlight categorization items and information for the project managers, helping them identify errors and immediately correct relevant parameters and conditions, thereby accelerating the categorization process.

4.3. Verifying the CCP Efficiency of Spare Parts

A flowchart is illustrated in Figure 4:

1. Before submitting a requisition, the requesting departments should cross-reference the coordination and procurement of spare parts with the information on the SCPS to ensure the procurement sources and manufacturer/part codes. In accordance with the navy's Regulations for Material Acquisition, the requesting departments should select the sources for acquisition and establish manufacturer/part codes to enhance the accuracy of the categorization data, ensure the integrity of categorization data and conditions, and avoid delays stemming from bidder doubts (#10: prior action principle) [17]. The requesting departments can compare their inventory management information with the data in the system during review to individually screen each categorization criterion. This process enables the requesting departments to revise system information immediately, saving at least three working days for the revision of stock management information. It also prevents delays stemming from bidder doubts after categorization approval but before opening tender, saving at least three days on procurement operations and seven days on tendering (#4: mediator principle). Highlighters can be used to mark categorization items and information for the project managers, helping them identify errors and immediately correct relevant parameters and conditions, thereby accelerating the categorization process (#32: color change principle).
2. The counseling officer submits the requisition to project managers in segments on the basis of the requesting department (branch or plant) or vessel type: the requesting department allocates the procurement cases to dedicated project or categorization managers depending on the department type (vessel type) or required parts. The requests of departments operating similar vessels or requiring similar parts can be consolidated for review. Moreover, subcategorizing spare part categories facilitates price negotiations and quotes (#1: segmentation principle).
3. The project manager issues a procurement project number to the required spare parts. Projects are then posted online to attract bidders. Bids are analyzed, categorized, and approved for subsequent procurement tasks and processes: Procurement volume is calculated once demands are cross-referenced with the stock information listed on the SCPS and approved. Procurement plans are formulated and submitted to the procurement department for tender listing and procurement 18 months prior to the target year.

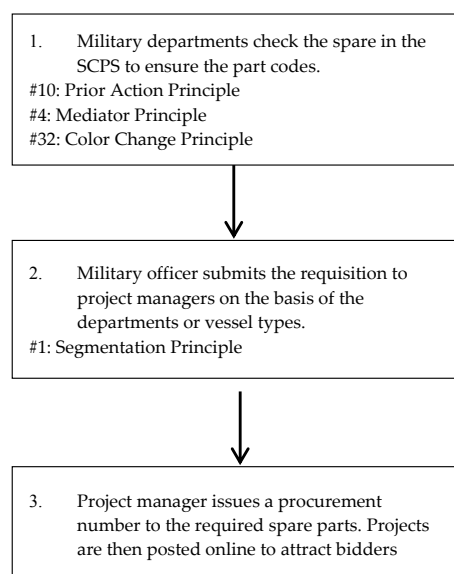


Figure 4. Improved NMRC-AMU categorization procedure for the procurement of spare parts.

4.4. Validation Results

The NMRC-AMU improved and non-improved CCP procedures involved procedures that combined the information of annual reports and the operating procedure mechanisms for repair and material preparation. The procedures reference related job content and protocols, related review mechanisms, past bid and market prices, and price comparison data to conduct CCP, in contrast to previous procedures which examine price indices, economic growth, and initial coordination, and procurement prices.

Prior to improvements, the implementation of the annual repair and manufacturing plans for various maintenance and servicing departments were examined to determine the demand of the departments. These demands were cross-referenced with the data in the SCPS. The maintenance and repair consumption data served as a basis for supply and feedback operations and analysis of the reasons for unused stock. Moreover, a requirement review mechanism was proposed. Requesting departments are required to determine material sources and manufacturer/part codes before submitting their requisitions, thereby improving CCP efficiency.

Once the causes of the problems were identified using the TRIZ hierarchy analysis method, the TRIZ solution was incorporated into the NMRC-AMU. The CCP efficiency is defined as completed requests divided by total requests. Before improvement, total 6925 requests for coordination and procurement were submitted. Of these requests, 4366 requests had been completed (with a total of 102 cases), and the CCP efficiency is 63.0%. After improvement, a total of 4529 items were submitted and 3592 executed items were completed (with a total of 172 cases), and the CCP efficiency is 79.3%. Please check Figures 5–7. The improvement percentage of the CCP efficiency and completed cases are 30.6% and 68.6%, respectively.

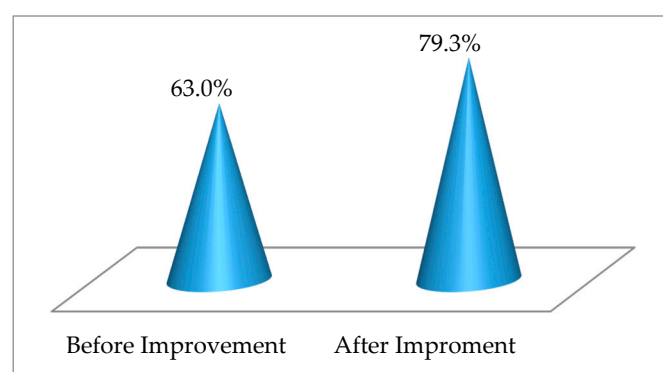


Figure 5. The change of CCP efficiency.

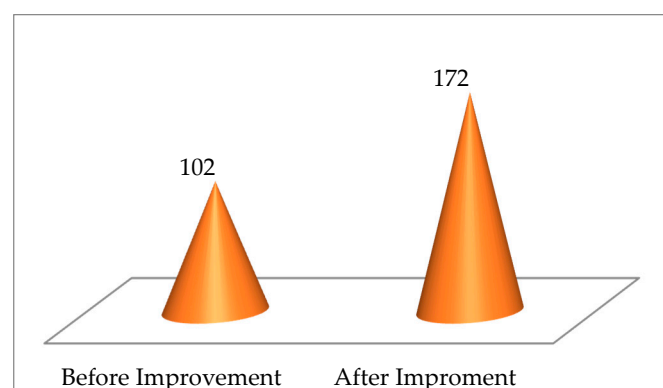


Figure 6. The change of completed cases.

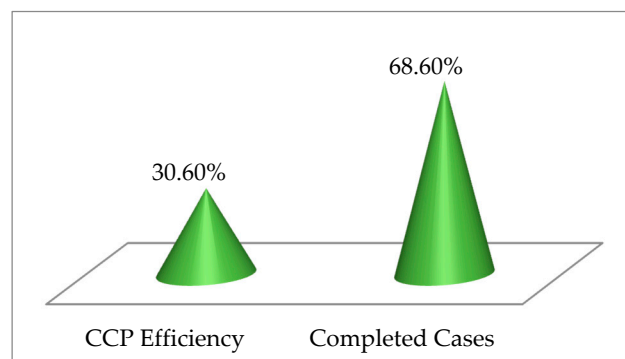


Figure 7. The improvement percentage.

5. Conclusions

The adequate functioning of navy ships hinges on maintenance and servicing. This is particularly true in the navy, where navy fleets have been in service for over two decades. Spare parts for outdated equipment are often difficult to acquire because of discontinuation or manufacturer relocation. Moreover, procurement processes are often inefficient because of poor stock control of spare parts, failure to modify part names and codes, and erroneous manufacturer/part codes. The CCP processes are long and tedious and often hinder the CCP efficiency of spare parts. The coordination and procurement efficiencies of spare parts directly affect the appropriateness of navy ships and relevant equipment. Therefore, improving CCP processes and the accuracy of procurement operations can enviably benefit the coordination and procurement of spare parts and, by extension, significantly accelerate the acquisition of spare parts, supporting navy repair missions and satisfying ship maintenance and servicing demands, and safeguarding the oceans of Taiwan.

Simplified categorization processes that solely rely on manager or supervisor experiences cannot effectively meet future market environments and organization reform. The main purpose of the TRIZ methodology is to identify and compare the flaws in various processes. The analysis results can serve as a reference to execute, improve, and simplify operating processes, thereby enhancing CCP efficiency.

The results of this study showed that the CCP efficiency was increased from 63% to 79% after the TRIZ solution was implemented, yielding an improvement rate of 16%. This improvement in efficiency is directly reflected in the categorization completion rate of planned and unplanned long-term acquisition projects, which are complex and contain extended turnaround periods. However, whether the solution improves the spare part support rate of a requesting department once the procurement project is transferred to the procurement department depends on the procurement process of the procurement department and the performance of the supplier. The coordination and acquisition of spare parts is a long and tedious process in the navy, and the categorization department is only a small segment of the process. Improving categorization is a short-term goal for the navy. The long-term goal is to integrate logistics, coordination, and acquisition procedures into a single, unified supply chain with the requesting departments at the top of the chain to the material reception departments at the bottom. The entire process should be segmented, modulated, and then reconstructed. The TRIZ method can be used to cross-reference and analyze the various operating parameters to greatly improve the existing coordinating and procurement performance of the navy. The methodology and procedures proposed in the present study can be applied to various departments in the future to facilitate them in adapting to the streamlining and organizational reforms of the navy.

There are several directions for future research and management improvement. The results of this study are sound. Integrate more different methodologies can continue improve efficiency of NMRC-AMU. The CCP efficiency is 79.3%. This is good, but not good enough. There are still chances to improve more by spending more on research efforts. Moreover, investigate the training, skills, and jobs dispatching among procurement project managers and the impact of efficiency. Better information

systems and better inventory systems could be also have the chance to enhance the operations of NMRC-AMU. Furthermore, the improvement concept and method of procurement process can be applied to other military maintenance forces to improve operation efficiencies.

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Conflicts of Interest: The authors declare no conflict of interest.

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