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Research Article

Assessment of ICT Resources onboard PCG vessels for Maritime Search and Rescue Operations

Leandra M. Cacao*

Philippine Merchant Marine Academy Graduate School, National Headquarters, Philippine Coast Guard, 139 25th St, Port Area, Manila 1018

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**Corresponding author:*
E-mail:
cacaolee23@gmail.com

ABSTRACT

This study evaluates the effectiveness, availability, and efficiency of information and communications technology (ICT) resources onboard Philippine Coast Guard (PCG) vessels to support maritime search and rescue (SAR) operations. It focuses on key ICT components, including data management platforms, navigation tools, communication systems, and human resource capacity.

A mixed-methods approach was employed, combining quantitative analysis across different vessel categories with qualitative data from in-depth interviews. Interviews with vessel Commanding Officers and CASB holders provided deeper insight into operational challenges and system limitations.

Findings highlight several critical issues: outdated or insufficient ICT equipment, inconsistent connectivity in remote maritime areas, inadequate training on ICT utilization, and the absence of standardized system protocols. Despite these challenges, personnel demonstrated strong appreciation for technological improvements and a clear understanding of ICT's importance in mission success

To enhance the PCG's SAR capabilities, the study recommends upgrading onboard ICT systems, establishing standardized operating procedures, and strengthening technical training. Ultimately, improving ICT infrastructure and personnel readiness is essential to boosting response effectiveness and ensuring the safety of lives and property during maritime emergencies.

Keywords: *Philippine Coast Guard, Search and Rescue, ICT Assessment, Maritime Communication Systems, Technical Training*

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Introduction

Particularly in an archipelagic country like the Philippines, search and rescue (SAR) activities are essential to maritime safety. For communication, coordination, and operational effectiveness, the Philippine Coast Guard (PCG), which is required to conduct SAR operations under Republic Act No. 9993, also known as the "Philippine Coast Guard Law of 2009," mainly depends on ICT tools. The integration and operation of onboard ICT resources are ever more crucial as marine events increase and need for quicker, more coordinated responses. Despite the PCG's modernization initiatives, there are still issues with the reliable and efficient use of ICT systems. These consist of problems with availability, maintenance, interoperability, and the preparedness of human resources. Thus, the purpose of the study is to evaluate the ICT capabilities currently available aboard PCG vessels and how they affect SAR operations.

This study's importance stems from its objective of evaluating the present condition of ICT resources aboard PCG vessels and figuring out how well they work in real-world SAR operations. By means of this evaluation, the research aims to pinpoint deficiencies in personnel preparedness, operational effectiveness, and technology deployment, and to suggest methods for enhancing the incorporation and application of ICT technologies. Enhancing the PCG's capacity to respond to marine emergencies and save lives at sea requires an understanding of these processes. The Philippine Coast Guard is making significant improvements to its command-and-control system with the goal of enhancing communications and information systems. A clearer view of missions will be provided by digitalized information, which will also make some of the jobs currently carried out manually by onboard ship personnel that actively engaged in operations at sea easier.

The function of Communications System is to deliver rapid and reliable communications operations to Coast Guard operational commanders, joint and interagency partners, civilian organizations, and the maritime public. The Communication System, and CGWCEISC as a functional command, provide capabilities and are vital contributors to PCG mission performance. The performance of the PCG Communications System is inextricably tied to overall PCG operational performance. (PCG Communications Assessment Report, 2023) **I**n accordance with the International Maritime Organization (IMO) Convention of Safety of Life at Sea (SOLAS), PCG conducts Maritime Search and Rescue (MARSAR), and is the national maritime search and rescue service of the country. Effective SAR response depends on communication and the ability to maintain a common operating picture through the constant flow of information. One of PCG functions is to render aid to persons and vessels in distress and conduct search and rescue in marine accidents within the maritime jurisdiction of the Philippines, including the high seas, in accordance with applicable international conventions.

A systematic method for improving cybersecurity in shipboard OT systems is offered by the paper "Guidelines for Cyber Risk Management in Shipboard Operational Technology Systems" by Priyanga Rajaram, Mark Goh, and Jianying Zhou (2022). It centers on ICT systems for navigation and communication, which are essential to maritime operations and are increasingly being targeted by cybercriminals. The authors offer cybersecurity checklists customized for OT systems and describe thorough risk assessment procedures. These frameworks can be directly applied to SAR ICT resources aboard PCG vessels, helping to reinforce cyber defenses and identify weaknesses in mission-critical systems including internal communication networks, radar, GPS, and AIS (Automatic Identification System).

The authors of the companion study "Vessels Cybersecurity: Issues, Challenges, and the Road Ahead" by Maurantonio Caprolu et al. (2020) examined shipboard communication systems and pinpoint significant security flaws in antiquated marine communication technologies. These include of email-based messaging services like GMDSS, VHF radios, and SATCOM systems. Additionally, the paper suggests mitigating techniques such the use of intrusion detection systems, network segmentation, and secure authentication. Because they direct the necessary upgrades and protocol changes to

secure onboard communication infrastructure that is essential for SAR operations, these insights are especially pertinent to PCG vessel ICT systems.

The study "Maritime Search and Rescue Missions with Aerial Images: A Survey" by Juan P. Martinez Esteso et al. (2024) investigates the incorporation of UAV (Unmanned Aerial Vehicle) technologies into SAR missions, offering an additional level of operational understanding. It explores ICT elements including edge computing, onboard sensors (such thermal and optical imaging), and real-time UAV-to-control center communication systems. The research emphasizes how crucial ICT is for improving situational awareness and decision-making in SAR operations. Since it offers a roadmap for evaluating and improving onboard ICT systems to facilitate aerial coordination and real-time data analysis, this is extremely relevant to the PCG's developing use of UAVs in SAR scenarios.

Lastly, in their paper "A Framework for Assessing the Capability of Maritime Search and Rescue in the South China Sea," Xiao Zhou et al. (2019) offer a model based on GIS and ICT that assesses the response times and capacities of SAR vessels in several countries, including the Philippines. The study highlights the strengths and weaknesses in regional SAR readiness by simulating SAR situations using geospatial data and ICT techniques. Through data-driven assessments, this model helps the Philippine Coast Guard identify ICT infrastructure needs and optimize response methods, making it a useful benchmarking and planning tool.

Methods

This study used quantitative and qualitative research design to achieve the purpose of the study using survey by assessing the information and communications technology (ICT) resources onboard PCG vessels. This study includes the effectiveness, efficiency and challenges encountered by the Officers and Non-Officers onboard during the deployment and conduct of maritime SAR Operations. The researcher focuses only to the operation, efficiency, and effectiveness of ICT resources onboard PCG floating assets while conducting maritime search and rescue missions. By gathering and analyzing pertinent data from PCG personnel, this design will enable the researcher to methodically characterize the current ICT infrastructure and its function in SAR operations.

Respondents of the study are the personnel from PCG who are assigned to different major maritime assets or vessels and directly participate in maritime SAR operations. With designations in Deck and Bridge such as Radio operators and SAR team members are a few examples of these. People who are sufficiently knowledgeable and experienced in using ICT technologies during SAR operations will be chosen through the use of a purposive sampling technique. Expert's respondents are those who have completed the PCG Sea Service or the Command-at-Sea Badge holders and present Commanding Officers of PCG vessels who represented the types of respondents for the interview. As soon as secured the agreement of the invited respondents to participate in the study, the respondents for answering Google forms for the status of ICT resources onboard PCG vessels will send to their respective email, while scheduled face-to-face or virtual consultations for the interview. The researcher will conduct interviews, lasting at least 30 minutes to one (1) hour in the gathering of data.

Result and Discussion

The five (5) interview participants, hold various ranks within the Philippine Coast Guard (PCG), ranging from Lieutenant (LT) to Captain (CAPT). Among them, three participants hold the rank of Lieutenant Commander (LCDR), while the remaining ranks are represented by one Captain (CAPT), and one Lieutenant (LT). Their onboard experience varies from six to fifteen years, with the most experienced officer having served for 15 years and the least experienced officer serving for six years (Table 2).

Table 2. Profile of the Interview Participants

Participant	Rank	Length of Onboard Experience (years)	Name of Previous Vessel Assignment	Vessel Profile: Year Acquired	Vessel Profile: Vessel Category	Vessel Profile: Vessel Readiness
1	LCDR	8	BRP FRANCISCO DAGOHOY (MMOV-5002)	11-15	Category III	Ready for Service (RFS)
2	CAPT	9	BRP GABRIELA SILANG OPV-8301	11-15	Category III	Ready for Service (RFS)
3	LCDR	9	BRP SINDANGAN MRRV-4407	11-15	Category II	Ready for Service (RFS)
4	LCDR	15	BRP MELCHORA AQUINO MRRV-9702	6-10	Category III	Ready for Service (RFS)
5	LT	6	BRP PANGLAO FPB-2402	11-15	Category I	Ready for Service (RFS)

All participants were previously assigned to different PCG vessels, with most having served on Multi-Role Response Vessels (MRRVs), Offshore Patrol Vessels (OPVs), or Fast Patrol Boats (FPBs). Notably, Participant 3 was assigned to BRP Gabriela Silang (OPV-8301), the PCG's most advanced offshore patrol vessel, while Participant 5 was assigned to BRP Melchora Aquino (MRRV-9702), one of the newest MRRVs in the fleet. The majority of the vessels were acquired 11 to 15 years ago, except for BRP Melchora Aquino, which was acquired within the past 6 to 10 years.

Regarding vessel categories, four out of the five vessels fall under Category III, which includes large patrol and response vessels capable of offshore operations, while one vessel, BRP Panglao (FPB-2402), is categorized as Category II, typically consisting of smaller fast patrol boats designed for nearshore and rapid response missions. Despite variations in vessel acquisition and category, all vessels were reported as Ready for Sea (RFS) at the time of assignment, indicating their operational status for maritime law enforcement, search and rescue (SAR), and other PCG missions.

These findings suggest that the interview participants possess extensive experience in command roles and have operated aboard a diverse range of vessels with varying capabilities. The predominance of Category III vessels in their assignments reflects the PCG's reliance on larger, multi-role ships for extended SAR operations. Furthermore, the operational readiness of these vessels highlights the PCG's commitment to maintaining a capable and responsive fleet for maritime security and SAR missions.

Vessel Readiness

As presented in Figure 2, the updated pie chart showing the readiness of the vessels: 4 vessels are Ready for Sea (RFS), making up about 57.1%, and 3 are Not Ready for Sea (NRFS), comprising about 42.9%.

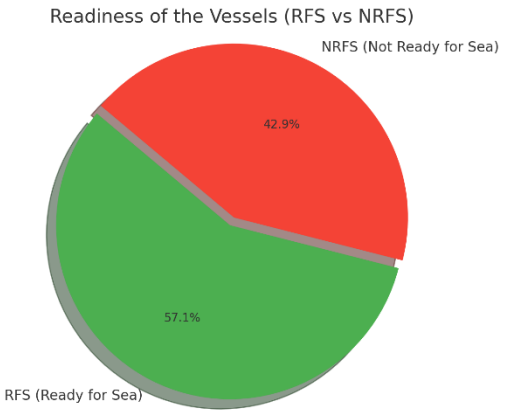

Figure 2. Readiness of the PCG Vessels (Surveyed)

The high percentage of operational vessels of major maritime assets suggests that most PCG vessels are available for SAR missions, ensuring continuous response capability. However, the presence of non-operational vessels, though minimal, raises concerns about

potential gaps in SAR coverage, especially in cases where vessel availability is crucial for emergency response. The readiness of vessels directly impacts the efficiency of SAR operations, and ensuring the full operational status of all units remains essential in maintaining an effective maritime safety network.

Reasons of vessel's Not Ready for Sea (NRFS) or not operational. The primary causes of vessels declaring themselves not ready for sea or not operational include problems with the propulsion or main engine, steering gear malfunction, electrical system failure (power outage, generator problems), malfunctioning navigation or communication equipment, fuel or water contamination, hull breaches, or major damage.

Status of the ICT Resources of PCG Vessels for Maritime Search and Rescue Operations (SURVEY)

A survey instrument was used to assesses the availability, functionality, effectiveness and efficiency of various ICT resources, including radio communication equipment, GMDSS ship radio systems, satellite communication equipment, and ship communication systems. The results are detailed in this section.

Respondent 1 assessment for ICT resources for MARSAR Operations onboard 97-Meter PCG Vessel (Ready for Sea)

Availability of ICT Resources. According to the assessment, the majority of essential ICT equipment is available on board, especially in the radio communications equipment category. Examples of this equipment include the Marine VHF Portable Radio, HF Base Radio, Marine VHF Mobile Radio, and Direction Finder. GMDSS Ship Radio System: Every system on the list is operational, including the AIS Receiver, EPIRB, and GMDSS Console. Satellite communication equipment, such as satellite phones and INMARSAT systems, was fully available. Ship communication equipment includes mobile phones, laptops, public address systems, and intercoms. High availability of critical ICT systems supports the readiness of SAR operations, according to the general findings.

Efficiency of ICT Resources. The majority of equipment, including the entire line of radio communication devices, GMDSS systems, satellite communication systems, and ship-based ICT equipment, was scored as "Efficient" by respondents. The notable evaluations of INMARSAT C, Fleet Broadband, and Satellite Phone as "Not Efficient" may have been caused by out-of-date gear or connectivity problems. The main issue is that, even though satellite communications are readily available, their efficiency is low, indicating the need for either greater signal infrastructure or system modifications.

Effectiveness in SAR Operations. For SAR operations, the majority of respondents gave equipment ratings in the "Effective" to "Very Effective" range. While some, including the Navtex receiver and satellite phone, were only rated as "Somewhat Effective," radio and GMDSS equipment were regularly scored as "Effective." Laptops, public address systems, and marine wifi are examples of ship communication equipment that was rated as "Very Effective" to "Extremely Effective." For the Insight: Although some components still need to be optimized, ICT resources are thought to be functionally capable of enabling SAR operations.

Availability: Strong infrastructure provisioning is demonstrated by the majority of ICT systems needed for SAR being onboard. Efficiency: Satellite communication systems demonstrated performance disparities despite being classed as generally efficient. And Effectiveness: The systems, especially shipboard systems and traditional communication devices, are thought to be effective in meeting operational SAR needs.

Table 3. *Assessment for ICT Resources of 97-Meter Vessel*

Category	Key Finding	Rating
Availability	25 of 26 ICT systems available	★★★★☆ (4/5)
Efficiency	23 systems rated as "Efficient", 3 "Not Efficient"	★★★☆☆ (3/5)
Effectiveness	Majority rated "Effective" to "Very Effective"	★★★★☆ (4/5)

Respondent 2 assessment for ICT resources for MARSAR Operations onboard 83-Meter Vessel (Ready for Sea)

Availability of ICT Resources Onboard. Twenty-three (23) of the 29 ICT equipment items evaluated are available, while six (6) are not. With the exception of important directional and airband tools, radio communications equipment is the most readily available. GMDSS systems and satellite communication are fully functional and accessible, and ship communication tools, with the exception of mobile phones, are also readily available. With only a few minor gaps in sophisticated or specialized radio tools, 79% are available, suggesting strong readiness.

Efficiency of ICT Resources. No equipment was rated as "Not Efficient" or "Very Efficient." All of the equipment on the list was evaluated as "Efficient." Although none of the communication technologies on board the ship is regarded as very effective, they are practical. This suggests dependable systems that lack top-tier improvements or may be antiquated. Operational efficiency rating ranges from moderate to high, but time-sensitive SAR may not benefit from a high-performance edge.

Effectiveness in SAR Operations. On the given Likert scale, all ICT systems received a rating of "Effective," or three out of five. There were no "Very Effective" or "Extremely Effective" (1 or 2) ratings for any system. Neither "Not Effective" nor "Somewhat Effective" (4 or 5) were assigned to any system. Although there is potential for improvement, integration, or training, this demonstrates baseline operational effectiveness.

Table 4. *Assessment for ICT resources of 83-Meter vessel*

Category	Key Finding	Rating
Availability	23 of 29 ICT systems available	★★★★☆ (4/5)
Efficiency	All systems rated as "Efficient"	★★★☆☆ (3/5)
Effectiveness	All systems rated as "Effective"	★★★☆☆ (3/5)

Situational awareness may be limited in the absence of a VHF Direction Finder, Airband Transceiver, and SCS HF Modem, particularly in air-sea coordination. No ICT system achieved the "Very Effective" classification, suggesting room for improvement in legacy system upgrades, operator training, and system optimization.

Respondent 3 Assessment of ICT Resources Aboard 56-Meter Vessel – NRFS (Not Ready for Sea)

Availability of ICT Resources. Out of the 29 ICT items that were assessed, 12 of them (41%) were unavailable and 17 items (59%) were available. Critical tools like the GMDSS Console, Satellite Phone, and Marine WiFi were absent, but there were plenty of core radio communication devices and satellite communication systems.

Efficiency of ICT Resources. The equipment's efficiency evaluation showed that 24 items (83%) were rated as "Not Efficient," while only 5 out of 29 items (17%) were deemed efficient. Notably, devices including the satellite phone, SCS HF radio modem, GMDSS console, and MH/HF base radio were thought to be functionally deficient.

Effectiveness of ICT Resources. Seven items (24%) received the "Effective" rating for their performance in SAR missions. Among these were the mobile phone, radar SART, and marine VHF portable radio. Nonetheless, 76% of the items—particularly those in the satellite systems and GMDSS categories—were judged to be "Somewhat Effective," "Not Effective," or underperforming.

Table 5. Assessment for ICT Resources of 56-Meter Vessel

Category	Key Finding	Rating
Availability	17 of 29 ICT systems available; key systems like GMDSS Console and Sat Phone missing	★★☆☆☆ (2/5)
Efficiency	Only 5 of 29 systems rated "Efficient"; 83% not efficient	★☆☆☆☆ (1/5)
Effectiveness	Only 7 of 29 systems rated "Effective" or better; majority only "Somewhat Effective"	★★☆☆☆ (2/5)

Given that 41% of essential ICT tools are unavailable, compromising operational readiness; 83% of systems are inefficient, compromising reliability during urgent SAR operations; and 76% of ICT resources were only moderately effective, with limited capacity to support robust emergency communications, the 56-meter PCG vessel, which was deemed Not Ready for Sea, exhibits serious ICT readiness deficiencies. A major obstacle to guaranteeing real-time communication, coordination, and safety in marine situations is the lack of a GMDSS console, satellite phone, and wideband receivers, as well as the ineffectiveness of the technologies that are currently poor place.

Respondent 4 Assessment of ICT Resources Aboard Buoy Tender for MARSAR Operations– (Not Ready for Sea)

Availability of ICT Resources. Twenty-two items (76%) of the 29 ICT components that were reviewed were reported as available, while seven items (24%) were reported as unavailable. Moderate; major systems are there, but certain necessary tools are absent (e.g., Sat Phone, GMDSS).

Efficiency of ICT Resources. Regarding ICT equipment efficiency, 29 items (100%) were evaluated as efficient, while 0 items (0%) were rated as very efficient. All systems operate at baseline standards; they are consistent but not exceptional.

Effectiveness of ICT Resources. One item (3%), the Gyro Compass Repeater, was rated as ineffective in SAR operations, most likely because it was unavailable. In contrast, 28 items (97%) were rated as effective. This shows operational performance that is functional but not outstanding. High; even with missing parts, the majority of systems efficiently support SAR operations.

Table 6. Assessment for ICT Resources of Buoy Tender Vessel

Category	Key Finding	Rating
Availability	22 of 29 ICT systems available; 7 key components missing	★★★☆☆ (3/5)
Efficiency	All 29 systems rated "Efficient"; none "Very Efficient"	★★★☆☆ (3/5)
Effectiveness	28 of 29 systems rated "Effective"; 1 not rated due to unavailability	

The majority of the ICT equipment is available (76%), functionally efficient (100%), and effective in supporting SAR (97%), even though the vessel is classified as not ready for sea. The lack of high-performance efficiency ratings and essential parts like satellite phones, intercoms, and P25 radios, however, indicate that the vessel's communication capabilities could not yet be fully operationally suited for an instant SAR deployment.

Respondent 5 Assessment of ICT Resources Aboard 44-Meter PCG Vessel (RFS) for MARSAR Operations

Availability of ICT Resources. Of the 29 items of ICT equipment that were evaluated, 28 (97%) were reported as available, while one (3%), the Marine Wifi in particular, was highlighted as unavailable. This suggests that the 44-meter vessel has a high degree of equipment presence and readiness. The availability of communication tools is almost total.

Efficiency of ICT Resources. Only one item (3%), the Airband Transceiver, was rated as inefficient in terms of operational efficiency, whereas 28 items (97%) were rated as very efficient. This implies that in the majority of places, ICT systems are not only accessible but also functionally capable. dependable operation of every significant system.

Effectiveness of ICT Resources. 27 equipments (93%) were assessed as effective in search and rescue operations, while 1 item (3%) was rated as extremely successful and another item (3%), the Airband Transceiver, was classified as ineffective. high level of support and operational success during SAR missions.

Table 7. Assessment for ICT Resources of 44-Meter Vessel

Category	Key Finding	Rating
Availability	28 of 29 ICT systems available	★★★★☆ (4.5/5)
Efficiency	28 systems rated as "Very Efficient", 1 "Not Efficient"	★★★★☆ (4.5/5)
Effectiveness	27 systems rated "Effective", 1 "Extremely Effective", 1 "Not Effective"	★★★★☆ (4.5/5)

In terms of ICT assets, the 44-meter PCG vessel is well-maintained and outfitted. The findings demonstrate a very strong infrastructure for information and communication systems that facilitates successful and efficient maritime search and rescue missions. To significantly improve overall mission capability, however, small flaws like the ineffective airband transceiver and the absence of marine Wi-Fi should be fixed.

Respondent 6 Assessment of ICT Resources Aboard 35-Meter Vessel – NRFS (Not Ready for Sea)

Availability of ICT Resources. Ten equipment (34%) were unavailable out of the 29 ICT items assessed, including the P25 Mobile VHF Radio, AIS Receiver, Satellite Phone, GMDSS Console, and NHE Public Addressor. The bulk of the equipment (19 items, or 66%) were available.

Efficiency of ICT Resources. None of the 29 items received a "Very Efficient" or "Not Efficient" rating; all were evaluated as "Efficient." This shows that although systems operate as planned, performance is mediocre and falls short of expectations.

Effectiveness of ICT Resources. 25 items (86%) were rated as "Effective" for aiding SAR operations, while 4 items (14%)—such as the Radar SART and AIS Receiver—were rated as "Very Effective" or went unrated because they were unavailable.

Table 8. Assessment for ICT Resources of 35-Meter Vessel

Category	Key Finding	Rating
Availability	19 of 29 ICT systems available; 10 critical items including GMDSS unavailable	★★★☆☆ (3/5)
Efficiency	All 29 systems rated “Efficient”; none rated “Very Efficient”	★★★☆☆ (3/5)
Effectiveness	25 of 29 systems rated “Effective”; 4 rated “Very Effective” or unrated	★★★★☆ (4/5)

The 35-meter PCG vessel with a Not Ready for Sea (NRFS) rating exhibits a moderate level of ICT proficiency: 66% of ICT tools are available, including essential systems like satellite communication units and marine radios; 100% of operational equipment is efficient, but none of it reaches very high performance thresholds; and 86% of it is effective in real SAR use cases, though some critical systems, like radar SART and AIS receivers, have higher ratings. Long-range and automated emergency communication is threatened by the unavailability of several essential parts, such as the satellite phone and GMDSS Console.

Respondent 7 Assessment of ICT Resources Aboard 24-Meter Vessel – RFS (Ready for Sea) for MARSAR Operations

Availability of ICT Resources. Six items (21%) are lacking, while 23 items (79%) are available out of the 29 ICT components evaluated. There are important systems like GMDSS, radio communication, and the majority of ship communication gear. The VHF/UHF Automatic Filter, INMARSAT systems, Satellite Phone, and Marine WiFi are some of the noteworthy exceptions, though.

Efficiency of ICT Resources. Only two items (7%) were classified as "Not Efficient," while 20 out of 29 items (69%) were rated as "Efficient" and seven items (24%) as "Very Efficient." This indicates that all of the equipment, particularly the GMDSS and communication radios, has a high degree of operational functionality.

Effectiveness of ICT Resources. 22 items (76%) and 5 ICT equipment (17%) were classified as "Very Effective" and "Effective," respectively, based on effectiveness assessments conducted during actual SAR operations. Merely two items (7%) were rated as "Somewhat Effective." Nothing was categorized as "Not Effective."

Table 9. Assessment for ICT Resources of 24-Meter Vessel

Category	Key Finding	Rating
Availability	23 of 29 ICT systems available; 6 systems including INMARSAT and Sat Phone missing	★★★★☆ (4/5)
Efficiency	27 of 29 systems rated “Efficient” or “Very Efficient”; 2 “Not Efficient”	★★★★☆ (4/5)
Effectiveness	27 of 29 systems rated “Effective” or better; only 2 “Somewhat Effective”	★★★★☆ (4.5/5)

With about 80% of its ICT resources available, the 24-meter PCG vessel that is currently Ready for Sea has a high level of ICT readiness and competence for maritime SAR operations. 93% of all ICT devices are operating effectively or extremely well. During operations, a strong 93% of the systems are assessed as effective or extremely successful. These findings imply that there are few restrictions on the vessel's ability to carry out and support SAR missions.

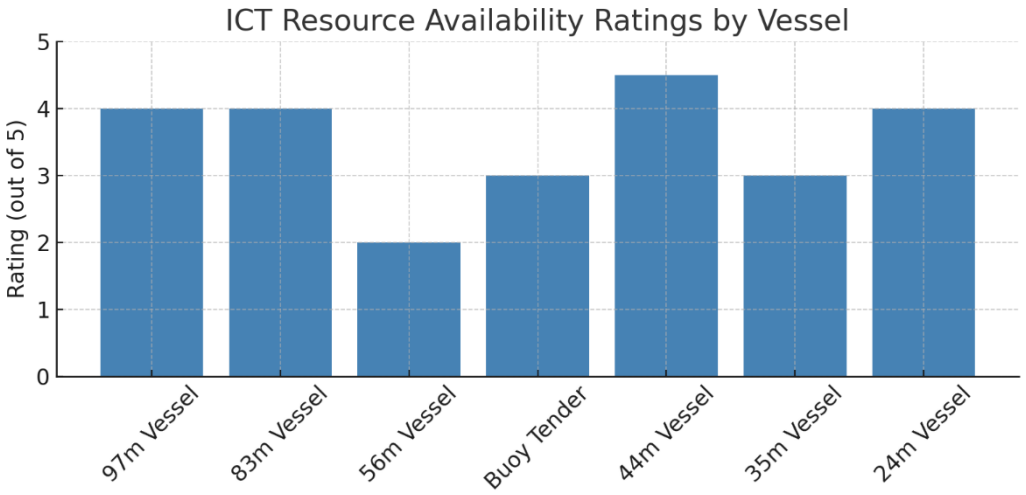

Figure 3 ICT Resources Availability Ratings by Vessel

Figure 3 shows how many ICT systems are operational or present on each vessel type. A higher rating suggests better equipment presence and readiness.

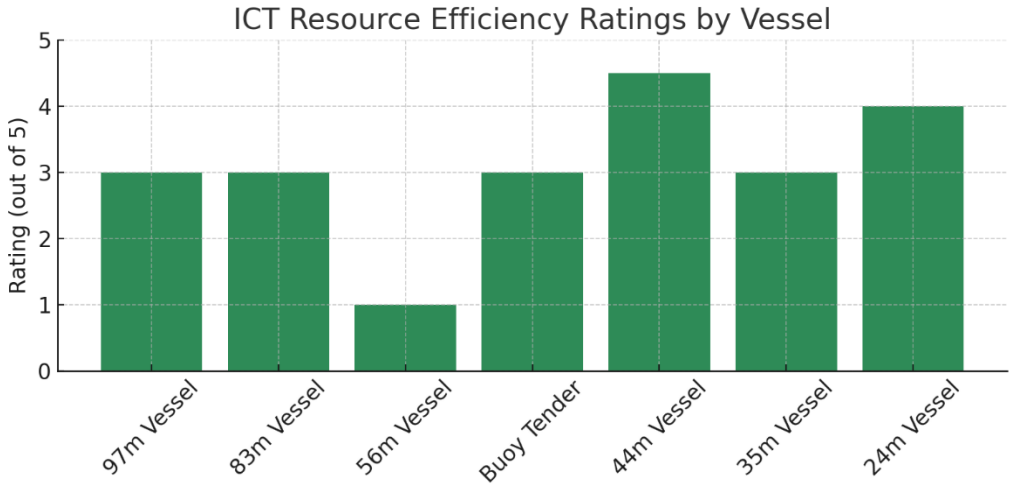

Figure 4 ICT Resources Efficiency Ratings by Vessel

Figure 4 Reflects how well the available systems perform in terms of operational efficiency. Higher scores indicate more systems rated as "Efficient" or better.

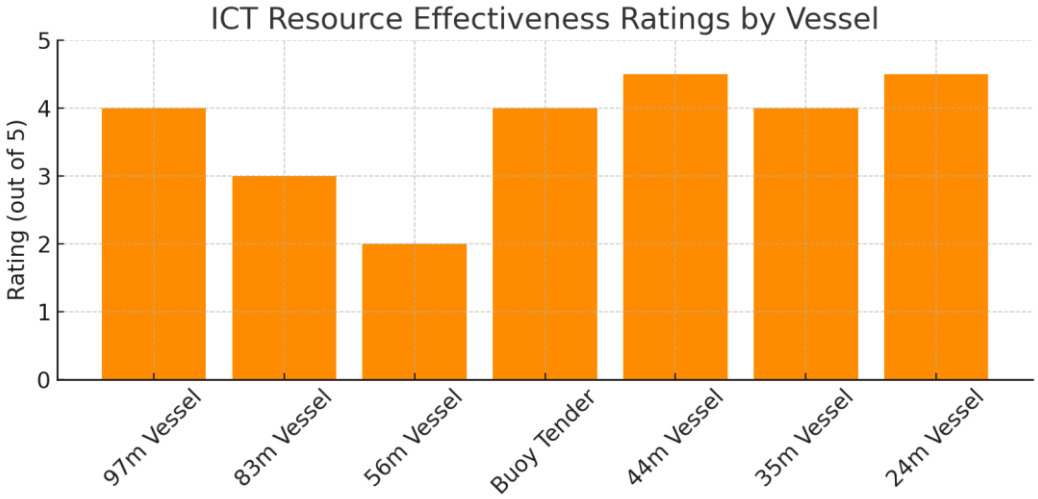

Figure 5. ICT Resources Effectiveness Ratings by Vessel

Figure 5 Indicates how well the ICT systems meet their intended purpose, based on ratings like "Effective" or "Very Effective."

Challenges Encountered by PCG in the Use of ICT Resources for Maritime Search and Rescue Operations (INTERVIEW)

The interview responses from the five PCG officers with Command-at-Sea Badges highlight several challenges in the use of ICT resources for maritime search and rescue (SAR) operations. These challenges can be categorized into issues related to connectivity, equipment limitations, accuracy of distress reports, and personnel training.

Connectivity Limitations in Remote Areas

One of the most persistent challenges in using ICT resources for maritime search and rescue (SAR) operations is maintaining stable communication, particularly in remote areas. Participant 1 noted that *"missions relying on internet broadband and cell sites face difficulties when there is no signal in certain areas."* Simi-

larly, Participant 4 emphasized that *"communication with distress vessels is difficult, especially in remote areas where signal coverage is limited."* This problem is further exacerbated by outdated ICT systems, as Participant 1 stated that *"long-range transmissions and satellite connections require costly subscriptions, making it difficult to sustain efficient communication."* Participant 2 added that *"ship-to-shore communication is essential for providing status reports on ongoing SAR operations and receiving guidance from the Operational Control Unit Commander,"* but this is often unreliable.

Weather and Environmental Factors Affecting ICT Stability

Weather conditions pose another major challenge, as they can disrupt the effectiveness of communication systems. Participant 2 highlighted that *"the stability and reliability of communication systems are highly dependent on prevailing weather conditions during SAR operations."* Likewise, Participant 5 noted that *"adverse weather conditions, challenging terrain, and hazardous environments pose significant difficulties"* in maritime SAR operations. The unpredictability of sea conditions means that communication and navigation tools may not function optimally when they are needed most.

Insufficient ICT Equipment and Resources

The availability of ICT equipment remains a significant concern, limiting the effectiveness of SAR operations. Participant 5 pointed out that *"there is an insufficient availability of equipment and other essential resources, including wide-range communication signals and information systems."* This shortage reduces the operational capability of PCG vessels and affects their ability to respond quickly and effectively to distress situations.

Inaccurate and Incomplete Distress Reports

One of the most common problems encountered during SAR operations is the inaccuracy of distress reports. Participant 3 explained that *"SAR operations often rely on the location provided by victims in distress, but in many cases, the reported coordinates do not match the actual location, requiring additional verification or surveys."* Similarly, Participant 5 noted that *"distress reports frequently contain incomplete or inaccurate location details, making search efforts more challenging."* These discrepancies can significantly delay response times and increase the risk of unsuccessful rescue attempts.

Equipment Interoperability and Compatibility Issues

Another significant challenge is the lack of interoperability between different ICT systems used by PCG vessels. Participant 3 stated that *"equipment interconnection and interoperability issues are common. The National Headquarters and other vessels use relatively older equipment compared to the advanced systems onboard BRP Gabriela Silang, leading to compatibility challenges."* This mismatch between older and newer systems complicates communication and coordination during SAR operations.

Training Gaps and Knowledge Transfer Issues

A lack of structured training programs for personnel operating ICT systems presents another challenge. Participant 1 mentioned that *"newly aboard personnel receive actual training based on the experience and knowledge of senior personnel, with additional training provided by CGFLEET before deployment."* However, there is inconsistency in training programs, as Participant 2 noted that *"there is no formal training program available."* Participant 4 added that *"training mainly consists of Troops Information and Education (TI&E), where experienced personnel share their knowledge with newly onboard personnel, but there is no structured course."* This reliance on informal training methods may result in personnel struggling to use ICT resources effectively. Participant 6 further pointed out that *"a lack of training among personnel remains a key issue."*

Slow Transmission of Reports Due to Communication Gaps

Delays in transmitting crucial reports can hinder SAR operations. Participant 1 stated that *"connectivity issues often arise during MARSAR operations. Communication with commanders is crucial, but delays occur when there is no signal, resulting in late transmission of reports."*

These communication gaps can affect coordination and response times, making it difficult for decision-makers to provide timely instructions.

Limited Technical Support and Maintenance Issues

The maintenance of ICT equipment is also a challenge. Participant 4 observed that *"older ICT equipment, particularly those not updated since 2017, has limited range and restricted radio communication, often resulting in blind spots in remote areas."* The lack of regular maintenance and difficulty in sourcing spare parts further hinders operational efficiency. Participant 5 also noted that *"availability in the market is a concern, as new ICT resources are readily available, whereas old ICT equipment is becoming increasingly difficult to procure and maintain due to obsolescence."*

Cybersecurity Risks in the Future

While not currently a major issue, cybersecurity threats could pose risks in the future. Participant 1 warned that *"new ICT systems may be vulnerable to hacking, and if vessels become autonomous, attackers could potentially take control of critical systems."* As the PCG continues to modernize its ICT infrastructure, addressing cybersecurity vulnerabilities will be essential.

Overall, the findings suggest that the PCG faces multiple challenges in utilizing ICT resources effectively for SAR operations. Connectivity issues, environmental factors, equipment shortages, inaccurate distress reports, system interoperability problems, training gaps, slow transmission of reports, and maintenance difficulties all contribute to operational inefficiencies. Additionally, future cybersecurity threats pose potential risks. Addressing these concerns through infrastructure improvements, enhanced training programs, equipment modernization, and cybersecurity measures will be crucial in strengthening the PCG's SAR capabilities.

In the study Peter Marsh (1995) highlights significant challenges in maritime communication, in the results of the interview with five PCG officers revealed several challenges in utilizing ICT resources for maritime search and rescue (SAR) operations. Key issues include connectivity limitations in remote areas, where stable communication is often hindered by a lack of signal. Officers noted that missions relying on internet and cell sites struggle in these areas, and outdated ICT systems further complicate communication, particularly due to the high costs associated with long-range transmissions and satellite connections. Additionally, reliable ship-to-shore communication is crucial for reporting on SAR operations and receiving guidance, but it remains inconsistent.

ICT Resources for Maritime Search and Rescue Operations Being Utilized Onboard Coast Guards Vessels of Other Countries (INTERVIEW)

The interview responses from the five PCG Officers reveal that Coast Guards from other countries, such as the United States Coast Guard (USCG) and the Japan Coast Guard (JCG), employ a variety of advanced ICT resources to enhance maritime search and rescue (SAR) operations. Communication technologies play a vital role, with several participants highlighting the use of KA band (VSAT), CA and KU band, Fleet Broadband, and satellite internet services such as Starlink to ensure reliable connectivity at sea.

As noted by Participant 1, *"various communication and surveillance technologies are being used, including KA band (VSAT), CA and KU band (limited bandwidth), text messaging systems, and drones for aerial monitoring."* Similarly, Participant 2 noted that *"Fleet Broadband is utilized to provide reliable internet and communication services at sea,"* reinforcing the importance of stable connectivity. Participant 5 added that *"satellite internet such as Starlink and Harris radios are also in use for distress communications, alongside AIS (Automatic Identification System) and GPS for navigation."* These technologies support real-time communication and vessel tracking, crucial for SAR missions.

Surveillance and detection systems are another vital aspect of SAR operations. Participant 4 shared that *"during training onboard the Japan Coast Guard training ship KOJIMA, it was observed that they utilize an unmanned aerial system and large drones, making search operations more efficient without excessive resource*

consumption." This aligns with observations from Participant 3, who noted that *"the USCG expressed interest in assisting the PCG by providing advanced SAR equipment, including drone systems."* Participant 5 reinforced this point, emphasizing that *"additional advanced technologies include drones for aerial surveillance, satellite communication systems, and databases for tracking vessel information, ensuring more efficient SAR operations."* The integration of drones and unmanned aerial systems reflects a global trend in modernizing SAR operations, enhancing coverage and response times while reducing operational costs.

In terms of navigation and distress signal detection, international Coast Guards employ sophisticated systems to improve SAR effectiveness. Participant 3 recounted that *"a Royal Navy vessel from the USCG visited the Philippines in 2024, and aboard the vessel, many of the navigation equipment were similar to those on the PCG's Gabriela Silang."* However, they also observed that *"the USCG still relies on older radio systems like Harris for distress communications but supplements them with advanced equipment such as EPIRB (Emergency Position Indicating Radio Beacon) and SART (Search and Rescue Transponder)."* Similarly, Participant 4 mentioned that *"the JCG employs an advanced detection system that integrates satellite technology, allowing them to locate distress victims by inputting coordinates rather than relying on manual scanning."* This level of automation enhances the speed and accuracy of SAR missions.

Participant 5 further highlighted the importance of radar technology, stating that *"radar systems operating on X-band and S-band frequencies provide enhanced situational awareness,"* crucial for navigating challenging maritime environments. These findings suggest that while the PCG has comparable navigation equipment to foreign coast guards, as observed by Participant 3 regarding the similarities between the USCG and PCG's Gabriela Silang, there is a pressing need to transition from outdated communication and surveillance systems to more advanced ICT solutions.

Overall, the increasing reliance on satellite communication, drone technology, and integrated detection systems among leading maritime agencies highlights the importance of modernizing the PCG's SAR capabilities. Upgrading ICT resources will significantly improve operational efficiency, enhance situational awareness, and ensure a more effective response to maritime emergencies.

According to Peter Marsh's (1995) survey, the majority of users deem the US Coast Guard's vessel communication to be insufficient. The findings from interviews with Philippine Coast Guard (PCG) Officers indicate that while international Coast Guards, such as the US Coast Guard (USCG) and Japan Coast Guard (JCG), utilize advanced ICT resources for maritime search and rescue (SAR) operations, the communication capabilities of the USCG are often viewed as inadequate by users. Participants noted the use of various technologies, including satellite internet services, drones, and advanced navigation systems, which enhance real-time communication and vessel tracking. However, despite having comparable navigation equipment, the USCG still relies on older radio systems for distress communications, highlighting a need for modernization. The integration of advanced technologies like drones and automated detection systems is crucial for improving Maritime SAR effectiveness. Generally, the findings emphasize the necessity for the PCG to upgrade its ICT resources to enhance operational efficiency and response to maritime emergencies.

Conclusion

The interview participants possess extensive experience in command roles and have operated aboard a diverse range of vessels with varying capabilities. The predominance of Category III vessels in their assignments reflects the PCG's reliance on larger, multi-role ships for extended SAR operations. Furthermore, the operational readiness of these vessels highlights the PCG's commitment to maintaining a capable and responsive fleet for maritime security and SAR missions.

Majority of PCG vessels are relatively new, with 90% of them acquired within the last ten years. This reflects ongoing efforts to modernize the PCG fleet, potentially integrating more advanced ICT systems to enhance SAR operations. However, the presence of aging vessels,

particularly those over 20 years old, indicates that some units may still rely on outdated ICT resources, which could pose challenges in search and rescue missions.

The predominance of Category III vessels suggests that smaller, more maneuverable units form the backbone of PCG's SAR operations. These vessels, typically suited for nearshore operations, play a critical role in responding to maritime emergencies in coastal waters. Meanwhile, the relatively lower percentage of Category I vessels highlights the limited number of larger, ocean-going ships capable of extended SAR operations in deeper waters, which could affect response capabilities in distant maritime zones.

The high percentage of operational vessels suggests that most PCG units are available for SAR missions, ensuring continuous response capability. However, the presence of non-operational vessels, though minimal, raises concerns about potential gaps in SAR coverage, especially in cases where vessel availability is crucial for emergency response. The readiness of vessels directly impacts the efficiency of SAR operations, and ensuring the full operational status of all units remains essential in maintaining an effective maritime safety network.

The findings emphasize that for ICT resources to be truly effective in SAR operations, availability must be complemented by both functionality and efficiency. Addressing inefficiencies through regular system upgrades, improved maintenance, and enhanced user training will be crucial in ensuring that all available and functional ICT resources contribute to a more responsive and effective SAR capability for the PCG.

PCG vessels are equipped with effective ICT resources, with Ship Communication Equipment being the most effective and Radio Communication Equipment showing the most room for improvement. The high ratings of the Mobile Phone, AIS Receiver, and Satellite Phone demonstrate the reliability of these tools in SAR operations, while lower ratings for the Wideband Receiver, Weather Facsimile, and INMARSAT Fleet Broadband suggest areas where enhancements are needed. Addressing these gaps could further strengthen the efficiency of maritime search and rescue efforts.

PCG faces multiple challenges in utilizing ICT resources effectively for SAR operations. Connectivity issues, environmental factors, equipment shortages, inaccurate distress reports, system interoperability problems, training gaps, slow transmission of reports, and maintenance difficulties all contribute to operational inefficiencies. Additionally, future cybersecurity threats pose potential risks. Addressing these concerns through infrastructure improvements, enhanced training programs, equipment modernization, and cybersecurity measures will be crucial in strengthening the PCG’s SAR capabilities.

The increasing reliance on satellite communication, drone technology, and integrated detection systems among leading maritime agencies highlights the importance of modernizing the PCG’s SAR capabilities. Upgrading ICT resources will significantly improve operational efficiency, enhance situational awareness, and ensure a more effective response to maritime emergencies.

Through a combination of technology advancements, organized staff training, calculated investments, and international collaboration, the PCG must overcome present ICT constraints in order to improve marine SAR operations. These specific suggestions, which are based on personal experience and international best practices, offer a workable plan for enhancing the PCG's operational preparedness and reactivity in maritime crises.

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