Journal of Geospatial Surveying (2025) 5:2
DOI: https://doi.org/10.4038/jgs.v5i2.65

ORIGINAL ARTICLE

Managing Diverse Datasets to Ensure Bathymetric Data Accuracy in Marine Spatial Data Infrastructure (MSDI)

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ARTICLE INFO

Article history:
Received 10 February 2025
Received in revised form 29 April 2025
Accepted 6 May 2025
Available online 4 June 2025

Keywords:
Marine Spatial Data Infrastructure (MSDI)
Bathymetric Data
Accuracy
Metadata

ABSTRACT

Any research study requires the data to be in a generic format, rather than tailored for a specific product or a limited user group. The path from data to information and to knowledge is well-known, and emphasizes the principle that data serves as the foundation of knowledge; validating and ensuring its reliability will enhance its intrinsic value. While the accuracy standards for bathymetric data in hydrographic surveys intended to ensure safe navigation are explicitly outlined in IHO (International Hydrographic Organization) standards based on area-specific descriptions, bathymetric data utilized within the Marine Spatial Data Infrastructure (MSDI) may not always be derived directly from systematic surveys. MSDI relies heavily on the accuracy of bathymetric data, which often vary in source, format, and uncertainty. These variations can compromise data reliability and hinder effective decision making. The lack of a user-friendly framework to asses and access the accuracy status of bathymetric data sets has been identified as a drawback, making it difficult for users to determine their suitability for various applications. This study adopts a mixed-methods approach, combining qualitative and quantitative analyses, to establish robust accuracy levels for diverse data sources integrated into MSDI. Key IHO standards, including S-44 (Minimum Standards for Hydrographic Surveys), S-67 (Mariners' Guide to Accuracy of Depth Information in Electronic Navigational Charts), and S-57 (Transfer Standards of Digital Hydrographic Data), were referenced, with accuracy levels classified into three main categories as; high, moderate and low. This classification enhances the reliability and quality of the final product for users, serving as a foundational pillar of MSDI and supporting its long-term sustainability.

1 Introduction

Spatial Data Infrastructure (SDI) is often used to denote the relevant basic collection of technologies, policies and institutional arrangements to facilitate the availability of and access to spatial data. The SDI provides a base for spatial data discovery, conveyance, evaluation, and application for users (Aalders and Moellering, 2001). The term 'open' is used for data that anyone can access, use, modify, and share – subject, at most, to measures that preserve provenance and openness. Two dimensions of data openness are recognized: data must be both legally and technically open (Izdebski et al., 2021). The SDIs facilitate the platforms to publish open data in a standard manner.

Marine Spatial Data Infrastructure (MSDI) is an integrated framework that enables the comprehensive data management of marine spatial data. MSDI facilitates data management, data sharing, data storing, and data reusing (Tares, 2013) for all users. Additionally, MSDI is a specialized form of SDI that can be introduced as a marine domain of SDI (IHO-C-17, 2023). MSDI is designed to improve the re-use of data supporting a wide range of applications such as safety of navigation, marine spatial planning, coastal zone management, maritime security and maritime law, marine conservation, marine geology, marine resources management, and so on (Foglini and Grande, 2023).

Bathymetric data is used to map the underwater topography of ocean floors and is fundamental for a wide range of marine activities, especially maritime safety. Charting for safe navigation is the primary purpose for bathymetric data and it is used in many other activities such as marine spatial planning, environmental studies,

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underwater construction, coastal zone management, and so on (Kearns and Breman, 2010). The accuracy of bathymetric datasets is important for any marine activity. Bathymetric data accuracy is especially crucial for the safety of navigation and decision-making purposes. Inaccuracies may lead to significant economic losses, environmental and infrastructure damages, and even threats to human safety (Hell et al., 2012).

Accuracy of bathymetric data is a crucial factor in ensuring the reliability of MSDI as it affects the overall quality of the outputs. However, bathymetric data exhibits significant variability due to different sources, acquisition technologies, diverse format, and processing methods that introduce varying uncertainties and accuracy parameters (Li et al., 2023). Accuracy may vary from dataset to dataset, and as a consequence, there would be a problem whether this bathymetric data can directly be included in the MSDI without considering the accuracy status (IHO-S-44, 2022). While MSDI itself does not prescribe explicit accuracy standards, it relies on internationally recognized frameworks such as the International Hydrographic Organization (IHO) standards (e.g., S-44 for hydrographic surveys and S-57 for digital hydrographic data transfer) to assess and classify data accuracy. The integration of bathymetric information into MSDI is based on the accuracy criteria of the respective datasets, which are typically evaluated following internationally accepted standards, e.g. total propagated uncertainty (TPU), total vertical uncertainty (TVU), total horizontal uncertainty (THU), and compliance with Category Zone of Confidence (CATZOC) levels. This requires an adequate identification procedure to determine dataset suitability by evaluating accuracy before data insertion into MSDI (Contarinis et al., 2018).

Accurate bathymetric data are needed because many users will reuse data through MSDI. Sharing of accurate bathymetric data is the responsibility of Hydrographic Offices and other respective data-gathering agencies. Users should easily be able to find the accuracy status of datasets through MSDI, as it is a step forward in hydrographic data management. It provides a framework of geographic data, metadata, users, and tools that are interactively connected to use spatial data efficiently and flexibly. MSDI refers to the guidelines in the C-17 publication SDI "The Marine Dimension" Guidance for Hydrographic Offices under ISO 19115 and ISO 19157. C-17 describes accuracy, completeness, logical consistency, usability, validity, and timeliness as data quality dimensions of the overall quality of MSDI (IHO-C-17, 2023).

Accuracy, in this context, is defined by both the proximity of recorded depth values to the true seabed depth and the methodologies used to determine these values. This includes factors such as sensor calibration, data density, environmental conditions, and error correction techniques. The standardization of bathymetric data accuracy within MSDI is achieved by employing metadata documentation, accuracy classification systems, and adherence to quality control frameworks such as IHO S-67. By incorporating these accuracy assessment methods, MSDI ensures that users can reliably select data suited to their specific applications while maintaining a structured and systematic approach to data integration.

The accuracy and quality of bathymetric data that are appropriate for MSDI have become a significant problem. Therefore, there is a major issue with the accuracy of data for MSDI users for production purposes. The background research indicates a lack of adequate methods to emphasize bathymetric data accuracy on database platforms or metadata cataloguing systems like MSDI (Gao, 2009). Additionally, there are no effective systems or concepts for users to easily find or access the accuracy status of bathymetric datasets.

This study mainly focuses on reviewing the accuracy of bathymetric data and emphasizing the methods of maintaining accuracy for easy and efficient handling of bathymetric data in MSDI. This study aims to provide suggestions for maintaining bathymetric data accuracy in MSDI while considering the main aspects related to bathymetry. The goal is to review the theoretical and conceptual background of bathymetric data accuracy handling in MSDI and propose solutions to provide a user-friendly accuracy classification that enables easy decision making when users select datasets for their specific purposes. Additionally, this study seeks to identify appropriate bathymetric datasets that meet standard criteria on MSDI for both production purposes and user needs. It will guide in maintaining required bathymetric data accuracy on MSDI under IHO C-17 publication requirements, considering the correlation between accuracy and other data quality parameters. This integrative review focuses on developing a standard procedure to ensure uniformity in data quality for various uses, while referencing the internationally adopted S-44 and S-67 frameworks.

The methods described are designed to be adaptable for global use; however, their effectiveness could depend on local technological capabilities, available survey methods, and institutional data management practices (Hare et al., 2011).

Pointing to the technological variabilities in data collection of bathymetries according to geographical location, this research highlights the imperative of a versatile methodology for measuring accuracy. Variability in the methods of collecting data—stretching from multibeam echosounders (MBES), single-beam echosounders (SBES), to satellite-derived bathymetry—is incorporated into the classification model, accommodating for regional limitations. Additionally, the specification for metadata documentation is created to accommodate various technological environments, in a way that data from diverse sources can be incorporated into MSDI with the right indicators. Pursuing international best practices, while also allowing regional adaptation, this study aims to provide a scalable solution that can apply to both global interoperability and local requirements for data handling.

Table 1: Bathymetric data uncertainty variation corresponding to data acquisition method.

Data Acquisition Method	Vertical Uncertainty (TVU)	Average	Source/Reference
Multibeam Echo Sounder (MBES) - Advanced (Modern Systems)	0.10 - 0.30 m	0.1	(IHO-S-44, 2022)
Multibeam Echo Sounder (MBES) - Early Generation	0.50 - 1.00 m	0.5	(IHO-S-44, 2022), (Li et al., 2023)
Single Beam Echo Sounder (SBES) - High Grade	0.50 - 1.00 m	0.5	(Kearns and Breman, 2010), (IHO-B-11, 2019), (Chen et al., 2021)
Single Beam Echo Sounder (SBES) - Basic/Legacy	1.00 - 2.00 m	1	(IHO-B-11, 2019), (Li et al., 2023)
Satellite-Derived Bathymetry (SDB) - Optimized (Clear Waters)	2.00 - 5.00 m	3.5	(Ashphaq et al., 2021), (Foglini and Grande, 2023), (IHO-B-13, 2024)
Crowdsourced Bathymetry (CSB) - Early Stage / Non-Calibrated	> 5.00 m	5 (More than)	(Klemas, 2011), (Hell et al., 2012), (IHO-B-12, 2022)

Table 2: Uncertainty variation corresponding to technological advancement of MBES.

Year	Sample Multibeam System	Vertical Accuracy	Horizontal Accuracy	TPU	Area of Coverage	Depth Range	Source
1990	Early Multibeam Prototype	±1.0 m	±2.0 m	±2.24 m	1 km^2	20-2000 m	(Mayer, 2006), (Hughes Clarke, 2017)
1995	SeaBeam 2112	±0.8 m	±1.5 m	±1.7 m	2 km^2	20-2500 m	(Lurton, 2002), (Hughes Clarke, 2017)
2000	Simrad EM3000	±0.5 m	±1.0 m	±0.7 m	3 km^2	0-1500 m	(Lurton, 2002), (IHO-S-44, 2022)
2005	Reson SeaBat 7125	±0.3 m	±0.6 m	±0.4 m	3.5 km^2	3-1500 m	(Lurton, 2002)
2010	Kongsberg EM 2040	±0.2 m	±0.5 m	±0.3 m	4 km^2	0-600 m	(Dunlop et al., 2018), (IHO-S-44, 2022)
2015	Teledyne RESON T50-R	±0.15 m	±0.3 m	±0.2 m	4.5 km^2	1-400 m	(Teledyne, 2021), (Anderson, 2022)
2018	Kongsberg EM 302	±0.2 m	±0.5 m	±0.3 m	4 km^2	10-6000 m	(Sonardyne), (Hoy et al., 2020)
2019	Reson SeaBat 7125	±0.15 m	±0.3 m	±0.2 m	2.5 km^2	3-1500 m	(Kongsberg), (Dunlop et al., 2018)
2020	Teledyne Odom MB1	±0.25 m	±0.4 m	±0.35 m	1.5 km^2	0-300 m	(Teledyne-Odom)
2017	Sonardyne Solstice	±0.1 m	±0.25 m	±0.15 m	3 km^2	0-100 m	(Sonardyne, 2021)
2021	Fugro Equator system	±0.05 m	±0.2 m	±0.1 m	5 km^2	20-4000 m	(FUGRO-EQUATOR, 2021), (Huang et al., 2023)

2 Literature Review

Hydrographic surveying and bathymetric mapping have evolved substantially over the last century, with significant advancements in sensor technologies, data processing, and data collection methodologies. A critical parameter in bathymetric data quality is vertical uncertainty, often called Total Vertical Uncertainty (TVU). Vertical uncertainty measures the potential error in the reported depth values and is typically expressed in meters (m). It reflects our confidence that the measured depths represent the true seafloor elevation within a given error range. Lower vertical uncertainty indicates higher confidence and more accurate depth measurements (IHO-S-44, 2022). Fig. 1 depicts how the TVU varies with the advancement of technology with respect to previous studies explained in Table 1.

Early multibeam systems, such as the SeaBeam 2112 (1995) and Simrad EM3000 (2000), exhibited vertical accuracies around ±0.5 to ±1.0 m, with coverage expanding up to 3 km^2 (Hughes Clarke, 2017; Lurton, 2002).

Advancements in the Reson SeaBat 7125 (2005) and Kongsberg EM 2040 (2010) further refined the accuracy, reducing Total Propagated Uncertainty (TPU) to ±0.3 m while improving coverage to 4 km^2 (Dunlop et al., 2018). Modern systems, such as the Fugro Equator (2021), have achieved exceptional accuracy (±0.05 m) and broader coverage (5 km^2) (Bird and Mullins, 2005; FUGRO-EQUATOR, 2021).

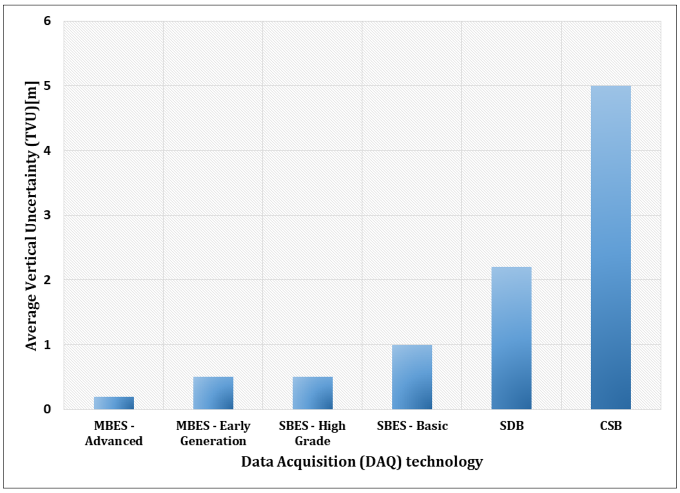

Fig. 1: Bathymetric data uncertainty variation with data acquisition method.

MBES uncertainty variations are shown in Fig. 2 based on reference sources explained in Table 2.

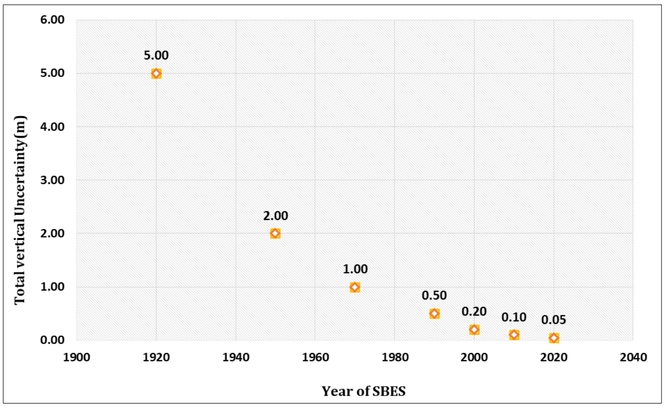

Fig. 2: Uncertainty variation with technological advancement of MBES.

SBES technology has progressed from mechanical sounders in the 1920s with vertical accuracies of ±5.0 m to modern AI-enhanced SBES in the 2020s capable of achieving ±0.05 m accuracy (Foglini and Grande, 2023) The introduction of GPS-integrated SBES (in 1990) and high-frequency SBES (in 2000) significantly improved positional accuracy and penetration depth (IHO-S-44, 2022; Kearns and Breman, 2010). SBES uncertainty variations are shown in Fig. 3 based on reference sources explained in Table 3.

Despite the advances in bathymetric data acquisition and MSDI realization, there are several research gaps. The lack of common methods for integrating heterogeneous data sources hinders global data interoperability (IHO-C-17, 2023; Racetin et al., 2022). In addition, automatic accuracy classification techniques using AI and machine learning are less developed, which limits the efficiency of real-time data updating (Li et al., 2023). Furthermore, metadata documentation and data provenance tracking need to be enhanced to enable transparency and usability in MSDI (IHO-S-67, 2020; IHO-S-102, 2022). Addressing these gaps will lead to improved MSDI reliability, data quality, and decision-making for various marine applications (Foglini and Grande, 2023; Kearns and Breman, 2010).

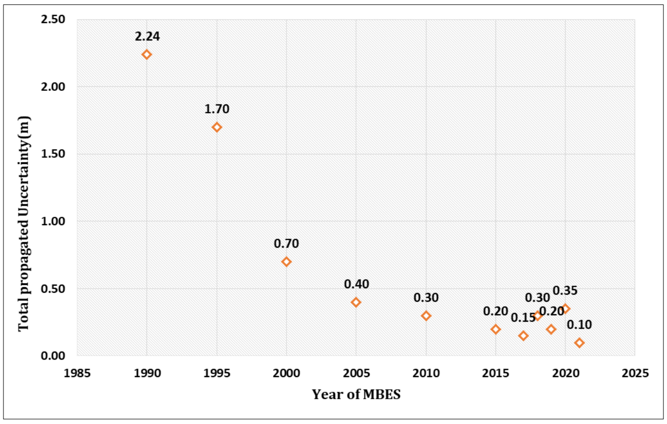

Fig. 3: Uncertainty variation with technological advancement of SBES.

3 Methodology

3.1 Study Area

The geographical extent of the study area spans from the southern end of the Colombo District, Sri Lanka, located at 6° 35' 13.04" N, 79° 57' 21.09" E, to the northern end of the Gampaha District, at 7° 16' 19.85" N, 79° 50' 31.00" E. This region includes the coastline along the border of the Colombo and Gampaha districts, and extends from the baseline to the margin of Sri Lanka's Territorial Waters (TW) as shown in Fig. 4.

The geographical coastal region was selected as the study area due to its strategic maritime importance and the availability of reliable bathymetric data. This area includes Sri Lanka's main commercial port (Port of Colombo) and several key fishery harbours, which require regular hydrographic updates for navigation safety and operational efficiency. As a result, the region has comparatively frequent and detailed bathymetric surveys, making it a suitable candidate for analysing data accuracy and metadata availability. The selection was also guided by the accessibility of historical and recent datasets from the National Hydrographic Office (NHO), ensuring comprehensive data coverage for the study.

Table 3: Uncertainty variation with technological advancement of SBES.

Year	System Type	Vertical Accuracy	Coverage Area	Depth Range	Source
1920	Early Mechanical SBES	±5.0 m	Single line	0-100 m	(Urick, 1982), (IHO-S-100, 2010)
1950	Analog SBES	±2.0 m	Single line	0-200 m	(IHO-S-100, 2010), (Lurton, 2011)
1970	Digital SBES	±1.0 m	Single line	0-500 m	(Lurton, 2002)
1990	GPS-Integrated SBES	±0.5 m	Single line	0-800 m	(Kearns and Breman, 2010)
2000	High-Frequency SBES	±0.2 m	Single line	0-1500 m	(IHO-S-44, 2022), (Li et al., 2023)
2010	Multi-Beam SBES	±0.1 m	Single line	0-3000 m	(Van Walree et al., 2006), (IHO-S-44, 2022)
2020	AI-Enhanced SBES	±0.05 m	Single line	0-4000 m	(Foglini and Grande, 2023), (Li et al., 2023)

Table 4: Classification based on CATZOC (*Source*: IHO-S-67, 2020).

ZOC	Position accuracy	Depth accuracy	Seafloor coverage
A1	± 5m + 5% depth	0.50 m + 1% depth	Full area search undertaken. Significant seafloor features detected, and depths measured.
A2	± 20m	1.00 m + 2% depth	Full area search undertaken. Significant seafloor features detected, and depths measured.
B	± 50m	1.00 m + 2% depth	Full area searches not achieved; uncharted features hazardous surface navigation is not expected but may exist.
C	± 500m	2.00 + 5% depth	Full area searches not achieved; depth anomalies may be expected.
D	Worse than ZOC C	Worse than ZOC C	Full area searches not achieved; large depth anomalies may be expected.
U	Unassessed – The quality of the depth data has yet to be assessed.		

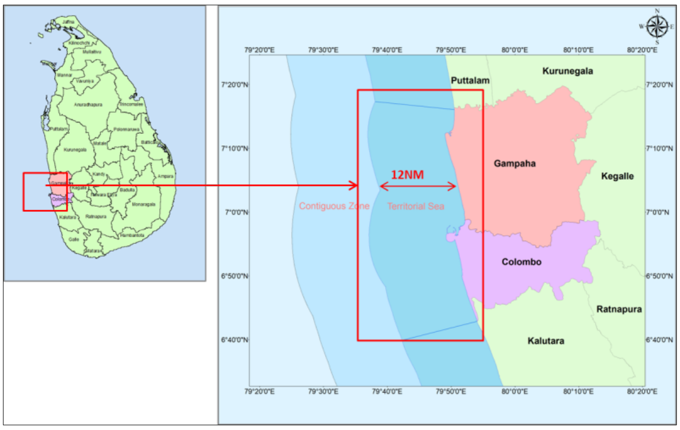

Fig. 4: Study area, area from the baseline to the margin of Territorial Water (TW) along the Colombo and Gampaha Coast.

3.2 Data and Resources

The NHO, established in 1984 under National Aquatic Resources Research and Development Agency (NARA) and accredited by the IHO, serves as the focal point for hydrography in Sri Lanka. The study utilized hydrographic datasets from the NHO, which include systematic data collected from inshore, nearshore, and offshore areas within the Exclusive Economic Zone (EEZ) of Sri Lanka, as well as inland water-bodies. These datasets were integral to the analysis and development handling of the bathymetric data accuracy in the MSDI for the selected study area. While this study specifically utilizes data from the NHO of Sri Lanka, the proposed methodologies and accuracy classification frameworks are adaptable to regional, global, and organizational implementations, aligning with international best practices in MSDI.

3.3 Methods

This study follows the mixed-method, including both qualitative analysis and quantitative analysis. The systematic data extraction process was used to extract data for review analysis. The following main steps were done;

i. Systematic Review for Data Extraction
ii. Review Analysis
iii. Data Analysis

3.3.1 Systematic Review for Data Extraction

For data extraction for the qualitative analysis, this study systematically selected and extracted data from both academic databases [Google Scholar and IEEE; peer-reviewed research articles were considered using mentioned online available research databases] and IHO publications, following the procedure outlined in Fig. 5.

While quantitative analysis relies on NHO data, the process of identification, screening, eligibility, and inclusion in qualitative data collection is essential for developing the proposed accuracy classification matrix. A systematic literature review ensured that the classification framework is aligned with international standards, incorporated best practices, and addressed gaps in existing methodologies.

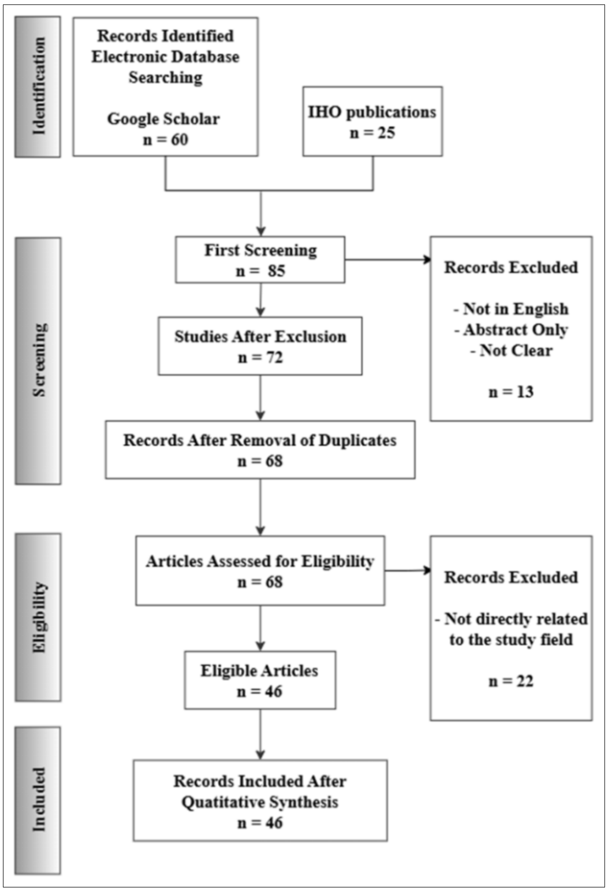

Fig. 5: Methodology for data extraction.

3.3.2 Qualitative Approach of Review Analysis

The relevant data were extracted during this step as outlined in Fig. 6, and parameters were identified using the included articles. CATZOC is a comprehensive framework to classify data in MSDI, similar to nautical charts. It provides six categories as; A1, A2; B; C; D; U (IHO-S-67, 2020), shown in Table 4.

S-44 was also considered during this step, and it emphasizes; Survey orders and specifications; Total propagated uncertainty; Total vertical uncertainty; Total horizontal uncertainty; Minimum bathymetry standards; and Minimum other standards; All considerable guidance for hydrographic surveys (IHO-S-44, 2022). The other information that was also derived in the qualitative analysis using Google Scholar included articles and IHO B-11, IHO B-12, IHO B-13, IHO S-100, and IHO S-102 were included. S-102 describes; Discovery Metadata; Structure Metadata; Quality Metadata; Acquisition Metadata; Exchange Set Metadata (IHO-S-102, 2022). A detailed description about the IHO publications series are listed in Table 5. Table 6 illustrates the key point of publications and relativity between the study and publication.

Table 5: Detailed descriptions of IHO publication terms.

Series	Detailed Description
B	B - Bathymetric Publications (Mainly related to GEBCO).
C	C - Capacity Building Publications
M	M - Miscellaneous Publications (including Basic Documents)
P	P - Periodic Publications
S	S - Standards and Specifications

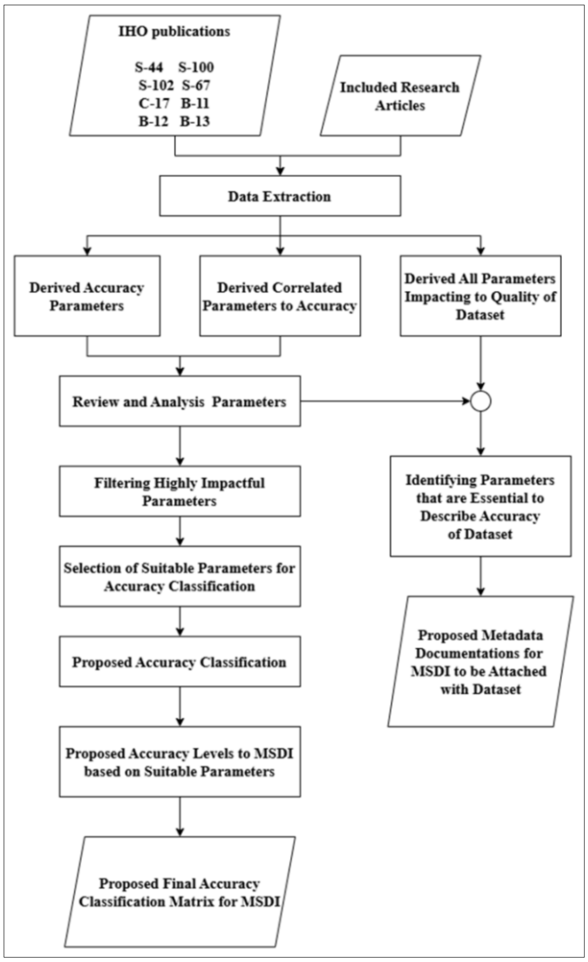

Fig. 6: Methodology flowchart of review analysis.

Table 6: IHO parameters selected for this study.

Series No	Key Focus	Highlighted	Relation to Research Study
B-11	Bathymetric Data Processing	Guide on data cleaning, gridding, and validation methodologies	Techniques for data accuracy and uncertainty analysis
B-12	Guidance to Crowdsourced Bathymetry	Standards, quality control, and key methods for crowdsourcing	Quality control metrics and data validation processes
B-13	Guidance to Satellite-Derived Bathymetry	Techniques, standards, and suitability for satellite-derived bathymetry	Data validation processes and uncertainty analysis
C-17	Marine Component of Spatial Data Infrastructure	Data management frameworks and MSDI standardization	MSDI data standards and framework implementation
S-102	Specification for Bathymetric Surface	Product specification standards for bathymetry	Bathymetric data accuracy and formats
S-44	IHO Standards for Hydrographic Surveys	Survey methodologies, calibration, and validation procedures	Accuracy standards and specifications
S-67	Mariners' Guide to Accuracy of Depth Information in ENC	Depth interpretation, ZOC utilization, and navigation safety	Impact of ZOC on navigation safety
S-100	Universal Hydrographic Data Model	Data model framework compatible with various hydrographic data types	S-100 standard for data accuracy and interoperability

3.3.3 Quantitative Approach to Data Analysis

The bathymetric datasets were analyzed and the metadata documentation discovered via the review analysis was filled out during this step. The data analysis was done to check the effectiveness and success of the review analysis which followed the procedure outlined in Fig. 7.

Bathymetric data analysis refers to the process of evaluating bathymetric datasets and identifying the various parameters and numeric values that affect the data accuracy. The analysis is for the purpose of identifying parameters and errors, defining uncertainty, and data classification based on the recommended classification. The process also encompasses identifying missing parameters for accuracy classification.

Metadata documentation is the structured recording of key information about a dataset. For bathymetric data, it includes details on data accuracy, collection methods, positioning systems, and processing history. In MSDI, metadata helps users understand data quality and suitability, supporting informed decision-making and ensuring data reusability in line with standards like ISO 19115 and IHO S-102. Pre-survey documentation is the composite set of documents prepared prior to fieldwork in the reconnaissance and planning stages.

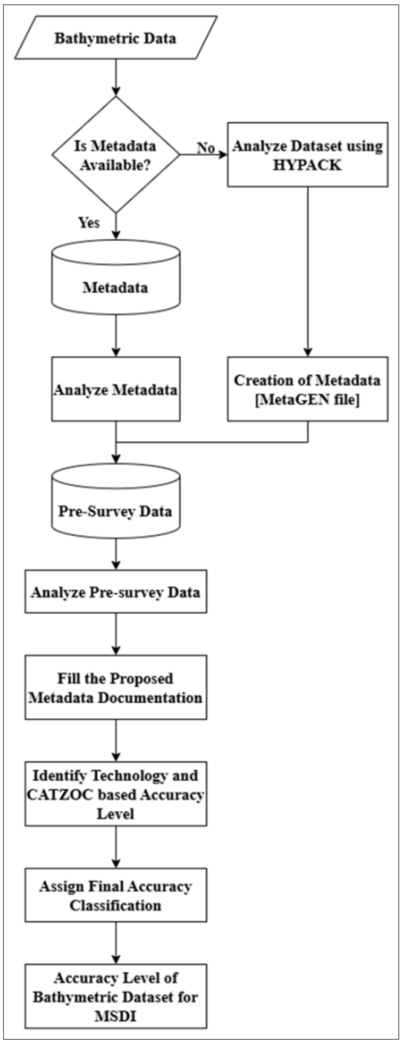

Fig. 7: Methodology flowchart of data analysis.

4 Results and Discussion

4.1 MSDI-Appropriate Accurate Bathymetric Dataset

All bathymetric datasets, even those of lower quality, are valuable to MSDI for certain applications. Low-quality datasets for example, may still provide important information for scientific research. Therefore, all datasets were appropriate for MSDI. The accuracy classification with different levels was suggested as a user-friendly way of identifying the accuracy status of bathymetric datasets. Hence all datasets would be appropriate with the proper metadata documentation including accuracy levels.

4.2 Accuracy Classification Systems in MSDI

Accuracy classification is critical for handling various bathymetric datasets and maintaining data quality in MSDI. The classification system follows IHO standards, resulting in a systematic review approach.

The Primary Accuracy Classification System is composed of a secondary classification system to easily identify the basic level of accuracy efficiently. This approach enables MSDI users with basic understanding to easily and efficiently asses the accuracy status of datasets for various applications, as shown in column 1 of Table 7.

The secondary Accuracy Classification System is a proposed classification system that integrates CATZOC accuracy levels with technology-based classification, derived from the comprehensive review analysis. This secondary classification system offers users a deeper understanding of dataset accuracy, enabling more informed data selection within the MSDI as shown in column 2 of Table 7. Table 8 maps CATZOC levels to corresponding survey quality tiers, indicating that higher CATZOC aligns with better survey levels, while lower CATZOC or "Below D" corresponds to less reliable survey data. Table 9 explains CATZOC categories to corresponding tier-based data quality levels, indicating the suitability of hydrographic survey data for various purposes and Table 10 explains associated terms for suitability.

Table 7: Proposed accuracy classification levels for MSDI.

Proposed Primary Accuracy Level	Proposed Secondary Accuracy Level
Level 1 - High	Level 1 - Ultra-High Accuracy
	Level 2 - High
	Level 3 - Enhanced Plus
	Level 4 - Enhanced
Level 2 - Moderate	Level 5 - Standard Plus
	Level 6 - Standard
	Level 7 - Standard Low
Level 3 - Low	Level 8 - Basic
	Level 9 - Provisional

The bathymetric data provided by the NHO had been collected through a variety of methods. The main equipment utilized involved the Kongsberg EA440 Echo Sounder for depth measurement, POS MV for position monitoring, and Sound Velocity Profile (SVP) sensors and tide gauges as secondary equipment. These technologies fall under Tier 4 of the proposed classification system, denoting a level of medium accuracy. This rating is also comparable to CATZOC Level B, denoting standard quality data for general maritime use.

Table 8: Proposed accuracy classification matrix.

CATZOC ↓ / Tier →	Tier 1	Tier 2	Tier 3	Tier 4	Tier 5	Tier 6	Tier 7
A1	Level 1	Level 2	Level 3	Level 4	**Unclassified**	**Unclassified**	**Unclassified**
A2	Level 2	Level 3	Level 3	Level 4	Level 6	Level 7	**Unclassified**
B	Level 3	Level 3	Level 4	Level 5	Level 6	Level 7	Level 8
C	Level 4	Level 4	Level 5	Level 5	Level 6	Level 7	Level 8
D	Level 5	Level 5	Level 6	Level 6	Level 6	Level 7	Level 8
Below D	Level 6	Level 6	Level 7	Level 7	Level 7	Level 8	Level 9

Table 9: Proposed accuracy classification matrix with relation to strength descriptions.

CATZOC ↓ / Tier →	Tier 1	Tier 2	Tier 3	Tier 4	Tier 5	Tier 6	Tier 7
A1	Level 1 *(Primary)*	Level 2 *(Fallback)*	Level 3 *(Lower Bound)*	Level 4 *(Min for A2)*	**Unclassified**	**Unclassified**	**Unclassified**
A2	Level 2 *(Fallback)*	Level 3 *(Primary)*	Level 3 *(Primary)*	Level 4 *(Fallback)*	Level 6 *(Weak)*	Level 7 *(Very Weak)*	**Unclassified**
B	Level 3 *(Fallback)*	Level 3 *(Fallback)*	Level 4 *(Primary)*	Level 5 *(Primary)*	Level 6	Level 7	Level 8
C	Level 4 *(Fallback)*	Level 4 *(Fallback)*	Level 5 *(Fallback)*	Level 5 *(Primary)*	Level 6 *(Primary)*	Level 7 *(Primary)*	Level 8 *(Fallback)*
D	Level 5 *(Fallback)*	Level 5 *(Fallback)*	Level 6 *(Fallback)*	Level 6 *(Fallback)*	Level 6 *(Fallback)*	Level 7 *(Primary)*	Level 8 *(Primary)*
Below D	Level 6 *(Fallback)*	Level 6 *(Fallback)*	Level 7 *(Fallback)*	Level 7 *(Fallback)*	Level 7 *(Fallback)*	Level 8 *(Fallback)*	Level 9 *(Primary)*

Table 10: Proposed accuracy classification matrix with relation to strength description explanations.

Term	Explanation	Based On	Typical Usage
Primary	The best possible accuracy level achievable when the technology is ideally matched to the CATZOC requirement.	Ideal tech–CATZOC match	Used in official charts, navigation, and certified hydrographic data.
Fallback	A lower classification given when higher-end technology is used on lower CATZOC areas or less rigorous survey environments.	Overqualified tech for zone	Used in AI processing, metadata tagging, and quality-adjusted outputs.
Minimum Supported Accuracy	The lowest allowable classification level based on the CATZOC category as per IHO S-44 or equivalent standards.	CATZOC requirement baseline	Acts as risk threshold for safe usage in MSDI and mapping.
Lower Bound	The minimum level where data just meets the expected threshold. Used in marginal cases.	Technically acceptable	Used for low-confidence metadata and edge-case approvals.
Weak	Acceptable but lacks confidence for high-reliability applications.	Barely passes minimum QA/QC	For general awareness, non-navigational planning.
Very Weak	Often fails key QA/QC checks. Limited to informal uses only.	Inconsistent or poor-quality inputs	Used for rough visual references, not reliable for decisions.
Unclassified	"Unclassified" is not an acceptable fallback or result when the technology simply cannot support the CATZOC requirement.	Normally not happened.	

Most of the metadata for these datasets, however, were originally unavailable. Critical components such as pre-survey documentation, calibration logs, error logs, and overall accuracy parameters were also incomplete or missing. To overcome this, the research created dataset metadata using HYPACK software, reproducing information by examining the dataset. When this process was completed, the absence of original metadata created challenges in ensuring data traceability and authenticity within the MSDI. This highlighted the need to implement standardized metadata protocols at the data collection stage.

Based on the literature review, technology is the most crucial parameter for accuracy classification. This is because it gets updated quite quickly compared to other identified accuracy parameters and blending conditions. This study proposed the classification based on the technology as an intermediate finding, which is indicated in Table 11.

Table 11: Proposed accuracy classification based on technology.

Technological Level Tier	Technologies	Accuracy Level
Tier 1: Ultra- High Accuracy	Advanced Multibeam Echosounders High-Precision LiDAR AUVs/ROVs	Very High
Tier 2: High Accuracy	Standard Multibeam Echosounders High-grade Single-Beam echo sounders	High
Tier 3: Standard Accuracy	Standard Single-Beam Echosounders and Side-Scan Sonar Mid-range AUVs/ROVs	High to Moderate
Tier 4: Moderate Accuracy	Early-generation multibeam systems Single-beam echo sounders	Moderate
Tier 5: Broad Area Coverage	Satellite-Derived Bathymetry	Moderate to Low
Tier 6: Low Accuracy	Basic sonar technologies Early-stage crowdsourced data	Low
Tier 7: Very Low Accuracy	Any technology/ Old data collections	Very Low

This result was used to define the final classification systems for MSDI. The proposed final system is based on a combination of the technological accuracy levels and CATZOC based classification.

The primary accuracy classification system provides an easy-to-understand framework for users. The secondary accuracy classification system makes the deep accuracy classification. This system is suggested for users who want more classified datasets for various reasons. Both classification systems are designed to maintain user-friendly accuracy handling within MSD. The goal is to create an efficient and accessible environment for users to select a dataset based on accuracy parameters. These two systems are expected to make a user-centric classification.

The records include various parameters that influence bathymetric data accuracy as explained in Table 12. Since accuracy variations are directly linked to these parameters, they can serve as effective criteria for accuracy classification. Among all available parameters, those with the greatest impact on accuracy were selected for classifying bathymetric data. However, incorporating all listed parameters into the classification system would be impractical for several reasons: it would create unnecessary complexity, reduce efficiency, and make the system difficult for users to navigate. After evaluation, technology type and CATZOC classification emerged as the most appropriate parameters for developing a practical and effective accuracy classification system.

The parameters selected for accuracy classification were identified through a systematic literature review and statistical correlation analysis. They were identified after consulting and following: key documents including IHO S-44, S-67, and S-102, along with publications such as IHO B-11, B-12, and B-13. These sources define and recommend the critical accuracy parameters used in hydrographic surveys and MSDI implementation. Parameters like vertical and horizontal accuracy, data density, resolution, and positioning system precision are consistently highlighted as primary factors influencing bathymetric data quality.

The selection process prioritized parameters based on their direct impact on bathymetric accuracy, frequency of mention in standards, and relevance to modern data acquisition technologies. Sensor technology, for example, directly affects multiple accuracy aspects, including data resolution, uncertainty, and depth measurement precision. The following reasons are considered; direct impact on data quality, technological advancement rate, versatility in various conditions, calibration and validation, integration with other systems, reduction of errors, and incorporation of latest innovations.

The influence of sensors is supported by evidence in IHO guidelines and numerous case studies demonstrating how advanced sensors improve data quality across different marine environments. Instrumentation and sensor technology is one of the most important parameters within the bathymetric dataset. It can affect many accuracy parameters directly and indirectly because many parameters depend on sensor advancement. Furthermore, sensor technology has shown a high frequency of updating, along with accuracy advancement.

Based on this analysis, the derived accuracy parameters must be displayed with metadata to ensure efficient bathymetric data handling while maintaining accuracy standards. The parameter framework includes; Aspect; Accuracy: Vertical Accuracy, Horizontal Accuracy; Resolution Spatial Resolution, Temporal Resolution: Completeness: Coverage, Data Gaps; Consistency: Cross-dataset Consistency, Temporal Consistency; Timeliness: Data Age, Update Frequency; Reliability: Data Integrity, Error Tracking; Precision: Precision; Usability: Interoperability Formats.

The CATZOC accuracy classification method is well-suited for bathymetric data. This is specifically designed for nautical charting, but can describe the accuracy status of bathymetric datasets as well. Therefore, this categorization is important in this type of research. The following reasons were considered; Standardized Evaluation, Enhances Data Usability, Ease of Use, and Global Recognition.

Table 12: Suitable accuracy classification parameters.

Attribute	Aspect	Impact
Resolution	The area can be captured at once	Higher resolution detects smaller seafloor features and lower resolution may miss finer details.
Coverage	The extent of the area surveyed in a single pass	Broader coverage enhances efficiency for large-area mapping but may compromise resolution.
Depth Penetration	Maximum depth accurately measured	Essential for deep-sea surveys, affecting the range and applicability of the technology.
Data Density	Amount of data points collected over an area.	Higher data density provides a more detailed representation of the seafloor.
Environmental Factors	Environmental conditions affecting accuracy.	Water clarity, sea state, and bottom type can all impact the accuracy and effectiveness of bathymetric surveys.
Calibration and Validation	Instrument calibration and data validation capabilities.	Ensures data accuracy and reliability by aligning measurements with known standards.
Sensor Technology	Type and quality of sensors used.	Significantly impacts data accuracy, with advanced sensors potentially offering superior data collection capabilities.
Data Processing and Correction	Effectiveness of data processing and correction algorithms.	Critical for reducing noise and correcting errors, impacting the quality and usability of the data.
Positioning and Navigation Accuracy	The precision of the positioning system used during data collection.	Affects the geospatial accuracy of bathymetric data, essential for mapping and analysis purposes.
Data Age	Time since data collection or last update.	Indicates data currency, with older data potentially less relevant due to environmental changes.
Total Uncertainty	Combined level of doubt or error in measurements.	Provides an overall indication of measurement reliability and precision, encompassing both systematic and random errors.
CATZOC Accuracy Classification	Standardized assessment of hydrographic data quality.	Ranges from A1 (highest accuracy) to U (unassessed), indicating the confidence level in the data based on depth and position accuracy, seafloor coverage, and survey standards.

Table 13: Results of assigned accuracy classification for sample dataset, CONCMBH001_2023.

Project_NO	Data_Set_ID_MSDI	Data_Set	Accuracy_Tier	CATZOC Accuracy Level	Proposed Secondary Accuracy Level	Proposed Primary Accuracy Level
CONCMBH001_2023	SL/NR/NHO/2023/0001	Bathymetric Survey at Negombo for SLLRDC	Tire 4	B	Level 5 - Standard Plus	Level 2 - Moderate

Table 14: Results of assigned accuracy classification based on technology for sample dataset, CONCMBH001_2023.

Technology			**Accuracy_Tier**
Sounding	Positioning	Supplementary	
Kongsberg EA440 Echo Sounder	Stonex RTK	SVP / Tide Gauge	Tire 4

Table 15: Results of assigned accuracy classification based on CATZOC level for sample dataset, CONCMBH001_2023.

CATZOC Accuracy Level				
Position Accuracy	Depth Uncertainty	Bottom Coverage	Feature Detection	Accuracy Level
5m	2m	Moderate	Moderate	B

Table 16: Assigned final accuracy classification for sample dataset, CONCMBH001_2023.

Proposed Secondary Accuracy Level	**Proposed Primary Accuracy Level**
Level 5 - Standard Plus	Level 2 - Moderate

4.3 Assigned Accuracy Classifications to Sample Bathymetric Dataset

The sample dataset analysis demonstrates a systematic approach to classifying bathymetric data for MSDI, and a sample is shown in Table 13. Using the Negombo survey as an example, the research presents a multi-tiered classification method that integrates technological capabilities, accuracy levels, and metadata documentation. The classification process involves: Detailed technology assessment (Kongsberg EA440 Echo Sounder) is shown as an outcome in Table 14, Accuracy level determination (CATZOC Level B) and Proposed accuracy classification are given in Table 15.

This methodology provides a standardized framework for users to quickly understand the reliability and characteristics of bathymetric datasets. By creating a transparent classification system as shown in Table 16 for sample data, the research enables more informed decision-making across marine spatial applications, from navigation safety to environmental research. The approach addresses a critical need in marine data management: transforming raw survey data into a structured, easily interpretable format that maintains the integrity and usability of bathymetric information within SDIs.

Metadata Documentation was systematically filled out, the data were verified, and they were included with the datasets. The missed data were filled out with a created metadata file (metagen file) using HYPACK with the help of dataset analysis through the software. . The metadata documentation was designed to include all essential details required for comprehensive data cataloging, ensuring bathymetric data accuracy is maintained within the MSDI framework. As a result of this process, accuracy parameters were assigned to the analysed dataset during the data analysis.

The accuracy parameters are an essential part to describe the bathymetric accuracy in metadata documentations. Table 17 shows the accuracy classification parameters for a classified sample dataset CONCMBH001_2023.

Table 17: Accuracy parameters of classified sample data from Metadata Documentation.

5.0	**Accuracy Parameters**	
5.1	Primary Accuracy Level	Moderate
5.2	Secondary Accuracy Level	Level 5 - Standard Plus
5.3	Survey Specification	1B
5.4	Accuracy	
5.4.1	Total Positioning Uncertainty (TPU)	2.01m
5.4.2	Total Horizontal Uncertainty (THU)	2m
5.4.3	Total Vertical Uncertainty (TVU)	0.2m
5.5	Resolution	
5.5.1	Spatial Resolution	
5.5.1.1	Across Track Resolution	1.5m
5.5.1.2	Along Track Resolution	0.09m
5.5.2	Temporal Resolution	No temporary updating.
5.6	Coverage	

5.6.1	Coverage	Constant Spacing
5.6.2	Coverage as percentage	75%
5.6.3	Line spacing	200m
5.6.4	Data Gaps	None
5.7	Consistency	
5.7.1	Cross-dataset Consistency	Non-checked
5.8	Timeliness	
5.8.1	Data Age	After 2020
5.8.2	Update Frequency	As needed
5.9	Reliability	
5.9.1	Data Integrity	Non-verified
5.9.2	Error Tracking	☑Real Time Error Tracking ☑Apply Quality Assurance ☑Apply Quality Control in field
5.10	Precision	High
5.11	Usability	
5.11.1	Interoperability	Partially Interoperable
5.11.2	Interoperability constraints	No
5.12	CATZOC accuracy level	B

4.4 Metadata Documentations

The metadata handling of datasets is the crucial part of handling the accuracy of datasets. Therefore, correct metadata documentation should be available with the datasets. Metadata documentation provides essential information about the discovery metadata, structure metadata, quality metadata, acquisition metadata, and exchange set metadata, reflecting bathymetric data accuracy, facilitating its discovery, evaluation, and use by various stakeholders. Metadata documentation and guidelines on completing them are proposed for both raw datasets and processing datasets.

For metadata documentation of raw data, 72 parameters are included, covering 7 main categories especially including accuracy parameters derived from review analysis. Following categories are included to metadata documentation of raw data, and relevant percentages are shown in Fig. 8;

- General
- Identification information
- Description
- Extent
- Accuracy parameters
- Point of contact
- Meta – metadata

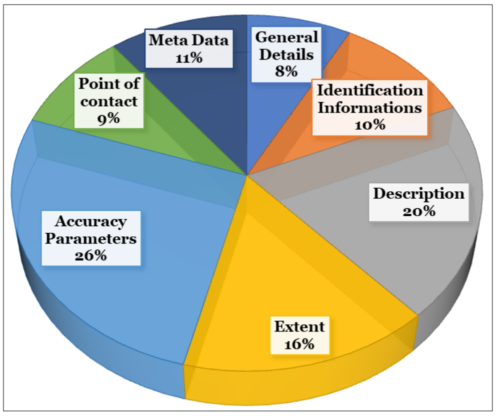

Fig. 8: Essential category of metadata parameters for raw bathymetric data in MSDI.

For metadata documentation of processed data, 78 parameters are included, covering 8 main categories with an extra that includes the processing status, as follows and the associated percentages are shown in Fig. 9;

- General
- Identification information
- Description
- Extent
- Accuracy parameters
- Point of contact
- Meta – metadata
- Processing status

The bathymetric data within the MSDI needs to be updated systematically and regularly for filling the gaps in data and the documenting information. The analysis of the available metadata and pre-survey details indicated the availability and lack of some critical parameters related to accuracy. However, the NHO as the responsible agency for authorized bathymetric data in Sri Lanka, has been found to generally lack adequate practices for maintaining and updating their datasets. The following suggestions are made in light of identified shortcomings in the handling of bathymetric datasets.

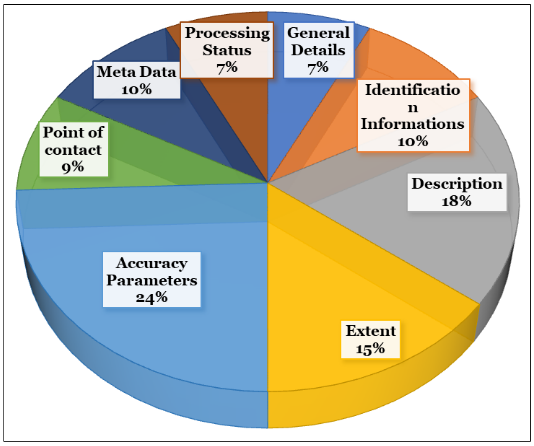

Fig. 9: Essential category of metadata parameters for processed bathymetric data in MSDI.

This will ensure that any information required is captured at the outset in pre-survey planning. Pre-survey documentation should be prepared consistently and attached to future datasets. For existing datasets, this information can be reconstructed from surveyor logs; where these are not available, pre-survey records should be created using at least the minimum available information. All the supporting data, for example, tidal and SVP profiles, co-required to clarify ambiguities during analysis, should be stored along with the datasets.

An accessible instrumentation logbook should be available during data collection, detailing but not limited to the name of the instrument, brand, uncertainty, and calibration status, which will help in ensuring traceability and reliability of the data.

Another critical aspect is metadata handling. Standardization of metadata documentation using dedicated software tools is recommended, with formats such as HYPACK for raw data files and metagen (GEN file) for supplementary metadata. For legacy datasets, an attempt should be made to create metadata documentation using whatever minimum information is available.

It is recommended that a shift to geodatabase enhances the data storage in a way that datasets are systematically organized and properly documented with metadata. It is also desirable to have a centralized data catalog database which will help the access and management of data.

Most of the datasets lacked proper records with regards to pre-survey information, metadata, processing status, supportive information like tidal and SVP data, and accuracy parameters. The datasets must be properly documented with information on pre-survey, metadata records, tidal and SVP data, data acquisition and processing reports, progress reports, and final descriptive reports.

5 Conclusion

This study underscores the critical importance of accurate bathymetric data in various maritime operations and decision-making processes within the MSDI framework, with a focus on the NHO in Sri Lanka. The research identified and evaluated bathymetric datasets suitable for integration into MSDI, assessing their compliance with standards established by the IHO and geospatial authorities. A significant outcome was the development of an accuracy classification system for MSDI users, providing a clear and user-friendly method to determine data reliability.

The study also emphasized that comprehensive metadata documentation is a key factor in maintaining data accuracy and quality, recommending robust guidelines for metadata management. It revealed that while lower-quality data can still be valuable for certain applications, current practices at the NHO require enhancement to reflect initial accuracy conditions and ensure seamless integration with MSDI. Specific recommendations include attaching metadata to datasets, converting file-based databases into geodatabases, and adopting systematic techniques for managing raw, processed, and future data. These measures aim to improve data management efficiency and connectivity within MSDI frameworks, ensuring long-term sustainability and usability.

Acknowledgement

The authors are grateful to the National Hydrographic Office (NHO), National Aquatic Resources Research and Development Agency (NARA), Sri Lanka, for their support during the research work.

This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

Author Contributions

Conceptualization K.M.D.H., methodology and analysis K.M.D.H., A.N.D.P. and M.D.E.K.G., writing - original draft preparation, K.M.D.H., review A.N.D.P. and M.D.E.K.G. and editing, K.M.D.H. All authors have read and agreed to the published version of the manuscript.

Conflict of Interest

The authors declare no conflict of interest.

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Appendices

Appendix A: Generic Metadata Format Sample for Bathymetric Data.

Identification_Information:
Citation:
Citation_Information:
Originator: National Hydrographic Office
Publication_Date: 20240324
Title: Bathymetric Survey at Negombo for SLLRDC
Geospatial_Data_Presentation_Form: map
Series_Information:
Publication_Information:
Publication_Place: National Hydrographic Office
Publisher: National Hydrographic Office
Larger_Work_Citation:
Citation_Information:
Series_Information:
Publication_Information:
Description:
Abstract:
Bathymetric Survey was done in Negombo for Sri Lanka Reclaiment and Development Corporation (SLLRDC).
Purpose: Site inspection survey bottom sand dredging
Time_Period_of_Content:
Time_Period_Information:
Single_Date/Time:
Range_of_Dates/Times:
Beginning_Date: 20231129
Ending_Date: 20231217
Multiple_Dates/Times:
Currentness_Reference: Publication Date
Status:
Progress: Complete
Maintenance_and_Update_Frequency: As needed
Spatial_Domain:
Bounding_Coordinates:
West_Bounding_Coordinate: 381817.05
East_Bounding_Coordinate: 389202.90
North_Bounding_Coordinate: 513150.89
South_Bounding_Coordinate: 502856.24

Access_Constraints: Copyright
Point_of_Contact:
Contact_Information:
Contact_Person_Primary:
Contact_Organization_Primary:
Contact_Organization: National Hydrograpgic Office
Contact_Person: Cheif Hydrographer
Contact_Position: Bathyemetry
Contact_Address:
Address_Type: mailing and physical address
Address:
National Aquatic Resources
Research and Developement
Agency, Crow Island, Mattakkuliya
Colombo 15
City: Colombo 15
State_or_Province: Western
Postal_Code: 10500
Country: Sri Lanka
Contact_Voice_Telephone: +94 112521006
Contact_Electronic_Mail_Address: postmaster@nara.ac.lk
Hours_of_Service: 8am - 4pm
Contact_Instructions: If you want to dataset contact via phone,email and mail.
Security_Information:
Security_Handling_Description: Copyright
Security_Classification: Sensitive
Security_Classification_System: Copyright
Cross_Reference:
Citation_Information:
Series_Information:
Publication_Information:
Data_Quality_Information:
Attribute_Accuracy:
Attribute_Accuracy_Report:
Primary: Level 1 - Low
Secondary: Level - Moderate
Quantitative_Attribute_Accuracy_Assessment:
Attribute_Accuracy_Value: 2
Logical_Consistency_Report: Non-checked
Completeness_Report: No Data Gaps
Positional_Accuracy:
Horizontal_Positional_Accuracy:
Horizontal_Positional_Accuracy_Report: Low
Quantitative_Horizontal_Positional_Accuracy_Assessment:
Horizontal_Positional_Accuracy_Value: 2m
Vertical_Positional_Accuracy:
Vertical_Positional_Accuracy_Report: High

Metadata_Reference_Information:
Metadata_Date: 20240324
Metadata_Review_Date: 20240324
Metadata_Future_Review_Date: 20230324
Metadata_Contact:
Contact_Information:
Contact_Person_Primary:
Contact_Organization_Primary:
Contact_Organization: National Hydrographic Office
Contact_Person: Cheif Hydrographer
Contact_Position: Bathymetry
Contact_Address:
Address_Type: mailing and physical address
Address:
National Aquatic Research
Resources and Development
Agency, Crow Island, Mattakkuliya
City: Colombo 15
State_or_Province: Western
Postal_Code: 10500
Country: Sri Lanka.
Contact_Voice_Telephone: +94 112521705
Contact_Electronic_Mail_Address: postmaster@nara.ac.lk
Metadata_Standard_Name: ISO19115
Metadata_Standard_Version: 1
Metadata_Use_Constraints: Copyright
Metadata_Security_Information:

Appendix B: Sample Metadata Documentation for CONCMBH001_2023.

Bathymetric Raw Data
National Hydrographic Office
National Aquatic Resources Research and Development Agency
Catalogue of Metadata Documentation for Bathymetric Datasets in MSDI

1.0	**General**	
1.1	Dataset Name	Bathymetric Survey at Negombo for SLLRDC
1.2	Dataset Description	The bathymetric survey was done by request of Sri Lanka Reclaimant and Development Corporation (SLLRDC)
1.3	Dataset ID	SL/NR/NHO/2023/0001
1.4	Published Date	3/23/2024
1.5	Dataset Keywords	Bathymetry, Dredging, InspectionSurvey, BathymetricSurvey, IHO
1.6	Category in MSDI	Bathymetry
2.0	**Identification Information**	
2.1	Alternative Title	Bathymetric Survey at Negombo for SLLRDC
2.2	Project No	CONCMBH001_2023
2.3	Creation Date	29.11.2023
2.4	Identifier	National Hydrographic Office
2.5	Originator	National Hydrographic Office
2.6	Custodian	National Hydrographic Office
2.7	Online Resources	Not Available
2.8	Access Constraint	Copyright
3.0	**Description**	
3.1	Primary Purpose	Site inspection survey bottom sand dredging
3.2	Status	Completed
3.3	Device Category	SBES
3.4	Device Name	Kongsberg EA440 Echosounder
3.5	Device Uncertainty	No device uncertainty during the survey.
3.6	Positioning Device	POS MV
3.7	Positioning Device Name	Stonex RTK(Corsnet)
3.8	Platform category	Marine Vessel [Ship]
3.9	Platform Name	RV Samudrika
3.10	Other Supplementary Instruments	Sound Velocity Profile (Valeport) - SVP Autonomous Pressor Guage - Tide
3.11	Average Vessel Speed	5knots
3.12	Data Acquisition Software	Hypack
3.13	Format	Catalog File / ASCII / .log
3.14	Type of Data	Raw Data

3.15	Distribution Format	.log
4.0	**Extent**	
4.1	Time extent	
4.1.1	Begin Date	11/29/2023
4.1.2	End Date	12/17/2023
4.2	Spatial extent	
4.2.1	Spatial Area Name	Negombo
4.2.2	Area	
4.2.3	Top left corner	381817.05, 381817.05
4.2.4	Bottom left corner	383842.00, 502847.22
4.2.5	Top right corner	388174.18, 513153.92
4.2.6	Bottom right corner	389202.90, 502856.24
4.2.7	Horizontal Datum	Kandawala
4.3	Vertical extent	
4.3.1	Minimum depth	23.10m
4.3.2	Maximum depth	35.32m
4.3.3	Vertical Datum	MSL
5.0	**Accuracy Parameters**	
5.1	Primary Accuracy Level	Moderate
5.2	Secondary Accuracy Level	Level 5 - Standard Plus
5.3	Survey Specification	1B
5.4	Accuracy	
5.4.1	TPU	2.01m
5.4.2	THU	2m
5.4.3	TVU	0.2m
5.5	Resolution	
5.5.1	Spatial Resolution	
5.5.1.1	Across Track Resolution	1.5m
5.5.1.2	Along Track Resolution	0.09m
5.5.2	Temporal Resolution	No temporarily updating.
5.6	Coverage	
5.6.1	Coverage	Constant Spacing
5.6.2	Coverage as percentage	75%
5.6.3	Line spacing	200m
5.6.4	Data Gaps	None
5.7	Consistency	
5.7.1	Cross-dataset Consistency	Non-checked
5.8	Timeliness	
5.8.1	Data Age	After 2020

5.8.2	Update Frequency	As needed
5.9	Reliability	
5.9.1	Data Integrity	Non-verified
5.9.2	Error Tracking	☑Real Time Error Tracking ☑Apply Quality Assurance ☑Apply Quality Control in field
5.10	Precision	High
5.11	Usability	
5.11.1	Interoperability	Partially Interoperable
5.11.2	Interoperability constraints	No
5.12	CATZOC accuracy level	B
6.0	**Point of Contact**	
6.1	Owner	
6.1.1	Owner Name	Will be disclosed upon request
6.1.2	Owner Position	Will be disclosed upon request
6.2	Division	Will be disclosed upon request
6.3	Organization	National Aquatic Research Resources and Development Agency
6.4	Email	Will be disclosed upon request
6.5	Telephone number	Will be disclosed upon request
6.6	Address of point of contact	Crow Island, Mattakkuliya, Colombo 15, Sri Lanka.
7.0	**Meta - Metadata**	
7.1	Published Date	Not Published Yet
7.2	File Identifier	CONCMBH001_2023.gen
7.3	Metadata Source	HYPACK metagen associated with dataset
7.4	Metadata Language	English
7.5	Metadata Standards	ISO 19115
7.6	Contact point of meta data	National Hydrographic Office
7.7	Telephone of Contact point	Will be disclosed upon request
7.8	Email of Contact point	Will be disclosed upon request