

# Analysis of Crowdsourced Bathymetry Concept and It's Potential Implications on Safety of Navigation

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**ABSTRACT:** Crowdsourced bathymetry (CSB) is relatively new concept of collecting bathymetric data. CSB can be defined as the collection and sharing of depth data (and metadata) measured and collected by non-traditional survey vessels equipped with navigation instruments, while maintaining their usual operations at sea. International Hydrographic Organization (IHO) has developed Guidance on CSB. This document provides framework for data collection, processing and information about data uncertainty. IHO has also developed model within CSB concept in order to make standardization of CSB data. The data collected using CSB may represent valuable supplement to the existing data collected by hydrographic survey. Despite this fact it is necessary to emphasize that CSB data cannot be used as official data. CSB data collection has also potential legal issues due to the character of sounding passage within territorial and internal waters of coastal states. This paper emphasized the differences between hydrographic survey and CSB. Advantages and disadvantages are analyzed with it's potential implication on safety of navigation. Due to the CSB data collection model limitations, development of bathymetric data collection model on national level is recommended.

## 1 INTRODUCTION

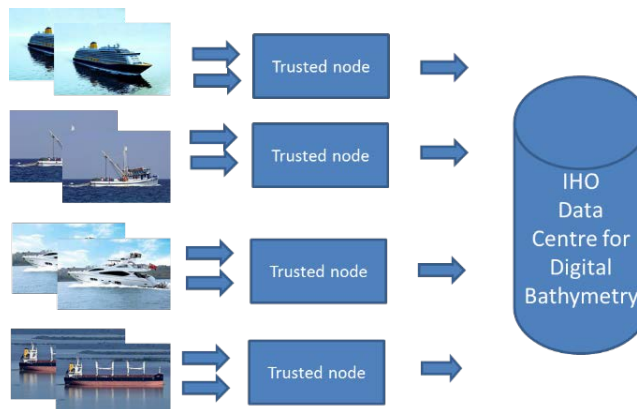
Collecting data for nautical charts is one of the basic tasks of national hydrographic organizations (HOs). Data are being collected by hydrographic survey that is standardized in terms of methodology and requirements for accuracy and reliability of collected data. Standards are international and national. International standards for hydrographic survey are issued by IHO, while the national ones are issued by HOs. National standards for the accuracy and reliability of data should be equal to or rigorous than international ones. The collection of data for the production of nautical charts is possible only by hydrographic survey, while their verification and updating can be done by some auxiliary methods. International and national standards of hydrographic survey are necessary in order to achieve the

maximum possible uniformity in the production of nautical charts used in international and national navigation. Nowadays we can say that relatively good results have been achieved at the level of hydrographic survey standardization. Nevertheless, a relatively large part of the world's sea is not adequately surveyed in line with current standards. Data on surveyed areas vary depending on the source and range from 1 to 15% [11], while other depth data on nautical charts were largely estimated. For this reason, the data on depths shown on nautical charts are not reliable enough in certain parts of the world sea. An interesting fact is that the distance between two adjacent depths on nautical charts is about 10 kilometers for more than half of the world's sea [21], while more than 80% of the oceans floor is still not mapped even at a resolution of 1km using the echo sounding method [14]. Although HOs make great

efforts in performing the hydrographic survey it will take a long time for the survey to be done in accordance with the applicable standards. Therefore, the IHO pointed to the need to introduce a new concept of bathymetric data collection, which is based on the use of other data sources than official ones. At the 5th Extraordinary Hydrographic Conference 2014, the IHO established a Crowdsourced Bathymetry Working Group (CSBWG) tasked with developing guidelines for collecting bathymetric data from public sources, ie, from ships using standard echo-sounders for navigation and positioning systems. [11]. Companies that produce electronic chart systems (eg, Olex, Navionics, Garmin, Lowrance, Survice, etc.), companies that create their own databases (eg, Active Captain) and other voluntary organizations (SeaID, TeamSurv, OpenSeaMap) are also engaged in collecting data from public sources.[4, 19]. These companies and organizations have their own CSB-related protocols. The collection of bathymetric data by the CSB cannot replace the hydrographic survey, but this concept is a complement to the hydrographic survey. Its main advantage is the fact that collection of bathymetric data can be done by using any type of vessel. The fundamental disadvantage is the fact that the CSB cannot replace the hydrographic survey. The paper analyzes the role of IHO in the development of the CSB concept, legal problems that arise due to the collection of bathymetric data and the possibility of applying this data in order to increase safety of navigation at the global and national level with special emphasis on the development of the national CSB model.

## 2 IHO CSB CONCEPT DEVELOPMENT

The IHO has developed the CSB concept with the aim of increasing the amount of seabed data collected, in order to improve seabed mapping. Since the term CSB derives from the term "crowdsourcing", it means that it is addressed to a large number of persons, ie ships that can collect bathymetric data. In this way, it is possible to collect a relatively large number of bathymetric data in a relatively short time, all at low cost. These facts, together with the limitations of hydrographic survey, led to the development of the IHO CSB concept. The IHO CSBWG has developed the publication *Guidance on Crowdsourced Bathymetry*, which defines the concept, equipment, methodology, format and uncertainty of data collection, processing and storage. [8, 23]. It should be noted that this publication provides a framework for the CSB and it is neither authoritative nor binding, but has the character of guidelines: The IHO CSB concept is based on the Trusted Node model (Figure1).



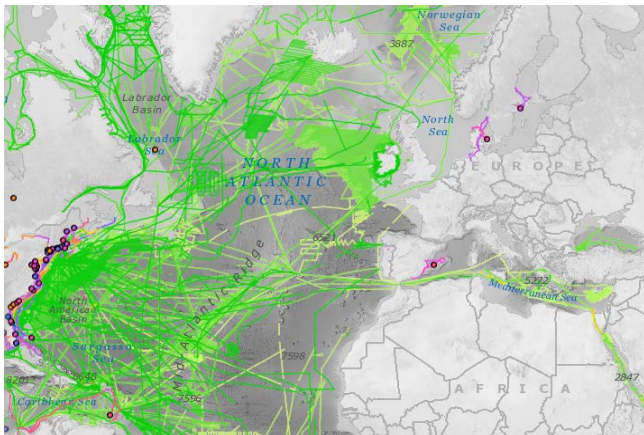
Source: Authors (in accordance with [8])  
Figure 1. CSB data flow through Trusted Node model

According to the model, bathymetric data can be collected by any type of ship (e.g., passenger, cargo, public, fishing, pleasure boats, etc.). Data are collected voluntarily during navigation, or during other regular ship activities. In doing so, ships use navigation echo-sounders (usually single beam – SBES) for data collection, while they use Global Navigation Satellite System (GNSS) for positioning. The collected data are submitted to the Trusted Node. Trusted Nodes are organizations or individuals that serve as a liaison between ships and the IHO Data Center for Digital Bathymetry (IHO DCDB). In accordance with IHO B-12 Trusted Node performs tasks and assist the mariner by supplying data logging equipment, providing technical support to vessels and downloading data from data loggers [8]. The IHO DCDB works with each individual Trusted Node to standardize the data and metadata that will be included in the database. The IHO DCDB assigns unique keys for data authentication to each individual Trusted Node. Authentication is performed to ensure data integrity and an appropriate level of anonymity of data sources [8]. Bathymetric data collected from ships are provided to Trusted Node. The IHO recommends that Trusted Node verify the data, calculate uncertainty, and correct the data. After verification and processing, the data is stored in the IHO DCDB. This information is available to the public online via interactive web map services for various purposes related to seabed mapping [10]. Simply put, the concept of IHO CSB means that data can be collected by anyone and made available to anyone.

## 3 CSB DATA AVAILABILITY

The IHO established the DCDB in 1990 [9] as a global database of bathymetric data for the development of General Bathymetric Chart of the Oceans (GEBCO). IHO DCDB is hosted by U.S. National Oceanic and Atmospheric Administration (NOAA) National Centers for Environmental Information [9, 17]. Data are publicly available using the IHO DCDB Data Viewer (Figure 2). The interactive menu map provides access to data obtained using SBES, multibeam echo-sounders (MBES), surveys conducted by NOAA, and data obtained via CSB. Analysis of the IHO DCDB interactive map shows that there is a relatively large amount of data obtained from single beam and multibeam surveys, while the amount of data

obtained through the CSB is relatively small and mostly data from the east and west coasts of the United States. It is interesting to note that in the Mediterranean Sea, only one measurement from the CSB is currently included in the IHO DCDB.



Source: The IHO Data Center for Digital Bathymetry (tracks in green belongs to the GEBCO Project, other tracks are CSB Data)

Figure 2. Part of IHO DCDB interactive map

Currently, the IHO DCDB contains more than 117 million bathymetric data [17]. The number of bathymetric data is very small in relation to the total area of the world's oceans. It is assumed that over time there will be a development of the CSB, which will result in an increase in the number of these data.

#### 4 CSB TECHNICAL REQUIREMENTS

The CSB is not a fully standardized bathymetric data collection process, such as hydrographic survey. Nevertheless, in publication B-12, the IHO set out the basic principles relating to the CSB. Vessels participating in voluntary CSB data collection should be equipped with a GNSS for positioning and a SBES for depth measurement. These equipment must meet the requirements of Chapter V (Regulation 19.2.1.6 and 19.2.3.1) of the International Convention for the Safety of Life at Sea [13]. The equipment must meet IMO Recommendations on performance standards so that ships have the ability to collect bathymetric data (along with position and time) of standardized reliability. Data from GNSS and SBES on ships are transferred in the National Marine Electronics Association (NMEA) 0183 standard protocol [8]. The collected data must be stored on board. Data storage is done using a data logger (which is delivered by Trusted Node to the ship) or some other media on board. The stored data is transferred from the ship to the Trusted Node. The mode of data transfer in IHO Publication B-12 is not strictly defined. This publication sets out the principles of simplicity and economy of data transfer, while the precise method is defined between each individual Trusted Node and the ship that collects data. [8]. In order to achieve the required level of standardization, the IHO DCDB accepts bathymetric data in certain (default) formats. These formats are GeoJson, CSV or XYZT format. The XYZ format contains longitude, latitude, and depth. Since the depth at the same position changes

over time depending on the sea level, it is also necessary to have time data (T). In this way, the user of the measured bathymetric data can correct them at the time of measurement. Therefore, bathymetric data must be in XYZT format. For ships whose draught changes significantly, there should be the possibility of entering draught data (together with date and time). Due to the vertical distance between the waterline and the position of the echo-sounder transducer draught can have a significant impact on depth measurement. The IHO also recommends automatically integrating or recording vertical and horizontal sensors offset into the data. When recording sensor offsets, seafarers provide this information to Trusted Nodes. By applying these principles, CSB is standardized because it can only come from Trusted Node and in valid file types. The data collected in this way have a certain value in a whole range of activities related to the improvement of seabed mapping.

#### 5 CSB LEGAL PROBLEMS

CSB in its nature represents the collection of bathymetric data, i.e., the measurement of sea depth. Measuring the sea depth from ships is subject to restrictions, except for navigation purposes. Restrictions depend on the legal regime of maritime areas. The legal regime of maritime areas is defined by the provisions of the United Nations Convention on the Law of the Seas (UNCLOS). According to the provisions of UNCLOS, the level of rights of coastal states decreases with distance from the coast. Internal waters are under the sovereignty of the coastal state as well as its mainland [16], therefore, any depth measurement, except for navigational purposes, may be considered prohibited. In the area of the territorial seas, a foreign ship "carrying out research or survey activities" violates the right of innocent passage in accordance with the provision of Article 19.2 (j) of UNCLOS [18]. In the straits, research or survey activities shall be considered a violation of the right of transit passage in accordance with the provision of Article 40 of UNCLOS [18]. In the Exclusive Economic Zone, the coastal state shall have sovereign rights and jurisdiction over marine exploration in accordance with the provision of Article 58.1 (a and b) of UNCLOS. In the High Seas, all states have the right to scientific research in accordance with the provision of Article 87 of UNCLOS. According to the current definition of CSB, coastal states have the right to impose restrictions on the collection of bathymetric data within CSBs in maritime areas in which they have sovereignty, sovereign rights and jurisdiction. UNCLOS recognizes neither the term CSB nor the term "passage sounding," which IHO links to CSB in Publication B-12. The IHO recommends that the CSB can be considered equivalent to other voluntary environmental data collection initiatives, which are intended to be used for the common good. [8]. If the coastal state interprets CSB as scientific research, then CSB can be considered permissible only in the high seas. However, coastal states may allow (with restrictions) CSBs within maritime areas under sovereignty, sovereign rights and jurisdiction. The solution to these legal problems can be a clearer

definition of the CSB in order to eliminate issues with the provisions of UNCLOS [15] with the aim of resolving possible political or security problems for coastal states. Because the data collected is publicly available in the IHO DCDB, certain legal problems may arise there as well. These problems may relate to publicly available data, their redistribution, and reliability. Therefore, the IHO in Publication B-12 has fenced off in such a way that all participants in the CSB need to be aware of the conditions of the licensing regime under which the bathymetric data will be made available [8]. In this sense, the IHO CSB Program operates under the Creative Commons licensing framework. The IHO also stressed that every user should use the data in good faith, taking into account the fact of the nature and the uncertainty of the data [8]. Furthermore, the data user must list the IHO DCDB as the data source, and indicate if he has made any changes to that data. Thus, the IHO assumes no legal responsibility for either the collection or the use of CSB data. In order to, in some way, solve the mentioned legal problems, IHO envisaged "filter" in its concept of CSB data flow. This filter refers to the collection and availability of the collected data. Coastal states, i.e., their HOs have the option of setting limits on the collection and disclosure of CSB data. The IHO filter is based on the right of coastal states to accept in full, accept with caveats or not to accept CSB in national waters of jurisdiction. The same principle applies to the availability of CSB data in the IHO DCDB [12, 8]. Thus, coastal state must give explicit consent to the collection and publication of CSB data in waters under national jurisdiction. In Circular letter 11/2019, the IHO called on member states to comment on the acceptance of CSB in national waters of jurisdiction. So far, only 15 states have given their consent to CSBs in these waters, of which only the United States has given unrestricted consent in all waters [7].

## 6 APPLICATION OF CSB DATA

Although CSB data have certain shortcomings they can be used for a whole range of offshore activities. Since CSB data has the character of unofficial data, they can be applied to:

- Support in different initiatives connected with seabed activities,
- Support in different scientific studies,
- Supplemental data for safety of navigation,
- Support in coverage the sea areas with not sufficient, not adequate or no data existence,
- Help to prioritize survey areas by HOs,
- Determination of survey priorities and
- Determination of charts adequacy.

Currently, a number of initiatives have been developed around the world aimed at developing programs and projects that encourage seabed exploration. These initiatives can be global or regional level. CSB data can make a significant contribution to the implementation of these projects. The possibility of using CSB data in order to increase navigation safety is analyzed below.

### 6.1 *Application of the CSB in increasing navigation safety at global level*

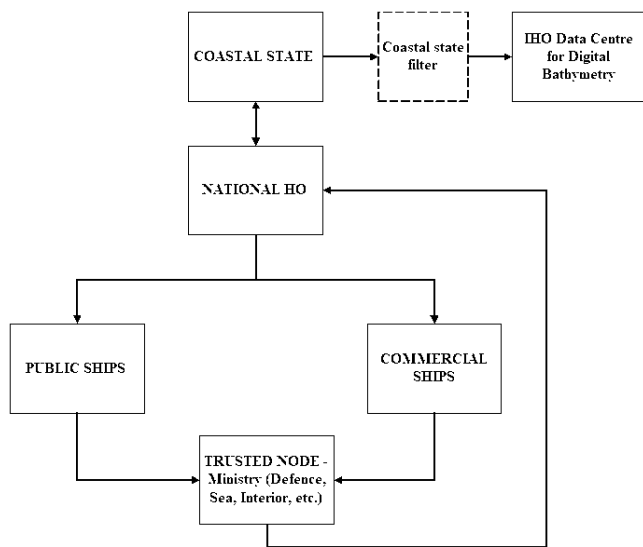
Regarding the application of the CSB concept in navigation safety, there is currently no publicly available comprehensive research. Possible reasons are unofficial nature of this data and the fact that this is a relatively new concept. Although IHO and HOs point out that a relatively large amount of data on charts was collected using old positioning and depth measurement systems, there is still no way to include CSB data in the information content of nautical charts. Today's positioning and depth measurement systems on ships are more reliable than the systems used by hydrographic ships before the advent of GNSS and SBES. Obviously, data collected through the CSB are more reliable than a relatively large amount of official data. According to Baxter CSB data meet the requirements of 1b and 2 Order of 5th Edition of IHO standards for hydrographic surveys (IHO S-44). He also concluded that the analyzed data meet the IHO S-57 Category Zone of Confidence (CATZOC) Class C, although there are elements for both Class A1 and A2 (but the CSB data are not considered satisfactory as it is not a systematic hydrographic survey) [2]. Despite to these facts, CSB data cannot be included in electronic navigational charts (ENC), because ENC is an official database created by a national hydrographic office for use with Electronic Chart Display Information System. [22]. Although the data are unofficial, their use could find application in increasing navigation safety. The use of CSB data can potentially detect new dangerous objects on waterways. Furthermore, by identifying significant deviations of existing official data on nautical charts from CSB data can have a significant impact on the safety of navigation in the area of Special and 1a Order of hydrographic survey. Using the data, it is possible to determine and display in more detail the relief of the seabed in areas with low data density. Certainly, the use of CSB data contributes to a better situational awareness of seabed relief in areas that are not adequate or not measured at all. These examples of applications are possible both globally and nationally. However, one should take into account the fact that currently only 15 countries are included in the CSB concept. The reason for this should be sought in the fact of confidentiality of hydrographic data, vagueness of legal concept, relatively small number of hydrographic vessels and limited resources of HOs. In order to expand the application of the CSB concept in national waters of jurisdiction, a model of application at the national level is proposed below.

### 6.2 *Application of the CSB in increasing navigation safety on national level*

Figure 3 shows a proposal for a model for applying the CSB concept in national waters of jurisdiction. In order to meet the preconditions for the application of the proposed model, it is necessary to define the legal framework at the coastal state level. Given the fact that HOs have a relatively small number of hydrographic vessels in relation to the sea area for which they are responsible, it is proposed to hire public and commercial ships flying the coastal state flag to implement the CSB concept. In this way, the number of vessels engaged in data collection would



be multiplied by the CSB concept. Public and commercial ships would send the collected data on the principle of the CSB concept according to the appropriate Trusted Node. Trusted Node would verify data according to the same principles as specified in the IHO CSB concept. At the national level, it is possible to organize the Trusted Nodes system in the relevant ministries or within the HO. Public or commercial ships would collect data on the principle of the CSB concept as part of their voyage, or usual operations at sea. Trusted Nodes sends the collected and verified data to the national HO, which consolidates them into a national database and, on behalf of the coastal state, filters the data which will be sent to the IHO DCDB.



Source: Authors

Figure 3: Model of application of CSB in national waters of jurisdictions

The proposed model has a general character. At the particular level of application, variations adapted to the organizational structure of each coastal state are possible. Applying this model significantly increases the number of ships participating in data collection.

## 7 CONCLUSION

The IHO has developed the CSB concept with the aim of increasing the amount of sea depth data. The concept is based on crowdsourcing which means that a large number of ships can participate in the data collection. The condition for participation is the possession of GNSS and SBES and a data logger device provided by Trusted Node. GNSS and SBES should meet IMO recommendations on performance standards. Data is delivered to Trusted Node via the NMEA standard protocol. Trusted Node verifies the data and forwards it to the IHO DCDB. The IHO DCDB accepts data in GeoJSON, CSV or XYZT format. The data was publicly used in the IHO DCDB data viewer. This means that the data is available to the user at any time. This concept also has legal issues related to the collection and publicly available data. Data collection is primarily carried out on the high seas and secondarily in national waters of jurisdiction with the express approval of the coastal state.

Approval information is available on the IHO website. As a possible solution to legal problems, the IHO has provided filters that can protect coastal states from collecting and publishing data in national waters of jurisdiction. In this way, relatively large areas of the World Seas may remain outside the IHO CSB concept. Therefore, a national CSB model is proposed that envisages the use of governmental and public ships of the coastal state. This significantly increases the ability of coastal states to collect data in national waters of jurisdiction which has a direct impact on navigation safety. From the examples of possible application of CSB data, it can be seen that they can relate to increasing navigation safety primarily as additional data, and secondarily as basic data in marine areas where there are insufficient, inadequate or no official data obtained by hydrographic survey. In this sense, these data can be used to determine the adequacy of nautical charts and as an efficient tool to HO in determining priorities for performing a new hydrographic survey or re-survey in some areas with data deficiency. Despite all the advantages of this concept, it is necessary to emphasize once again that these data have an unofficial character.

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