한국항해항만학회지 제46권 제5호
J. Navig. Port Res. Vol. 46, No. 5 : 409-418, October 2022 (ISSN:1598-5725(Print)/ISSN:2093-8470(Online))
DOI : http://dx.doi.org/10.5394/KINPR.2022.46.5.409

A Study on Construction of Aids to Navigation Big Data Based on S-201

† *Yunjee Kim · Se-woong Oh* · Minsu Jeon***

† *Researcher, Maritime Safety and Environmental Research Division, Korea Research Institute of Ships&Ocean Engineering*
**Principal Research Engineer, Maritime Safety and Environmental Research Division, Korea Research Institute of Ships&Ocean Engineering*
***Technical operations manager, International Association of Lighthouse Authorities*

Abstract : *The International Association of Lighthouse Authorities (IALA) utilizes a questionnaire to investigate the status of Aids to Navigation (AtoN) around the world. However, results of the IALA questionnaire have limited use because respondent understanding is inconsistent. In addition, there is uncertainty regarding the appropriateness of the questionnaire content. Furthermore, the overall response rate is low. Therefore, the status of AtoN is not clearly understood. AtoN data from around the world are generated hourly. Thus, big data solutions are required to effectively exploit the information. Digitization of analog data is an important component of building big data. Hence, the IALA has developed a Maritime Resource Name (MRN) scheme and an information exchange standard. Here, we used the AtoN information exchange standard and designed an S-201-based big data construction process that could collect and manage global AtoN information. In this study, construction of an IALA AtoN portal was proposed as the core of the construction of the AtoN big data. The process was divided into three stages. IALA AtoN portal is developed by IALA with the goal to provide various meaningful statistical analysis results based on AtoN data while managing AtoN information around the world based on S-201. If an AtoN portal capable of constructing S-201-based big data is developed, then a data collection and storage system that can gather basic S-201 AtoN data from the IALA and global AtoN management agencies could be achieved. Furthermore, insightful statistical analysis of AtoN status worldwide and changes in manufacturing technology will be possible.*

Key words : *Aids to Navigation(AtoN), S-201, big data, International Association of Lighthouse Authorities(IALA), AtoN Portal*

1. Introduction

In the Fourth Industrial Revolution era, and as part of the Korean New Deal, many artificial intelligence (AI)-based marine and fishery studies are being conducted, such as the Maritime Autonomous Surface Ships(MASS) study and studies concerned with fishery management. In particular, global research related to digitization and standardization of marine information is being actively conducted in response to the rapidly changing marine environment, involving smart ports, smart containers, and smart aids to navigation (AtoN). For example, the S-200 series information exchange standards have been developed for efficient and systematic provision and management of AtoN data, in collaboration with the International Association of Marine Aids to Navigation and Lighthouse Authorities (IALA). AtoN aids ship navigation and ship/obstacle location via light, sound, and radio waves. The role of AtoNs is changing with the development of smart AtoNs, as an information platform supporting marine traffic environments (by collecting and analyzing information from existing navigation facilities, among other cooperative systems). AtoN information is important for maritime safety management, as it is a key indicator of maritime traffic flow and conditions. In addition to various sensors attached to the AtoN, the AtoN itself can generate big data, including information related to various management tasks such as checking and replacing the AtoN, and bringing it to the surface. In the course of a single day, AtoNs can generate an enormous amount of data. As such, given the increasing importance of AtoN-based information for maritime and fishery operations, as well as the large amount of data requiring processing and dissemination, proper management of AtoN big data is necessary. Currently, information aiding navigation in Korea, such as that obtained and stored by AtoNs, is managed by computerized management systems, such as that of the Yeosu Regional Office of Oceans and Fisheries, while status information is stored and managed by AtoN management and operation systems, such as those of the Regional Office of Oceans and Fisheries and National Maritime PNT Office. Despite recent revisions to S-201,

† Corresponding author, yunjee0531@kriso.re.kr 042)866-3722
* osw@kriso.re.kr 042)866-3692
** minsu.jeon@iala-aism.org +33 (0)6-76-05-11-38

which is the AtoN information exchange standard, many countries still manage AtoN data according to their own guidelines. This is problematic because there are various formats of AtoN data, depending on the management guidelines of each country; moreover, in numerous cases multiple organizations manage this data within a single country, making access and utilization more difficult. A standardized data format is required for data compatibility and convergence, to allow for meaningful and efficient evaluation and exchange of big data for AtoNs among users. In this study, we propose a plan for collecting, processing, and integrating AtoN big data based on the S-201 standard.

Currently, to construct big data aiding navigation, the IALA issues a questionnaire on AtoNs to individual countries, in an attempt to understand the current status of AtoNs and analyze global trends. This questionnaire covers all AtoNs, including those of the Vessel Traffic Service (VTS). It is requested that member states complete the questionnaire every 2 - 4 years. This questionnaire is a very powerful and unique tool for collecting and analyzing global AtoN data. However, the inconsistent 2 - 4-year questionnaire distribution cycle makes it somewhat difficult to determine the current status. Here, we examine the current status of the IALA survey, which is the only tool currently available for constructing AtoN big data, and attempt to identify the information that most requires management and the best methods to do so. Based on the results, we present a method for constructing S-200-based AtoN big data involving three key steps.

2. Status of the IALA Questionnaire

To understand the current status of AtoN data worldwide, the IALA issues the IALA Questionnaire to collect AtoN-related information from member countries every 2 - 4 years, as stated above. When the questionnaire was first introduced, the goal was to conduct the survey biennially; however, due to the low response rate and absence of an organization to conduct/oversee the survey, the questionnaire was issued inconsistently (every 2 - 4 years). The questionnaire consists of various questions related to AtoNs, such as the respondent's affiliated organizations, the roles of those organizations in maritime navigation assistance, and "fixed and floating" AtoN information. The questionnaire is detailed in Table 1.

Most of the questionnaire items are numeric, although there are also many questions requiring a 'yes' or 'no' response (e.g., questions about quality management, such as performance indicators and ISO certification, and the role of the respondent organization). However, due to the lack of definition of terms in the questionnaire, the same term may be interpreted differently depending on the country and respondent. Additionally, in some cases, the interpretation of questions and terms is particularly difficult, if not impossible. Such issues are believed to be the main reason for the low response rate to the IALA Questionnaire.

In particular, for a question from the 2017 survey regarding who is in charge of navigation indicators, the responses "directly responsible" and "national" were in fact the same (Fig. 1).

Number of AtoN						
	Directly responsible			National		
Country	Category 1	Category 2	Category 3	Category 1	Category 2	Category 3
Argentina	381	1326	272	381	1326	272
Australia	960	1762	5470	960	1762	5470
Belgium	0	0	0	0	0	0
Bermuda	10	100	32	10	100	32
Brazil	3274	1748	1337	3274	1748	1337
Bulgaria	0	0	0	0	0	0
Canada	1861	10774	4672	1861	10774	4672
Chile	70	837	739	70	837	739
Colombia	135	92	0	135	92	0
Croatia	270	374	305	270	374	305
Cuba	0	0	0	0	0	0
Cyprus	0	0	0	0	0	0
Denmark	186	1971	4382	186	1971	4382
Ecuador	64	289	70	64	289	70
England	154	949	10733	154	949	10733
Estonia	176	345	626	176	345	626
Finland	0	0	0	0	0	0
France	0	0	0	0	0	0
Germany	1837	3930	4850	1837	3930	4850
Greece	140	1092	363	140	1092	363
Ireland	69	592	1964	69	592	1964
Italy	150	1662	1174	150	1662	1174
Japan	975	2783	2719	975	2783	2719
Latvia	123	93	92	123	93	92
Netherlands	165	1665	2222	165	1665	2222
Norway	0	0	0	0	0	0
Portugal	53	86	939	53	86	939
Russia	1622	2501	476	1622	2501	476
Scotland	423	1344	784	423	1344	784
Singapore	0	70	100	0	70	100
Spain	334	1097	1482	334	1097	1482
Sweden	563	373	167	563	373	167
Turkey	240	180	191	240	180	191

Fig. 1 Part of the results of the 2017 AtoN questionnaire. Response results for 'Directly responsible' and 'National'

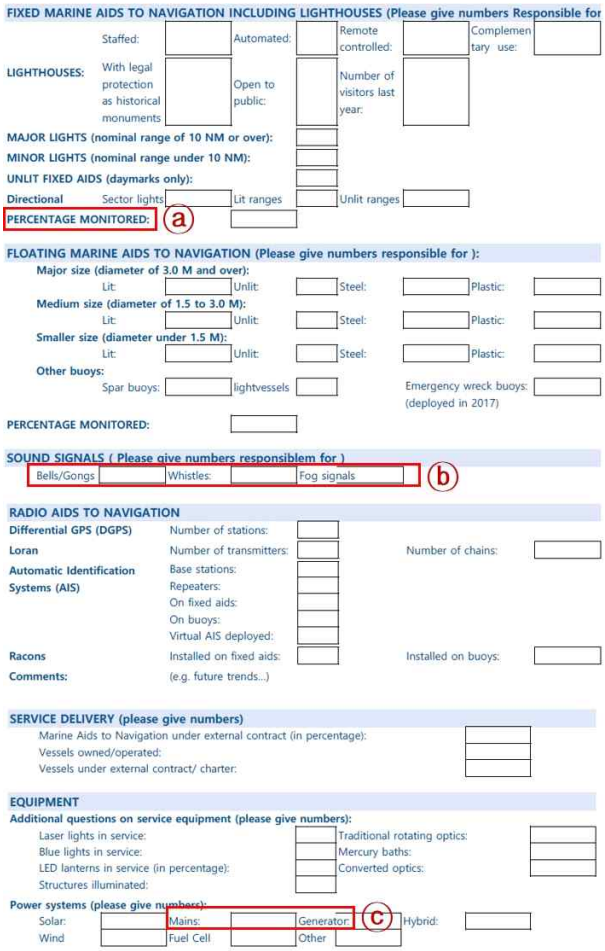

Fig. 2 Example of IALA Questionnaire ⓐ Questions that cannot be answered without existing data, ⓑ Questions that are difficult to answer because the classification criteria for the same signal in each country are different, ⓒ Questions that lack definitions of terms

The difficulties related to the survey questions are believed to arise from interpretation issues. For example, the survey respondent may be in charge of a state-owned AtoN, the interpretations of the questioner and respondent may differ due to the lack of definition of the term “directly responsible”, and there may be no privately owned AtoN. Also, the fact that the survey results are the same for all countries indicates that the questionnaire needs to be updated.

The majority of the survey questions concern the current status of AtoNs. However, many questions are difficult to answer without current data, and due to different standards being used by individual countries and the presence of poorly defined terms (Fig. 2). Thus, completing the questionnaire is not an easy task.

Regarding IALA members, there are 325 organizations in 92 countries (as of May 22, 2022). About 30 % of members complete the questionnaire every year, which is the only tool available at present for evaluating AtoN globally, as stated above. However, the difficulty of questionnaire completion, and the low and unreliable response rate, prevent the information collected from being used for constructing big data for AtoNs. Thus, a new survey, or new methods for acquiring the necessary AtoN data, is required.

In the IALA Questionnaire, basic information classified as “fixed marine AtoN”, “floating marine AtoN”, “signal signals”, “radio AtoN”, and “equipment”. Here, we present a method for constructing big data for AtoNs comprising three major steps, described in the following.

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Table 1 The contents of IALA Questionnaire

Category 1	Category 2	Contents	Response format
Organization	-	· organization information(name, type) · type of authority	TEXT
Quality Management	-	· performance indicators · ISO certification · risk management tools · other certification	YES/NO
Organization Responsibilities	-	· AtoN provider, supervision of AtoN providers, AtoN training · hydrographic services, pilotage, AIS, VTS · aquaculture, offshore petroleum, sea dumping, renewable energy, marine spatial planning	YES/NO
Marine Aids to Navigation Staff	-	· main office, district depots · lighthouses, ships / vessels	NUMBER
Marine Aids to Navigation	directly responsible	· *AtoN category 1~3	NUMBER
	total national		
Fixed Marine Aids to Navigation including Lighthouses	Lighthouses	· staffed, automated, remote controlled, alternatively used · with legal protection as historical monuments · open to public · number of visitors last year	NUMBER
	Major lights (nominal range of 10NM or over)	· number of lights	
	Minor lights (nominal range under 10NM)	· number of lights	
	Unlit fixed aids (daymarks only)	· number of lights	
	leading lines	· number of lights · lit ranges · unlit ranges	
	Percentage monitored	_	
Floating Marine Aids to Navigation	Major size (diameter of 3.0 M and over)	· lit · unlit · steel · plastic	NUMBER
	Medium size (diameter of 1.5 to 3.0 M)		
	Smaller size (diameter under 1.5M)		
	Other buoys	· spar buoys · lightvessels · emergency wreck buoys (deployed in 2017)	
Sound Signals	-	· bells/gongs · whistles · fog signals	NUMBER

*The details of AtoN Category are described in Table 2.

Table 1 (Continued)

Category 1	Category 2	Contents	Response format
Radio Aids to Navigation	DGPS	· number of stations	NUMBER
	Loran	· number of transmitters · number of chains	
	AIS	· base stations · repeaters · on fixed aids · on buoys · virtual AIS deployed	
	Racons	· installed on fixed aids · installed on buoys	
Equipment	Additional questions on service equipment	· laser lights in service · blue lights in service · LED lanterns in service (in percentage) · structures illuminated · traditional rotating optics: · mercury baths: · converted optics:	NUMBER
	Power systems	· solar, mains, generator, hybrid	
Levy on Shipping	· National organization · Private organizations, · Port authorities · Provincial authorities · Regional authorities	· whether the organization charges users any fee · the type of vessel that pays (commercial, fishing, leisure) · funds from (public, private)	YES/NO
		· when to pay	TEXT
Service Delivery	-	· marine aids to navigation under external contract (in percentage) · vessels owned/operated · vessels under external contract/charter	NUMBER
**Vessel Traffic Services (VTS)	-	· national legislation for the appointment of a competent authority	NUMBER
		· national legislation for the appointment of a VTS authority	
		· use of IALA Guideline 1014 on accreditation and approval process for VTS training	
		· VTS personnel trained according to IALA recommendation V-103	
		· accident statistics for the VTS areas	
		· near-miss statistics for the VIS areas	
		· number of VTS centers	
		· number of VTS areas	
		· number of SRS	
		· number of VTS centers operation outside territorial waters	
		· number of organizations accredited for VTS training	

**Vessel Traffic Services (VTS) questionnaires were only responded to those who are come under a VTS category.

Table 2 IALA Category 1 to 3

Classification	Definition
Category 1	An Aid to Navigation (AtoN) or a system of AtoN that is considered by the Competent Authority to be of vital navigational significance Example) lighted aids to navigation and racons that are considered essential for marking landfalls, primary routes, channels, waterways, dangers or the protection of the marine environment
Category 2	An AtoN or a system of AtoN that is considered by the Competent Authority to be of important navigational significance Example) it may include any lighted aids to navigation and racons that mark secondary routes and those used to supplements the marking of primary routes
Category 3	An AtoN or a system of AtoN that is considered by the Competent Authority to be of necessary navigational significance

Source : IALA Recommendation O-130 On Categorization and Availability Objectives for Short Range Aids to Navigation, IALA, 2004

3. Stepwise approach to constructing AtoN big data based on S-201

Big data is constructed via the following process: data collection, pre-processing, and storage. The stored data are then analyzed, visualized, and disposed of (Fig. 3). The core method for constructing big data is data standardization (i.e., pre-processing). In this study, as stated above, we propose a method for constructing big data aiding navigation by applying the S-201 standard. The S-201 is an international standard for exchanging AtoN information established by the IALA. This standard is applied for the creation and distribution of datasets, to enable the exchange of information between AtoNs installed in the sea or along the coast for safe navigation of ships. This standard was based on the S-100 standard of the International Hydrographic Organization; S-201 has been updated continuously since the release of version 1.0.0 in 2019.

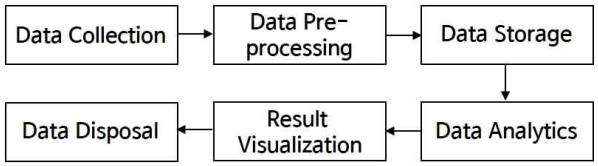

Fig. 3 Flowchart of big data life cycle

In the three-step process to construct AtoN big data mentioned above, the S-201 standard is applied to standardize and digitize the acquired AtoN analog data to aid navigation. In the S-201 standard, AtoN information is divided into a structural part (corresponding to the surface) and an equipment part. This standard covers all types of navigation signals, such as light waves, shapes, sound waves, and radio waves, and has the advantage of being easily expandable as needed. The Geography Markup Language (GML) data format for information exchange is used by AtoN information management and collection agencies; data can be produced and transmitted in GML data format according to the S-201 standard.

In Korea, the total number of AtoN is 6,043, of which 3,310 are national owned (as of 22.10.23). In addition, there are 53,815 equipment, and the equipment that accounts for the largest proportion is storage batteries (44.5 %). More than 50,000 equipment and products are managed in Korea alone, and a vast amount of AtoN information has been managed around the world. Therefore, it is necessary to enable the utilization of AtoN big data through systematic data construction and management.

3.1 Design of the AtoN DB based on S-201

The first step for constructing S-201-based AtoN big data is to design a DB based on this standard. The PostgreSQL DB of the “S-201 testbed” can store GML datasets (Fig. 4). S-201 DB Schema is composed of

“catalogs”, “features”, “boundedby”, “dataset identification infromation”, etc. centered on the “dataset”. The data types of “lowercorner” and “uppercorner” of “boundedby” class are geometry, and most data types except for this are composed of varchar, integer, and float.

PostgreSQL is a powerful object-relational open-source DB that provides users with the ability to create various arbitrary DB objects, such as operators and extensions, to support unstructured data. In addition, the JavaScript Object Notation(JSON) data type is used as the “official” data type, allowing various functions and operations to be executed via the SQL, such as processing data according to an extensible schema.

An AtoN DB was developed with the object structure of the S-200 data model, to prevent performance degradation both when inputting large amounts of data in S-201 GML and Excel format, and when extracting data in S-201 GML format. In addition, to prevent performance degradation during object information query, which is required for symbol mapping, the AtoN DB should allow for continuous improvement of the DB schema. Figure 4 shows the DB schema designed based on the S-201 standard.

Another important consideration when designing an AtoN DB is compatibility with the Maritime Resource Name (MRN) service. The MRN is the only system available for identifying marine services/resources, and can be used to manage AtoN data.

A DB based on the S-201 standard compatible with the MRN service could be built using List of Lights information. Although the precise information provided by the List of Lights depends on the type of AtoN, it provides basic information allowing attribute linkage, as well as information on specific AtoN features. The floating AtoN, which is the most common type, uses a lighted beacon (Table 3).

The IALA focuses on both VTS and AtoN information. The S-201 standard used for big data construction can also be applied for management of VTS data. In this study, the VTS questionnaire was analyzed, and an S-100-based VTS system and data model providing information on operation status were designed. The VTS data model is composed around two feature types (“VTS_Survey”, “Competent Authorities”). “VTS_Survey” consists of basic information about VTS such as VTS name, type, number of sectors, and record information. And “Competent Authorities” consists of information on authorities, such as the number of competent authorities and whether or not to appoint VTS authorities. These two features consist of both simple (basic details, classification codes, VTS name and type, etc.) and complex (VTS equipment, service quality records, etc.) data types (Fig. 5). The initial AtoN DB is intended to deal with both simple (MRN and AtoN type) and complex (survey date, management organization information) information, based on the VTS questionnaire.

Table 3 List of Lights Example for floating AtoN

Basic Information	AtoN number	1450
	national number	M4375.5
	Korean name	교석추 등표
	English name	Gyoseokchu
	WGS84(latitude)	35-09-27.9N
	WGS84(longitude)	129-12-11.1E
	Coastal division	East sea
Light Information	Light characteristic	Q(3) W 10s 20m 7M
	Nominal range	7
	Geographical range	10
AtoN Information	AtoN type	East cardinal mark
	Height	20
	Structure	circle
	Heigth of structure	18
	Color	black yellow black
	Material	concrete
Attribute Linked Information	Radar beacon	-
	Fog signal	-
	AIS	-
	DGPS	-
etc. Information	Reference	Busan Regional Office of Oceans and Fisheries
	Related chart	2131

Source : http://www.khoa.go.kr/buoy.do, KHOA, 2022

3.2 Linkage of S-201-based with the IALA AtoN portal

The second step is to link the S-201-based AtoN DBs of member countries with the IALA AtoN portal. The IALA AtoN portal is an information linkage system that will collect, manage, and analyze global AtoN DB information. It is scheduled for operation in the year 2026.

In this step, using the initial DB built in the previous step, IALA members will request DB updates based on the S-201 standard. In some countries, entities such as ATONIS: Aids to Navigation Information System (of the

United States Coast Guard) and the Système d'Information de Positionnement des Aides (of the Canadian Coast Guard) have begun construction of S-201-based DBs; it is expected that more member countries will participate in this development phase within the next few years.

Linking S-201-based DBs with the IALA AtoN portal allows the latter to perform various statistical analysis functions related to fixed and floating AtoNs, and their associated radio signals, according to various standards. In particular, a Web-based geographic information system (GIS) with a spatial analysis function can be applied for mapping and cross-validation.

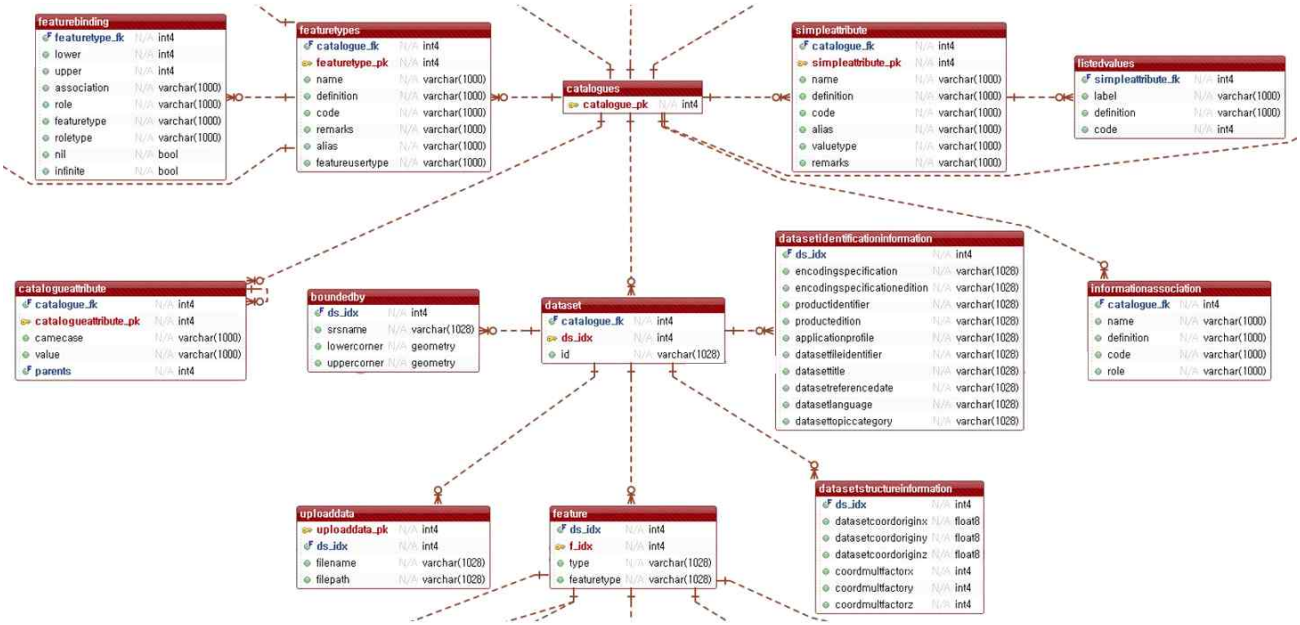

Fig. 4 DB Schema for S-201 data model

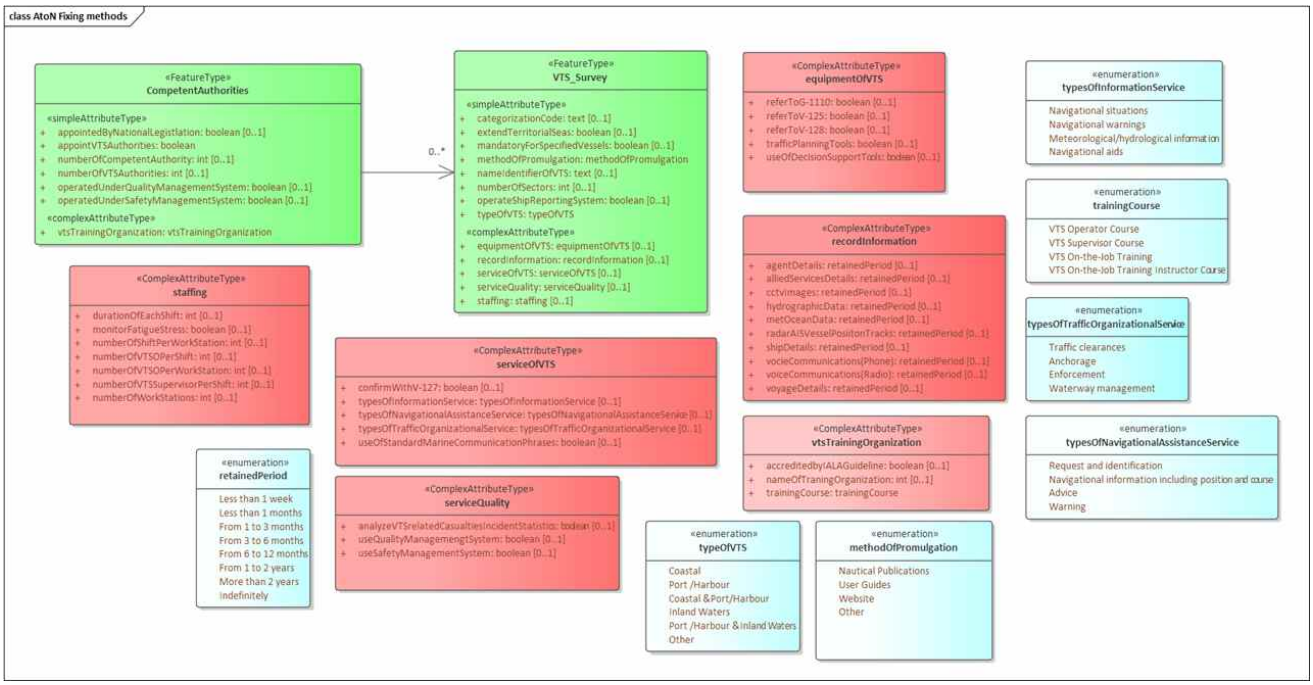

Fig. 5 The VTS questionnaire model

3.3 Updating S-201-based DBs

The last step is to update the AtoN DBs of member countries in association with the IALA AtoN portal. In this step, IALA member countries will apply the S-201 standard for management of time-series AtoN data. This will facilitate identification of global trends in AtoNs, including their general status and position, to aid maritime navigation. Furthermore, statistical analysis of global auxiliary AtoN big data could inform international policy and technology development.

If most IALA member countries apply the S-201 standard to manage AtoN data, information exchange would be possible between departments and the Hydrographic Bureau, and among countries, without the need for data processing (thus improving efficiency). In this manner, more meaningful statistical analyses could be performed.

IALA AtoN portal system-compatible S-201-based DBs could be operated in conjunction with the MRN service to aid navigation. As stated above, AtoN big data can be standardized based on S-201, or spreadsheets provided by IALA member countries (Fig. 6). This would aid various Web-based GIS statistical analyses.

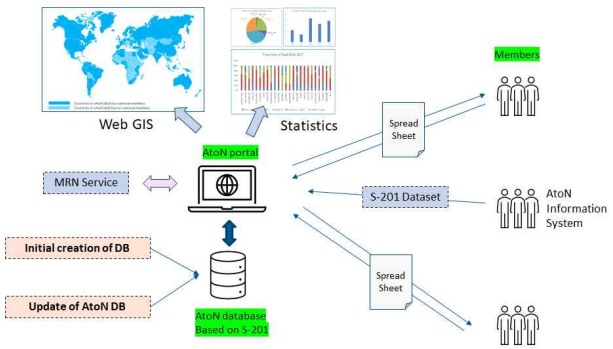

Fig. 6 A schematic diagram of IALA AtoN Portal system

4. Conclusion

Recently, perceptions of data have changed, and the amount of open-access public data has increased. Previously, access to data was restricted for security reasons. More organizations are now disclosing data, leading to issues with data management, utilization, and storage. More accurate and efficient data collection and information exchange schemes are needed.

The main focus of all research is data acquisition. However, big data for AtoNs obtained via the IALA Questionnaire have not yet produced meaningful results, due to the difficulty of completing the questionnaire and low response rate; these limitations are linked to a lack of understanding of the survey questions, or different interpretations thereof among respondents. Therefore, in this study, a method of constructing the AtoN big data through DB modeling was presented in order to utilize the AtoN information efficiently. Specifically, the method of reconstructing the existing AtoN data to the S-201 standard, storing it in the DB and linking it with the IALA AtoN portal, was proposed in three steps. In the first step, an S-201-based DB aiding navigation was constructed using the List of Lights. In the second step, member countries' DBs are linked with the IALA AtoN portal; this action will likely be undertaken by advanced IALA countries. In the third step, instead of surveying the AtoN data with an IALA questionnaire, the AtoN DB of each country and the DB of IALA AtoN portal are linked in order to investigate the AtoN data automatically without a separate response process. Through this, member countries update time series data for various statistical analyses and feedback with the aid of a Web-based GIS service. This will also allow for cross-validation of the data with map-based statistical analyses. Currently, it is almost impossible to check the current AtoN status and related statistics around the world, and only the domestic data managed by each country can be checked. Each country manages the AtoN information according to the standards of the respective country. As a result, interpretation of the same terms asked in the IALA questionnaire have different responses. If AtoN information is managed with the S-201 standard, it is thought that ambiguity about terms and questions will be eliminated because data structures are produced, stored, and managed based on the same standards. In other words, rather than managing each country's subjective AtoN data, it is managed with the same data standard worldwide, making it possible to collect usable data, which is an important process in big data analysis. This does not mean that there is a large amount of data, but this means that the amount of available data is large. It is thought that it will be possible to analyze the trends of AtoN around the world, which was difficult with the IALA questionnaire.

To deal with the enormous amount of data generated by AtoNs globally on an hourly basis, we introduce a method to build AtoN DBs based on S-201, for linkage with the

IALA AtoN portal. With further development of the IALA AtoN portal and establishment of S-201-based AtoN DBs in many countries, we believe that AtoN data collection, management, and dissemination will be improved. Verification of the DB will be done through a “S-201 testbed” in further study. Moreover, rapid analysis of maritime environments could be achieved, as well as analysis of the current status of AtoNs to improve security/safety at sea, facilitate decarbonization efforts, and provide the infrastructure necessary for the introduction of smart ships.

Acknowledgements

This research was supported by the 'Marine digital AtoN information management and service system development(2/5) (20210650)', funded by the Ministry of Oceans and Fisheries, Korea and ‘Development of Positioning and Navigation for Maritime Safety based on Smart device (PES4440)’, funded by the Korea Research Institute of Ships & Ocean Engineering.

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Received 11 October 2022
Revised 18 October 2022
Accepted 25 October 2022