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Problems with positioning inland vessels on the Western Oder River section between the Długi and the Kolejowy Bridges in Szczecin

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Abstract

The main aim of this article is to present a method to process Inland AIS (automatic identification system) data that is part of RIS (river information services), as well as to synthesize and visualize information obtained from it for further analysis. This article presents problems with imaging the position of inland navigation units in the immediate vicinity of the Długi and Kolejowy Bridges in Szczecin. The passing of 80 inland units on this section of the Western Oder River was analyzed. Data were obtained from the AIS message database and industrial cameras of the RIS Monitoring Centre at the Inland Navigation Office in Szczecin. 35 units were equipped with AIS messaging devices. This article analyzed the data after previous processing, which consisted of selecting appropriate research units and decoding AIS messages recorded in the VDM message type (VHF Data Link Message). Then, the acquired positions of inland navigation units on the map were visualized to calculate the number of errors and their location. The obtained data were used to illustrate the locations of interference during the operation of transmitter-receiver equipment that prevented determining the exact position of inland navigation units in the immediate vicinity of the above-mentioned bridges.

Introduction

Automatic identification systems (AIS) are used to exchange static and dynamic data between ships and coastal stations. AIS allows the identification of the name of a vessel, its dimensions, and parameters such as its destination port, type of goods being transported, its position, course, speed, heading, and other vessel traffic parameters. By receiving such transmissions, the AIS on-board a vessel or ashore allows radio stations to automatically locate, identify, and track AIS-equipped vessels on an appropriate display, such as an ARPA radar or ECDIS maps. AIS devices are widely used in maritime navigation and are divided into two classes. Class A represents mobile stations, which are mandatory for maritime vessels covered by the IMO SOLAS Convention. Class B are mobile stations with limited functionality that are used by e.g., recreational craft and base stations onshore (Duda, 2011; Stateczny, 2011).

Due to increasing freight transport by inland waterways and the continuous expansion of internationally-important waterway classes, there is a need to ensure safe navigation in these areas. Since the publication of the European Parliament Directive on harmonized river information services in 2004, the fleet of inland waterway vessels has been gradually equipped with devices to increase navigational safety. One of these devices, which is required for the skippers of vessels navigating on inland waterways, is Inland AIS (Urząd Żeglugi Śródlądowej, 2010).

Inland AIS is a standardized procedure for the automatic exchange of navigational data between vessels and between vessels and land-based installations. As an instrument used to track and trace inland waterway vessels, it is one of the four key instruments for river information services (RIS) technology for inland navigation. Its aim is to improve the safety and efficiency in this area. It supports onboard navigation, land-based traffic monitoring through vessel traffic services (VTS), and other tasks, such as disaster mitigation. AIS is an additional source of information during the navigation process and is not a substitute for other vessel tracking methods such as navigation radar. It supports radar tracking, which is particularly useful in inland waters where radar tracking is limited by the length of the straight sections of inland waterways (Kazimierski & Stateczny, 2015).

Even though AIS plays only a subsidiary role, its indications are highly accurate. This is important given the short distances from passing obstacles by inland waterway vessels and the fact that the AIS information is integrated with other navigation systems. The accuracy of GPS (global positioning system) and DGPS (differential global positioning system) used by AIS has been thoroughly described in previous publications (Specht, Specht & Dąbrowski, 2019), as well as the availability of the DGPS system on the Lower Oder River (Banachowicz et al., 2008; Wiśniewski, Bruniecki & Moszynski, 2013). In addition to the purely technical conditions of a GPS, there are other elements that reduce the accuracy of the information transmitted by AIS devices. These are elements of road and rail infrastructure, whose construction and location adversely affect the transmission and reception signals of AIS devices.

Characteristics of the research area

The Inland Waterway Authority in Szczecin supervises the movement of inland waterway vessels in the Szczecin water interchange. An analysis of hazardous situations from 1990 to 2015 in the section of the Oder River from Ognica to the maritime boundary, clearly indicates that the largest number of incidents involved the collision of vessels with bridges. Collisions with bridges can be broken down into individual bridges in the lower section of the Oder River, which shows that the largest number of collisions occurred with the Długi and Kolejowy Bridges in Szczecin (Kujawski & Stępień, 2017). The research area covers the West Oder River between Długi Bridge and the Kolejowy Bridge near the railway station in Szczecin. The parameters of both bridges are shown in Table 1.

The inland AIS shore station is located on EWA Elevator in Szczecin at a distance of 2.3 km in a straight line from the Długi Bridge and 2.68 km from the Railway Bridge. AIS messages sent

Table 1. Bridge parameters on the West Oder River in Szczecin

No.	Bridge	Kilometer of the West Oder River [km]	Width of the nautical channel [m]	Minimum clearance at the highest navigable water [m]
1	Długi	35.95	17.5	3.78
2	Kolejowy	35.59	10	3.79

between inland waterway vessels and the shore station use a GPS with RTK (real-time kinetics) corrections thanks to a reference station located in Goleniów near the city of Szczecin.

Figure 1. Visibility area of CCTV cameras on the Długi Bridge and Kolejowy Bridge in Szczecin, — coverage area of camera Cam1 — coverage area of camera Cam2

Both analyzed bridges were equipped with video cameras, whose fields of view are shown in Figure 1. Images from each camera were used to confirm the correctness of the vessel passage maneuvers under the bridge spans.

Methodology

Inland vessel passage was considered to analyses discrepancies between the transmission of AIS messages within the steel structures of bridges. Navigation near the Kolejowy Bridge upstream and downstream of the Western Oder River and near the Długi Bridge in Szczecin were analyzed. Individual ships were selected based on CCTV images. Out of 135 video samples, 80 contained the passages of vessels on the Odra River between the analyzed bridges. Recognizing the names of the vessels in the CCTV image, MMSI numbers were identified in the Marinetraffic.com database, and MMSI numbers were used for SQL database queries. All 80 navigation situations were subjected to verification of data correctness in the AIS message database, which

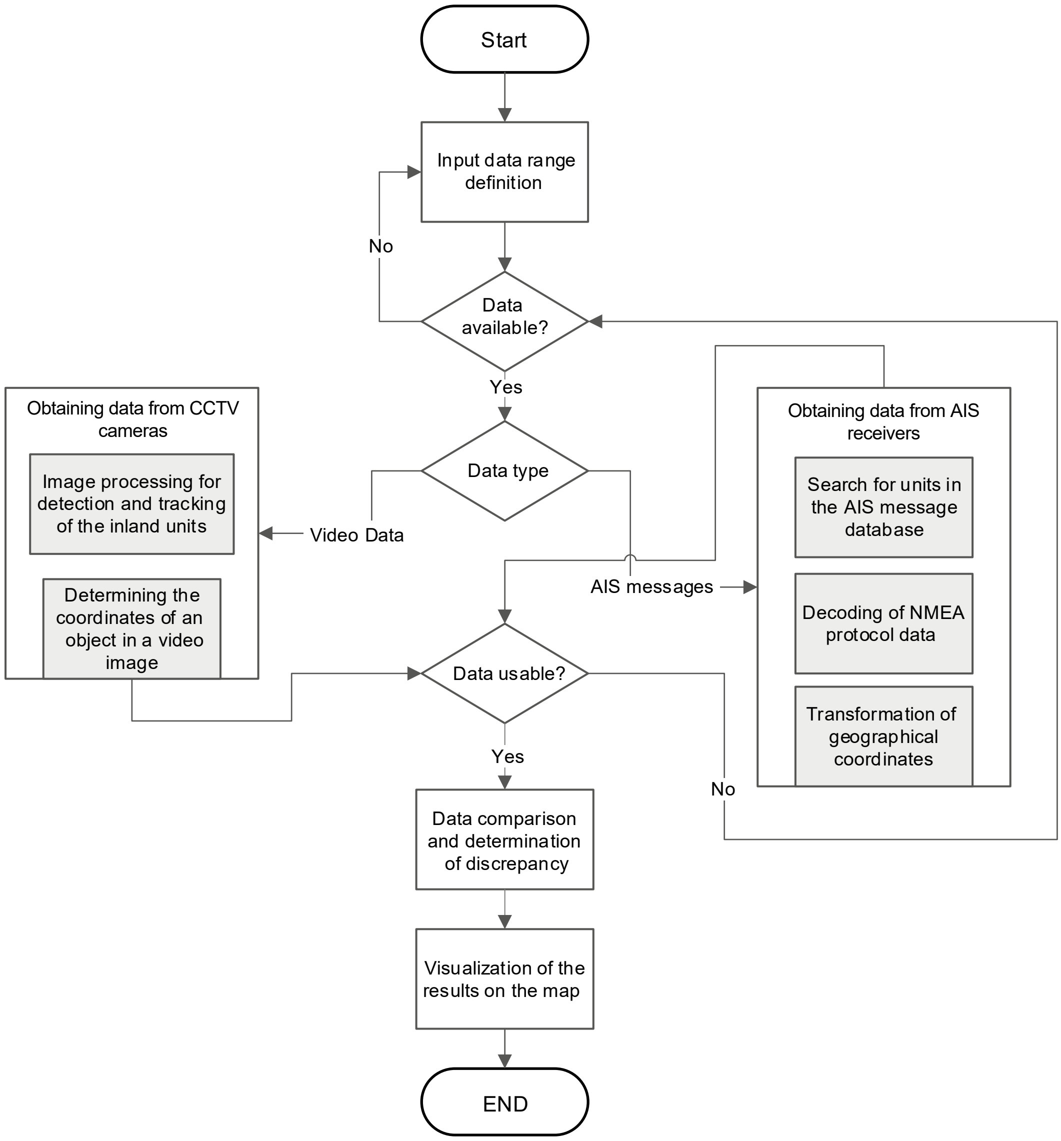


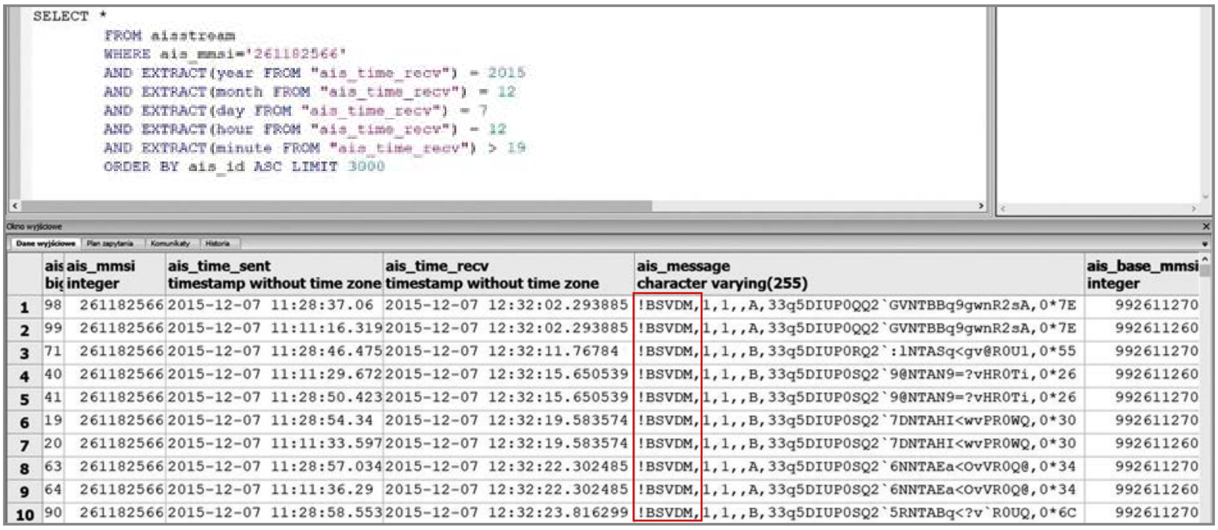
Figure 2. Methodology scheme for inland vessel position analysis

consisted of rejecting those vessels that contained incorrect or incomplete data or when a completely different position of the vessel was indicated in relation to what was presented in the CCTV image.

The recorded passages were taken from the AIS message database of the Inland Navigation Authority in Szczecin and cover the period from June to December 2015. Selected vessels were identified as transmitting an AIS signal on the section of the Western Oder River in Szczecin. The AIS messages were collected along with their counterparts in the form of video materials from a CCTV camera mounted on the Długi Bridge. The general model of the applied analysis methodology is presented in Figure 2.

Inland AIS messages were extracted from a database obtained from the Inland Navigation Authority in Szczecin based on the selection of existing video recordings from CCTV cameras from units over a specific period of time. An additional source of data in the form of CCTV cameras mounted on both analyzed bridges was used to identify the unit and the route of the analyzed Odra River section. The AIS messages from the Inland Waterways Authority were recorded as database records, and the selected vessel was extracted with an SQL query. Figure 3 shows the PostgreSQL database window with a query and the results obtained.

As can be seen in Figure 3, the data stored in the database were obtained from VDM-type vessels, which contains information about the date, time, and the longitude and latitude position of a given vessel. NMEA (National Marine Electronics Association) protocol was decoded to obtain access to particular parameters of selected vessels. Out of 80 selected vessels, only 35 met the criteria for having both forms of data (camera and AIS sentences).



```
SELECT *
       FROM aisstream
       WHERE ais_mmsi='261182566'
       AND EXTRACT(year FROM "ais_time_recv") = 2015
       AND EXTRACT(month FROM "ais_time_recv") = 12
       AND EXTRACT(day FROM "ais_time_recv") = 7
       AND EXTRACT(hour FROM "ais_time_recv") = 12
       AND EXTRACT(minute FROM "ais_time_recv") > 19
       ORDER BY ais_id ASC LIMIT 3000
```

	ais big	ais_mmsi integer	ais_time_sent timestamp without time zone	ais_time_recv timestamp without time zone	ais_message character varying(255)	ais_base_mmsi integer
1	98	261182566	2015-12-07 11:28:37.06	2015-12-07 12:32:02.293885	!BSVDM,1,1,,A,33q5DIUP0QQ2`GVNTBBq9gwnR2sA,0*7E	992611270
2	99	261182566	2015-12-07 11:11:16.319	2015-12-07 12:32:02.293885	!BSVDM,1,1,,A,33q5DIUP0QQ2`GVNTBBq9gwnR2sA,0*7E	992611260
3	71	261182566	2015-12-07 11:28:46.475	2015-12-07 12:32:11.76784	!BSVDM,1,1,,B,33q5DIUP0RQ2`:1NTASq<gv@R0U1,0*55	992611270
4	40	261182566	2015-12-07 11:11:29.672	2015-12-07 12:32:15.650539	!BSVDM,1,1,,B,33q5DIUP0SQ2`9@NTAN9=?vHR0Ti,0*26	992611260
5	41	261182566	2015-12-07 11:28:50.423	2015-12-07 12:32:15.650539	!BSVDM,1,1,,B,33q5DIUP0SQ2`9@NTAN9=?vHR0Ti,0*26	992611270
6	19	261182566	2015-12-07 11:28:54.34	2015-12-07 12:32:19.583574	!BSVDM,1,1,,B,33q5DIUP0SQ2`7DNTAHI<wvPR0WQ,0*30	992611270
7	20	261182566	2015-12-07 11:11:33.597	2015-12-07 12:32:19.583574	!BSVDM,1,1,,B,33q5DIUP0SQ2`7DNTAHI<wvPR0WQ,0*30	992611260
8	63	261182566	2015-12-07 11:28:57.034	2015-12-07 12:32:22.302485	!BSVDM,1,1,,A,33q5DIUP0SQ2`6NNTAEa<OvVR0Q@,0*34	992611270
9	64	261182566	2015-12-07 11:11:36.29	2015-12-07 12:32:22.302485	!BSVDM,1,1,,A,33q5DIUP0SQ2`6NNTAEa<OvVR0Q@,0*34	992611260
10	90	261182566	2015-12-07 11:28:58.553	2015-12-07 12:32:23.816299	!BSVDM,1,1,,B,33q5DIUP0SQ2`5RNTABq<?v`R0UQ,0*6C	992611270

Figure 3. Results of the database query for a selected inland vessel

Out of these 35 cases, only 20 were selected. The remaining cases had deficiencies in AIS transmissions and were not suitable for further analysis. Selected inland vessels were equipped with AIS devices with antennas placed on ship superstructures. The geographical coordinates of the vessel positions referred to the position of the GNSS antennas placed on the vessels.

Table 2. Inland vessels moving downstream of the river

No.	Name	MMSI	Type	Length [m]	Breadth [m]
1	Richard	211547550	Motor barge	80	8.2
2	Kienitz	211554730	Pusher	30.6	7.2
3	Pati	261182727	Motor barge	57	7.6
4	AGT-01	261182488	Motor barge	56	8
5	BM5229	261186021	Motor barge	57	7.6
6	Ardo	261182630	Motor barge	57	7
7	Bizon O 119	261182547	Pusher	110	8.3
8	Bizon O 62	261182045	Pusher	105	9
9	Bizon O 117	261182546	Pusher	138	9
10	Bizon O 156	261182566	Pusher	118.5	8.2

Table 3. Inland vessels moving upstream of the river

No.	Name	MMSI	Type	Length [m]	Breadth [m]
11	AGT-05	261182576	Motor barge	56.7	7.6
12	Bizon O 113	261182277	Pusher	118.5	8.2
13	AGT-01	261182488	Motor barge	56	8
14	AGT-05	261182576	Motor barge	56.7	7.6
15	Bizon O 113	261182277	Pusher	118.5	8.2
16	Bizon O 62	261182045	Pusher	20.9	9
17	Bizon O 146	261182014	Pusher	21.1	8.3
18	Bizon B-22	261186115	Pusher	118.5	8.2
19	NAWA S2	261182490	Motor barge	6.8	8.3
20	Andromeda	261182810	Motor barge	67	7.2

Each vessel generated a different number of AIS messages during its journey. It was necessary to determine the axis of the fairway for the individual passages between bridge pillars. For the Kolejowy Bridge, these were two centres for the right and left fairway. For the Długi Bridge, the crossings occurred in both directions on the same fairway. Then, the distance of each point with geographical coordinates (latitude, longitude) from the axis of the fairway was calculated. Taking into account the fact that the width of both fairways under the Kolejowy Bridge was 10 m and the width of the ships was between 7.2 and 9 m (Tables 1 and 2), the permissible shift in relation to the axis of the fairway should not exceed 0.5 to 1.8 m. The distance from the points to the straight and the root mean square distance was calculated using the following formulas:

$$d_{P,k} = \frac{|Ax_0 + By_0 + C|}{\sqrt{A^2 + B^2}} \quad (1)$$

where:
d – distance,
P – points of geographical coordinates,
k – line of a center of fairway,
A, B, C – polynomial coefficients.

$$D_{\mathrm{RMS}} = \sqrt{\frac{1}{n}\sum_{P=1}^{n} d_{P,k}} \quad (2)$$

where: D_{RMS} – root mean square distance, others as above.

Discussion of results

As a result of this research, AIS messages within two bridges were obtained, and their number was compared by dividing them into messages outside the bridge and under the bridge. The distances of individual points from the center of the fairway were also calculated. The results show that the number of messages under bridges decreased in most cases, and those registered were quite far from the center of the fairway. The precise results are shown in Figures 4–7, which are divided into vessels sailing downstream and upstream of the Western Oder River. The width between the pillars of the Kolejowy Bridge was 10.66 m for the right-hand route and 10.64 m for the left-hand route, respectively. For the Długi Bridge, the width was 17.5 m. As the above values and recorded errors in the AIS messages show, moving a vessel under the bridge a few meters to the left or right would cause the ship to collide with the bridge pillar. However, AIS indicates that the presence of the vessel is *de facto* misleading and that the position of the vessel is completely disturbed when the vessel is under the bridge.

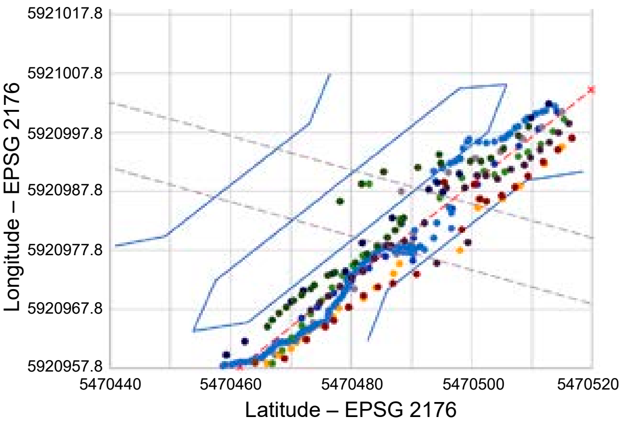


Figure 4. Positions of vessels passing the Kolejowy Bridge downstream of the river

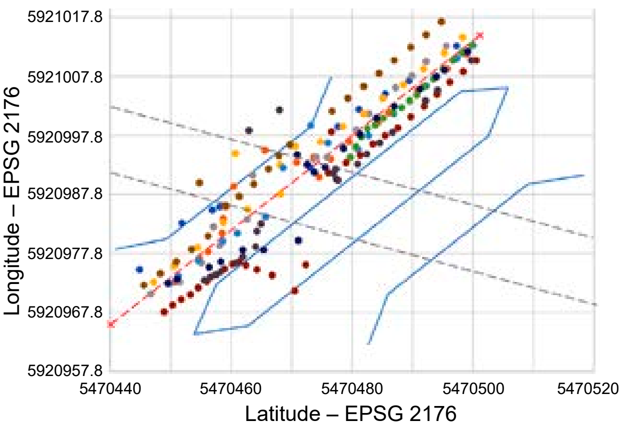


Figure 5. Positions of vessels passing the Kolejowy Bridge upstream of the river

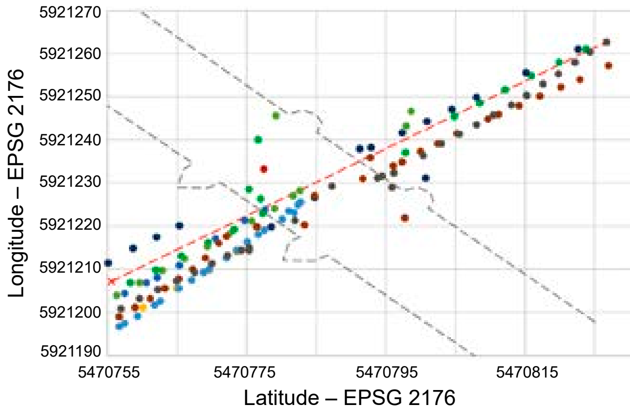


Figure 6. Positions of vessels passing the Długi Bridge downstream of the river

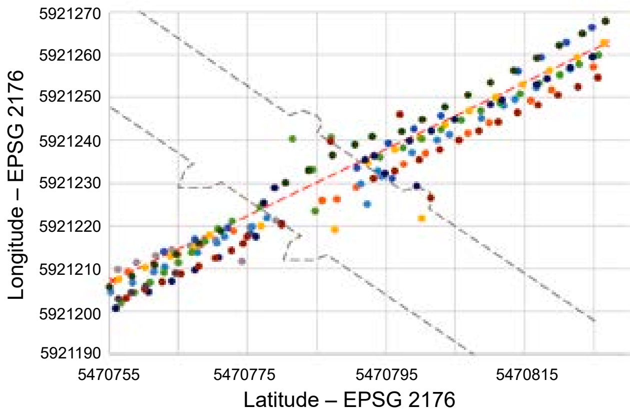


Figure 7. Positions of vessels passing the Długi Bridge upstream of the river

Figures 8 and 9 show the differences in the rate of AIS messages generated for individual vessels and how this rate changes when the vessel passes under both bridges. Since individual vessels took approximately 20 s to pass under the bridges, a measure of the number of messages sent and received for this amount of time was taken. We can clearly observe a decrease in the number of received messages from the shore station compared with the number of received messages outside the bridge area, i.e. in the open space per every 20 sec. The numbers on the horizontal axis represent the respective vessels from Tables 2 and 3.

The diagrams (Figures 8 and 9) show the number of generated messages and how it changes when the ship passes under a bridge. This means that apart from clear errors concerning the position of the ship, a much smaller number of messages is observed. Concerning the loss of AIS messages in the timetable for every 20 seconds of the ship's route, a 13.98% decrease in the number of reports was recorded for the Kolejowy Bridge and 25.26% for the Długi Bridge.

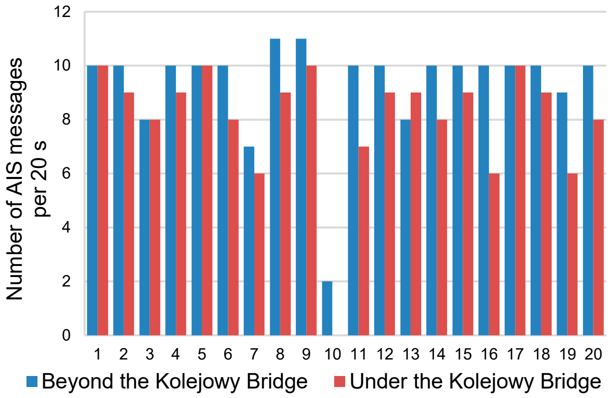


Figure 8. Rate of AIS messages near the Kolejowy Bridge

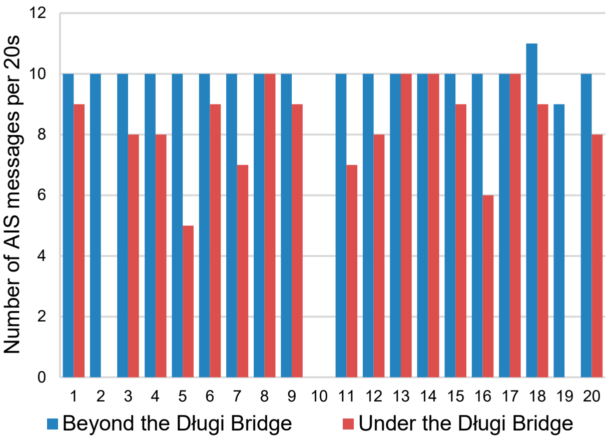


Figure 9. Rate of AIS messages near the Długi Bridge

The speed of the vessels' movement did not affect the number of reports generated. Figures 10 and 11 show the detailed relationship between the two cases and the recorded average speed, which are separated into maneuvers conducted outside and during the passage of vessels under the bridges.

It can be observed that the speed outside and under the bridges did not differ significantly. In the vast majority of cases, the speed was either the same or varied by only several percent. In two

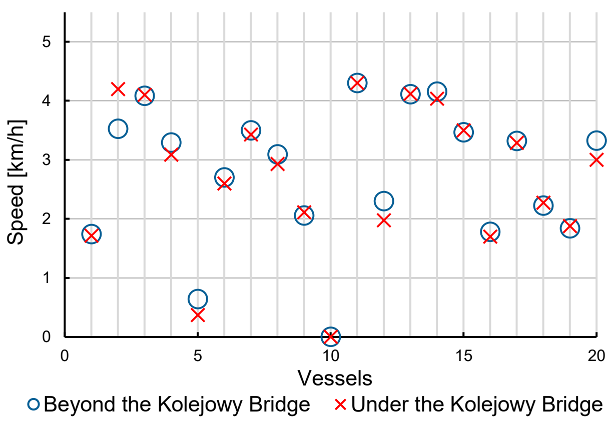


Figure 10. Average vessel speed from the Kolejowy Bridge area

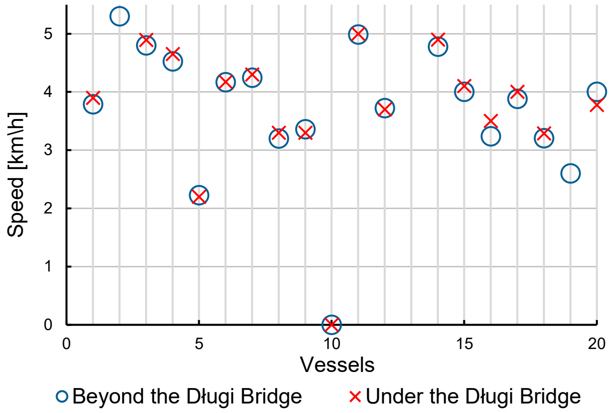


Figure 11. Average vessel speed from the Długi Bridge area

cases, for vessel 2 and vessel 19, during the passage maneuver under the Długi bridge, the messages transmitted disappeared completely. This was not the case for these ships when they crossed the Kolejowy Bridge. The measured root mean square distances (in meters) of a vessel from the center of the fairway is shown in Figures 12 and 13. The center of the fairway was used as a model, taking

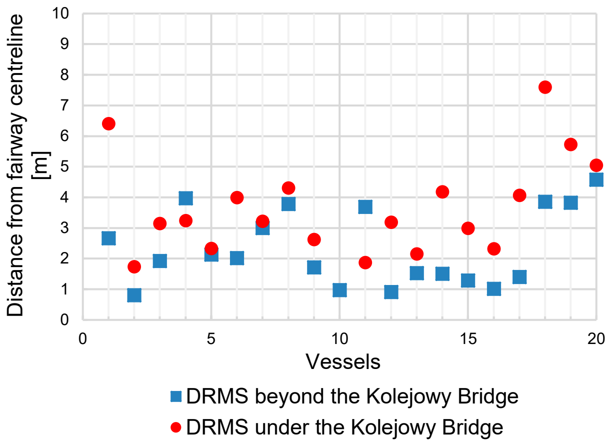


Figure 12. Root mean square distance of the calculated points for the Kolejowy Bridge

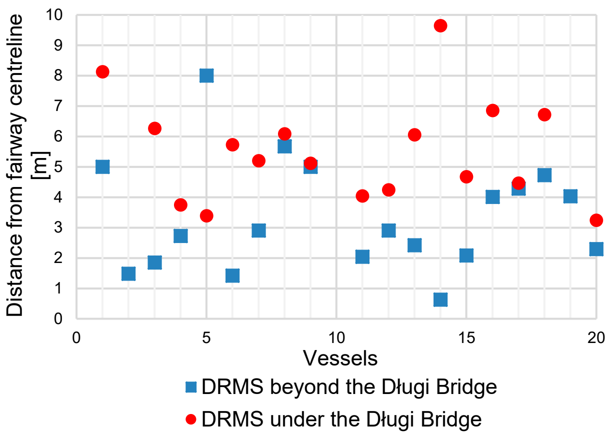


Figure 13. Root mean square distance of the calculated points for the Długi Bridge

into account the width of the fairway and the distances from the center of the fairway, which did not exceed 0.5 m for the Kolejowy Bridge and 4 m for the Długi Bridge.

It can be precisely observed that the distances from the center of the fairway for some measurements exceeded the entire permissible fairway width. According to the indications of the AIS devices, this should result in a collision between the ship and the bridge. As shown by the footage from CCTV cameras installed on bridges, no such situation occurred during the tests. The average distance error was 3.68 m for the Kolejowy Bridge and 5.49 m for the Długi Bridge. It should be noted that the ships being analyzed passed under both bridges during the same voyage, which suggests that the construction of the Długi Bridge had a greater influence on the quality of transmitted signals.

Conclusions

This article presented the relationship between navigational obstacles and discrepancies during the transmission and receiving of messages that would permit the identification of the position of a vessel. As shown in the article, there is a significant lack of information delivered by AIS equipment near the bridges, making it impossible to correctly determine the geographical position of the vessels using only this system. The main conclusion is that the AIS is not effective under specific conditions and should only be considered as ancillary equipment. Even further, it should not be taken into account as the only source of data when analyzing hazardous situations on the fairway under the conditions described in the article, nor as the only element for determining the position and visualization of a vessel on electronic navigational charts. In addition to the existing tools for determining the exact position of a vessel in specific conditions, there is a need for additional systems, such as existing CCTV camera systems. In former work (Kujawski, 2014; Kujawski & Stępień, 2017), the author noted that it was necessary to use existing visual devices mounted on bridges over waterways to automatically analyze navigational situations and the positioning of inland waterway vessels. Previous studies have shown that additional sources of information on waterway intersections with road and rail infrastructure from CCTV image analysis are needed to improve proper identification of vessel positions at the time of interference with existing navigation systems.

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