JOURNAL OF MARITIME RESEARCH

Vol XXIII. No. II (2026) pp 88–93

ISSN: 1697-4840, www.jmr.unican.es

Kuala Terengganu Drawbridge Impact Study on Marine Traffic Based on Ship AIS Data

Ahmad Faizal Ahmad Fuad[1,*], Mohammed Ismail Russtam Suhrab[2]

ARTICLE INFO

Article history:
Received 23 Mar 2025;
in revised form 16 Apr 2025;
accepted 21 May 2025.

Keywords:
drawbridge; marine traffic; automatic identification system

ABSTRACT

The iconic Kuala Terengganu Drawbridge (KTD), completed in 2019, introduced restrictions and additional costs for certain sizes of vessels entering the Terengganu River estuary. This study aims to identify and propose possible solutions for vessels affected by the structural limitations of the KTD. The methodology employed in this research involved several steps. First, Ship AIS data for the Terengganu River mouth area was collected for periods before and after the completion of the KTD. From this data, the air drafts of vessels were determined to identify those potentially impacted by the drawbridge's vertical clearance. The study also investigated the methods adopted by operators of vessels with air drafts exceeding 12 meters to continue operating in the Terengganu River estuary following the completion of the bridge. In addition, a literature review was conducted to examine drawbridge operation practices in other countries. The findings show that fewer vessels entered the Terengganu estuary in 2021 compared to 2018, with a notable reduction in the maximum vessel size. Furthermore, no sailing vessels were recorded entering the waters around Duyong Island in 2021, whereas such activity was observed in 2018. A review of drawbridge practices in the United States revealed that state authorities typically implement a combination of fixed schedules and on-demand openings, with waterway users generally given the right of way over land-based vehicle traffic.

1. Introduction.

A bridge serves as a structure to facilitate the crossing of roads, paths, railways, and other forms of transportation over obstacles such as rivers or roads (Study.com, 2022). Fixed bridges have a specific height or clearance from the water level, allowing vessels with certain air drafts to pass beneath them. However, vessels with air drafts exceeding the bridge's structure face limitations. To address this, movable bridges, known as drawbridges, are employed. Drawbridges are structures spanning bodies of water, featuring movable components that can be lifted, rotated, or swung to permit the passage of traffic through the waterway (Study.com, 2022). An alternative definition characterizes drawbridges as bridges designed to open for waterway traffic (United States Coast Guard, 2018). The three primary types of movable bridges are bascule bridges (rotating around the horizontal axis), swing bridges (rotating around the vertical axis), and vertical lift bridges (moving along the vertical axis) (Zantvliet, 2015).

This study specifically focuses on the bascule bridge, which pivots on a horizontal axis and incorporates a counterweight at one end (Zantvliet, 2015). The type of bascule bridge varies based on the position of its counterweight. The four main types of bascule bridges are simple trunnion bascule bridge, rolling bascule bridge, heel bascule bridge, and balance beam bascule bridge (Zantvliet, 2015).

Currently, there is only one drawbridge in Malaysia, located in the state of Terengganu. The Kuala Terengganu Drawbridge (KTD) was constructed between 2014 and 2019 and consists of four main structures: towers, bascule, pile-caps, and a sky-

[1]Faculty of Maritime Studies, Universiti Malaysia Terengganu, 21030 Kuala Nerus, Terengganu, Malaysia.

[2]Faculty of Maritime Studies, Universiti Malaysia Terengganu, 21030 Kuala Nerus, Terengganu, Malaysia.

[*]Corresponding author: Ahmad Faizal Ahmad Fuad. E-mail Address: faizalfuad75@gmail.com.

bridge, as depicted in Figure 1. The KTD is a simple trunnion bascule bridge, with a bascule length of 76 meters and a width of 23 meters. The clear span between the pile-caps measures 50 meters. The purpose of the KTD is to establish a road connection across the Terengganu River estuary, linking Seberang Takir to Kuala Terengganu City (TI Properties Sdn Bhd, 2020). Additionally, the bridge aims to stimulate the development of a new commercial center in Kuala Terengganu, reducing travel distance and duration from Kuala Terengganu city to Sultan Mahmud Airport by approximately 10 minutes (Zelan Bhd, 2023). Serving as an iconic tourist attraction, the bridge is also expected to enhance tourism and boost the local economy in Kuala Terengganu (TI Properties Sdn Bhd, 2020). Furthermore, the construction of the new drawbridge has significantly alleviated road traffic congestion at the Sultan Mahmud bridge (Zelan Bhd, 2017, 2023).

Figure 1: Kuala Terengganu Drawbridge (KTD) closed (left) and open (right).

Source: Authors.

The drawbridge is constructed across the main waterway that links the Terengganu River estuary with the South China Sea. KTD is the fourth bridge built to cross the Terengganu River. The previous three bridges are Sultan Mahmud bridge, Pulau Rusa bridge, and Pulau Sekati bridge (Jade Chan, 2020). Marine facilities available downstream of the bridge include an offshore crew change terminal, marina, shipyards, boatyards, fishing jetty, coastguard base, and boat ramps. The types of vessels using the waterway are offshore support vessels, fishing vessels, enforcement vessels, and leisure boats (sail and motor yachts). The bridge's vertical clearance is about 12.5 meters during high tide, as stated on the signage. Construction of the bridge began in August 2014 and was completed in June 2019 (Zelan Bhd, 2023).

Since the bridge became operational in August 2019, it has affected the operation of certain types of vessels with an air draft above 12 meters, namely offshore support vessels, sailboats, and a research vessel, due to the limited under-bridge clearance of KTD. For vessels with more than a 12-meter air draft, the KTD needs to be opened to allow them to pass. Currently, there is no schedule to open the KTD for waterway users; instead, users have to request the bridge's operator to open it, with a fee of RM1,500 (USD328) per lift lasting less than 20 minutes. Consequently, the cost for a vessel to enter the Terengganu River and return to the sea is approximately RM3,000 (USD655). This increases the operational costs for vessels based inside the Terengganu River estuary. Therefore, the objective of this study is to identify and propose possible solutions for vessels restricted by the KTD's structure. The specific objectives of the study are as follows: (i) to identify the trend of vessel traffic according to vessel types before and after the completion of KTD, (ii) to investigate the methods used by operators of vessels with an air draft exceeding 12 meters to operate in the Terengganu estuary after the completion of KTD, (iii) to examine the operation of drawbridges in other countries or locations, and (iv) to propose the best operational method for KTD in the interest of waterway users.

2. Methodology.

The overall methodology comprises four steps.

Step 1: To obtain Ship AIS data for the Terengganu River Mouth area before and after completion of KTD construction.

Step 2: To determine the air draft of all vessels obtained from the AIS data.

Step 3: To investigate the methods used by the operator of vessels with air drafts more than 12 meters to keep operating in the Terengganu River estuary after completion of KTD.

Step 4: To conduct a literature review on drawbridge operations in other countries.

In Step 1 of the study, the ship's Automatic Identification System (AIS) data for the Terengganu estuary area was obtained. This data was extracted using an online web AIS data service. The specific area of interest was determined by generating a polygon in the web AIS, as depicted in Figure 2. Subsequently, the ship's data for the years 2018 and 2021 were extracted from the AIS data. To ensure the data's relevance to the study, it was filtered and refined accordingly.

Figure 2: Terengganu River Estuary.

Source: Authors.

In Step 2 of the study, the air draft of all vessels obtained from the AIS web services was determined. The vessels were categorized into two main types: motor vessels and sailing yachts. The air draft for sailing yachts was calculated by multiplying the vessel's overall length (LOA) by a factor of 1.3, as suggested by (Storgaard, 2023). However, for motor vessels such as motor yachts, tug supply vessels, fishing vessels, research vessels, and enforcement vessels, there was no specific guideline for air draft calculation. To address this, a sample of 10 vessels with varying LOA ranging from 37 meters to 85 meters was selected. The plans for these 10 vessels were obtained, and the LOA and air draft were measured on the plans. The air draft was measured from the water level to the top of the ship's mast. The measurement results are presented in Table 1. Based on these measurements, ratios were calculated for each vessel by dividing the air draft by the LOA, and these ratios were averaged. The averaged value was then used to multiply the LOA of all motor vessels obtained from the AIS service, enabling the estimation of their air drafts.

Table 1: Ratio of LOA to air draft for motor vessels (source: Megalodon Marine Sdn Bhd, 2019).

Name	LOA (unit)	Air Draft (unit)	LOA / Air Draft Ratio
37m OSV	13	6.6	2.0
40m OSV	24.6	10.2	2.4
45m OSV	25.2	9.2	2.7
47m OSV	26.7	9.2	2.9
50m OSV	25.4	9.2	2.8
59m OSV	25.6	10.2	2.5
70m OSV	21.5	7.8	2.8
75m OSV	26.2	8.8	3.0
78m OSV	22.4	6.6	3.4
85m OSV	23.2	7.9	2.9
Average			2.7

Source: Authors.

In Step 3 of the study, the method used by vessels with an air draft of more than 12 meters operating in the Terengganu River estuary after the completion of the Kuala Terengganu Drawbridge (KTD) in August 2019 was investigated. Firstly, similar vessels that operated before and after the completion of KTD were identified in the AIS data. These vessels were then located and observed in the Terengganu River estuary. Subsequently, interviews were conducted with the operators of these vessels to determine the methods they employed to continue operating their vessels after the completion of KTD.

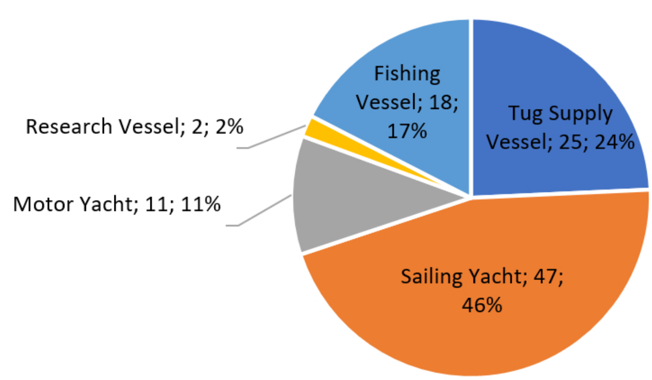
Step 4 involved conducting a literature review on the operational methods used by drawbridge operators in other locations. The literature search was conducted on online academic databases, industry publications, and relevant authorities to gather information on the operational practices and procedures employed by drawbridge operators in different contexts. This review aimed to gain insights and potential solutions that could be relevant to the operational challenges posed by the KTD and provide additional context for the study.

3. Results and Discussion.

3.1. *Trend of Vessel Traffic by Vessel Type Before and After Completion of the KTD.*

The construction of the KTD was completed in August 2019. To compare the vessel traffic before and after the completion of KTD, Ship's Automatic Identification System (AIS) data for the year 2018 and 2021 was selected for an estuary area between Duyong Island Marina and KTD. This area was chosen because it is situated after KTD from the sea, allowing for an analysis of the impact of the bridge on vessel traffic. Vessels with an air draft exceeding 13 meters are unable to pass under the structure of KTD. For the analysis, the count of vessel types was based on a specific vessel, regardless of the number of entries made by that vessel. The results for the year 2018 showed a total of 103 vessels that entered and left the area, while in the year 2021, there were 85 vessels, indicating a reduction of 18 vessels. Figure 3 displays the composition of vessel types in 2018. The types of vessels observed included sailing yachts (46%), tug supply vessels (24%), motor yachts (11%), fishing vessels (17%), and research vessels (2%). On the other hand, Figure 4 illustrates the composition of vessel types in 2021, which comprised of tug supply vessels (57%), fishing vessels (31%), motor yachts (4%), enforcement vessels (2%), and research vessels (1%). These figures provide an overview of the changes in the types of vessels entering the area after the completion of KTD.

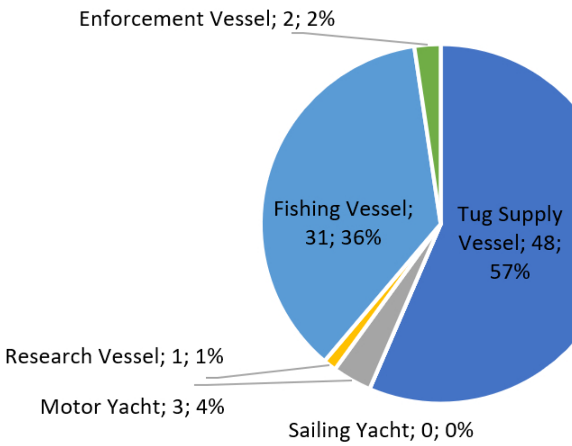
Figure 3: Types of vessels entering the Terengganu River estuary in 2018.



Source: Authors.

Table 2 provides a comparison of the number of vessel types in 2018 and 2021, as well as the differences between the two years. In 2018, there were 47 entries of sailing yachts, while in 2021, there were no entries recorded in the Duyong Island Marina area after the completion of the bridge. Instead, several sailing yachts were observed anchored at the Terengganu River mouth, just before the location of KTD. For motor yachts, the number of entries in the Duyong Island Marina area decreased from 11 in 2018 to 3 in 2021 following the completion of KTD. In contrast, the number of tug supply vessels entering the area increased from 25 in 2018 to 48 in 2021. This indicates that the KTD's structure did not significantly affect this type of vessel. The same trend was observed for fishing vessels, with an

Figure 4: Types of vessels entering the Terengganu River estuary in 2021.



Source: Authors.

increase in numbers. However, this increase was not due to an actual rise in the number of fishing vessels but rather the installation of vessel monitoring systems (VMS) on these vessels. Therefore, the increase can be attributed to improved tracking and monitoring capabilities rather than a direct impact of KTD. The number of research vessels and enforcement vessels remained the same between 2018 and 2021. This may be due to the absence of Automatic Identification System (AIS) installations onboard or the AIS not being switched on during the data collection period, resulting in no noticeable difference in entries for these vessel types.

Table 2: Number of vessels by type in 2018 and 2021.

Type	2018	2021	Differences
Sailing yacht	47	0	47
Motor yacht	11	3	9
Tug supply vessel	25	48	23
Fishing vessels	18	31	13
Research vessel	2	1	1
Enforcement vessel	0	2	2
Total	103	85	13

Source: Authors.

Table 3 presents a comparison of vessel dimensions before (2018) and after (2021) the completion of the bridge. In 2018, the maximum air draft recorded was 32.6 meters, whereas in 2021, the maximum air draft reduced significantly to 16.7 meters. The average air draft in 2018 was 15.9 meters, which also decreased to 11.3 meters in 2021. These findings indicate a significant reduction in both the maximum and average air drafts following the completion of KTD. Regarding the vessel's length overall (LOA), the maximum LOA in 2018 was 88.2 meters, whereas in 2021, it decreased to 45 meters. This indicates a substantial reduction in the maximum LOA after the completion of KTD. However, the average LOA increased from 24.1 meters in 2018 to 30.5 meters in 2021, suggesting a slight increase in the average LOA. In terms of beam, the maximum beam in 2018 was 21.3 meters, which decreased to 10 meters in 2021. This reflects a significant reduction in the maximum beam after the completion of KTD. On the other hand, the average beam slightly increased from 6.4 meters in 2018 to 6.9 meters in 2021. These findings indicate that there was a notable reduction in the maximum dimensions (air draft, LOA, and beam) of vessels after the completion of KTD. Additionally, the average dimensions showed mixed results, with an increase in LOA and a slight increase in beam.

Table 3: Comparison of vessel dimensions in 2018 and 2021.

Dimensions	Air Draft (m)		LOA (m)		Beam (m)	
	2018	2021	2018	2021	2018	2021
Minimum	3.7	5.6	8.0	15.0	2.0	4.0
Maximum	32.6	16.7	88.2	45.0	21.3	10.0
Average	14.7	11.3	24.1	30.5	6.4	6.9

Source: Authors.

3.2. Methods Used by Vessels with Air Drafts Above 12 m After Completion of the KTD.

Table 4 displays the list of vessels that operated after the completion of KTD in 2019. The air drafts for two vessels, RV Discovery and Setia Deras, were directly measured, while the air drafts for the remaining vessels were calculated. In total, there are 12 vessels with an air draft exceeding 12 meters listed in Table 4. The vessel with the highest air draft, measuring 19.9 meters, is the Marcap Galaxy.

Table 4: List of vessels operating after completion of the KTD.

No	Vessel	Type	Air Draft (m)	LOA (m)	Beam (m)
1	Marcap Galaxy	Tug Supply Vessel	19.9	53.8	13.8
2	Pelican Victory	Tug Supply Vessel	18.5	49.97	9.1
3	Aishah Aims 4	Tug Supply Vessel	16.6	44.75	9.6
4	Alkahfi Care	Tug Supply Vessel	15.6	42	8
5	Alkahfi Courage	Tug Supply Vessel	15.6	42	8
6	Jati Six	Tug Supply Vessel	14.8	40	7.5
7	Padas	Tug Supply Vessel	14.8	40	7.8
8	RV Discovery	Research Vessel	14.8	35	7.6
9	Nautica Gambir	Tug Supply Vessel	14.4	39	7.6
10	Nautica Langsat	Tug Supply Vessel	14.4	39	7.6
11	Nautica Tg Puteri	Tug Supply Vessel	14.4	39	7.6
12	Surya Kelang	Tug Supply Vessel	12.6	34	7.85
13	Setia Deras	Tug Supply Vessel	11	26	6
14	TFA 1542	Fishing Vessel	9.6	26	6
15	TFA 1611	Fishing Vessel	9.6	26	6
16	TRF 1400	Fishing Vessel	9.6	26	6
17	TRF 287	Fishing Vessel	9.6	26	6
18	Kejora Dua	Tug Supply Vessel	9.6	25.9	8.5
19	ONWA4370	Fishing Vessel	8.5	23	7

Source: Authors.

Observation of RV Discovery shows that the ship's mast had been modified from a fixed to a collapsible structure, as shown in Figure 5. This is to enable the vessel to pass under the KTD without lifting the bridge.

Figure 5: RV Discovery with original fixed mast in 2011 (left) and collapsible mast in 2019 (right).

Source: Authors.

Table 5 shows three vessels that had modified masts and obtained new air drafts. This allows the vessels to pass under the KTD, which saves costs and time for operation.

Table 5: List of vessels with calculated and modified air drafts (source: Aims Global Sdn Bhd).

No	Vessel	Type	Calculated Air draft (m)	New modified Air draft (m)
1	Alkahfi Courage	Tug Supply Vessel	15.6	11.62
2	Jati Six	Tug Supply Vessel	14.8	10.69
3	Nautica Langsat	Tug Supply Vessel	14.4	10.05

Source: Authors.

3.3. Case Studies of Drawbridge Operation in Other Locations.

The case studies were taken from two states in the United States, namely Florida and New Jersey. The case studies are presented in the following two sections. The drawbridges must be open promptly and fully for vessels to pass through upon receiving a request or signal to open (United States Coast Guard, 2018).

3.3.1. Drawbridge Operation in Florida, USA.

In the state of Florida, USA, there are approximately 140 drawbridges (Ringwald, 2018). These drawbridges are typically constructed in areas where building a high-level bridge is not feasible. The ownership and operation of these drawbridges are handled by the Florida Department of Transportation. In this case study, five specific drawbridges are included for analysis. The Indian Rocks Causeway Bridge in Indian Rocks Beach consists of two parallel single-leaf drawbridges (Ringwald, 2016a). Each drawbridge has two lanes, with one bridge dedicated to westbound traffic and the other for eastbound traffic. The Indian Rocks Bridge can be opened upon request by boaters or by contacting the bridge tender via marine VHF Channel 9. During bridge openings, motorists on land must wait as the Indian Rocks Bridge is a relatively short bridge.

The Park Boulevard Drawbridge in Indian Shores was constructed and opened in 1981, connecting Indian Shores with Seminole and Pinellas Park to the east (Ringwald, 2016b). Toll collection for the bridge began in 1981, with a charge of 50 cents for construction bond financing. However, tolls were discontinued in 1991. The Park Boulevard Bridge can be opened upon request by boats sounding their horn signal or by contacting the bridge tender on marine VHF Channel 9. The Madeira Beach Causeway Drawbridge is a high-level single-leaf drawbridge featuring four lanes of traffic (Ring, 2016). It operates on a predetermined time schedule during weekdays and weekends, and it also opens on demand to allow boats to pass through.

The John's Pass Drawbridge in Madeira Beach and Treasure Island is a twin-span drawbridge that was completed in 2011. The central section of the drawbridge was elevated higher than the previous drawbridge to reduce the frequency of bridge openings. The Treasure Island Causeway Drawbridge, connecting Treasure Island with St. Petersburg, underwent reconstruction in 2007. The original toll system for crossing the Treasure Island Causeway involved a fee of 50 cents each way, but it has since been replaced with SunPass technology for payment.

3.3.2. Drawbridge Operation in New Jersey, USA.

In the state of New Jersey, drawbridges operate according to a predetermined schedule (New Jersey Department of Transport, 2023). Outside of the scheduled times, the bridges can also open on demand based on boat traffic. According to the New Jersey DOT Chief Bridge Operator of the Central Region, the right of way is given to boats overland vehicles, as the boats are present in the waterway first (New Jersey Department of Transport, 2022).

3.4. Recommendations for KTD Operation.

The current operation of the KTD involves opening the bridge span only after the vessel's operator has paid in advance. This opening cost adds to the operational expenses for vessel operators or owners, particularly for those based in the Terengganu River estuary. The AIS data indicates that no sailing yachts entered the Duyong Island area in 2021 compared to 2018. Research and tug supply vessels based in the Terengganu River estuary had to modify their masts to pass under the 12.4-meter vertical clearance of the KTD. The state of Terengganu should adopt the same principle used by the New Jersey Department of Transportation, where waterway users are given precedence over motorway users in terms of the right of way. In this context, motorway users in Kuala Terengganu should bear the cost of operating and opening the bridge, rather than imposing fees on waterway users.

In the states of Florida and New Jersey, drawbridges are opened based on a combination of fixed schedules and on - demand requests. For waterways with high boat traffic, a combination of fixed schedules and on-demand openings is used, reserving on-demand openings for times outside the regular schedule. However, for waterways with lower boat traffic, relying solely on on-demand openings is more practical. Given the relatively high boat traffic in the Terengganu River, implementing a combination of fixed schedules and on-demand openings would be suitable for the KTD. The current method of financing the bridge operation through fees imposed on waterway users is not sustainable in terms of covering the KTD's operational costs. Based on the principle that "boats are here first before land vehicles," it would be unethical to collect fees from waterway users. The cost of bridge operation should either be borne by waterway users or covered by the state government.

Conclusions.

The analysis of Ship AIS data reveals a decrease in the number of vessels entering the Terengganu River in 2021 compared to 2018. Furthermore, the maximum size of vessels in terms of LOA and beam that entered the river in 2021 is significantly smaller than in 2018. Notably, no sailing yachts were observed entering the Duyong Island marina waters in 2021, in contrast to the 47 recorded in 2018. The number of motor yachts entering the Terengganu River also saw a significant decline in 2021 compared to 2018. These issues can be attributed to the physical restrictions imposed by the KTD. It is worth noting that the KTD operator partially finances the bridge's operation by charging a fee to waterway users for opening the bridge, which contradicts the principle applied by state authorities in the USA, where boats are given precedence over land vehicles. To address these challenges and promote increased vessel traffic in Terengganu, the following measures should be considered: implementing a combination of fixed scheduled and on-demand methods to open the KTD for waterway users and shifting the cost of KTD's operation to land vehicle users or the Terengganu state government. By aligning with the principles applied in other regions, it would be possible to mitigate the decrease in vessel traffic and enhance the efficiency of the KTD's operation.

Acknowledgment.

The research team would like to acknowledge HJS Maritime Sdn Bhd partly finance this research project and Aims Global Sdn Bhd on sharing of information.

Conflict of Interest Statement.

The authors have no conflicts of interest to declare. All co-authors have seen and agree with the contents of the manuscript and there is no financial interest to report.

References.

Chan, J. (2020) 'Glories of our bridges'. The Star.

Megalodon Marine Sdn Bhd (2019) Anchor Handling Tug. Available at: https://www.megalodonmarine.com/Anchor-Handling-Tug/q?cid=5&doit=showclass (Accessed: 5 June 2023).

New Jersey Department of Transportation (2022) Drawbridge operation [Video]. YouTube. Available at: https://www.youtube.com/watch?v=lFnxizmNPns&t=81s (Accessed: 5 June - 2023).

New Jersey Department of Transportation (2023) Drawbridge summer schedule. Available at: http://www.njcommuter.-com/51-2/ (Accessed: 7 June 2023).

Storgaard, M. (2023) How tall are sailboat masts? 9 examples. GoDownsize. Available at: https://www.godownsize.com/-how-tall-are-sailboat-masts/ (Accessed: 5 June 2023).

United States Coast Guard (2018) Title 33?Navigation and Navigable Waters. Code of Federal Regulations. Washington, DC: U.S. Government Publishing Office.

Van Zantvliet, P. S. (2015) Analysis of the force distribution on operating mechanisms in a bascule bridge. Master's thesis. Delft University of Technology.

Zelan Berhad (2017) Kuala Terengganu Drawbridge. Available at: http://www.zelan.com/our-business/engineering-construction/infrastructure-construction/drawbridge/ (Accessed: 7 - January 2017).

Zelan Berhad (2023) Drawbridge, Terengganu, Malaysia. Available at: http://www.zelan.com/our-business/engineering-construction/infrastructure-construction/drawbridge/ (Accessed: 5 January 2023).