Alternative Shipping Routes and Simulations of LNG Storage at Export / Import Terminals

Alternativni plovni putovi i simulacije LNG skladištenja na izvoznim/uvoznim terminalima

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Summary

The issue of the required LNG storage facilities at the terminals is mainly dependent on the weather conditions which may restrict the vessel's approach to the loading terminal and on the sea and ice conditions along the shipping route. Storms and heavy ice condition may result in considerable delays in the planned voyage schedules. Some of the weather delays can be compensated by the sea margin, when the ship sails faster in order to catch up with the schedule. This scientific paper discusses the issues related to transshipment and loading of LNG at the terminals exposed to severe weather conditions.

KEY WORDS
Port of Murmansk
LNG
Ships
Simulation of Storage Facilities
Weather Conditions

Sažetak

Pitanje potrebnih kapaciteta za skladištenje ukapljenog prirodnog plina (LNG-a) na terminalu određenom za iskorištavanje istoga uglavnom ovisi o vremenskim prilikama koje ograničavaju prilaz broda ukrcajnom terminalu, uvjetima na moru i uvjetima zaleđenosti na plovidbenoj ruti. Oluje i velika zaleđenost mora mogu uzrokovati bitnija kašnjenja u planiranim rasporedima plovidbe. Gubitak vremena uzrokovan vremenskim neprilikama može se nadoknaditi korištenjem pričuvne snage. Brod tada povećava brzinu plovidbe kako bi nadoknadio kašnjenje u rasporedu. O tom se pitanju raspravlja u ovom znanstvenom radu vezanom za prekrcaj i ukrcaj LNG-a na terminalima koji su izloženi teškim vremenskim uvjetima.

KLJUČNE RIJEČI
luka Murmansk
LNG
brodovi
simulacije kapaciteta skladišta
vremenski uvjeti

INTRODUCTION / *Uvod*

Due to the fact that shipping is an international activity whose economic structure is highly complex, the forecasts and projections of the shipping market are exceptionally demanding. However, they are expected to assist in making decisions affecting the performance of shipping business in future. Sea shipping routes present changeable aspects and are often varying, depending on the voyage length and the season. A total number of vessels that are needed for conveying cargo between ports depends on the type of vessel and her consumption, and on the time needed to complete the passage. This research tries to define financial savings that can be made through the correct selection of type, size and number of ships that would make the total fleet required for transporting LNG from the port of Murmansk to the import terminal, i.e. port of discharge. The port of Murmansk has two sea routes for exporting LNG and is potentially one of the Russia's largest LNG load terminals.

The issue of the required facilities for LNG storage at the terminals is mainly dependent on the weather conditions which may restrict the vessel's approach to the loading terminal, as well as on the sea and ice conditions along the shipping route. Storms and heavy ice conditions may result in considerable delays in the planned voyage schedules. Some of the weather delays can be compensated by the sea margin, when the ship sails faster in order to catch up with the schedule.

It is interesting to define the number of vessels that will be needed over the period of five years and this can be done by carrying out the simulations which are not expected to change much over the period of five years and longer. Given the considerable energy, development and other resources in certain regions, it is expected that the traffic and the employment time of the vessels and transshipment terminals will be increased, depending on the prevailing weather conditions.

AVAILABLE SHIPPING DIRECTIONS / *Raspoloživi morski pravci*

LNG load terminals are situated at the locations (ports) that are suitable for exporting LNG (Table 1). Some of these ports have alternative shipping routes, mainly towards west, around the island of Novaya Zemlya where sailing is possible along its northern and southern coasts. As for Asian destinations, the options include the Suez Canal and the Northern Sea Route (NSR), in particular during summer months (Figure 1).

Table 1 Distances of various navigational routes to transshipment ports.
Tablica 1. Udaljenosti raznih navigacijskih ruta do prekrcajnih luka

TRANSSHIPMENT PORTS	TOTAL DISTANCE [NM]	OFFSHORE DISTANCE [NM]	ESTIMATED DISTANCE OF ICE NAVIGATION [NM]
Zeebrygge (Kara Gate)	2551	1747	804
Zeebrygge	2540	1865	675
South Hook, UK (Kara Gate)	2731	1927	804
South Hook, UK	2716	2041	675
Cove Point, USA (Kara Gate)	5057	4253	804
Cove Point, USA	5040	4365	675
Chubu, Japan, Suez	13475	12671	804
Guangdong, China, Suez	12110	11415	695
Chubu, Japan, NSR	5175	2853	2322
Guangdong, China, NSR	6759	4437	2322
Honningsvåg	1130	326	804

Source: http://www.petroleum-economist.com/pdf/LNGInsight_April/LNG%20Shipping.pdf

Source/Izvor: http://upload.wikimedia.org/wikipedia/commons/thumb/a/aa/Northern_Sea_Route_vs_Southern_Sea_Route.svg/250px-Northern_Sea_Route_vs_Southern_Sea_Route.svg.png

Figure 1 Suez Canal and Northern Sea Route
Slika 1. Sueski kanal i ruta u Sjevernom moru

A round voyage consists of the following operations:

- loading, disconnecting cargo handling facilities, unberthing, leaving port;
- laden ship sailing;
- approach, mooring, connecting cargo handling facilities;
- discharging, disconnecting, unberthing, leaving port;
- sailing light;
- approach, berthing, connecting cargo handling facilities.

ASSUMPTIONS MADE ON THE ROUTES / *Pretpostavke o rutama*

The overall turn-round time at the port terminal is related to loading and discharging LNG. On the basis of the actual information gathered from the LNG shippers [9], during loading/unloading operations the turn-round time of the vessel at the terminal, from the approaching manoeuvre (end of passage – EOP) to the end of the leaving manoeuvre and getting under way full ahead on passage (FAOP), consists of:

- waiting for the allocation of the berth or anchorage – for about 3 hours (arbitrary value, statistical estimation);
- approaching manoeuvre until the final mooring operation – about 3 hours;
- from mooring to the beginning of loading – about 3 hours;
- estimated duration of loading/discharging operation is around 12 hours, while the ramp lifting/lowering lasts around 3 hours – about 15 hours in total;
- end of loading/discharging and unmooring – around 2 hours;
- sailing at reduced speed until FAOP – 4 to 5 hours.

The total turn-round time of the vessel at the loading or import terminal, from EOP to FAOP, amounts to 28 hours on average.

Industrial practice confirms that the ship's cargo pump capacity is designed for the nominal discharge duration of 12 hours, not including the time needed for lifting/lowering the ramp. In practice, it takes 15 hours to discharge cargo on average. The same goes for the LNG loading time so that it is assumed that the real time of cargo loading at the LNG terminal amounts to about 15 hours [2].

As for the duration of the approach, the usual approach time (from EOP to the final mooring) at offshore terminals amounts to 3-4 hours (obstacle-free offshore area). At the Far East terminals, where the intense maritime traffic requires particular attention and precaution, the approach is slower and lasts for about 4 to 5 hours. The assumed distance from the offshore area to the terminals is about 36 nautical miles. It should be taken into consideration that the assumed duration of approach at reduced speed and with tug assistance is 4.5 hours at the terminals in Chubu and Guangdong.

As for offshore passages and speed restrictions, it should be pointed out that the average speed of the laden or unladen ship is 19.5 knots on average. At least four extraordinary sea legs are expected on the shipping route. The passage through the Suez Canal in a convoy includes the approaching operation and the increase in speed after leaving the canal. According to the information provided by the Suez Canal authorities [10], the passage lasts about 14 to 16 hours. In the Straits of Singapore the speed is reduced to the manoeuvring speed of 8 to 9 knots in the passage that is over 60 NM long (from Tanjung Piai to Horsburgh lighthouse). A total of 8 hours is assumed for passing through the Strait, taking into consideration the slower sea leg, reducing the speed and the time needed for increasing the speed. According to Singapore Port Authorities [7], the passage through the Straits of Singapore lasts approximately 400 minutes or 6.7 hours, which applies to the ships carrying liquefied gas. Full speed is assumed while passing through the Strait of Malacca throughout 194 nautical miles from Tanjung Piai to Batu Mandi.

MAINTAINING SHIPPING SCHEDULES IN MARITIME TRANSPORT BY SPEED UTILISATION / *Pridržavanje s redom plovidbe u pomorskom prijevozu kroz prilagodbu brzine*

As it can be concluded from the previous chapter, navigational routes of LNG ships are exceptionally long and this is the reason for designing LNG tankers that are, as a rule, provided with the propulsion sea margin of 21% [1]. The purpose of the additional propulsion capacity is to ensure that the vessels maintain the shipping schedule, regardless of weather conditions, hull fouling and aging. It should be noted that the propulsion power in ice conditions is critical for the ships considered in this research. Therefore these vessels are powered by more than 21% of the sea margin. Here are the actual values (Table 2) of the sea margins [2].

The sea margin power is a useful feature as it enables the vessel to sail faster in order to compensate for the delays (e.g. due to ice conditions). Naturally, sailing at maximum speed results in the increased fuel consumption and diesel engine load. Table 3 provides reasons for unexpected delays, the consequences and the possible solutions which mainly consist of using the sea margin power. Inbound and outbound voyages are listed separately.

It is obvious that the sea margin power can be efficiently used on longer voyages for making up for the time which is commonly lost during ice navigation or under harsh weather conditions. On long voyages (10,000 NM and more) it is possible to achieve the equalisation of speed in order to sail according to the constant shipping schedule. In this case, the LNG carrier has to use combined sailing speed in high seas during a particular season.

It is not known how long the delay would be in case of adverse weather conditions lasting for several days, especially during the approach when it is not possible to carry out loading operations. According to the statistical meteorological data published in the Aker Arctic report (K-128), such weather conditions rarely occur [11].

EXPECTED SHIPPING UNCERTAINTIES IN MARITIME TRANSPORT / *Očekivani pomorski rizici u pomorskom prijevozu*

Simulation is the tool that should be used in order to estimate and thereby anticipate and prepare the expected level of LNG storage facilities [4]. This is the best method as it allows the user to simulate the probabilities of delay by entering necessary parameters into the programme and to predict the rate of delays of LNG carriers and their deviations from the planned cargo loading schedule due to various shipping uncertainties. The most important factors regarding the issue include the availability of vessels and specific weather conditions that are expected to restrict the approach of vessels or the availability of terminals. If the voyage distances are similar, the produced results will be similar as well, therefore the following cases are chosen for the purpose of the simulation:

Murmansk (load terminal) - Zeebrugge,

Murmansk (load terminal) - Cove Point, and

Murmansk (load terminal) - Chubu (via the Suez Canal).

Here are the relevant parameters that are likely to cause delays and are therefore used in simulations:

The load terminal can not be accessed by vessels when the wind is over 15 m/s [5]. For such cases, Table 4 provides the statistics regarding the wind force and sea condition.

Table 2 Sea margin of the ships considered in the research
Tablica 2. Sea margin brzina razmatrana u istraživanju

TYPE OF SHIP [m3]	MAXIMUM PROPULSION POWER [kW]	REQUIRED POWER AT 19.5 KN [kW]	AVAILABLE SEA MARGIN POWER [%]	MAXIMUM SPEED [knots]
Moss 205,000	42,000	32,447	29	21.0
SPB 205,000	42,000	33, 679	25	20.7

Source: the authors

Table 3 Consequences of delays in shipping routes
Tablica 3. Posljedice kašnjenja u plovidbenim rutama

DELAY	DIRECT CONSEQUENCES	COUNTER-MEASURE	CONSEQUENCE
Adverse weather conditions when approaching.	Request for storage.	Sufficient storage capacity.	Not relevant.
	Changes in the entire shipping schedule.	Use of sea margin to make up for the delay.	Increased fuel consumption.
Adverse weather conditions when leaving port.	Changes in the entire shipping schedule.	Use of sea margin to make up for the delay.	Increased fuel consumption.

Source: the authors

Table 4 Expected off-hire days at Murmansk load terminal.
Tablica 4. Očekivani dani izvan najma na ukrcajnom terminalu u Murmansku

MURMANSK	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
WIND												
(OVER 15m/s)	5.6	3.9	4.4	4.7	4.4	2.2	1.7	1.9	2.9	4.8	5.9	5.2
SEA	0	0	0	0	0	0	0.155	0.155	0.3	0.31	0	0
TOTAL	5.6	3.9	4.4	4.7	4.4	2.2	1.7	1.9	2.9	4.8	5.9	5.2

Source: WMO (http://weather.noaa.gov/weather/CL_cc.html).

Table 5 Estimated delays during voyage.
Tablica 5. Očekivana kašnjenja tijekom putovanja

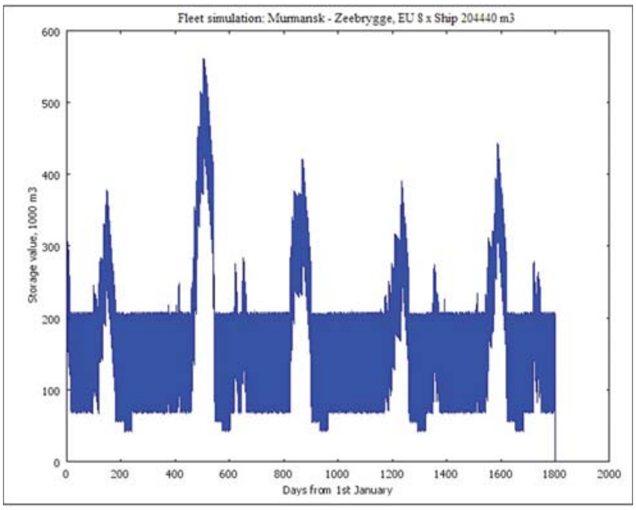
VOYAGE	Delay [h]	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
ICE	6	1.9	2.0	1.6	1.1	0.9	0.0	0.0	0.0	0.6	1.6	1.5	1.8
ICE	12	1.0	1.0	0.8	0.6	0.5	0.0	0.0	0.0	0.3	0.8	0.8	0.9
WIND	2	2.9	2.1	1.9	1.1	1.5	0.6	0.5	0.5	1.8	2.2	2.0	3.3
WIND	6	0.6	0.4	0.4	0.2	0.3	0.1	0.1	0.1	0.4	0.4	0.4	0.7

Source: the authors

Delays in shipping schedules are expected due to offshore weather conditions or in ice navigation, not including the approach to any particular region. Possible delays are estimated to be 2 h, 6 h and 12 h, and are shown as days/month in Table 5.

SIMULATION CASES AND RESULTS / *Simulacijski primjeri i rezultati*

The simulations refer to the period of five years because it has been estimated that the 5-year period produces the best results. If the simulation runs longer the results remain unchanged. The following figures present the results of the simulated LNG storage values at the terminals, featuring the selected sea shipping routes. The number of LNG carriers and their capacity is shown in the caption of each chart. The simulation starts on the 1st of January and lasts for five years as from that day.



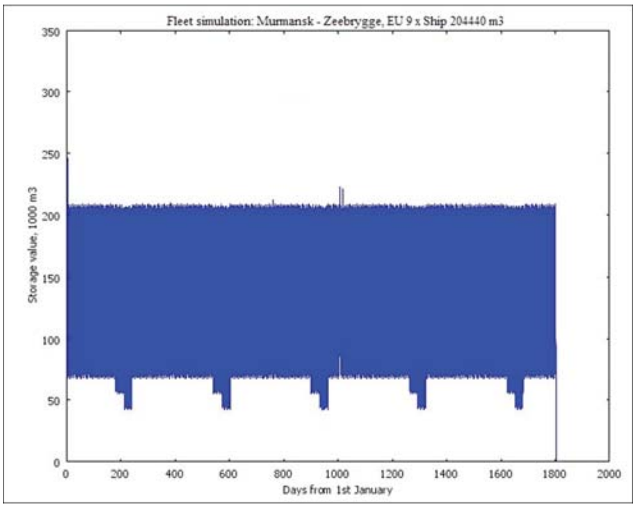


Figure 2 Simulation case: 205,000 m3 LNG carriers, route Murmansk – Zeebrugge
Slika 2. Simulacijski primjer: 205,000 m3 LNG brod, ruta Murmansk - Zeebrugge

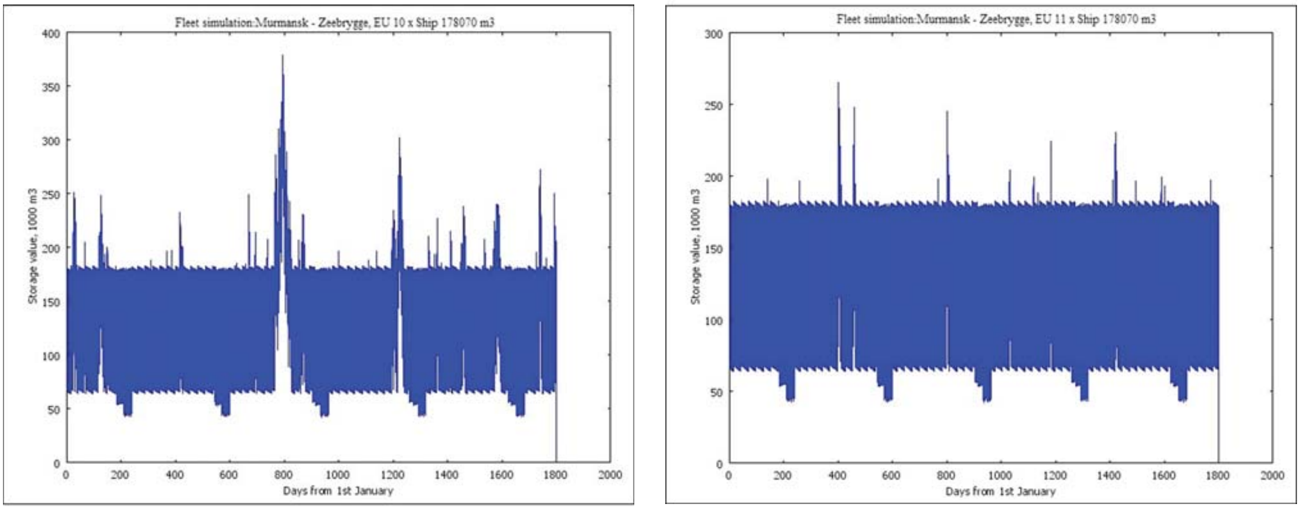


Figure 3 Simulation case: 183 000 m3 LNG carriers, route Murmansk – Zeebrugge
Slika 3. Simulacijski primjer: 183,000 m3 LNG brodovi, ruta Murmansk - Zeebrugge

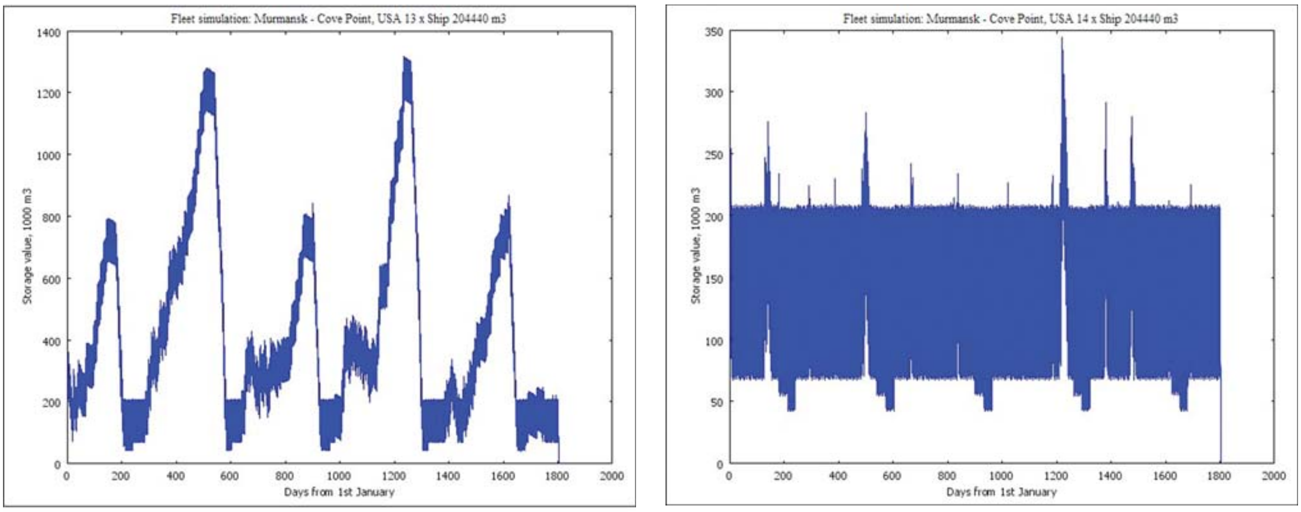


Figure 4 Simulation case: 205,000 m3 LNG carriers, route Murmansk – Cove Point
Slika 4. Simulacijski primjer: 205,000 m3 LNG brodovi, ruta Murmansk – Cove Point

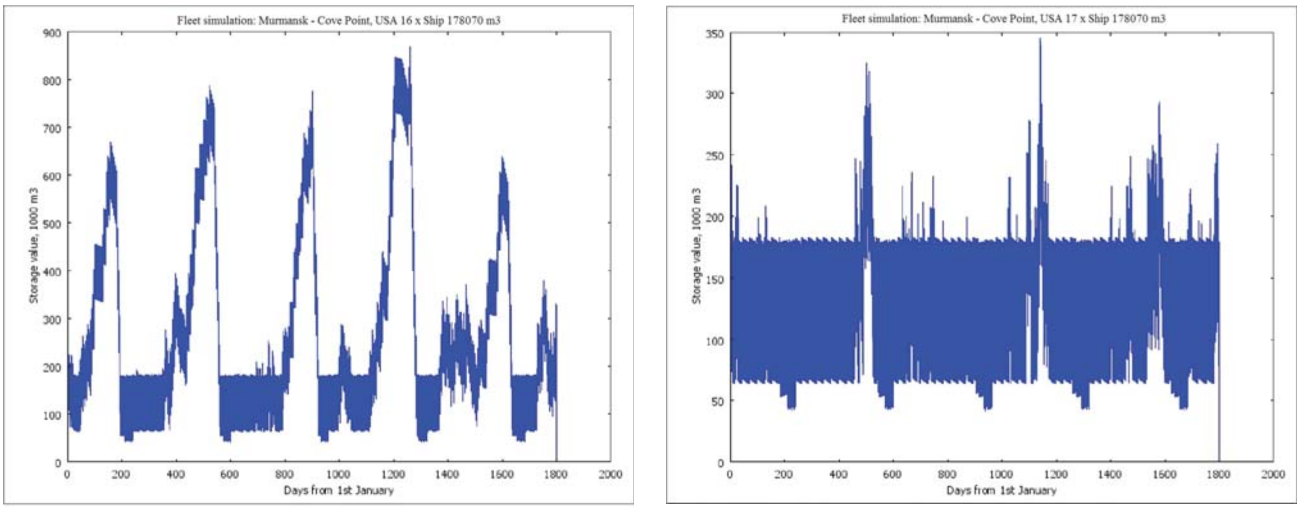


Figure 5 Simulation case: 183,000 m3 LNG carriers, route Murmansk – Cove Point
Slika 5. Simulacijski primjer: 183,000 m3 LNG brodovi, ruta Murmansk – Cove Point

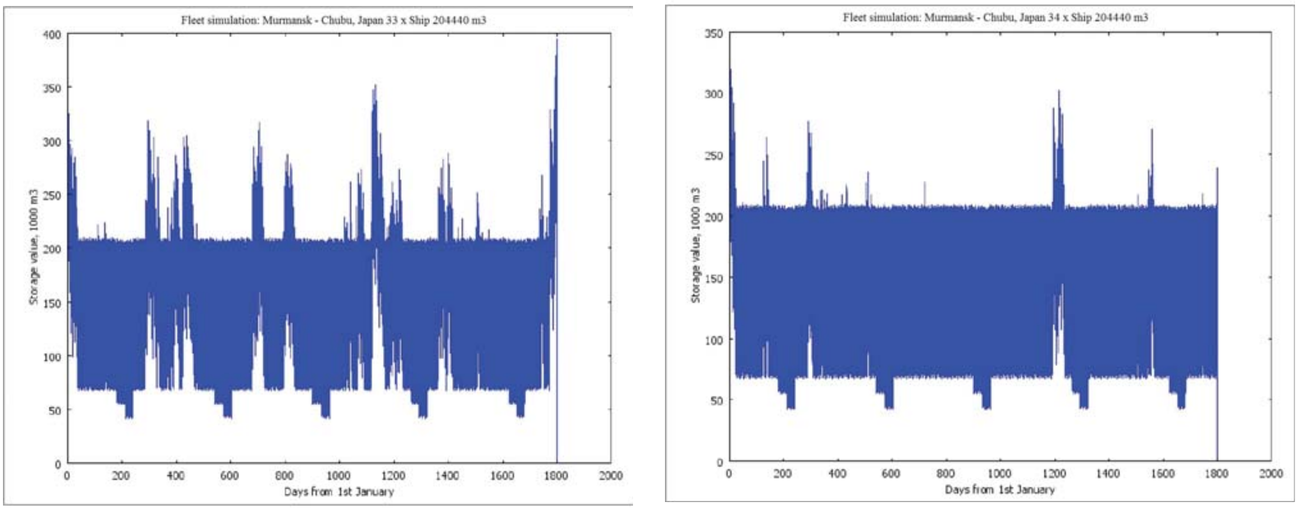


Figure 6 Simulation case: 205,000 m3 LNG carriers, route Murmansk – Chubu
Slika 6. Simulacijski primjer: 205,000 m3 LNG brodovi, ruta Murmansk - Chubu

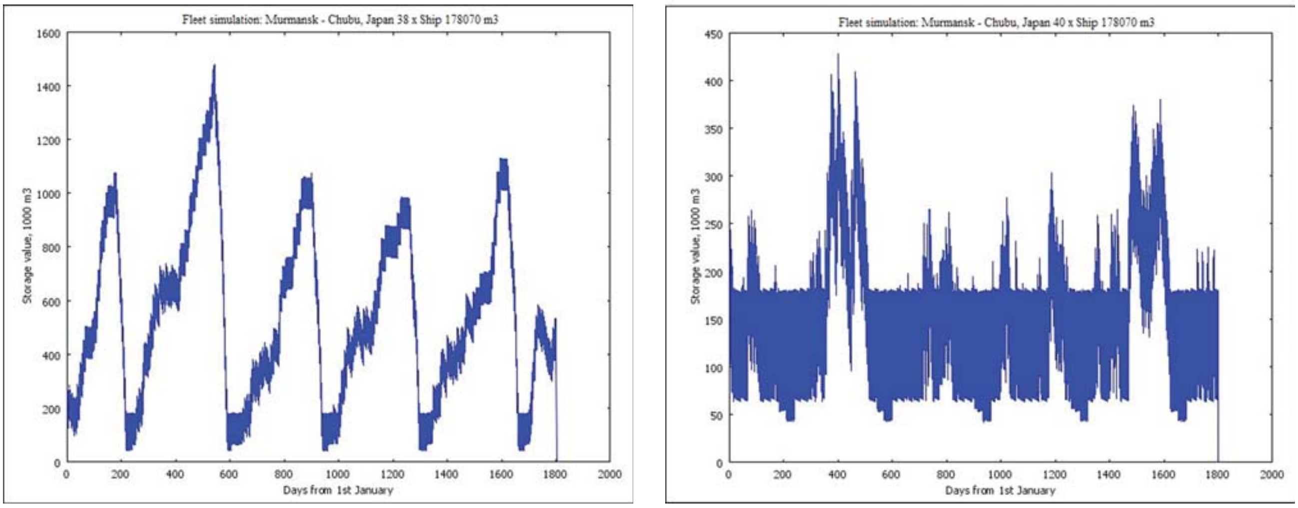


Figure 7 Simulation case: 183,000 m3 LNG carriers, route Murmansk – Chubu
Slika 7. Simulacijski primjer: 183,000 m3 LNG brodovi, ruta Murmansk - Chubu

CONCLUSION / *Zaključak*

Inspired by actual events in the LNG shipping industry, authors of this paper developed a simulation model for strategic estimation of LNG storage values. The components affecting the price of LNG seaborne transport are known. They include fuel price, daily consumption of fuel, crew wages, cost of the maintenance of the ship and ship's equipment, choice of the shipping route (via the Suez Canal or the Northern Sea Route). However, the greatest costs of LNG transport from the load port to the import terminal depend on the size and price of the vessels, the number of vessels required for transportation and the overall amount of cargo. The total number of ships that are employed for carrying the cargo varies with the type of ship, her fuel consumption and the duration of voyage. By properly selecting the type, size and number of vessels making the fleet that is needed for carrying LNG from the port of Murmansk to the import terminals, it would be possible not only to maintain the schedule in maritime transportation but also to reduce the LNG transportation costs. Namely, the performed simulations produce the following conclusions:

For the route Murmansk – Zeebrugge the number of ships having the capacity of 205,000 m3 should be increased to 9 ships in order to maintain the reliability of production. The simulation shows that 8 vessels are sufficient to handle the annual delivery of LNG production, but occasionally there is a risk of overflowing storage tanks with peak values amounting up to 600, 000 m3. In case the smaller vessels are used, 10 vessels would be fairly enough to handle the annual transportation requirements. However, in winter time, the amount of LNG requiring storage may amount to 400,000 m3. By increasing the fleet by just one vessel, the amount of LNG requiring storage at the terminal is surely reduced to less than 300,000 m3.

For the sailing route Murmansk – Cove Point, 13 larger carriers are sufficient for the transportation of the annual LNG production, but the shipping schedule delays cause considerable problems related to the reliability of loading. 14 ships are required in order to achieve safer results. The amount of LNG that needs to be stored increases only occasionally. It is expected that every winter the amount of LNG that needs to be stored will exceed the average ship's capacity before the next vessel is available, but by no more than 350,000 m3 in the worst case. If using smaller ships, the simulation forecasts that 17 ships provide good reliability regarding the storage of LNG.

For the route Murmansk – Chubu the fleet of 34 larger carriers ensures the reasonable level of reliability. In this case, the large number of vessels emphasises the effect of reliability of the approach to the terminal. Unlike other cases that featured fewer ships, for the route Murmansk – Chubu the efficiency decreases if the fleet is increased by one vessel. Therefore it is possible to reduce the fleet to 33 larger carriers but additional efforts should be made to ensure a reliable approach to the terminal. When employing smaller carriers, it is estimated that 38 vessels are able to handle the annual production, but the required storage capacity would be too large, amounting to 1.5 million m3. 40 ships would ensure the reliability, with a reasonable storage capacity of less than 500,000 m3.

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