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International
Journal
Of Modern Engineering Research (IJMER)

Multi-Criteria Decision Making for Oil Pollution Recovery Module for Swath Multifunctional Special Ships

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ABSTRACT: *Latvian naval forces are considerable element of national and regional maritime security and safety structure, demonstrating unique strategic and operational attitude of "dual purpose Navy", where pure military functions and responsibilities are organically interwoven with Coast Guard duties and even public services, such as Search and Rescue (SAR) and Maritime Assistance (MAS). Innovative, Small Waterplane Area Twin Hull (SWATH) shipbuilding national program has brought five patrol ships of unique design to be fully in-commissioned in 2015. As universal multifunctional platforms for merely unlimited purposes at sea, restricted just by dimensions of single "twenty-foot equivalent unit" (TEU) 20-foot-long (6.1 m) intermodal container, vessels can be filled with merely any kind of equipment and consoles. Risk of oil pollution in Baltic Sea is extremely high due to intensive marine traffic and presence of transportation hubs, and one of the primary tasks of Latvian Navy is to combat such pollutions at sea. SWATH ship concept foresees "ad referendum" (Latin: for further consideration elsewhere) to have TEU-aligned module specifically for pollution combating; however, future development and procurement of such anti-pollution design is being impeded by various financial and administrational issues. This title is an effort to analyze technical and functional requirements for SWATH-type, Latvian Skrunda-class vessels through the analysis of standard oil recovery methods and special equipment available "from the shelf".*

I. INTRODUCTION

The fulfilment of the governmental obligation is a most important task for the state organization. Capability to control territorial waters and exclusive territorial zone, to be capable to prevent or in case of necessity to localize and collect pollution are duty, obligations and responsibilities, for the all costal state. This problem can be solved by different way and different approaches. This are well covered bay International Maritime Organization Manual [11], Helsinki Convention requirements [9], recommendation from Admiral Danish Fleet HQ [1], researches Figas M.,Fingas, M[7,8], Barbara Ornitz, Michael Champ[4], Holt, Julie Ring-Hansen , Christina Parkhomenko[10], Wadsworth, Tim[16].

The research goal is to define the technical and functional requirements for the Multifunctional special SWATH Skrunda class patrol vessel's oil pollution combating module through the analysis of the oil recovery methods and equipment and determination of the vessel platform technical restrictions and equipment functional requirements. The authors brought an issue related to the fitting Skrunda class patrol vessel with oil recovery equipment which is one of the priority problems in the state obligation. Authors indicates that solution could be performed through the use of the equipment available on the market and manufacturing

II. SWATH PATROL SHIPS OF LATVIAN NAVY

The concept of "Small Waterplane Area Twin Hull" is a specific hull cross-section area minimizing design, where vessel's direct contact with sea surface is limited by couple of metal pillars. Geometrically speaking ship's volume is specifically distributed near the sea surface, where most of sea wave energy is concentrated, thus drastically improving overall stability in high seas without significant tactical speed reduction. The bulk of the displacement that makes vessel floating, stays beneath the waves, where excitation depends on depth, therefore, putting the basic part of a ship's displacement under the waves. It makes SWATH ships as much seagoing/seakeeping/stable vessel as classical mono hull vessel with 5 to 15 times bigger displacement Andrejs Zvaigzne [3], Дубровский, В. А. [17].

In 2007 Latvian Ministry of Defense has started impressive national shipbuilding program, with the intention to replace nine obsolete Coast Guard patrol ships by five innovative SWATH technology units, designed to be multipurpose, multifunctional platforms bearing standard maritime 20 feet container as the physical “shell” for numerous marine applications and tasks: fire power (naval guns), diving operations (decompression chamber), MCM (Mine countermeasure measures) equipment etc. By 2016 all five units have been successfully in-commissioned in Latvian Navy as ready platforms for further developments of multi functionalities. SWATH type ships were was ordered by Latvian government in 2008 and was named Skrunda class. Ships were built in cooperation by Abeking & Rasmussen Shipyard in Germany and Riga Shipyard in Latvia between 2009 and 2013. The Displacement of ship is 125 tons, Length 25.7 m, Beam 13.5 m, Draft 2.7 m, Propulsion 2 x MAN D 2842 diesels of 2170 horse power, ensuring 20 knots of speed. Operational range of the ship is 1,000 miles at 12 knots. Skrunda class is designed to execute several maritime missions, by changing the module between the bows of the two hulls, which is calculated for dimensions of a 20 feet ISO intermodal container with payload of 6 tons.

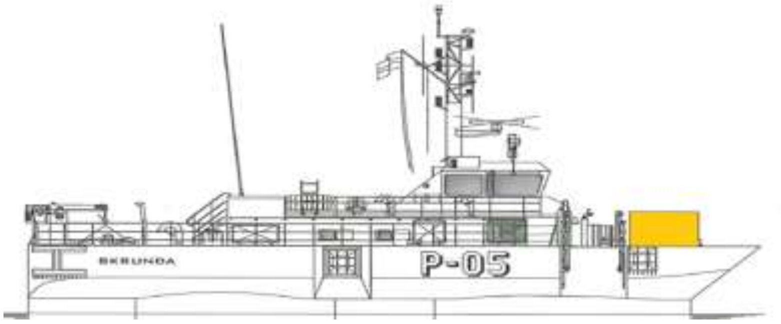


Fig. 1. The profile of Skrunda class ship with yellow colored installed 20 ft. modular container.

Skrunda-class modular equipment applications are based on a common mounting structure for use of different specified containers and equipment, therefore, all we need are brackets to replace standard container joint with the ship's electric circuit and wiring connectors, as well as appropriate additional consoles, if needed.

Fig. 2. In-built brackets for installing single 20 ft. standard container.

Fig. 3. Artist’s impression of a small-caliber naval gun installed on platform of TEU 20’ standard container.

The bridge of ship provides all-round visibility, with the helmsman's/watch officer station to starboard. A central engine control board is also focal point for all technical systems to be supervised. Ship has X-band radar also being technically ready for future installation of electro-optic sensors on the mast head. List of default upper-deck facilities includes crane aft and a small RIB for surf zone operations on depths less than 2 meters. Ship has quite unique hydraulic lift to starboard specifically for divers, boarding and recovery purposes, thus making ship as the highly effective rescue platform in cold waters of Baltic. Fixed fenders help to ensure efficient berthing and boarding maneuvers of the ship with the scarce manpower involved.

Skrunda-class concept introduces significant economic advantages of "a small vessel for small State", when SWATH technology means minimized life cycle expenses due to lower maintenance costs for a smaller ship with smaller propulsion system, optimal fuel costs and, most important, lower manpower expenses because of minimal amount of crew needed for normal operations at sea. A team (not crew) of up to eight individuals can be embarked for one week at sea merely in any weather conditions to work on any maritime task, including missions with partners in international assignments, where comfort is ensured by almost imperceptible vibrations and internal noise levels less than 65dB (noise of working vacuum cleaner). However, we choose the environmental, civilian, and, generally speaking, Coast Guard mission of oil spill containment and recovery as the primary one for creating imaginary module for SWATH unit.

III. OIL POLLUTION RISKS IN THE BALTIC SEA

Shipping intensity in the Baltic Sea is one of the highest in the world. HELCOM AIS summary information shows more than 2 000 different sized vessels in Baltic Sea at any one time. In average 3500-5000 large sized ships are crossing straits and traffic "bottle necks" in region monthly, providing imminent risk of accidents, collisions, disaster of different types, thus drastically increasing potential threats of oil pollution and general environmental disasters[14]. Countries of the Baltic Sea region introduces very serious efforts to calculate all risks related with the maritime traffic as well as to have technical assets and resources ready for efficient pollution combating measures, however, HELCOM sponsored survey "Sub-regional risk of spill of oil and hazardous substances in the Baltic Sea" (BRISK) finds out several serious gaps in regional readiness to combat all kind of potential oil spills, in particular, the central Baltic in the eastern part of the region has insufficient pollution combating equipment and capacity, also very uneven geographical distribution of designated units. For instance, total immediately available capacity of Latvia, Sweden and Estonia to collect spilled oil products from the sea surface is accounted to be 6000 metric tons, but individual national capacity of Latvia to combat spill at sea is not more than 800 metric tons, which is absolutely insufficient amount keeping in mind related risks and other factors. Latvian navy does not have specifically 'ad hoc' designed oil spill combating vessel, deploying middle sized hydrography vessel for this purpose. HELCOM study names two objects at sea as providers of extremely high oil spill and pollution risk, those are Butinge oil terminal, located literally on the national border of the Republic of Latvia, as well as Kravtsovskoye oilfield located about 25 miles west of Latvian Exclusive Economy Zone [10]. Such kind of neighborhood requires Latvian authorities to be very aware of all possible scenarios.

Taking in consideration quite limited dimensions and cargo capacity of SWATH patrol ship there could arise some questions and doubts about feasibility of SWATH-ship deployment as oil spills recovery vessel, especially keeping in mind, that potential scale of oil spill disaster could stretch far beyond of any capacity of any specialized service vessel in Baltic area, as it was in port of Klaipeda in November 1981, when vessel Globe Assimi has released 14000 tons of crude oil.

Fig. 4. Aftermath of vessel "Prestige" disaster on Spanish coast, March 2003

IV. BASIC METHODS OF OIL SPILL CONTAINMENT

Successful oil spill combating operation needs to deal with interconnected issues of the whole asset such as quantities of oil on site, containment, concentration, recovery and further storage. The purpose of any oil products recovery mission at sea is to collect all floating oil as effectively as possible. Unfortunately, statistic data on major oil spills shows that in average just 10% of spilled oil can recovered successfully from the sea surface. Each method of mechanical containment has its own limitations and technical constrain affecting the effectiveness of recovery efforts [4,11].

Traditional marine containment is usually a floating barrier, so called "booms" with freeboard and kind of "skirt" to prevent leaks under the boom. All installation must be done using buoyant material with sufficient longitudinal endurance for towing or pushing. Booms can be mounted in form of fence or curtain. Curtain type booms make better when currents and sea waves are presented on site and likely to affect the whole mission, however, they are much heavier and difficult to operate than fence-type counterparts. Good booms for containment are always compromise between strength, weight and expected performance. "Sweeping arms" or specific hull of a spill combating ship also can be used for containment, but those could effective solely against big floating tar balls and heavy-viscous oil.

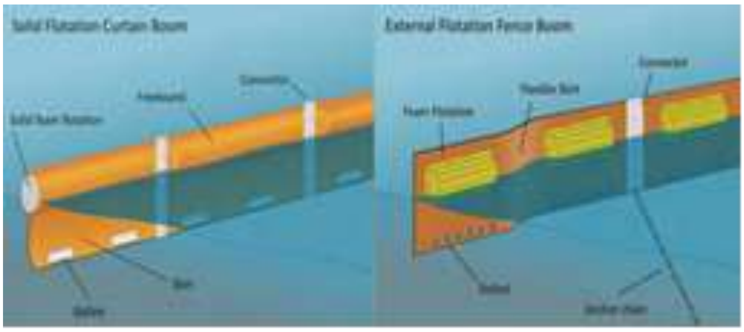


Fig. 5. The oil containment booms.

The recovery and pumping of oil normally is being done by a skimmer. The concept of a skimmer varies considerably in design, depending on the intended deployment, either at open sea, in surf zones or within ports and harbors. Skimmers of open sea normally include elements of buoyancy; they may be self-propelled, equipped with an in-built storage tanks and separation centrifuges. The recovery element may be discs, brushes, drums, or specific and complicated suction elements designed to collect or divert oil from water surface to an inlet of a pumping mechanism for further storage and recycling. The method of oil to be transferred from the water surface may be so called oleophilic systems, which use adhesion of oil to a moving parts, suction assemblies, and weir systems working on gravity, and sub-systems that intake oil by means of mechanical scoops, belts or shrubs.

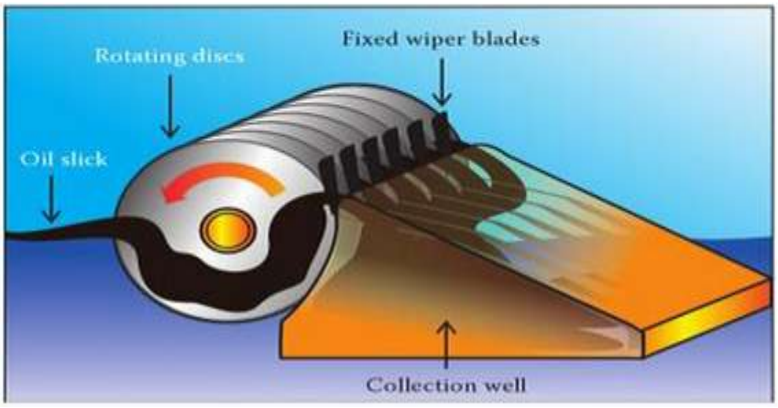


Fig. 6 .The "disc-method" of oil recovery from the surface of water.

Detailed description of all possible solutions for skimmers could be found in publications and manuals produced by the "International Tanker Owners Pollution Federation Limited". Methodology of multi-criteria evaluation, normally used in Project management, as well as Quality management science could be the tool for further evaluation of SWATH ship as future oil spill recovery vessel.

V. MODULAR FUNCTION DEPLOYMENT AS THE TOOL TO DEFINE SWATH OIL SPILL RECOVERY CAPABILITIES

Quality function deployment (QFD) is a Japanese method to transform so called Voice of the Customer into practical features of a product. Yoji Akao, [2] the original developer, described QFD as a "method to transform qualitative user demands into quantitative parameters, to deploy the functions forming quality, and to deploy methods for achieving the design quality into subsystems and component parts, and ultimately to specific elements of the manufacturing process." QFD method implements specific approach to customer desires and expectations, ranges up the weight of those desires, formulates technical characteristics prone to be relevant to cover mentioned desires, then correlates both blocks of data, verifies those initial correlations, and then finalizes goals and basic hierarchy for future system requirements.

The process can be implemented within any system's level: subsystems, components, sub-components of a product, and can allow for assessment of any abstracted level based on the output of particular matrices. The output of assessment normally is a matrix with customer expectation on one level and aligned non-functional requirement on the opposite one. In case of SWATH ship for environmental mission the initial argument for QFD system could be the set of expected operational requirements of the equipment to be installed on board. Operational requirements may be formulated as close to real life as possible by using practical results from Baltic States oil spill recovery exercise BALEX DELTA 2015 held in Polish territorial waters in 9-11 September 2015.

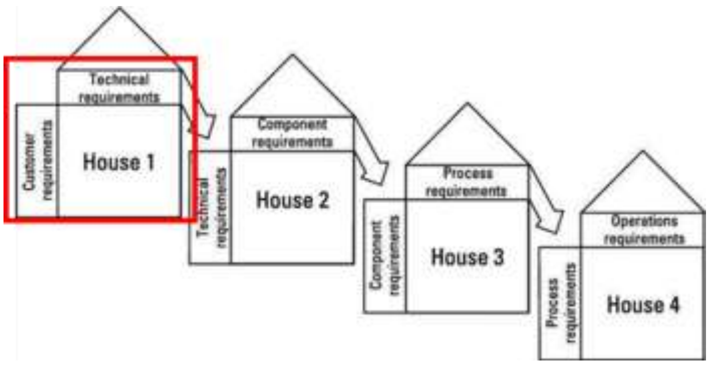


Fig. 7. The QFD cascade of functional requirements.

The fictional scenario for oil spill has been supported by real spill of oil-like substance named EXPANDED PERLITE followed with real activities of international units involved in collecting those spills, thus making exercise as real as possible. Based on real exercise BALEX DELTA 2015 result data analyses, we can modulate similar situation in Latvian area of responsibility and calculate Skrunda class effectiveness in oil pollution combating [12]. In our simulation case we have collision of two vessels in Irbe strait (80 nautical miles from Riga harbor), one of the vessel have a hole and have an oil pollution for 1000t. in 24 hours. Specific software "Sea Track Web" used by Latvian Coast Guard for predicting swath, limits and expansion of leaked oil depending on factual weather patterns and dominating winds and streams help us calculate area of operation, for the oil field movement prediction we use Swedish meteorological and hydrological institute meteorological data forecastle model.

Fig. 8. Performance of the vessels.

The Fig.8 shows the calculated performance result of the participated vessels. Blue is time to the operational area and orange is time needed for pollution collection.

We can sat Kay Performance Indicators (KPI) as

$\Sigma K = Ki+Kt+Kp+Kc+Ku$ (1)

Where ΣK is Kay Performance Indicator (KPI) for the oil pollution recovery system/vessel, what consist of:
Ki- KIP of the oil recovery system installation on board the vessel before departure for the operation area,
Kt –KPI for transiting to the area,
Kp- KPI for the equipment installation in the area,
Kc- KPI for oil pollution collection operation,
Ku- KPI for the utilization of collected pollution.

Analyses of KPI for the modelling situation clearly show advantages of the SWATH project vessel in transiting time needed; spills recovery time is compatible with specially build oil spills recovery vessels.

The thorough analysis of all inputs from practical exercise, fictional scenarios KPI, and existing technical constrains and limitations of the SWATH ship shall be finalized as follows:

- Total weight of oil pollution recovery module must not exceed 6 tons (ship stability),
- Must be controllable depth of skimmers,
- Hydraulic transmission is the optimal for operation of gears,
- Compact weather proof design,
- Minimal time of deployment.
- Shrubs (not discs or drums) are the most optimal type of oil recovery contact-element of skimmers,
- Vessel’s electrical circuits and installations must be integrated into foreseen module’s design.
- Collected oil product shall be stored in inflatable tank, in order to avoid filling of ship’s organic ballast tanks (impact on stability).
- Ship should not be the subject of any refitting and refurbishment in order to install recovery equipment.

After summarizing all above mentioned clauses we can evaluate marketing offer in matters of existing proven and operational equipment

Tab.1 Simplified operational requirements (QFD) for SWATH oil spill equipment as the result of synergy between real exercise BALTIC DELTA 2015 and digital simulation on Sea Track Web

Towed equipment	**Equipment design within 20’TEU dimension**	**Time of deployment**
Inflatable booms must be used attached to recovery skimmers	Ship must proceed with the speed at least 3 knots during all stages of operation (minimal impact)	Equipment must deployed immediately upon arrival on site (no additional procedures)
All system must be conjoined with module 20’TEU	The covered area of 1,3 square miles must be ensured with the speed 2 knots in 24 hours	Equipment must be deployed with the workforce of not more than 2 individuals (crew members)
No changes in ship design (rebuilds), no impact on normal ship manoeuvrability!		Equipment set-up time should not exceed 20 minutes

VI. SET OF OIL RECOVERY EQUIPMENT FOR SKRUNDA-CLASS SHIP

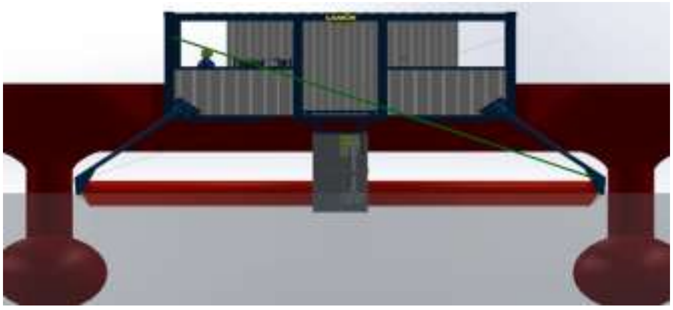
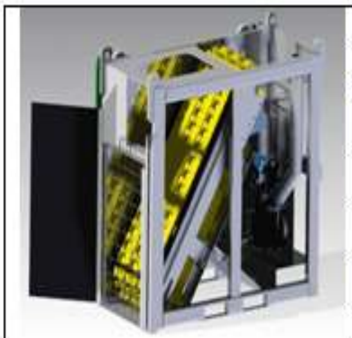


Fig. 8. Concept of oil recovery equipment installed on Skrunda class ship with inflatable (beneath of hull) tank for oil storage.

The final QFD created list of provisional oil spill equipment shall include elements as follows: set of booms, mobile or semi-mobile pump for oil products pumping, along with the organic set of flexible hoses and tubes, compressor, skimmers with vertical adjusting winch, set of electricity supply, inflatable tank for oil products and control console in a container. Market of oil spill recovery equipment is quite widespread in matter of delivered options and solutions. Companies working in environmental protection industry can be easily found in on-line catalogues on the Web, representing different regions, solutions and scales of involvement. However, we would like to select Finnish company Lamor [13] as the supplier of most holistic set of pollution response equipment, not as the matter of advertisement, but the source of reference for immediately available equipment as parts of puzzle to be compounded.

Tab. 2 Side cassette skimmer Lamor

	Lenght	2000 mm
	Width	1000 mm
	Height	1900 mm
	Weight	450 kg
	Working power	160 m³/h
	Max power	203 m³/h
	Pressure ops	100 - 200 bar

Tab. 3 Towing legs and booms Lamor

	Leg's Length	3 m
	Amount of legs	2
	Weight of leg	30 kg
	Booms	
	Length	
	Width	350 mm
	Height	900 mm
	Weight	90 kg

The first element of such a "puzzle" should be Lamor offered Side Cassette Oil Recovery System (LSC) which is an on-board mounted skimming system for small size ships. The design is set of stiff brush oil recovery technology adjusted with an outrigger arm and sweeping boom that deflects oil from a wide area into added side box for further storage and processing. The company's promised oil recovery rate is about 5 % from total water intake with vessel's speeds of up to 4 knots.

Tab 4. Inflatable oil storage tank attached to vessel

	Length	11000 mm
	Width	4600 mm
	Height of free board	1250 mm
	Draft	2000 mm
	Weight	450 kg
	Storage volume	50 m^3
	Towing speed	10 kn
	Towing speed when filled	4,5 kn

Above mentioned elements are readily available from the shelf and company delivers those completely attached with the hoses, tubes and electric infrastructure. The control over whole oil spill recovery operation shall be executed from attached container, filled with all means of necessary tools and means of communications.

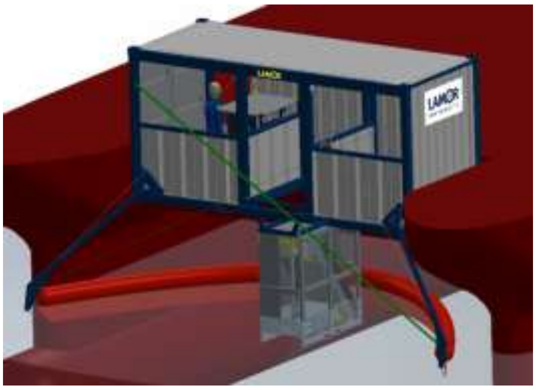


Fig. 9. Concept of Skrunda recovery set ready for engagement

VII. CONCLUSION

After the analysis of current situation with the development of SWATH-type ship concept in Latvian Navy, modern needs of having effective and rapidly deployable oil spill recovery equipment as dedicated resources, as well as the analysis of readily available pollution combating maritime tools "from the shelve" within the specialized market, we can come to conclusions as follow:

- Latvian Navy has extremely flexible SWATH type ships with potential payload of 6 tons aligned dimensionally to 20 feet (TEU) container. The projects of modules for this class of ship are pending.
- Quality Function Deployment (QFD) matrices might be used along with the outcomes and lessons learned from practical exercises at sea as a project management tool for defining SWATH ship as oil product recovery unit with appropriate functions and capabilities. Skrunda class ships are well suited for fast response oil spill missions on regional level.
- Immediately available oil spill recovery equipment "from the shelve" , exemplified by the inventory list from Finnish company Lamor, makes Skrunda class units potentially to be equipped as soon as possible without critical refitting works and modernizations.

  Use of Multi-Criteria Decision Making process for oil pollution recovery module allow find practical "from the shelf" affordable solution, for SWATH Multifunctional special Ships to solve problem of state obligation in oil pollution recovery.

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