The concept of a modular container shipyard as a tool to increase the mobility and efficiency of unmanned boats production

Vladimir A. Surikov

Astrakhan State Technical University,
Astrakhan, Russia, surikov.1996@mail.ru

Abstract. The concept of a modular container shipyard is proposed, designed to increase the mobility and economic efficiency of the production of unmanned boats, which is especially important in the context of the need for the rapid deployment of production facilities for the needs of ensuring the protection of the Russian Federation. An innovative approach to shipbuilding is proposed, based on the use of standard 20- and 40-foot containers, each of which has a strict specialized production or auxiliary function. The main advantages of a modular shipyard are considered, including mobility (the possibility of rapid deployment in various locations), scalability (adaptation of production capacities to changing needs), cost-effectiveness (reduction of capital and operational costs) and rapid deployment (reduction of commissioning time due to the stability of the shipyard). The applicable constraints, such as the shortage of qualified personnel and the difficulties of material and technical supply, are analyzed and ways to overcome them are identified. The basic configuration of the modular shipyard is presented, which includes an area for storage, material preparation, molding and lamination, hull assembly, electrical and mechanical installation, sensor installation, testing and fine-tuning, as well as administrative and management units. Preliminary technical and economic indicators (CAPEX and OPEX) for calculating a shipyard focused on the needs of the Ministry of Defense of the Russian Federation are presented, and the sensitivity of the main performance indicators to changes in cost and economic costs is analyzed, which leads to their leadership in the profitability of the project. The conclusion is formulated about the high investment attractiveness of the modular proposal in comparison with the capital construction of stationary shipyards, as well as about the significant potential for further development and taking into account this concept.

Keywords: unmanned boat, modular production, container shipyard, shipbuilding, mobility, feasibility study, logistics, sensitivity analysis

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Научная статья

Концепция модульной контейнерной верфи как инструмент повышения мобильности и эффективности производства безэкипажных катеров

Владимир Алексеевич Суриков

Астраханский государственный технический университет,
Астрахань, Россия, surikov.1996@mail.ru

Аннотация. Предложена концепция модульной контейнерной верфи, разработанная для повышения мобильности и экономической эффективности производства безэкипажных катеров, что особенно актуально в условиях необходимости оперативного развертывания производственных мощностей для нужд обеспечения защиты Российской Федерации. Предлагается инновационный подход к судостроению, основанный на использовании стандартных 20- и 40-футовых контейнеров, каждый из которых имеет строгую специализированную производственную или вспомогательную функцию. Рассмотрены основные преимущества модульной верфи, включая мобильность (возможность быстрого развертывания в различных локациях), масштабируемость (адаптация производственных мощностей к меняющимся потребностям), экономическую эффективность (снижение капитальных и операционных затрат) и быстрое развертывание (сокращение сроков введения в силу устойчивости верфи). Проанализированы применимые ограничения, такие как нехватка квалифицирован-

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Shipbuilding, ship repair and fleet operation

ных кадров и сложности материально-технического снабжения, и определены пути их преодоления. Представлена базовая конфигурация модульной верфи, включающая зону для складирования, подготовки материалов, формования и ламинирования, сборки корпуса, электро- и механического монтажа, установки датчиков, тестирования и доводки, а также административно-управленческих блоков. Приведены предварительные технико-экономические показатели (CAPEX и OPEX) для расчета верфи, ориентированной на нужды Министерства обороны РФ, и проведен анализ чувствительности основных показателей эффективности к изменениям стоимости и экономическим затратам, что приводит к их лидерству на прибыльности проекта. Сформулирован вывод о высокой инвестиционной привлекательности модульного предложения по сравнению с капитальным строительством стационарных верфей, а также о значительном потенциале для дальнейшего развития и с учетом данной концепции.

Ключевые слова: безэкипажный катер, модульное производство, контейнерная верфь, судостроение, мобильность, технико-экономическое обоснование, логистика, анализ чувствительности

Introduction

In the context of the current geopolitical situation and the increasing significance of maritime spaces, ensuring the security of sea borders and protecting the national interests of the Russian Federation are priority tasks. Unmanned boats (UBs) play an important role in solving these tasks, designed to perform a wide range of operations, including patrolling, reconnaissance, detection and destruction of surface and underwater targets, protection of port waters and important infrastructure facilities. Unmanned boats are a specialized, reusable device with dimensions up to 11 meters in length, 2 meters in width, and 1.9 meters in height [1-4].

The relevance of this research is due to the need to create efficient and flexible production facilities to meet the needs of the Ministry of Defense of the Russian Federation for modern UBs. Traditional approaches to shipbuilding, based on the construction and operation of large stationary shipyards, are characterized by high capital intensity, long construction times, dependence on infrastructure, and limited mobility [5].

Research objective: to develop and justify a concept for a modular container shipyard that ensures high operational efficiency and economic efficiency in the production of UBs for the needs of the defense industry.

Review of existing approaches and justification of the concept

An analysis of existing methods for organizing shipbuilding production shows that traditional shipyards do not always meet the requirements for deployment speed and mobility [6], especially in a rapidly changing geo-political environment. Alternative approaches exist, such as block shipbuilding, but they also require significant capital investment and infrastructure.

The concept of a modular container shipyard represents an innovative approach that overcomes the limitations of traditional methods. The basis of the shipyard is standardized 20- and 40-foot shipping containers, adapted to perform individual technological operations. This approach provides:

– mobility: the shipyard can be quickly deployed anywhere there is access to a body of water and the ability to connect to electricity and other utilities;

– scalability: production capacity is easily adapted to changing needs by adding or removing containers;

– economic efficiency: reduced capital costs through the use of ready-made modules and the optimization of technological processes;

– rapid deployment: the time to commissioning is significantly reduced compared to the construction of a traditional shipyard.

Methodology: structure and technological flow of the modular shipyard

The implementation of the modular container shipyard concept involves the formation of a production complex consisting of interconnected specialized modules.

Structural organization

The basic configuration of the shipyard (estimated production capacity of 10-15 UBs per year) includes the following key functional areas (Table 1).

Table 1

Functional structure of the modular container shipyard

Zone (module)	Typical container	Key function	Equipment (examples)
Raw material warehouse	2×40-ft HC	Storage and accounting of composite materials, metal, components	Shelving, accounting system (QR codes/RFID), forklift, scales, electric stacker
Material preparation	1×40-ft HC	Cutting, trimming of composites and metal	Automated cutting machine, plasma cutting machine, milling machine

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Ending of table 1

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Material preparation	1×40-ft HC	Cutting, trimming of composites and metal	Automated cutting machine, plasma cutting machine, milling machine
Molding / laminating	1×40-ft HC	Vacuum forming, laminating, temperature control	Vacuum bags, thermochambers, resin supply systems
Hull assembly	2×40-ft HC	Assembly of hull sections, connecting elements, grinding, sealing	Slipways, lifting mechanisms, welding equipment
Electrical installation	1×20-ft HC	Laying cables, installing electronics, checking electrical circuits	Electrician workstations, measuring instruments, testing equipment
Mechanical installation	1×20-ft HC	Installing engines, propulsion systems, steering, mechanical units	Tools, equipment for installing engines, shafts of various compositions, propellers
Sensor installation	1×20-ft HC	Mounting navigation equipment, sensors, cameras, control systems	Workstations, tools, calibration equipment
Testing and finishing	1×40-ft HC	Testing, calibration, painting, final assembly	Test benches, checking the alignment of the shaft line, paint booth, external environment simulators
Administration, management and auxiliary	2×20-ft HC + +1×40-ft HC	Office, quality control, workshop, power unit, sanitary and domestic module, control and design center	Office furniture, measuring equipment, diesel generator, compressors

Each container is a specialized module, optimized for performing specific technological operations [7]. Automation and robotization of technological processes allow for increased productivity, reduced labor costs, and ensuring high product quality.

Technological flow

The technological flow of UB production at the modular shipyard is organized according to the principle of a linear-parallel structure (Fig. 1). Materials enter the raw material warehouse, where they undergo incoming inspection. Then the raw materials go to the preparation area, where cutting and processing are carried out. Workpieces are transferred to the molding area, where hull elements are formed. Finished elements are assembled into hull sections, which are then joined in the assembly area. At the next stages, equipment installation, electrical installation, mechanical installation, and sensor installation take place. At the final stage, tests, finishing, and painting are carried out.
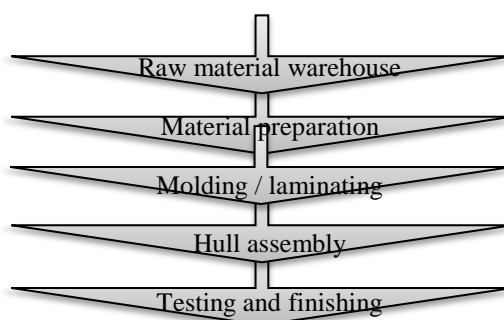

Fig. 1. Diagram of the UBs production process at the modular shipyard

A key element in increasing efficiency is the organization of continuous quality control at each stage of production [8]. This allows for the timely identification and elimination of defects, as well as ensuring that the products meet the requirements of the Ministry of Defense of the Russian Federation.

Deployment times

An estimate of the time for deploying a modular shipyard (taking into account the parallelization of work) shows that realistic commissioning times are 12-20 weeks. This includes:

– 14 days: transportation of containers to the site;

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Shipbuilding, ship repair and fleet operation

– 4 days: installation of containers and site preparation;

– 2 days: connection to the power supply;

– 1 day: connection of water supply and sewage;

– 30 days: configuration of equipment and software (estimated value, may vary);

– 6 days: testing and calibration;

– 5 days: additional time for unforeseen delays.

Technical and economic justification

To assess the economic efficiency of the proposed concept, an analysis of capital (CAPEX) and operating

(OPEX) costs was conducted.

CAPEX assessment

The CAPEX assessment is based on an analysis of the cost of equipment and site preparation expenses [9]. The basic configuration of the shipyard (14 containers) will require an investment of 42 790 000-114 920 000 rubles (Table 2). Within the framework of the technical and economic justification, the main components influencing CAPEX were analyzed (Fig. 2).

Table 2

Budget for the deployment of a container shipyard, rub.

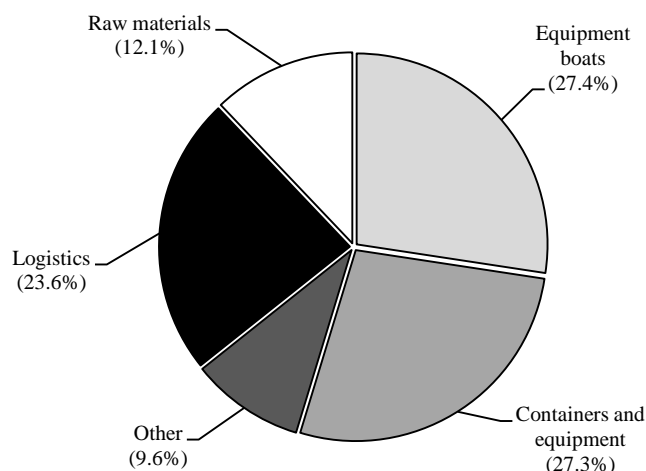| Item	Minimum estimate	Maximum estimate
Containers and equipment	11 050 000	31 400 000
Purchase of boat equipment (first year)	21 000 000	31 500 000
Purchase of raw materials (first year)	5 990 000	13 920 000
Launch logistics (Auto/Rail/SMP)	600 000	27 100 000
Design, documentation, commissioning	650 000	1 500 000
Site infrastructure (foundation, utility connections)	2 000 000	5 000 000
IT Infrastructure (servers, software, licenses)	1 000 000	3 000 000
Security systems (fire, security, video surveillance)	500 000	1 500 000
Total	*42 790 000*	*114 920 000*

Fig. 2. Structure of capital expenditures (CAPEX)

OPEX assessment

The assessment of operating costs (OPEX) includes costs for raw materials, materials, wages, electricity, equipment maintenance, and other expenses. A preliminary estimate of annual operating costs is 79 490 000-138 120 000 rubles (Table 3).

Table 3

Analysis of operating expenses (OPEX) considering projected inflation, rub.

Year	OPEX min	OPEX max	CAPEX min	CAPEX max	Total min	Total max
1	79 490 000.0	138 120 000.0	42 790 000.0	114 920 000.0	122 280 000.0	253 040 000.0
2	83 464 500.0	145 026 000.0	0.0	0.0	83 464 500.0	145 026 000.0
3	87 637 725.0	152 277 300.0	0.0	0.0	87 637 725.0	152 277 300.0
4	92 019 611.0	159 891 165.0	0.0	0.0	92 019 611.0	159 891 165.0
5	96 620 592.0	167 885 723.0	0.0	0.0	96 620 592.0	167 885 723.0
Total	*439 232 428.0*	*763 200 188.0*	*42 790 000.0*	*114 920 000.0*	*482 022 428.0*	*878 120 188.0*

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Sensitivity analysis

Sensitivity analysis revealed that the most sensitive parameters to changes in profitability are the cost of raw materials (±20%), logistics costs (which significantly increase annual operating expenses), and productivity (the volume of boat output) (Fig. 3). A financial planning model was constructed to reflect changes in key indicators with variations in crucial variables.
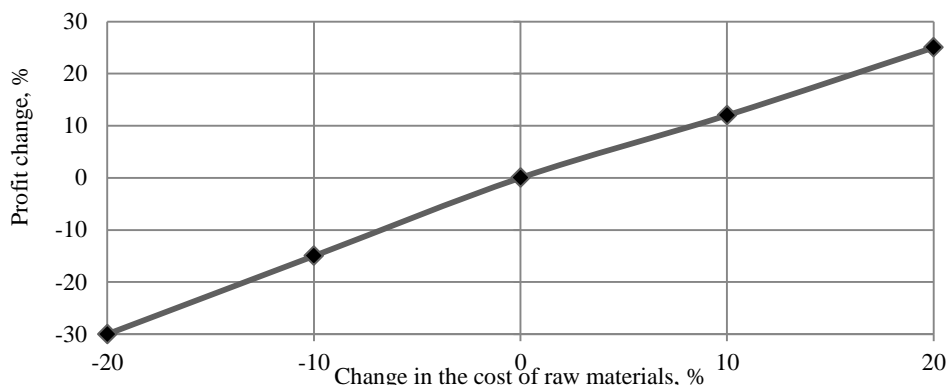

Fig. 3. Project sensitivity analysis to raw material costs

Logistics and risk management

Logistics and risk management logistics is a critical element for the successful implementation of the project [10]. A detailed logistics strategy has been developed to ensure uninterrupted supply of raw materials, materials, and equipment, including:

1. Selection of optimal suppliers: priority is given to Russian suppliers, which reduces currency and sanctions risks (Table 4).

2. Long-term contract strategy: fixing prices and delivery times, especially for critical components.

3. Development of a warehouse network: organizing storage warehouses near ports and major logistics centers.

4. Reserving strategy: storing reserves of materials and components in case of unforeseen delays.

5. Route optimization: utilizing multimodal transportation, including the Northern Sea Route where logistically appropriate.

Table 4

Approximate list of suppliers of raw materials and equipment

Raw material	Supplier	Delivery times
Fiberglass and carbon fiber	JSC Kamenskvolokno (Kamensk-Shakhtinsky)	2-6 weeks
Resins (epoxy, polyester)	JSC Pigment (Tambov), LLC Novochim (Perm)	2-5 weeks
Fillers (sand, aluminum powders)	Silicon CJSC (Bratsk)	4-8 weeks
Engines	PJSC Zvezda (Saint Petersburg), JSC Kolomna Plant (Kolomna)	6-12 months
Control systems	Concern Avtomatika JSC, Research Institute Vector JSC (Saint Petersburg)	4-12 months
Electrical and lighting, navigation equipment, control systems	Various suppliers	3-12 months

To manage risks, a system has been developed that includes:

– cargo and property insurance;

– reserving critical components;

– thorough supplier selection considering their reliability and reputation;

– systematic monitoring of the production process and logistics.

Business model

The optimal business model is a combined approach that includes:

1. State contract: production and supply of UBs within the framework of state defense orders, ensuring stable income and financing.

2. Turnkey supply and service contracts: providing a full range of services, including development, production, personnel training, warranty, and after-sales service of UBs. This approach ensures flexibility, risk diversification, and business sustainability. The revenue structure is shown in Fig. 4.

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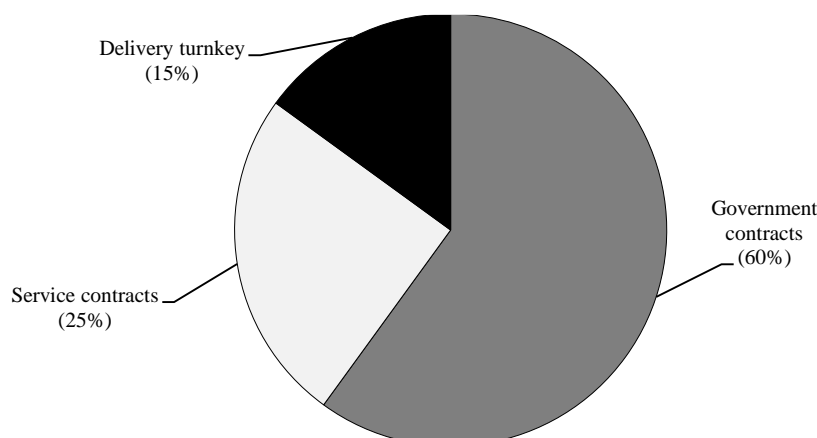
Fig. 4. Revenue structure

The proposed business model is based on a hybrid approach, encompassing the fulfillment of state defense orders to ensure stable income, and the provision of comprehensive "turnkey" solutions, including development, production, personnel training, and subsequent servicing. This hybrid strategy ensures business resilience, risk diversification, and adaptability to the changing needs of customers in the defense sector.

Conclusion

The presented concept of a modular container shipyard for serial production of UBs demonstrates high potential efficiency and competitiveness. It provides:

– rapid deployment: the shipyard is ready for operation within 2.5-4 months;

– high mobility: relocation to new sites in a short period;

– economic efficiency: reduction of capital costs and optimization of operating expenses;

– scalability: the ability to increase production capacity in accordance with customer needs.

The implementation of this project will create a modern production base for the output of UBs that meets the requirements of the Ministry of Defense of the Russian Federation and will make a significant contribution to strengthening the country's defense capabilities. Further research requires detailing engineering solutions, conducting additional economic calculations, and developing a detailed project management plan.

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Information about the author / Информация об авторе

Vladimir A. Surikov – Postgraduate Student of the Department of Shipbuilding and Power Complexes of Marine Technology; Astrakhan State Technical University; surikov.1996@mail.ru

Владимир Алексеевич Суриков – аспирант кафедры судостроения и энергетических комплексов морской техники; Астраханский государственный технический университет; surikov.1996@mail.ru

Суриков В. А. Концепция модульной контейнерной верфи как инструмент повышения мобильности и эффективности производства безэкипажных катеров