UDC 629.5
DOI 10.52171/herald263

The System Analysis and Mathematical Model of the Subsea Construction Vessels

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Abstract

Subsea operations cover a wide range of works carried out on the sea shelf using both divers and special subsea equipment. For the high-quality achievement of objectives, vessels capable of ensuring the functioning of the subsea equipment are required. These vessels include subsea construction vessels, diving vessels, Remote Operation Vehicle (ROV) & Autonomous Underwater Vehicle (AUV) support vessels, and manned submersible (MS) support vessels. For the development of a design technique for subsea construction vessels, it is necessary to systematize and create a model of the functionality of the subsea operations vessels. In the article, block diagrams of the use of subsea construction vessels, operating depths of diving vessels, and installation of ROV/AUV/MS apparatuses are provided. Based on the listed block diagrams, a system model of the subsea construction vessels has been developed.

Keywords: subsea operation, subsea construction vessel, supply vessel, diving vessel, technology equipment, special vessel, apparatus.

Submitted *30 July 2024*
Published *23 June 2025*

For citation:
R.J. Bashirov, O.M. Abdullayev, R.O. Abdullayev
[The System Analysis and Mathematical Model of the Subsea Construction Vessels]
Herald of the Azerbaijan Engineering Academy, 2025, vol. 17 (2), pp. 73-82

Sualtı texniki işlərin təminat gəmilərinin sistemli analizi və riyazi modeli

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Xülasə

Sualtı texniki işlər - dalğıclar, həm də xüsusi sualtı avadanlıqlardan istifadə etməklə dəniz şelfində aparılan işlərin geniş spektrini əhatə edir. Verilən tapşırıqları səmərəli şəkildə yerinə yetirmək üçün sualtı avadanlıqların işini dəstəkləyə bilən xüsusi gəmilər tələb olunur. Sualtı texniki işləri yerinə yetirən gəmilərə sualtı texniki işləri təchizat gəmiləri, dalğıc gəmiləri, uzaqdan idarə olunan sualtı nəqliyyat vasitələrini daşıyan gəmilər / avtonom heyətsiz sualtı nəqliyyat vasitələri (UİSNV/ AHNV) və heyətli sualtı nəqliyyat vasitələrini (HSNV) daşıyan gəmilər daxildir. Sualtı texniki işlər üçün gəmilərin layihələndirilməsi metodologiyasını hazırlamaq üçün sualtı texniki işləri yerinə yetirən gəmilərin funksional imkanlarının modellərini sistemləşdirmək və təkmilləşdirmək lazımdır. Bu işdə sualtı texniki işləri təminat gəmilərdə aparat və komplekslərin istifadəsi, dalğıc komplekslərinin işləmə dərinlikləri, daşıyıcı gəmilərdə texniki vasitələrdən istifadənin struktur diaqramları tərtib edilmişdir. Sadalanan blok diaqramlardan istifadə edərək sualtı texniki işləri təminat gəmilərinin sistem modeli hazırlanmışdır.

Açar sözlər: sualtı texniki işlər, sualtı texniki işləri təminat gəmiləri, dalğıc gəmiləri, texnoloji avadanlıqlar, ixtisaslaşmış gəmilər, aparat vasitələri.

Системный анализ и математическая модель судов обеспечения подводно-технических работ

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Аннотация

Подводно-технические работы охватывают широкий спектр работ, проводимых на морском шельфе с использованием как водолазов, так и специальной подводной техники. Для качественного выполнения поставленных задач требуются суда, способные обеспечить работу подводной техники. К судам, выполняющим подводно-технические работы, относятся суда обеспечения подводно-технических работ, водолазные суда, суда-носители телеуправляемых подводных аппаратов / автономных необитаемых подводных аппаратов (ТНПА / АНПА) и суда-носители обитаемых подводных аппаратов (ОПА). Для разработки методики проектирования судов обеспечения подводно-технических работ необходимо систематизировать и сформировать модели функциональных возможностей судов, выполняющих подводно-технические работы. В настоящей работе были сформированы структурные схемы применения аппаратных средств и комплексов на судах обеспечения подводно-технических работ, схемы рабочих глубин водолазных комплексов, а также схемы применения аппаратных средств на судах-носителях ТНПА / АНПА / ОПА. Используя перечисленные структурные схемы, разработана системная модель судов обеспечения подводно-технических работ.

Ключевые слова: подводно-технические работы, суда обеспечения подводно-технических работ, водолазные суда, технологическое оборудование, специализированные суда, аппаратные средства.

Herald of the Azerbaijan Engineering Academy
2025, vol. 17 (2), pp. 73-82
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Introduction

The design process of the Subsea Construction Vessel (SSCV) is difficult and multifaceted. Unlike specialized subsea vessels, the SSCV serves as a working platform that, when installing mobile diving complexes, ROVs/AUVs/MS, and technology equipment (TE), can perform the functions of specialized vessels. This capability is important in restricted environments such as the Caspian Sea.

This article presents the systematization and development of criterion functions for further research into the design of the main dimensions of the SSCV using a database method related to vessel purposes, considering the structural and technological conditions of mobile diving complexes, devices (ROVs/AUVs/MS), and technology equipment (TE).

Research objective

To systematize the functionality of devices, diving complexes, and technology equipment, and to develop criterion functions for further research into the design of the main dimensions of the SSCV, taking into account the apparatuses, diving complexes, and technology equipment used.

Problem definition

Vessels for subsea operations are subdivided into types, as shown in the diagram in Fig. 1 [1-5], which reflects the different types of vessels for subsea operations. This article aims to provide a systematic analysis of the functionality of devices, diving complexes, and technology equipment (TE), to create a system model and criterion functions for further research into the design of the main dimensions of the SSCV using a database method related to vessel purposes.

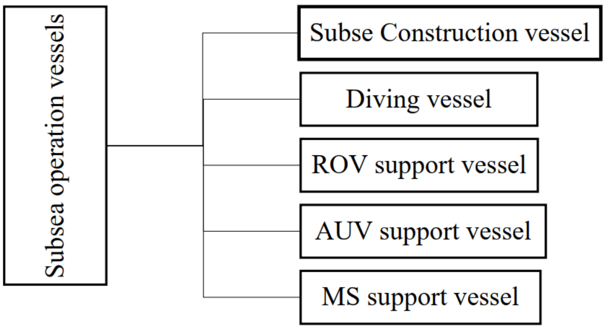

Figure 1 – Diagram of the Classification of Subsea Operation Vessels

Works on system analysis in technical sciences [6] and, in particular, on Subsea Construction Vessels, are discussed in sources [7-12]. Considering the designed vessel as a system, A.I. Gaykovich [10, 11] proposed an information model of the vessel, which can be represented by the four following sets, as reflected in formula (1):

$$A = A\ (W, M, R, P), \qquad (1)$$

Here W - is a set whose elements, along with their associations, provide information on the factors of the external environment affecting the designed system; M - is a set of elements and their associations, providing information on the elements and subsystems of the designed system; R - is a set whose elements provide information on the relationships between the components of the designed system, as well as on the interactions between the system and its components with the external environment; P - is a set whose elements contain information on the qualities of a system determined by factors of the external environment, the system's components, and the relationships between system components, as well as between the system and the external environment.

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The system analysis and mathematical model of Subsea Construction Vessels regarding the use of devices and diving complexes. In carrying out the system analysis of Subsea Construction Vessels, the primary goal is to describe a set whose elements provide information on the relationships between the components of the designed system, as well as the interactions between the system and its components with the external environment. This set is involved in function (1).

In the block diagram shown in Fig. 2, the apparatuses and diving complexes used in Subsea Construction Vessels are depicted. This diagram provides information on the relationships between the external environment and the components of the designed system.

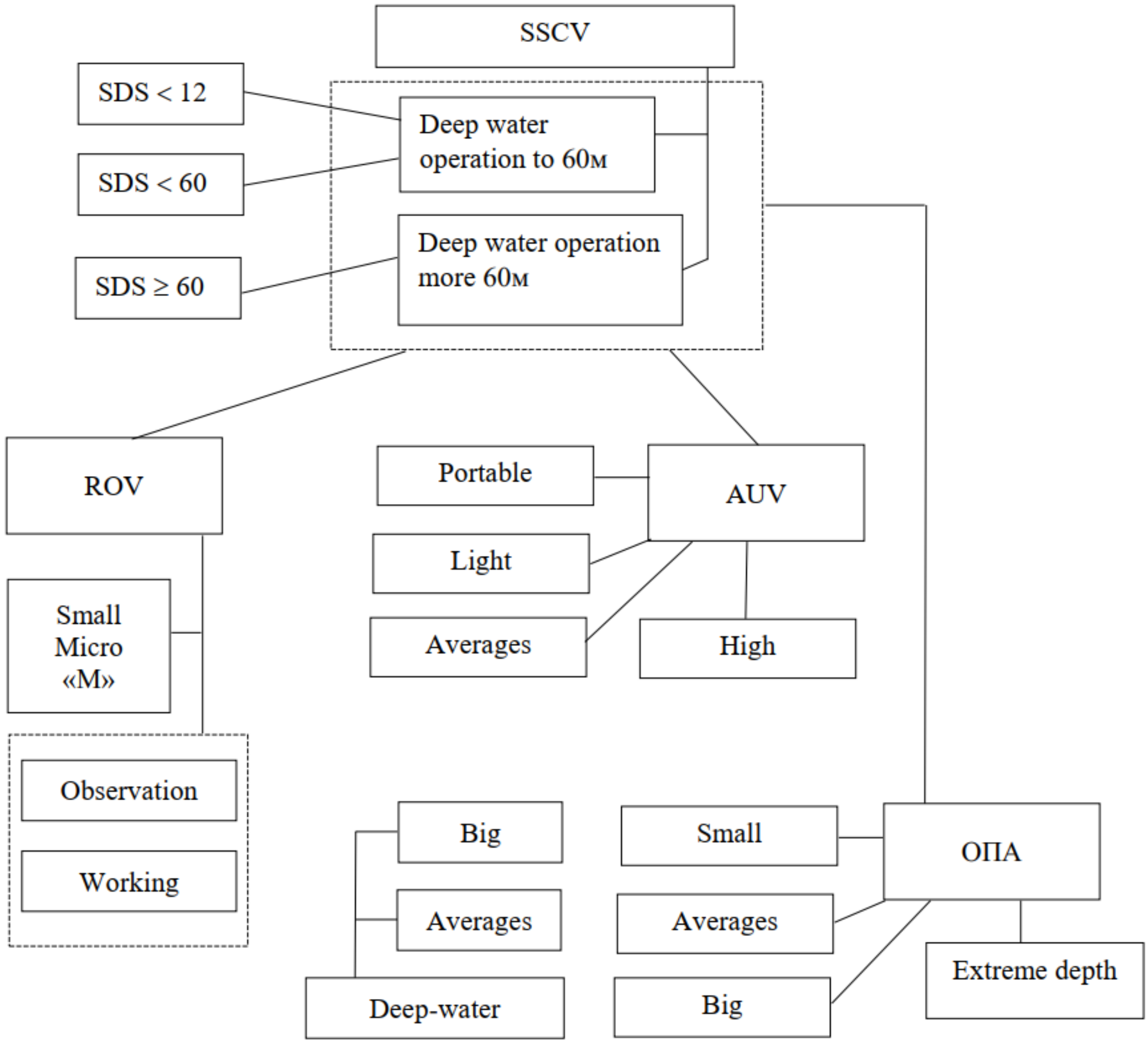

Figure 2 – Block Diagram of the Use of Apparatuses and Diving Complexes on Subsea Construction Vessels

The mathematical model of the information system for SSCV "A," based on the diagram shown in Fig. 2, is reflected in criterion function (3), taking into account the constant factors given in equation (2):

$$W, M, P = CONST, \quad (2)$$

$$A = W, M, P\, f\,(R_{D.C.}, R_{ROV.}, R_{AUV.}, R_{MS.}), \quad (3)$$

here $R_{D.C.}$ – set element reflecting factors of a diving complex; $R_{ROV.}$ – set element reflecting factors of a ROV; $R_{AUV.}$ – set element reflecting factors of a AUV; $R_{MS.}$ – set element reflecting factors of a MS.

System analysis and criterion function for diving complex installation on SSCV. The installation of mobile diving complexes on SSCVs is generally classified by immersion depth. As shown in the block diagram (Fig. 3), diving complexes are divided into:

−SDS<12 – diving complexes for operation at a depth to 12m;

– SDS<60 – diving complexes for operation at a depth to 60m;

– SDS≥60 – diving complexes for operation at a depth more 60m.

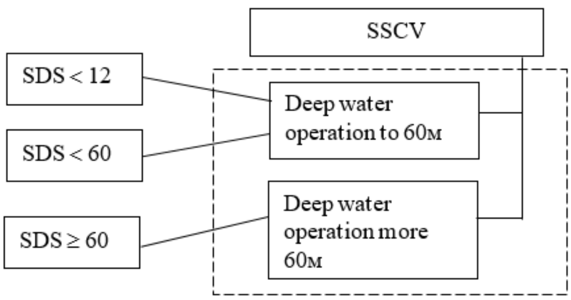

Figure 3 – Block Diagram of Operating Depths for Mobile Diving Complexes

Each type of diving complex has specific technical features and influences the design of the vessel. Depending on the type of mobile diving complex used on the SSCV, design requirements for the vessel are established at the early design stages.

The element of the diving complex set, as depicted in the diagram (Fig. 3), is described by criterion function (4):

$$R_{D.C.} = A\, f\,(H_{D.}, k_{d}), \quad (4)$$

here A – information models the vessel; $H_{D.}$ – depth of immersion of a diving complex; K_d – factor of design requirements of a diving complex.

System Analysis and Criterion Function for ROV/AUV Installation on SSCV. When performing operations on the seabed using SSCVs, ROVs are generally used. However, with the advancement of AUV technology, the likelihood of using AUVs in the future is increasing. Therefore, it is recommended to consider the use of AUVs when developing prospective SSCVs. The types and categories of apparatuses used are depicted in the block diagram (see Fig. 4). Each type and category of apparatus affects the design features of the SSCV. The elements of the ROV/AUV sets, as shown in the diagram (see Fig. 4), are described by criterion function (5):

$$R_{ROV.}, R_{AUV.} = A\, f\,(S_{ROV.}, S_{AUV.}, k_{A.C}), \quad (5)$$

here: S_{ROV} – factors of type the ROV; S_{AUV} – factors of type the AUV; k_{AC} – factor of design requirements of apparatuses to SSCV.

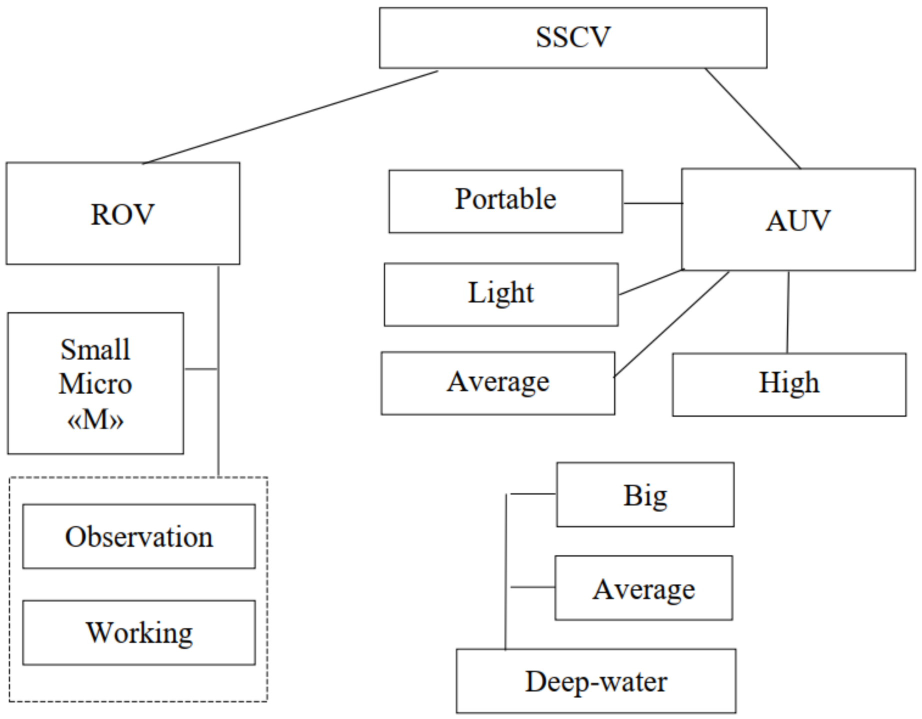

Figure 4 – Block Diagram of the Use of ROV/AUV Apparatuses on SSCV

System Analysis and Criterion Function for MS Installation on SSCV. The use of MS on SSCVs is rare. Typically, MS support is provided by specialized vessels. However, this does not exclude the possibility of using SSCVs as MS support, especially in constrained environments such as the Caspian Sea. The complexity of MS imposes specific design requirements on the supporting vessel.

A major factor affecting the design features of both the device and the support vessel for MS is immersion depth. This is illustrated in the diagram (see Fig. 5) and described by criterion function (6):

$$R_{MS.} = A\, f\,(H_{MS.}, k_{MS}), \qquad (6)$$

here: H_{MS} – immersion depth MS; k_{MS} – factor of design requirements MS.

System Model for Determining the Main Dimensions of SSCV. The system model, as depicted in the block diagram (Fig. 6), describes the model for determining the main dimensions of the SSCV.

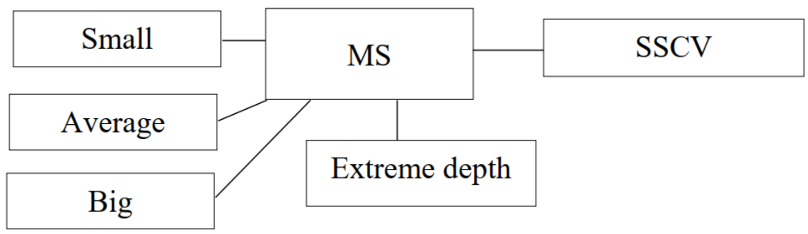

Figure 5 – Block Diagram of the Use of Manned Submersibles on SSCV

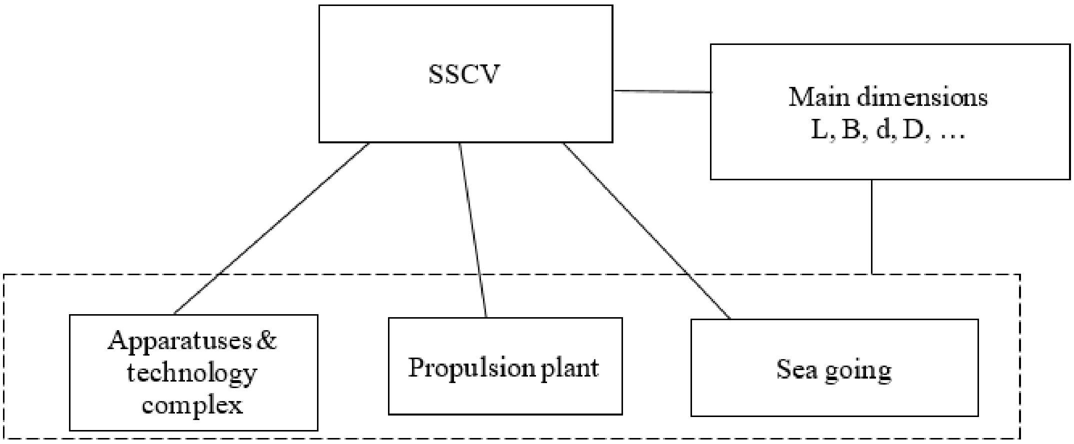

Figure 6 – System Model for Determining the Main Dimensions of SSCV

– Element apparatuses and technology complexes (ATC) are represented by the structural models shown in Figs. 2–5 and are described by criterion functions (3–6) and the criterion functions for technology equipment (7–13) discussed above.

– Element Sea Going (SG) refers to the vessel's ability to operate, stability, and load capacity, considering the installed mobile equipment.

– Element Propulsion Plant (PP) refers to the power, quantity, and configuration of the main and auxiliary engines required to ensure the operation of the SSCV.

Criterion Function for Cargo Crane Facilities Installed on SSCV. The Cargo Crane Facilities (CCF) are directly related to the main dimensions of the vessel through the SSCV system model (see Fig. 6). The criterion function for the cargo crane facilities, which influences the main dimensions of the vessel, is described by function (7):

$$R_{C.L.} = S_{C.L.}\, f\,(H_{C.C.}, L_C, H_{h.}), \qquad (7)$$

here: $R_{C.L.}$ – set element reflecting factors of cargo crane facilities; $S_{C.L.}$ – set element SSCV reflecting the main dimension connected with CCF; $H_{C.C.}$ – cargo capacity; L_C – crane boom; H_h – depth of immersion of a hook.

Criterion Function for the Main Dimensions of SSCV Considering the Factors of a Mobile Diving Complex. The functional and structural capabilities of a mobile diving complex impose design requirements on the SSCV. For the safe execution of diving operations, the optimal overall dimensions of the designing vessel, which are related to the diving complex, are essential. The criterion function for the main dimensions of the SSCV, considering the factors of the diving complex, is described by function (8):

$$S_{B.K.} = R_{B.K.}\, f\,(k_d), \qquad (8)$$

Here the factor of design requirements of the diving "k_d" complex is meant as the listed below factors: lifting gear; cargo space; propulsion plant; diving complex stock; workshops; diving post.

Criterion Function for the Main Dimensions of SSCV Considering the Factors of Apparatuses (ROV/AUV). The functional and design features of apparatuses impose specific design requirements on the SSCV. The criterion function for the main dimensions of the SSCV, considering the factors of the apparatuses, is described by function (9):

$$S_{A.} = R_{ROV.,}\ R_{AUV.}\ f\,(k_A), \qquad (9)$$

Here the factor of design requirements of “k_A” apparatuses is meant as the listed below factors: lifting gear; cargo space; hangar for apparatus storage; stocks; workshops; charging post; control post.

Criterion Function for the Main Dimensions of SSCV Considering the Factors of MS. The functional and design features of MS impose specific design requirements on the SSCV. The criterion function for the main dimensions of the SSCV, considering the factors of MS, is described by function (10):

$$S_{MS.} = R_{MS.}\ f\,(k_{MS}), \qquad (10)$$

Here MS, “k_{MS}” are meant by a factor of design requirements the listed below factors: lifting gear; cargo space; hangar for MS storage; stock; workshops; MS charging post; control post.

Criterion Function for the Main Dimensions of SSCV Considering the Factors of Drilling Equipment. Mobile drilling equipment is directly related to the main dimensions of the vessel through the SSCV system model (see Fig. 6). The criterion function for the mobile drilling equipment, which influences the main dimensions of the vessel, is described by function (11):

$$R_{D.} = S_{D.}\ f\,(k_D), \qquad (11)$$

Here the factor of design requirements of the diving “k_D” complex is meant as the required area of the cargo space and the area of the moon pool.

Criterion Function for the Main Dimensions of SSCV Considering the Factors of Pipe Laying Equipment. Unlike specialized pipe-laying vessels and watercraft, SSCVs can utilize both stationary and mobile pipe-laying equipment. The criterion function for the pipe-laying equipment, which influences the main dimensions of the SSCV, is described by function (12):

$$R_{P.} = S_{P.}\ f\,(k_P), \qquad (12)$$

Here the factor of design requirements of the pipelaying equipment " k_P" is meant as diameter of the laying pipes and pipe laying depth.

Criterion Function for the Main Dimensions of SSCV Considering the Factors of Cable Laying Equipment. Unlike specialized cable-laying vessels and watercraft, SSCVs can use both stationary and mobile cable-laying equipment. The criterion function for the cable-laying equipment, which influences the main dimensions of the SSCV, is described by function (13):

$$R_{C.} = S_{C.}\ f\,(k_C), \qquad (13)$$

Here the factor of design requirements of the cable laying equipment "k_C" is meant as sections of the cable diameter and cable laying depth.

Considering the factors which are listed above system model of formation of the main dimension of SSCV "A_{SSCV}" offered on the diagram "see figure 6" taking into account structure of functional dependences of SSCV "see figure 7", it is described by criterion function (14), taking into account constant factors (2).

$$A_{SSCV} = W, M, P\, f\,(R_{D.C.}, R_{ROV.}, R_{AUV.}, R_{MS.}\; R_{D.}, R_{P.}, R_{C.}), \quad (14)$$

here: $R_{D.}$ – set element reflecting factors of drilling equipment; $R_{P.}$ – set element reflecting factors pipe laying equipment; $R_{C.}$ – set element reflecting factors cable laying equipment.

In the block diagram of the system model for determining the main dimensions of the SSCV (Fig. 7), the interrelations among the elements that form the main dimensions of the SSCV are depicted. Explanations of the elements in the system are provided below:

– System the SSCV - The block diagram of use of apparatuses and diving complexes on SSCV (Fig. 2);

– Diving complex - Block diagram of operating depths of the mobile diving complexes (Fig. 3);

– ROV/AUV - The block diagram of use of ROV / AUV apparatuses on SSCV (Fig. 4);

– MS - The block diagram of use of manned submersibles apparatus on SSCV (Fig. 5);

– Main dimension model (cargo crane) – Criterion function of the cargo crane facilities installed on SSCV (form. 7);

–Main dimension model (diving complex) – Criterion function of the main dimension of SOPTR taking into account factors of a mobile diving complex, (form. 8);

– Main dimension model (ROV / AUV) – Criterion function of the main dimension of SSCV taking into account factors of apparatuses (ROV/AUV), (form. 9);

– Main dimension model (drilling equipment) – Criterion function of the main dimension of SSCV taking into account factors of drilling equipment (form. 11);

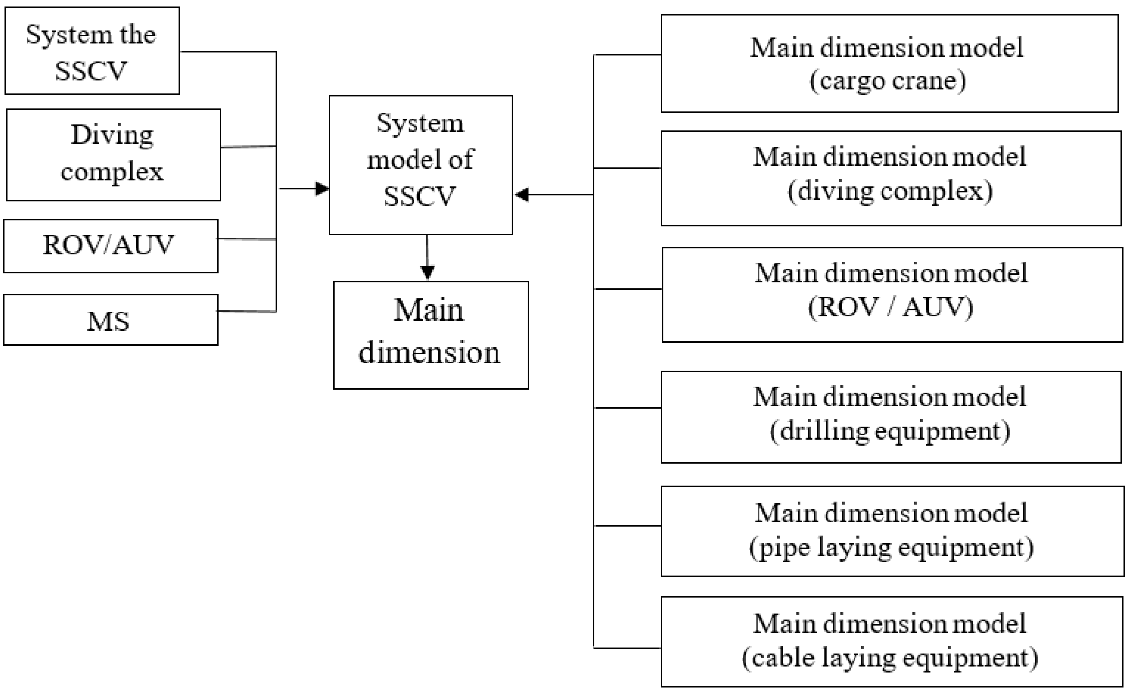

Figure 7 – Structure of functional dependences of SSCV

–Main dimension model (pipe laying equipment) – Criterion function of the main dimension of SSCV taking into account factors of the pipe laying equipment (form.12);

– Main dimension model (cable laying equipment) – Criterion function of the main dimension of SSCV taking into account factors of the cable laying equipment, (form.13);

– System model of SSCV - System model of formation of the main dimension of SSCV.

Conclusion

The installation of mobile diving complexes, apparatuses, and technology equipment on SSCVs is systematized.

The system model and criterion function are developed for further research into the determination of the main dimensions of SSCVs, taking into account the installation of mobile diving complexes, apparatuses, and technology equipment.

Conflict of Interests

The authors declare there is no conflict of interests related to the publication of this article.

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