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MECHANISMS OF MANAGEMENT OF SHIPBUILDING CLUSTER SYSTEMS

Summary

An effective tool for ensuring the competitiveness of shipbuilding enterprises is the application of a cluster approach. The shipbuilding cluster systems are functionally distributed logistics networks that evolve both nationally and internationally. The essence and features of the shipbuilding cluster systems in the work are considered. The mechanisms of the organization of shipbuilding clusters are suggested, as well as the indicators for evaluating the efficiency of their operation. The schemes of the interaction of enterprises participating in the shipbuilding cluster are developed. In this case, models and means of logistic management are used. For the logistics centre, the functions of logistics support and the tasks of creating and maintaining a common information space of the cluster system are defined. The analysis of the system of planning and accounting units in shipbuilding is carried out; the scheme of decomposition for the organizational structure of the cluster is substantiated. It was proposed to use the corridor-scale network diagrams when planning work in a cluster. The scheme of the interaction of the system of budgets and business processes at different levels of decomposition is substantiated.

Introduction

In modern conditions of growing competition in the international shipbuilding markets, an attractive strategy for Ukrainian shipbuilding enterprises is the creation of *shipbuilding cluster systems*. This is one of the fastest and most accessible ways of implementing a global strategy and represents such an organizational form of enterprise integration that allows for joint activities while maintaining the legal and economic independence by the participants. Clusters are long-term agreements between firms that go beyond the ordinary trading operations but do not bring the case to a merger of firms.

For Ukrainian shipbuilding and ship repair enterprises, the relevance of integration processes and the search for new forms of cooperation is due to a decline in production volumes, a lack of investment and working capital, and lack of government procurement.

In countries with a developed market economy, the positive experience of creating the strategic alliances in the form of *economic cluster systems* has been gained. Using the synergy of clusters, enterprises are intensively developing due to efficient cooperation on the use of knowledge, funds, technology, means of production, etc. In the framework of cluster systems, it is possible to mobilize the advantages of a powerful corporate structure while maintaining the national independence of its participants. A feature of cluster economic systems is the participation in them, except for business structures, government bodies and research centres.

The cluster systems are able to provide unification in the production of competition with cooperation; these are points of growth and stimulators of technical progress. Therefore, the cluster development of the national economy and individual regions is one of the characteristic features of a modern innovative economy.

The project of creating a cluster system is a complex problem, various areas of knowledge are interwoven in it, various elements are synthesized, namely economic, technological, social and ethical ones. As a result, due to the dynamic combination of these elements, the borders, subject area and structure of the project for the creation and development of the cluster system are being formed.

In addition, the cluster system effectively solves the following tasks:

– activation of the innovation activity at enterprises and organizations that are a part of the cluster system by attracting the scientific potential of participants to solve problems in the field of technology, production organization, management, logistics;

– activation of investment processes at enterprises and organizations included in the cluster.

For scientific and educational structures in the cluster system, favourable conditions are being created for the implementation of scientific research, the market of educational services is being activated.

In the efficient functioning of the cluster, regional authorities are interested in ensuring employment growth and, as a consequence, reducing social tensions in the region. At the same time, a significant factor is a real possibility of activating small and medium businesses, the implementation of socially significant regional programs.

Part 1. Logistics management in shipbuilding cluster systems

The aim of the organization and functioning of the shipbuilding cluster system is to ensure the competitiveness of Ukrainian shipbuilding enterprises, develop effective mechanisms for their participation in international macro-logistics systems for the design, construction, and operation of transport vessels.

The scheme of functional decomposition of the operating activities of the shipbuilding cluster system (SCS) can be represented as follows:

An effective tool for forming the structure of a cluster system is the expert evaluation method. The role of the focal firm of the cluster system, in accordance with the recommendations set out in [1], is performed by the shipyards of the region (functions F6 – F15). To perform work on the analysis of various segments of the shipbuilding market, it is advisable to organize a consulting firm in the cluster structure (function F1). The development of ship projects (functions F2 – F5) can be performed by design organizations of Ukraine that successfully compete at the global markets: LLC “Marine Engineering Bureau” (Odesa), PJSC “Chernomorsudoproekt” (Mykolaiv).

Table 1

Functional decomposition of the operating activities of the shipbuilding cluster system

Function number	Operational function
F1	Marketing analysis of transport shipbuilding markets, substantiation of competitive vessel parameters, analysis and evaluation of designers, builders and customers
F2	Development of vessel classification projects
F3	Development of technical projects
F4	Determination of builders, preparation of contracts for the construction of vessels
F5	Development of the working project taking into account the features of the builder
F6	Process design
F7	Material order, components and their delivery
F8	Manufacturing of parts of the vessel hull
F9	Manufacturing the nodes and sections of the hull
F10	Assembling the blocks on the pre-launching platform
F11	Formation of the vessel hull at the construction site
F12	Launching the hull
F13	Fitting-out, testing at the building berth
F14	Mooring and sea trials
F15	Vessel commissioning to the customer
F16	Improving the mechanisms and instrumental controls in shipbuilding
F17	Research work aimed at improving the technology and organization of shipbuilding production

Admiral Makarov National University of Shipbuilding (NUS) has sufficient scientific potential to solve problems of designing, technology and organization of construction of transport vessels (functions F16, F17). The NUS also develops a multi-stage system of training for the shipbuilding industry, where the concepts of creative education are implemented.

The expediency of using models and mechanisms of logistics in the process management of creation and functioning of shipbuilding cluster systems is determined by the presence a multitude of the flow processes in the cluster system and the complex information flows associated with them. To assess the efficiency of the elements in the cluster system, it is advisable to use the balanced scorecard (BSC) [3]. This system involves the selection and substantiation of the nomenclature of indicators, which reflect all aspects of the system, both financial and non-financial ones. The competitiveness of the BCS is determined by the following factors [5]:

– the total cost of design and construction of the vessel;
– terms for the ship construction work;
– product quality;
– the required level of technical maturity of the cluster participants.

Based on the analysis of the factors of competitiveness, the strategic concept and structure of the cluster system, on the basis of the existing competitive advantages of the cluster participants on the functions of operational and management activity, are developed. Each cluster participant performs a number of functions Fψ (ψ = 1.17). In turn, each function is implemented through the list of works Wiψ (i = 1, n; ψ = 1,17), where n is the number of works on the implementation of the function. Each work is characterized by the cost of the required resources Ciψ and duration of implementation. Thus, the total cost of design and construction of the head order Sp is determined by the expression:

$$S_p = \sum_{i=1}^{n} \sum_{\psi=1}^{17} C_{\psi i} \quad (1)$$

Based on the analysis of the network model of the mock-up project, it is possible to determine the share of expenses necessary for the implementation of the functions of each participant in the cluster system. This information can be used in the decision-making process when preparing a contract for the design and construction of a vessel.

It is advisable to form a network model for the design and construction of the ship to manage the cluster system in two stages.

1. Development of fragments of the network model of work within the functions that are implemented by each participant of the cluster system with resource levelling within each participant.

2. Integration of network model fragments and resource levelling within the cluster with subsequent adjustment of the models of fragments.

The resulting model allows creating the expenditure part of the cluster budget on the project. The expenditure part of the budget of each cluster participant is determined by the parameters of work that implement the functions of this participant. These tasks are efficiently being implemented in MS Project.

For planning the budget revenues, it is advisable to use *a balanced model.* The balanced model allows solving the following tasks, with the help of which the cluster system management processes are implemented:

– prediction of availability and cash flow on the project;
– verification of the financial feasibility of the project;
– analysis of the expediency of using borrowed funds;
– determination of the terms and amount of required borrowed funds;
– monitoring and adjustment of the financial plan of the project taking into account its actual implementation.

In general, the balance model is represented by the functional B(t):

$$B(t)=P(t)-R(t), \quad (2)$$

where P(t) is the integral value of project revenue; R (t) – the integral value of the project expenses.

A sufficient condition for the financial implementation of the project is the positivity of the functional B(t) during the period of the ship construction project implementation.

Table 2

Nomenclature of balanced indicators of the shipbuilding cluster system

Strategic goals	Performance indicators
Ensuring the financial stability of individual participants and the cluster system as a whole	– Minimization of deviations from the budget of expenses – Return on investment
Increasing customer loyalty	– Customer loyalty index
Improving the operational activity of cluster participants	– Minimization of deviations by the terms established by the integrated network model – Index of implementation of plans for improving the quality of technological processes and management
Improving staff skills and abilities	– Increasing the number of employees that meet the qualification requirements – Index of implementation of the plan for staff development

In the process of developing the balanced scorecard of individual cluster participants and responsibility centres of various levels (cascading indicators), the explicit (calculated) and implicit causal relationships between key performance indicators are determined.

Part 2. Logistics centres in the mechanisms of logistics support for shipbuilding cluster systems

In the world shipbuilding markets, there are profound transformations. They are associated with the optimization of organizational and technological processes, the introduction of effective automated systems for ship design and production management. These changes lead to a redistribution of the positions of participants in the shipbuilding market, the formation of new conditions for the development of world shipbuilding. In conditions of instability and, accordingly, unpredictability of environmental factors, enterprises of the shipbuilding and ship repair complex of Ukraine need to develop and implement new forms of integration, form promising niches of specialization. The use of modern integration mechanisms will allow enterprises and organizations of shipbuilding to reach a competitive level in certain segments of the shipbuilding market.

An important factor in ensuring the stability and competitiveness of shipbuilding cluster systems is the creation of efficient *logistics support mechanisms* for enterprises that are participants of the cluster association. Shipbuilding cluster integration is a macro-logistics chain, where logistics operations and functions are implemented (in the generalized form, logistics activities). The decomposition of the logistics process of the shipbuilding cluster to the level of a set of functions corresponding to the individual stages of the design and construction of ships is described in [6]. The separation of logistics functions is directly related to the clustering at the enterprises of the structural divisions of the logistics service, providing management of procurement, storage, delivery of materials and components to production sites. These functions are practically fully implemented within the traditional management system that has developed in shipbuilding.

To follow the concept of logistics, operational management functions should be supplemented by the functions of *logistics coordination*:

– analysis of the market for the services for suppliers of materials and components for shipbuilding;

– identification and analysis of the need for material resources for enterprises of the cluster and specific production departments;

– the establishment of the dynamics of the needs for material resources, depending on the running of production processes for the implementation of ship construction projects.

Logistics management is characterized by the fact that goal-setting, the development of criteria for the efficiency of achieving the set goals is of paramount importance.

The features of the shipbuilding industry are small-scale and single-part production, as well as a long cycle of shipbuilding. In these conditions, the volume of stocks and work in progress is large in relation to the output, the flow rate of the material flow from input to output is very small. These features require the construction in the structure of shipbuilding clusters of effective tools for managing material flows at all stages of ship construction.

In domestic and foreign literature, the key concepts and practical techniques of integrated logistics management are described in detail. The results of the researches of functional fields, forming the system of enterprise logistics, including information exchange, inventory management, an organization of logistics support of production, are presented. The theoretical bases of the management of material and information flows in the sphere of circulation were revealed in [7, 9], special attention is paid to the management of storage and transport facilities of logistics systems at the macro and micro levels.

In shipbuilding, methods and models of project management that are implemented in matrix organizational structures have become widespread. Moreover, so-called *balanced matrices* are used. Here, the project manager has extensive project management powers, up to 60% of all organizational resources of the enterprise are involved in projects. The project activity has a priority over functional activity.

The paper [4] describes the peculiarities of constructing a network model for ship construction, taking into account the peculiarities of its implementation in the environment of the shipbuilding cluster. At the second stage of the formation of the network model when integrating its elements, it is expedient to use so-called network matrices. Their peculiarity is that the arrows (works) are structured along the horizontal corridors corresponding to individual performers participating in the cluster. The network matrix allows linking the logical-temporal project structure and the organizational structure of managing a shipbuilding project into a single integrated tool.

The obtained model allows forming a list of necessary material and technical resources for the project implementation: raw materials, materials, components. The main task of the management of material and technical resources is to ensure their optimal use to achieve the ultimate goal of the project. This means the construction of a ship with planned indicators, established by the contract terms, cost and quality.

In general, logistics support for projects includes two groups of processes.

1. Procurement of materials and equipment.
2. Inventory management, resource allocation and supply to production sites.

To ensure the sustainable functioning of the shipbuilding cluster system, it is proposed to organize a logistics centre in its structure, which will ensure the implementation of innovative logistics tools and a reliable logistics service (Fig. 1).

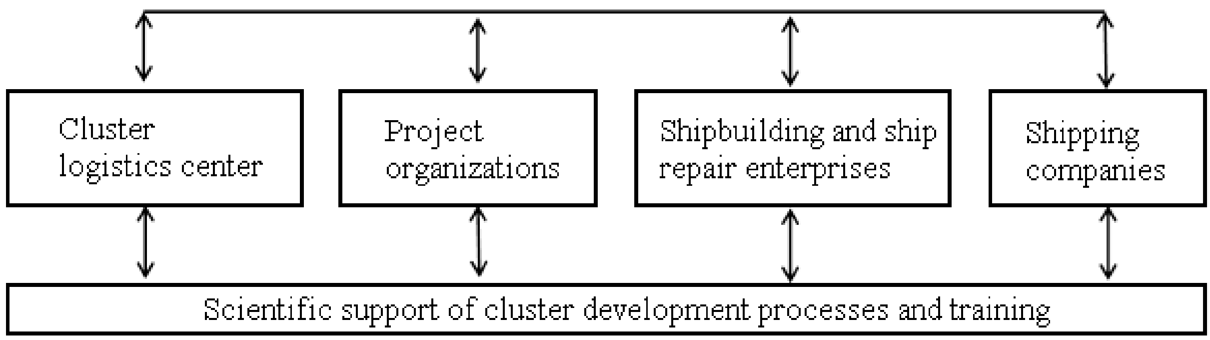

Fig. 1. Logistics centre in the structure of the shipbuilding cluster

Logistics Centre (LC) in the structure of the shipbuilding cluster is proposed to establish the following functions:

1. Management of the corporate information system of the cluster.

2. Development of network models of design and construction of ships for each project.

3. Development of plans of the logistics support for each project.

4. Integration of plans of the logistics support on the portfolio of cluster orders, in general.

5. Management of procurement of materials, equipment and components.

6. Management of the inventory of material and technical resources.

7. Management of supply of materials and components to production sites.

To implement these functions as a logistics centre in the cluster structure, it is advisable to organize an independent integrator company. According to the classification of logistics concepts, such company belongs to the 4PL class (4 Party Logistics) of logistics providers. Its main function is the implementation of logistics operations within the cluster with an emphasis on ensuring the efficiency of the entire supply chain.

To implement the above logistics service, it is necessary to use modern network computer technologies [7]. An important task of the logistics centre of the shipbuilding cluster is the formation of a single information space for the purpose of sharing information resources at all stages of ship design and construction.

The corporate information system of the cluster is divided into two parts.

1. *The information model of the vessel* is formed at all stages of design and process design. These works are being carried out in design organizations and technological services of the builders. An important task of the logistics centre is to ensure the integrity and consistency of the model elements, as well as the organization of controlled access to each section of the model.

2. *The information system of the cluster management* is an organizational and technological complex of methodical, technical, software, and information tools aimed at maintaining stable organizational relations of cluster participant. With the introduction of standards for data exchange between systems, the expansion of network and web technologies, new opportunities have been created to develop mechanisms to support cluster management processes.

It is necessary to note the peculiarity of budget-planning mechanisms in the shipbuilding cluster management system. Production resource planning is implemented in the MS Project or Prima Vera systems based on MRPII. These systems provide for the possibility of processing a set of ship projects, as well as procedures for calculating financial needs. Fragmentary resource and financial planning allow us to plan a system of budgets of enterprises – participants of the cluster. On the basis of resource and financial planning, the phasing of the needs of resources over time is realized, namely, basic information for accomplishing the main task of the logistics centre, that is, the timely provision of production sites with materials and components.

Part 3. Process-oriented management in shipbuilding cluster systems

In world shipbuilding, there are significant changes. The market for new types of specialized vessels is developing: gas processing and oil refining vessels, the need of vessels for the extraction of hydrocarbons on sea shelves is expanding, researches are being carried out to develop a system for the transportation of compressed natural gas by sea. Vietnam, India, and the Philippines are confidently claiming to be the group of countries leading in the shipbuilding market. Technologies for the non-slipway conveyor construction of medium tonnage vessels are being developed, computer technologies of design and technological training in shipbuilding are being improved.

For shipping companies of Ukraine, there is a dire need for modern transport river vessels and ones of the "river-sea" type. The need to append the fleet for service at sea and river ports is increasing. Shipbuilding enterprises of Ukraine have the necessary potential to participate in cluster systems at the regional, national, and international levels.

Models and mechanisms for organizing cluster systems are quite deeply described in the works of domestic and foreign authors. Creating efficient tools for coordinating the activities of shipbuilding cluster participants, efficient resource management are topical issues, solutions of which will ensure the stability and competitiveness of cluster associations.

Proposals for organizing the shipbuilding cluster can be initiated within the cluster policy of a region or country, as well as by individual stakeholders, who form strategic priorities for ensuring the competitiveness of the shipbuilding industry. The objectives of cluster initiatives are complex and include the following elements:

1. Development and implementation of modern mechanisms for managing the construction projects of vessels within the innovation cycle from design development to the vessel commissioning, as well as organizational and technological development of production.
2. Implementation of the modern forms of financing the construction of ships using leasing tools or concessional lending.
3. Organization of the efficient research centres in the cluster structure.
4. Establishment of state support mechanisms for the cluster system.
5. Ensuring the continuous increasing of staff qualification aimed at improving technological processes, reducing production costs and shortening the ship construction cycle.
6. Optimization of value chains within a cluster.
7. Reducing the transaction costs

The scheme of functional decomposition of the operational activity of the shipbuilding cluster is proposed and substantiated in [6]. This scheme is the basis for the formation of the organizational structure of the cluster system, the selection of participating enterprises, as well as in the management of production activities.

A feature of shipbuilding production management is the use of a specialized system of planning and accounting units (PAU) of works. PAU refers to the volume of work corresponding to a certain level of management. The lower level of the hierarchy consists of *shipyard technological sets* (STS) and is the primary planning and accounting unit used in interdepartmental operational planning. STS are formed on the principles of design and technological unity of work in the process of shipbuilding production. The use of the STS scheme creates opportunities to control production processes at the level that allows making and implementing efficient management decisions.

The information model of the shipbuilding cluster system can be represented in the form of a *responsibility matrix*. In project management, the responsibility matrix coordinates the structure of work on the project with the organizational structure of project management [2; 4].

The organizational structure of the cluster is represented in three levels.

1. Enterprise is a participant of the cluster Ei (I = 1, n), where n is the number of enterprises and organizations that are participants of the cluster.

2. Structural divisions of the enterprise Sig (g = 1, p), where p is the number of structural divisions of the enterprise Ei.

3. Production sites Digf (f = 1, r), where r is the number of production sites of the division Sig.

In the rows of the responsibility matrix, the codes of the STS Kjigf belonging to the project P_j (j = 1, m) are located, where m is the number of projects under construction in the shipbuilding cluster. The igf index identifies a production site where the work of the STS with K_{jigf} code will be performed.

The responsibility matrix is an information base for the development of network graphs for the design and construction of ships in a shipbuilding cluster. In this case, it is expedient to use network matrices – corridor-scale network graphs. In these graphs, arrows (works) are structured along horizontal corridors, which correspond to the individual performers – cluster participants. Vertical lines determine the matrix time scale.

The network matrices establish the correspondence of work packages and the timing of their implementation to the performers – participants of the cluster. The network matrix allows assembling the logical-temporal structure of the ship construction project and the organizational structure of the project management in a cluster system into a single integrated tool. In this case, the network model should be presented at three levels. The top-level matrix on the horizontal corridors displays the list and interaction of the cluster participants and the work packages that implement the operational functions determined by them. The second and third levels include a system of network matrices for the structural subdivisions of enterprises and production sites, where the corresponding work packages are displayed in the horizontal corridors. After constructing the network matrix system, all known methods for calculating parameters and optimizing models can be used for them.

The proposed mechanism for developing network models for the construction of ships in a shipbuilding cluster determines the production sites as *centres of process responsibility*, as they implement the business processes of the low level of structuring. Business processes using a specific technology turn input resources into outputs that are valuable to the consumer. The consumers of business process products are entities (legal entities, functional divisions, and other business processes) that use the results of the process. For them, value and timing of the reporting of results are important.

The process approach to management in the shipbuilding cluster provides an opportunity to optimize the corporate management system, make it transparent for the administration and able to respond to changes in environmental factors. The process-oriented management is effectively integrated with the budgeting mechanisms set out in [3]. In this case, the main (basic) object of budgeting is business processes (STS). The structure of budgets should correspond to the structure of planning and accounting units of the shipbuilding cluster, which will allow accounting and control of income and expenses at all levels of management. In addition, the system of budgets allows analysing the obtained and predictive financial indicators and using them to manage the resources of both individual business processes and enterprises of the cluster system. Also, the process approach provides an orientation to the development of work creating the use value of products.

Conclusion

1. The formation of the structure of a high-tech shipbuilding cluster system is based on an analysis of the results of the functional decomposition of the operating system for the design and construction of transport vessels. Effective management of the cluster system is based on the use of the principles of logistics and balanced scorecard.

2. A properly constructed balanced scorecard, supported by special software, allows each cluster member to focus their resources (financial, human, technological, and informational) on the implementation of the strategy and ensure a steady movement towards the goals set. In addition, the balanced scorecard provides the connection between strategic objectives and plans at various levels (strategic, tactical, and operational plans). All this ensures the manageability and efficiency of the cluster system.

3. The proposed schemes of interaction between enterprises – participants of the shipbuilding cluster provide an accelerated output of products to a competitive level. Modern logistics tools allow building an efficient system of logistics support for the production of enterprises that are part of the cluster.

4. The logistics centre plays a key role in the functional integration of enterprises and organizations included in the cluster. The nomenclature of functions that are determined by the logistics centre requires constant analysis and adjustment at various stages of the cluster life cycle.

5. The use of process budgeting in the management of the shipbuilding cluster will allow:

– to determine the cost price of each process at cluster enterprises with the required level of detail;

– to form a cost structure for all technological packages;

– to conduct effective monitoring and analysis of costs for all centres of financial responsibility of the cluster;

– to evaluate the activities of individual enterprises and the cluster as a whole from the standpoint of management at various levels or shareholders to make effective management decisions;

– to implement tasks using software tools based on the methodology of EPR systems within the corporate information system of the cluster.

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