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Article

Strategic factors for ensuring the sustainability of economic development of industrial complexes (on the example of shipbuilding industry)

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Abstract: Shipbuilding industry is characterized by high price competition, as well as tight deadlines for product design and production. The dominant positions in the civil shipbuilding market are occupied by the countries of Southeast Asia, and for a number of reasons, participants from other countries are uncompetitive. Thus, in order to ensure the sustainable development of companies in the global civil shipbuilding market, it is necessary to identify and analyze the main factors that provided the competitive advantages of industry leaders. Assessment of further directions of shipbuilding development is a necessary condition for the formation of competitive advantages of new market participants. The article analyzes the main directions of development of the world civil shipbuilding in the period after World War II, as well as prospects for the future. As a result of the analysis of the latest organizational management concepts, the concept of modular production in shipbuilding is proposed, and directions for further research are determined.

Keywords: shipbuilding; lean manufacturing; resource efficiency; customer value creation; flexibility (mobility); large-block ship construction; clustering; block-modular concept; production system modules

1. Introduction

Shipbuilding is characterized by high complexity and cost of products, as well as a significant duration of the production cycle and high price competition. The dominant positions in the civil shipbuilding market are occupied by the countries of Southeast Asia, and for a number of reasons, participants from other countries are uncompetitive. Thus, in order to ensure the sustainable development of companies in the global civil shipbuilding market, it is necessary to identify and analyze the main factors that provided the competitive advantages of the industry leaders.

The concept of sustainable development includes three main components—social, environmental and economic.

The environmental aspect is primarily related to the need to sustainably provide the economy with primary natural resources while simultaneously preventing environmental pollution problems, the possibility of reusing resources within the framework of a circular economy and the potential for the development of future generations of people based on new and existing primary and secondary resources. This aspect of sustainability is more related to the "infrastructural" factors of the entire economy than to individual enterprises or complexes, including the energy transition as a necessary condition for environmentally friendly production (Nguyen et al., 2024; Radoushinsky et al., 2023), energy efficiency (Marinina et al., 2023; Nevskaya et al., 2023; Shishlyannikov et al., 2023), new energy sources and resources for the economy

(Cherepovitsyn et al., 2021; Nechitailo and Marinina, 2022; Romasheva et al., 2022), carbon neutrality (Pshenin, 2024; Skobelev et al., 2023; Shchirova et al., 2021) and others. From the point of view of ecology, more complete use of natural resources and assimilation of industrial waste in the natural environment, there are a large number of publications that largely relate to the extractive sector of the modern economy (Kirsanova et al., 2024; Romasheva and Dmitrieva, 2021; Semenova and Martínez Santoyo, 2024), as well as state policy in this area (Litvinenko et al., 2023; Lapinskas et al., 2023; Stroykov et al., 2021). We can also talk about the creation of environmental monitoring systems (Kusimova et al., 2023; Rogachev et al., 2021; Yuri et al., 2024), etc.

The economic and social aspects of the sustainability of enterprise development are currently being combined on the basis of the concept of maximizing value for customers, which simultaneously contributes to solving the economic problems of inefficient use of resources by enterprises. This study will be devoted to these issues.

The purpose of the study is to identify the main factors and directions for ensuring the sustainable development of shipbuilding enterprises based on the analysis of statistical and theoretical material.

The object of this study is the process of development of industrial shipbuilding complexes. The subject of the research is the patterns of economic development processes, methods and tools for managing the development of enterprises in the industry.

Structurally, the study is structured in a consistent solution of the following tasks corresponding to the sections of the article:

1) Study of the structure of the global civil shipbuilding market, identification of the main trends in the development of the industry;
2) Research of the main strategic directions for improving the efficiency of shipbuilding companies-industry leaders and the main development problems;
3) Analysis of new organizational management concepts in leading innovative companies;
4) Short methodology description;
5) Drawing conclusions based on the results of the study.

2. Literature review

2.1. Features of the development of the global civil shipbuilding market in the period after World War II

Currently, more than 90% of the global civil shipbuilding market is divided between China, South Korea and Japan (**Figures 1** and **2**) (The Shipbuilders' Association of Japan, 2024). In many ways, this situation is due to the high competition in the industry, which has significantly increased after a large number of Japanese, and then South Korean and Chinese companies entered the world market, and these companies developed their competitive advantages.

According to the data (The Shipbuilders' Association of Japan, 2015), for the period 1976–2013 (**Figure 3**) the number of personnel of Japanese shipbuilding enterprises decreased by more than 3 times, with approximately the same production volumes in the corresponding years. This indicates at least 3-times growth in labor productivity over the specified period.

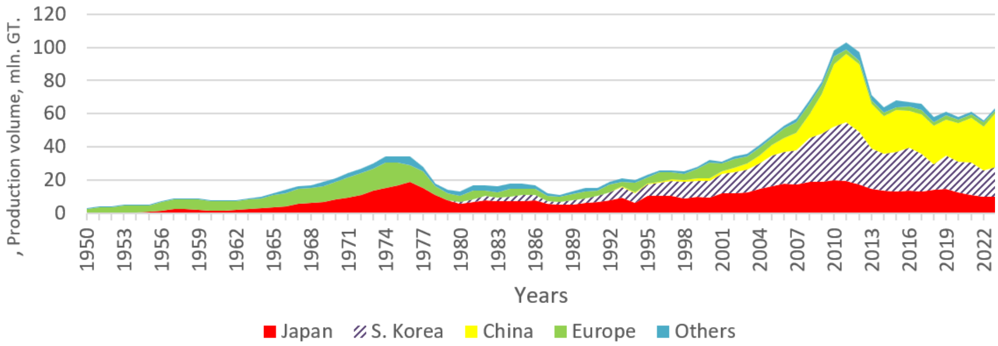

Figure 1. Statistics of the world civil shipbuilding in the period 1950–2023.

Source: Author's own compilation.

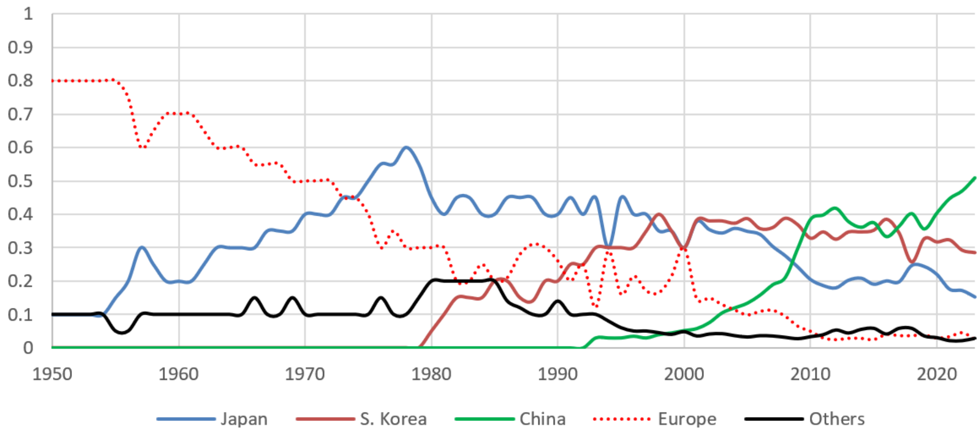

Figure 2. Dynamics of distribution of shares of the civil shipbuilding market among key participants.

Source: Author's own compilation.

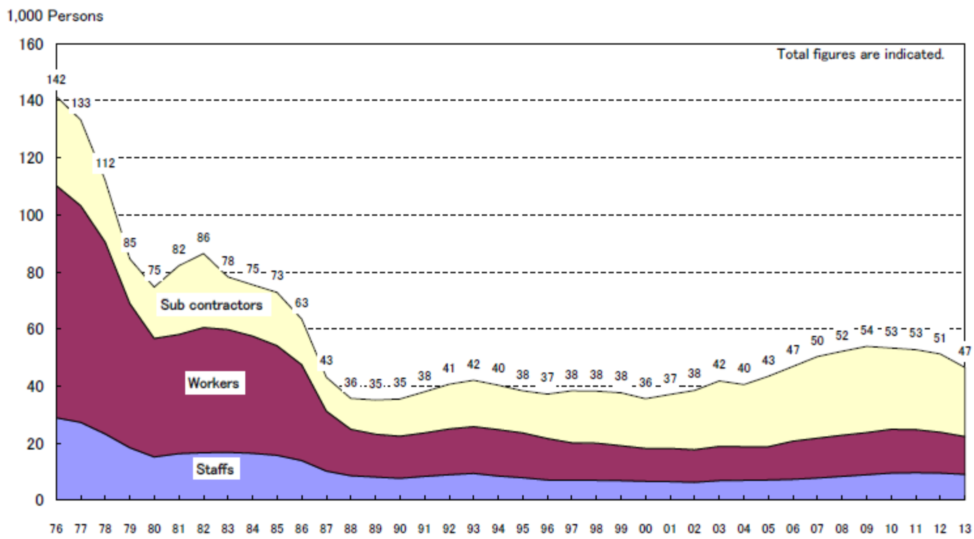

Figure 3. The dynamics of the number of personnel of shipbuilding enterprises in Japan for the period 1976–2014.

Source: The Shipbuilders' Association of Japan (2015).

Increasing labor productivity and the use of other organizational and technological measures contributed to reducing the cost of ship construction in Japan and South Korea, with uneven changes of this indicator in Europe (**Figure 4**) (Shamray, 2011).

State support for shipbuilding can partially compensate for the cost of ships, which is a necessary but not sufficient condition for competitiveness (Shamray, 2011). Government support for shipbuilding is strongest in the United States, and the most significant investments in the industry were made in Germany (about €500 billion after reunification), but the share of these countries in the global market of civil ships is currently small.

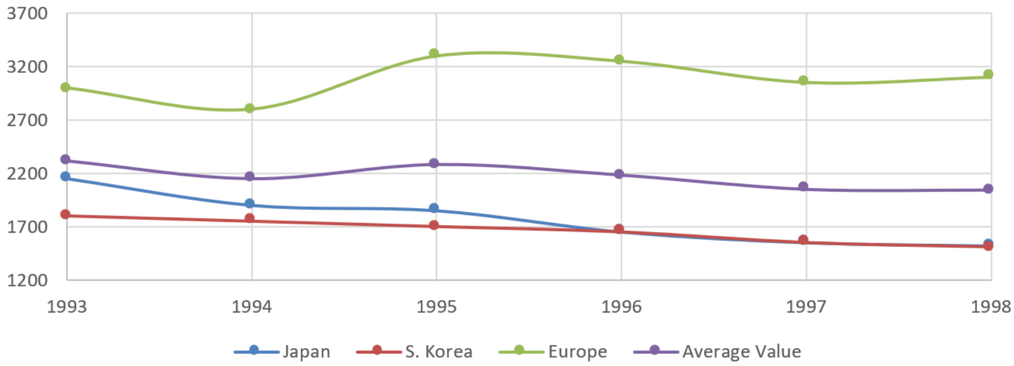

Figure 4. Dynamics of the unit cost of ship construction in various countries, in US dollars per CGT unit (Compensated Gross Ton, a unit of measurement of shipbuilding production volume).
Source: Shamray (2011).

2.2. The main measures to improve the efficiency of shipbuilding companies in the industry-leading countries

The process of enterprise development has two aspects—a progressive change within the life cycle curve (gradual improvement in the products' quality, labor productivity, etc. as a necessary condition for survival) and transformational changes in the face of sudden unpredictable fluctuations in demand and prices, rapid change of basic production technologies in the industry. Both aspects should be reflected in management systems as criteria for ensuring the strategic sustainability of industrial enterprises and complexes.

The first aspect corresponds to a "smooth" and to a certain extent predictable change of the enterprise (due to increasing the resource efficiency, focusing on long-term interests and goals). Ignoring the second aspect can quickly neutralize the existing competitive advantages and even lead the company to bankruptcy. To increase the adaptive properties of the enterprise, it is necessary to develop the properties of "flexibility" or "mobility".

In shipbuilding, as a rule, more attention is paid to the first aspect of strategic management than to the second. For this reason, the structures of most shipbuilding companies remain "rigid", which creates certain risks in the event of sudden changes in the shipbuilding market.

There can be distinguished three main approaches to improving business efficiency in shipbuilding: the organization of shipbuilding clusters, the transition to large-block shipbuilding and the introduction of lean manufacturing systems. All the rest, including processes' automation, digital transformation, and standardization also fits well into the principles of lean manufacturing (Chu et al., 2021; Sharma and Gandhi, 2016).

2.2.1. Large-block ship construction (using the example of Samsung Heavy Industries Corporation)

In conditions of the industrial territories high density (being typical for the countries of Southeast Asia), one of the priority tasks of enterprises is to increase capital turnover and return of funds. Samsung Heavy Industries (SHI) has found a simple solution for this—to assemble ships on floating docks, within the nearby water area.

To speed up work in 2001, it was proposed to assemble ships in blocks containing all the necessary equipment, ship communications, built rooms, etc. Calculations carried out by SHI specialists showed that the larger the blocks used, the shorter the time spent by the assembled vessel on a floating dock, and the more ships can be produced per year at the enterprise (Eunhee Sohn et al., 2009; Samsung's Mega-Block Revolution, 2005) (see **Table 1**). At the same time, the cost of a floating dock was 15%–20% from the cost of a conventional dry dock, i.e., such a solution looked economically attractive.

Table 1. Dependence of the docking time on the size and number of ship blocks.

Number of ship blocks, units	Block size, tons	Docking time, days	Berthing time of the vessel (between launching and delivery), days
130	250	No data	No data
12	2300	96	80
10	2760	37	45
8	3450	29	42

Source: Samsung's Mega-Block Revolution (2005).

Up to 60% or more of the ship blocks were transferred to third-party organizations for production, which made it possible to significantly unload the main production site, while speeding up the work process several times. This assembly technology was called "Samsung Mega-Block", and assumed a maximum block size of up to 2900 tons, with a total number of blocks of about 10. With this assembly technology, each floating dock could add up to 9 vessels in addition to the company's annual production program.

Gradually, the company switched to the "Giga-Block" assembly technology (using 5–8 ship blocks or less), which made it possible to additionally produce more than 12 ships per year from each floating dock. In 2007, the Tera-Block technology was also introduced, which allows building up to 10 large ships per year or up to 14 smaller ones on each floating dock based on the connection of only two blocks.

Further productivity growth can be achieved by applying other technological and organizational activities. Nowadays, large-block ship construction is widespread both in South Korea, China and Japan.

2.2.2. Development of shipbuilding clusters (using the example of Hyundai Samho Heavy Industries Corporation)

The active development of South Korean shipbuilding began in the 1970s. At that time, the country's natural competitive advantage was the low cost of labor. The first vessels produced in the established shipbuilding corporation Hyundai Samho Heavy Industries were tankers—technically simple, but labor-intensive ships (Hassink and Shin, 2005).

Gradually, the cost of labor in the South Korean economy began to rise, and for the development of corporations, it was necessary to increase the level of personnel qualification and of key corporate scientific and production competencies. Some of the most labor-intensive and easy-to-perform activities began to be outsourced to third-party organizations.

Such production complexes are self-sufficient, although not very flexible in terms of the speed of restructuring in accordance with changes in the market environment (Moura and Botter, 2012). Intra-corporate competition and individual entrepreneurship within corporations are practically absent.

For this reason, the 1998–1999 the crisis in Asia led to the need to restructure Daewoo, which was divided into two independent parts. Also, during the crisis of 2008–2009, there was a problem of underutilization of production capacities of South Korean corporations, which had been operating unprofitably for several years in a row. In the event of revolutionary changes in shipbuilding technology, the traditional market players may not be able to compete with new manufacturers with greater flexibility (Chen, 2014).

2.2.3. Introduction of lean manufacturing in shipbuilding industry

The lean methodology has a number of tools to eliminate losses in business processes, as well as general principles that must be consistently followed so that the enterprise can maximize the available reserves of productivity growth and cost reduction, with constant and comprehensive quality control and resolution of emerging problems.

Lean systems are primarily organizational and operational in nature, since in most cases only the organization of labor and production changes (losses are eliminated), and production technologies remain virtually unchanged.

In a number of publications, it is believed that only a number of Japanese companies (Phogat, 2013), in particular, Kawasaki, IHI Kure and Oshima (Liker, 2002), have successful experience in implementing lean manufacturing systems in shipbuilding, thus significantly reducing the volume of "frozen" working capital. The main principles of such companies are working on the basis of "Just-in-time" schedules, the use of methods of group processing for intermediate products, visual control, staff training (Liker and Lamb, 2001), etc.

In (Liker, 2002) examples of the use of the lean approach in the production of pipelines (according to the "supermarket" principle) and in ship design (Sullivan et al., 2018) are considered. Recommendations are given on the use of such lean tools as value stream mapping, the Kanban pulling system, Total Productive Maintenance (Skobelev et al., 2023), leveling the production lines load "Heijunka", embedding quality in the process ("Poka-Yoke", "Andon", etc.), "5S", etc.

There are also many publications on the problems of introducing lean manufacturing in shipbuilding in Norway, China, the USA, Singapore (Lai et al., 2020), Russia, Brazil and a number of other countries (Oliveira and Gordo, 2018; Song and Zhou, 2021). Traditionally, for lean systems, the main focus in publications is on eliminating losses, organizing effective interaction with suppliers, implementing "best practices" for work performance, etc. (Dugnas and Oterhals, 2008).

An organic continuation of the lean approach is the development of the "flexibility" of the enterprise, which helps to respond quickly and effectively to any changes in the external environment (Eisenhardt and Martin, 2000; Yusuf et al., 1999). There can be distinguished the following directions for increasing the companies' flexibility (Sharifi and Zhang, 1999):

1) Modularization of ships, i.e., assembling products based on interchangeable standard modules (Dugnas and Oterhals, 2008; Erdem and Wouter, 2015; Phogat, 2013), including large blocks (Lang et al., 2001).
2) Modularization of the production system itself (Song and Zhou, 2021), organizing standard production modules;
3) Decomposition of planning systems (Dugnas and Oterhals, 2008), goals and processes, standardization of components of complex processes to facilitate the solution of complex tasks and establish personal responsibility for the result of work (Song and Zhou, 2021). Decomposition itself is one of the necessary conditions for modularizing the production system;
4) Application of flexible production automation systems (Van Klink and De Langen, 2001);
5) According to the authors of the work (Moura and Botter, 2012), a flexible shipbuilding enterprise should also have a number of fairly developed subsystems:
    - CIM (Computer-Integrated Manufacturing);
    - TQM (Total Quality Management);
    - MRP II (Manufacturing Resource Planning);
    - BPR (Business Process Reengineering);
    - OPT (Optimization of Production Technologies).

Unfortunately, in shipbuilding, the introduction of these systems can be very problematic due to high costs and duration of implementation.

6) Creation of corporate competence centers that help to more effectively solve a number of issues related to the development and production of ships (Lang et al., 2001);
7) Solving the problems of personnel communication in lean projects (based on the use of change management tools) (King and Anderson, 1995), as well as optimizing the entire value stream at enterprises.

2.3. Traditional key factors of ensuring the sustainability of the economic development of shipbuilding complexes

Thus, the main factors in the development of shipbuilding in the leading countries of the industry have become an increase in labor productivity, a reduction in the unit cost of products and the timing of ship design and construction (**Table 2**). All these factors relate to the "static" aspect of strategic management, and are only slightly associated with the flexibility of companies.

Leading shipbuilding corporations are rather rigid structures, which significantly slows down the speed of reaction to sudden unpredictable changes in the external environment, and can even lead to a crisis, while simultaneously contributing to a slowdown in the development and implementation of innovations in the industry, since standard, well-proven organizational and technological solutions are mainly used (Hannan and Freeman, 1984).

The main problem of shipbuilding in general is the application of a predominantly "static" aspect of management, in which industrial clusters develop predictably within the life cycle curve (Shin and Hassink, 2011; Van Klink and De Langen, 2001), in conditions of structural rigidity and a one-variant approach to development. If this trend continues, it is likely that new shipbuilding companies will emerge in the future, more flexible and economically sustainable in the long term, which will leave traditional market participants far behind.

Table 2. The main factors of ensuring the sustainability of the economic development of shipbuilding complexes*.

Factors of sustainable development	Type of factors	Areas of management	Effectiveness and application features
Reduction of the unit cost of ships	The "static" aspect of management	Lean philosophy in general (through the elimination of all losses in business processes, more complete use of the internal potential of the enterprise)	Effective in combination with detailed planning and standardization
Reduction of design and construction time		Large-block construction of ships (parallelization of work, standardization, increasing the efficiency of space use)	In Japan, China and South Korea, the maximum productivity has been reached (Tera-Block technology)
Improving labor productivity		Clustering (parallelization of work, outsourcing of simple types of work to subcontractors, concentration of key competencies within the parent organization of the corporation)	Mass production of large objects, the level of customization is low
		Centralization of management (creation of large clusters, with centralization of scientific and production competencies for the main types of ship components)	"Modularity" in the organization of enterprise structures and complexes
Flexibility and mobility of enterprises	The "dynamic" aspect of management	Practically not used, except for several types of modular production structures	The effectiveness in other industrial sectors is high

Note: * means compiled by the author.

2.4. Factors of sustainable development of industrial enterprises and complexes in a dynamic environment

The "dynamic" aspect of management assumes that an enterprise has the ability to adapt quickly and at low cost to sudden unexpected changes in the external environment, the property of mobility or flexibility (Lorenz, 1994; Pino and Greve, 2006). Author of this study identifies three main directions for increasing the mobility of companies—resource, organizational and technological.

A) Resource mobility of production is the ability of a company to accelerate the renewal of its product range. It is determined by how the future product is designed and put into production. There are three main ways of designing and assembling a product—sub-detailed, sectional-nodal (aggregate) and block-modular. Each of the methods is characterized by a certain speed of design and production, cost and prototyping capability.

B) Technological mobility is the ability of an existing technological equipment complex to be used for the production of other types of products. This is most possible in the case of Flexible Manufacturing Systems (FMS), the implementation of which is associated with significant organizational difficulties and high financial costs.

C) Organizational mobility is the ability of an enterprise to flexibly respond to changes in demand for products, while maintaining the profitability of its core business. The levels of organizational mobility should be considered depending on the variants of the structure of the enterprise, which can be shopless (flat), workshop, distributed production network or block-modular.

From the point of view of the development of the mobility property in general, it is necessary to take into account the industry dynamics corresponding to the volatility of demand and prices, the frequency of product series changes, etc. The implementation of measures to increase mobility should be economically feasible.

2.5. New forms of management organization in leading innovative corporations

Modern management organization concepts pay attention to various factors—the formation of a favorable psychological climate in the teams, reducing the number of management levels and the amount of bureaucracy, achieving technological superiority, close communication with customers, etc. All this manifests itself in the formation of a certain organizational culture. Let's look at some typical examples of new organizational management models.

2.5.1. Haier management model: RenDanHeYi

A unique model (industrial ecosystem) has been created in Haier (Greeven et al., 2023). The company does not have the average-level management and consists of about 4.5 thousand microenterprises (ME) on average 10–15 people each. ME functions as a separate business, interacts with others on a contractual basis in terms of the supply of products and services.

Through the association of ME, networks of micro-enterprises are being formed that supply goods and services to customers, "micro-communities" (MC). If the MC is successful in solving its tasks, then its members jointly participate in the total profit. The entire workflow of MCs, as well as MEs, is conducted on the Haier platform, which allows you to have a complete set of corporate competencies in a single database, as well as effectively organize communications between process participants.

The role of the central management of the corporation in these conditions is to create a context, elaborate a network platform that helps Haier to develop. The principle applies: "Zero distance to the client and everyone is an entrepreneur" (Yangfeng, 2019).

The results of using this network model have allowed the company to steadily increase revenue and profit for many years, while simultaneously ensuring a very high level of capital turnover.

In general, the RenDanHeYi system is a development and continuation of the lean approach. The lean principles are implemented in this model more fully and with new content (**Table 3**).

Table 3. Comparative characteristics of lean systems and RenDanHeYi*.

No.	Parameters	Characteristics	
		Lean Systems	**RenDanHeYi model**
1	Organizational basis	Lean Philosophy	Haier's Management philosophy
2	The nature of the system	Primarily operational in nature, focusing on continuous improvement of existing processes and more efficient use of resources.	The system's focus on the future, as well as on optimal ways to use resources
3	The Center of Philosophy	Creating value for the customer, which involves the elimination of losses in the production and management processes.	Creating value for the customer, including through industry leadership. The salary level is determined by the value created.
4	Priorities	Long-term goals: to prevent slipping into short-term profits to the detriment of the strategy.	Long-term goals, creating value together with the client
5	Working with the customer	Customer orientation, including through the application of the principle of "pulling" (custom work).	Everyone is a customer and a client. Zero distance to the client as a necessary condition for success.
6	Continuous improvement	Continuously implemented small and large changes in organization.	The culture of continuous improvement has been built into a system: Daily planning, recommendations for improving existing processes, self-monitoring of activities, salary depends on the amount of value created in the amount of work performed.
7	Personnel development	Creative and professional skills.	Creative and entrepreneurial abilities.
8	Losses	Elimination of losses as a principle of increasing efficiency.	Losses as suboptimal job performance (worse than the industry average).
9	Value Creation	The key role is given to those processes that create value for customers.	Value is created by all participants in the process, including through assistance in choosing the most optimal methods for solving problems and organizing processes.

Note: * means compiled by the author.

In its current form, the RenDanHeYi model is adapted to conditions for the production of household appliances and electronics (Frynas et al., 2018). Additional research is needed to apply its elements in shipbuilding. In ecosystems, all process participants effectively interact with each other according to the principle of symbiotic relationships (Iansiti and Levien, 2004).

2.5.2. Xiaomi's development and business model

Xiaomi has a single network platform that combines logistics, development, marketing, research, sales, etc. There are also offline channels. The Internet of Things and artificial intelligence platforms have been created (Piao et al., 2021).

The structure of the corporation is flat; it includes three levels—8 co-founders, heads of departments (about 12) and employees. Departments are formed according to the main types of products of the company. This structure ensures high speed of decision-making and responding to customer requests. Xiaomi actively involves startups in its work.

Products promotion is carried out on the principle of "word of mouth", since contact with customers is carried out through social networks. At the same time, employees of the corporation must necessarily be "fans" of the Xiaomi brand.

The corporate structure is relatively rigid. A significant economic effect is achieved due to the mass production, i.e., there is no high level of customization for different consumers. As in Haier, there is virtually no middle management, which speeds up the decision-making process.

2.5.3. Overview of management systems and general trends in HUAWEI Corporation

The structure of the corporation is hierarchical and traditionally has a large number of management personnel at all levels. 14 functions have been defined (HUAWEI, 2024). Employees of the corporation are expected to have a very high level of dedication, self-discipline and resolute performance of their duties, as well as a loyal attitude towards management. At the same time, all employees (about 80 thousand people) own part of the company's shares and receive dividends, which additionally stimulates the company to achieve high profits. When an employee is fired, his part of shares must be bought out by the corporation.

Information and communication technology divisions are gradually developing a global digital platform to serve the corporation's employees, as well as suppliers and wholesale buyers.

Thus, HUAWEI's structure is similar to Xiaomi, but is even more rigid. At the same time, HUAWEI is even more committed to mass production and has a narrow range of products. The corporation's value system includes customer orientation.

2.5.4. The concept of an automatic modular production system

Another approach to the formation of production systems is automatic modular production systems (MPS), based on the principle of "open architecture", well known from computer technology.

Attempts to transfer the principle of "open architecture" to modern industrial enterprises have been observed over the past 20–25 years, mainly in the USA and EU countries. One of the first works in this direction is the article (Rogers and Bottaci, 1997), which proclaims the need for the formation of industrial enterprises from a system of modules interconnected by special management ties.

An example of the application of a modular approach to industrial production is Festo MPS® (Modular automation for flexible production, 2024). The modules implement a variety of production sub-processes. The system operates on the basis of a central computer, under the control of the operating system (**Figure 5**).

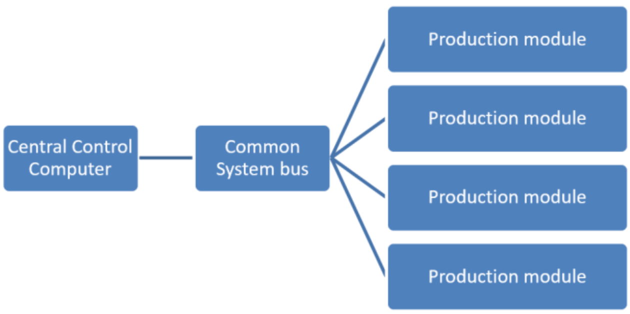

Figure 5. Architecture of an automatic MPS.

Source: Author's own compilation.

In recent years, Festo has transited to a new generation of MPS, in which the modules are FMS. So, each module performs a wide range of functions.

Thus, the architecture of Festo MPS is similar to the RenDanHeYi model, which has a common network platform ("system bus"), to which individual participants (or modules) in the process connect and, after receiving the task, independently determine how to ensure execution.

Among the disadvantages of such systems are: limited number of resources to be used, the weak opportunities to work with personnel and of inter-factory cooperation, limited production and machined parts sizes, and the need for almost complete automation of processes. In this form, MPS cannot be organized in large shipbuilding complexes. The approach to the construction of MPS must be significantly supplemented and clarified.

2.5.5. Problems of production structures modularization in shipbuilding

In production based on modular concepts, it becomes possible to more accurately take into account the resources of production and management, as well as to carry out "targeted" restructuring of the enterprise if individual modules do not meet the needs of production. For the functioning of modular structures, it is necessary to organize management accounting systems and a detailed production planning system that allows evaluating and monitoring the state of the production system at any given time and, as necessary, adjusting the operation of modules.

Modular concepts in the construction of production systems are one of the mechanisms for organizing "production cells" in shipbuilding (Liker and Lamb, 2001), when similar products are grouped according to certain production modules and, thus, can be performed faster, with fewer equipment changeovers and lower cost, it becomes possible to organize a continuous flow (Kolic et al., 2012) and process automation. Also, in the works (Erdem and Wouter, 2015; Lee Storch and Lim, 1999), it is proposed to form modules for saturating ship blocks and performing other work.

Taking into account the practical experience of Haier Corporation in the decomposition of its structure into micro-modules ("microenterprises"), it can be assumed that there are practically no restrictions for modulating all structures of shipbuilding complexes. Nevertheless, it is necessary to initially determine the characteristics of the modules, their types, etc.

It seems possible to form three types of modular units corresponding to the organizational structure of the company—production, pre-production and management, which can be linked by a customer-supplier relationship. At the first stage of the transformation of a shipbuilding company, it is possible not to create completely independent businesses based on modules, but to limit oneself to varying the salary level in supplier modules depending on the degree of satisfaction of customer modules.

To form modules, it seems advisable to use the concepts of an object-oriented hierarchy of objects used in computer programming. It also seems advisable to deepen the lean philosophy from the point of view of ensuring management flexibility. Our next studies will be devoted to the study of these issues.

3. Methods

The methodology of this study is presented by the analysis of statistical and theoretical material in the field of shipbuilding industry, analysis and synthesis, and other methods.

The following data are selected as the information base of this study:

- Annual reports of the Association of Shipbuilders of Japan: https://www.sajn.jp;
- Annual data of the Korean Association of Shipbuilders: https://www.koshipa.or.kr;
- Data of JSC "Center for Shipbuilding and Ship Repair Technology" https://www.sstc.spb.ru;
- Scientific publications on the problems of the introduction of Lean Manufacturing in shipbuilding and other industries;
- Scientific publications in the field of the Haier ecosystem model (RenDanHeYi);
- International scientific publications in the field of modular production systems;
- Scientific publications in the field of strategic management;
- Literature sources in the field of object-oriented approach to information structuring and computer programming;
- Materials from Samsung Heavy Industries: http://www.samsungshi.com/en;
- Materials from Hyundai Samho Heavy Industries: https://www.hshi.co.kr/eng;
- Materials in the field of Festo® automatic modular production systems: https://www.festo.com;
- Previous publications and research materials by the author of this study;
- Data from international consulting companies and agencies, other analytical and research materials in field of shipbuilding industry.

4. Conclusion and discussion

Based on the presented materials of this study, a number of conclusions can be formulated:

1) The development of world shipbuilding in the period after World War II took place due to the improvement of the organization of production, labor and management, which allowed the leading companies in the industry to increase labor productivity 3–3.5 times; reduce the unit cost of ship construction and reduce the duration of the design and construction processes several times. Technological factors had a much smaller impact on the industry, while most shipbuilding companies practically do not pay attention to structural flexibility, which significantly slows down the introduction of innovative developments in the industry, alternative organizational and technical solutions are rarely considered.

2) Clustering, large-block shipbuilding and the introduction of lean manufacturing systems have become key management tools in shipbuilding, which have ensured an increase in the competitiveness of companies in China, South Korea and Japan. Large-block construction as a method of increasing productivity has almost exhausted itself. In most cases, industrial clusters are organized as rigid structures, with the concentration of core competencies within the parent organizations, and require reorganization. Lean manufacturing is primarily operational in nature, and the effectiveness of its implementation varies from company to company. Further development is possible only on the basis of a more complete consideration of the needs of specific customers, including by creating a competition in the areas of R&D and the development of design and organizational and technical solutions.

3) The logical continuation of lean systems is the RenDanHeYi model developed in the Haier corporation, which flexibly responds to market needs and quickly

eliminates emerging "suboptimalities" in processes. Potentially, the use of such management systems is possible in almost any branch of industrial production, but this requires additional research.

4) As the main measures that increase the flexibility of shipbuilding enterprises and complexes, various forms of production systems' and manufacturing products' modularization are proposed, while increasing the flexibility of technological equipment.

5) Among the methods of enterprise structures modularization, concepts such as RenDanHeYi, the formations of automatic MPS Festo, as well as the creation of production cells in lean systems are highlighted. Based on the evolutionary methodology from biology, it is possible to develop an intermediate concept of modular production for shipbuilding and other industries, taking into account the possibilities of gradually creating network enterprises based on the decomposition of production and management processes, modularization of functions and a customer-oriented approach.

6) In order to continue research in the field of strategic factors of sustainable economic development of industrial complexes, it is necessary to form an appropriate methodology, as well as a system of economic and mathematical models. It is assumed that the methodology is to be based on the ecosystematic approach to building the industrial systems and complexes. Consideration of this issue is the subject of subsequent research by the author of this publication.

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