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TOWARD SHIPBUILDING 4.0 - AN INDUSTRY 4.0 CHANGING THE FACE OF THE SHIPBUILDING INDUSTRY

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Review paper

Summary

The *Shipbuilding 4.0* at the principles of the *Industry 4.0* will transform the design, manufacturing, operation, shipping, services, production systems, maintenance and value chains in the all aspects of the shipbuilding industry. Over the last few years, the fourth industrial revolution has spread in almost all industries. The whole world is talking about Industry 4.0 which has increased implication in the manufacturing process and the future of the work. The impact of the *Shipbuilding 4.0* will be significant. In the past, shipbuilding industry where continuously improved with new machines, software and new implemented organizational restructuring. In today shipbuilding industry, there are three main problems that are considered; production efficiency, the ship safety, cost efficiency and energy conservation and environmental protection. In order to create new value, the ship must become a Smart Ship capable of "thinking", and to be produced in Smart Shipbuilding Process. The aim of this article is a review of the present academic and industrial progress of this new industrial revolution wave in the shipbuilding sector called *Shipbuilding 4.0* (*Shipping 4.0, Maritime 4.0, Shipyard 4.0*). Reviewed publications were analyzed different topics and level of improvements in the industrial aspects of the society. The implementation of the Shipbuilding 4.0 in the shipbuilding industry, presents the future, creating new value in the process, creating new demands with reduction in production and operational cost while increasing production efficiency.

Key words: *Industry 4.0; Shipbuilding 4.0; Smart Ships; Smart Shipbuilding Process; Review of the online available publications; Shipyard 4.0*

1. Introduction

Industry 4.0 has been defined as "a collective term for technologies and concepts of value chain organization" which draws together Cyber-Physical Systems, the Internet of Things and the Internet of Services (Jasperneite J. "Was hinter Begriffen wie Industrie 4.0 steckt", Web magazine computer-automation.de, 19th December 2012.), but the Industry 4.0 concept has existed since 1991, since its introduction by Mark Weiser, [1]. He described the vision of the future with the term of "Ubiquitous Computing". From that period a lot of the things become reality as are smart mobile phones, cars as wheeled computer system, smart homes.

The first industrial revolution was introduction of water and steam-powered mechanical manufacturing, the second industrial revolution was the implication of electrically-powered mass production; the thirds industrial revolution was introduced to use of electronic and information technologies (IT) to achieve further automation of manufacturing, [2,3]. The Industry 4.0 is based on the Cyber-Physical Systems, it represents the mass customization of the products turned to the wishes of the customer with the implementation of the intelligent, smart and optimal solutions embedded in the products visible on the Figure 1, [4, 5].

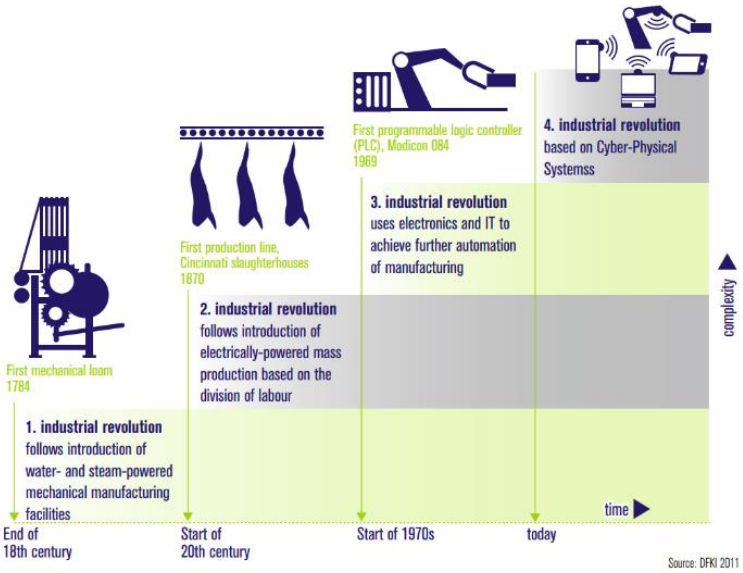

Fig. 1 The four stages of the Industrial Revolution, [2]

The Industry 4.0 is strategic initiative and it represents the synonym for the transformation of today factories into Smart Factories which will be capable to overcome the challenges of the product lifecycle, highly customized products and to stay in the race with ubiquitous competitors. The smart products from the Smart Factories are customized, identifiable and know their current status and target state, [2]. The whole concept is based on Cyber-Physical Production System (CPPS), Internet of Things, Big Data and Internet of Services and interaction of the real and virtual world, [6]. It presents development that changes the overall traditional industries and includes design, technology and innovation cycles which is seen as an important strategy to remain competitive in the future, [7]. The smart products from the smart factories will allow the "last minute" changes to the customer requirements. This dynamic business and engineering process enables the production, delivery and flexibility to disruption and failure during production. For the smooth functioning of the concept, it will be important horizontal and vertical integration through across the value chain, [2].

This paper will analyze, review of the new concept Shipbuilding 4.0 as the follow-up of the Industry 4.0 concept applicable in the shipbuilding industry.

The shipbuilding industry where continuously improved with new machines, software and new implemented organizational restructuring; but still is facing difficulties with large number of changes during construction and large number of ships series led to the loss of control over costs and quality control. The burden of the crisis submitted the shipyards that could not fully meet quality requirements, safety, cost efficiency and the shipbuilding market fluctuations. All above have generated losses.

The paper is organized as follows. Chapter 2 introduces the Industry 4.0 in Maritime Sector and changes in the shipbuilding industry while the Chapter 3 is presented Shipbuilding 4.0 the new industrial path. In the Chapter 4 is presented Shipyard 4.0 design principles and strategy. Chapter 5 presents an implementation concept, methodology proposal. Finally, there are conclusion and guidelines for the future research.

2. Industry 4.0 transformation in Maritime Sector and Shipbuilding industry

Industry 4.0 has strong impact on the worldwide industries and the all aspects of the human society. In this chapter will be presented its influence in Maritime Sector, and the transformation that will come in the shipbuilding industry. Figure 2 illustrates overall connectivity in the Cyber-Physical System of the Maritime 4.0.

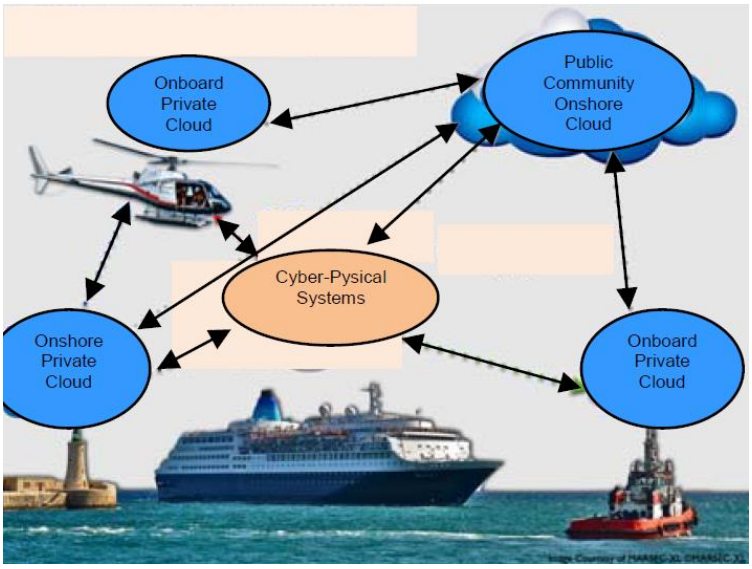

Fig. 2 Exchanging data via Cyber-Physical System, [2].

According to the Capgemini′s recent report, smart factories as the base of the Industry 4.0 will be adding up to 500 billion dollars in value to the global economy. Also, almost 76% manufacturers in the world already have some level of a smart factory initiative.

The main items of the *Industry 4.0* applicable in the Maritime Sector and supported industries are:

- Cyber-Physical systems,
- Big Data,
- Digitization of the Industry,
- Internet of Things,
- Internet of the Services,

- Strong and liable cooperation in the whole supply network,
- Human-machines, interaction,
- Production logistics with Cyber-Physical embedded system,
- Agile, digital, flexible production,
- Standardization,
- Changes of the demographic and cultural society,
- Significant changes in the education system.

Almost all mayor players in shipbuilding industry are preparing themselves for the changes that will come in next 10 to 20 years, and strongly working on their own steps toward fourth industrial revolution. In the history, the industrial revolution usually brings the strong changes in the all aspects of the human society supported by the governments:

- In the Germany:

  The official "Industrie 4.0" document was originally released in 2013 by the Germany Federal Ministry for Economic Affairs and Energy. Industry 4.0 (Industrie 4.0) keywords means a development that changes the traditional industries fundamentally, [7]. Almost 12 billion Euros will be invested into the innovations and turnover the shipbuilding industry in the Shipbuilding 4.0. With the high export rate of 74 per cent confirms the Germany the leader in the international marine equipment sector, [8]. According to the "Maritime Agenda 2025" and the "Study on Industrial and Technological Competences in the Naval Sector", the maritime industry has the annual turnover of EUR 18 billion, and abt. 70 to 80 percent of the value is added in the shipbuilding. The defense budget (military) is growing and the German naval shipbuilding is becoming the push industry for shipbuilding innovations in Shipbuilding 4.0 era.

- In the USA:

  American corporations founded the Industrial Internet Consortium (IIC), and five of them started with the increasing the market size of the Internet of the Things in the shipbuilding industry. In the US military shipbuilding was increased current shipbuilding goal from 308 to 355 ships per year. All the new vessels are more technologically advanced and complicated than any previous generation, faster and better than ever before. Also, the ships of the new generation will last longer and be more adaptable to changing the needs throughout their lives. Today US shipbuilding, especially the Navy, facing a tidal wave of increased demands; the NNS (Newport News Shipyard) shipyard is on his way to the Shipbuilding 4.0 digitization process. It is expected, that this approach will generate 15 percent more cost savings over the traditional shipbuilding methods, [9].

- In the China:

  The Chinese government in 2015. issued "Made in China 2025" the initiative strategy draws direct inspiration from Germany Industry 4.0. The plan is creating the innovation centers from 15 to 2020 year to 40 by 2025. Shipbuilding 4.0 in the Chinese shipbuilding industry is called 5S, a ships operation intelligent service system that features Sea, Ship, System, Smart and Services. The smart demo ship is highlighted priority development in "Made in China 2025", [10, 11]. This means ship status safety assessment, ship energy efficiency monitoring, analysis, assessment and optimization, status, assessment and maintenance optimization, sea route, ship navigation and operational control, all connected via Big Data. The delivery of the vessel is expected to be at the end of the 2017, [12].

- In the Japan:

  The Industry 4.0 idea had announced in 2014, but it is become official in 2016, with the joint declaration of future German-Japanese cooperation signed by two parties in Tokyo. According to the McKinsey & Co, Japan is behind the US and German in the researches. The Industry 4.0 in the Japan is named Industrial Value Chain Initiative (IVI), which is working on the collaboration of the companies, [13].

- In the Korea:

  Korean version of the Industry 4.0 is called "Manufacturing Innovation 3.0 Strategy" and is published in 2015. Also in 2015 as part of the new change in the industrial innovation, the Korea has launched an innovation center in the shipbuilding capital of Ulsan, Busan. Three major shipbuilders Samsung Heavy Industries, Daewoo Shipbuilding & Marine Engineering and Hyundai Heavy Industries will be in charge of the new Ulsan innovation center. It is expected to be abt. 25 hundred patents dedicated to building the smart ships in the smart shipbuilding environment based on the idea of the Shipbuilding 4.0, [14].

- In the Spain:

  In 2014 the Galicia started the Agenda for Industrial Competitiveness, as a tool for planning, industrial policy implemented by the Xunta de Galicia in the period 2015-2020. The ACLUNAGA (Cluster Association of Naval Galicia) is a collaboration of the Galician Innovation Agency - GAIN, IGAPE and AIMEN Technology Center has first started with the implementation of the Shipbuilding 4.0 in 2016. The Ferrol shipyard Navantia, Navy Company is a leader of the changes in the shipbuilding sector, [16].

- In the Australia:

  The digital transformation of the Shipbuilding 4.0 era started in the Adelaide Australian Navy shipyard. The transformation of the shipyard will start in 2018, by investment of 1.5 billion Australian dollars in the design and engineering to become the most advantages Navy shipyard in the world. Almost 100 million Australian dollars will be invested in information and technologies, [17].

The strong changes toward new industrial revolution in the shipbuilding industry are also in the level of the preparation phase in the Norway, Sweden, UK, France, Finland, and Brazil.

3. Shipbuilding 4.0 - new industrial path

The review principles in the article, analyses the overall progress of the forth industrial revolution in the shipbuilding sector named: "*Shipbuilding 4.0*", "*Shipyard 4.0*", "*Shipping 4.0*", "*Naval 4.0*", "*Maritime 4.0*", "*Smart Yards*", "*Smart Shipbuilding*". The keywords that are explicitly mentioned in the articles were carried out to provide a preliminary view of the Fourth Industrial Revolution in shipbuilding, shipping, vessel operation, progress of new shipbuilding standards, technologies and shipbuilding enabling features.

The world's shipbuilding industry at the beginning of the Fourth Industrial Revolution is at a historic turnaround. There were a lot of changes in the international shipbuilding industry that will be different compared to the previous three industrial revolutions. Some shipyards failed to follow the changes that were coming with the revolutions, but some shipyards were followed revolutionary changes and succeed to survive and make profit. The modern shipbuilding industry is expected to remain healthy in the future, especially in the market segments of higher added value and with larger sales value. All of these resulting on

the higher requirements for design, ship construction and operation which are crucial for success. The goal of *Shipbuilding 4.0* is intelligent shipyard which is characterized by adaptability, resource efficiency and ergonomic but also close integration between shipowner and shipbuilder with the crucial cooperation shipyards - suppliers, the partners in the business and value processes, [18].

In the 2013 the International Maritime Organization (IMO) introduced regulation, energy efficiency design index (EEDI), the regulation that defines the energy efficiency standard for the new ships (IMO 2016). Meeting the cap required from the shipbuilders and operator significant care to fulfill the requirement; all ships built after 2025 will be at least 30% more fuel efficient, [17]. Eco-friendly shipping and the energy efficiency are now the key criteria for the construction of the new ships, [19]. This involves almost all systems on the ships; it requests the environmentally friendly shipbuilding and progressive supplier solutions.

A major transformation is underway in the shipbuilding sector; from the shipowners, and fleet operators, it is requested to order and develop more energy-efficient, reliable and environmentally friendly ships with better overall performance and lower operating costs. Most of them requests from the shipbuilders to meet these requests and their challenges before signing the contract. Shipbuilders have to design and built ships faster and better than ever before. This requires a totally different approach to ship design and construction. The shipbuilders need to meet the shipowner expectations to have rapidly modernized the fleet with the energy efficiency systems solutions on the ship.

Shipbuilding sector needs to improve total enterprise collaboration, synchronization and productivity, as well as the lifecycle ship maintenance and support by optimization of the shipbuilding process. During the design of the new vessel, there are several tasks that need to be accomplished: achieving greater performance, lower ownership cost, higher fleet availability and reliability, and greater quality and compliance with the latest marine safety and regulatory requirements. The ships need to be easier to build and repair; it needs to be lowered ship construction, service and total ownership costs.

Today, especially European shipyards mostly building special type of the vessels, usually unique and highly complex, with the special requirements in term of the quality, safety and design and production. In the production of the new unique vessel, need to be designed state-of-the-art tools and designed processes. New type shipbuilding supports design and manufacturing trends that are moving toward higher creativity, lower cost, and better respond to the shipowner need, while at the same time preparing the on-demand production of optimal and intelligent solutions, [18, 20].

To give the best results on the Internet of Things revolution, the shipbuilders will have verified and trusted suppliers, linked with shipyard and service personnel with production schedules and 3D models of all aspects of the design. Shipbuilders need to benefit from the new innovative solutions to provide immediate access to just the right relevant data; and service teams will benefit from this data to the appropriate supply chain to reduce service and overhaul cycle times. There are quite a few challenges arising out of this, namely the need for new approaches in collaboration and transaction support in terms of bridge-connected to suppliers and subcontractors.

In Shipbuilding 4.0 era, the shipyards need to have skilled engineers, specialists in technical science, but also in IT science and all relevant technical data from successful ship classes. In the design phase, it needs to be minimized the design period, but also the engineering costs of future classes of ships. This holistic solution spans the entire shipbuilding enterprise and lifecycle to enable shipbuilders to integrate their organizational knowledge,

automate processes throughout the product lifecycle and improve efficiency, accuracy and execution to reduce time-to-delivery.

Several features need to be implemented in the Shipbuilding 4.0, [16]:

- Identification and classification of the shipbuilding standards,
- Internet networks,
- Wireless sensors,
- Software and hardware,
- Horizontal integration,
- Vertical integration,
- End-to-end integration,
- Smart services,
- Human-machine, interaction,
- Machine tool components,
- Safe and environmentally friendly production,
- Interoperability,
- Digital modeling technology,
- Virtualization,
- Visualization technology,
- Automation,
- Industrial internet,
- Cloud Computing,
- Big data,
- Flexibility (Plug-and-Work),
- Safety and Security (data privacy),
- Analysis of the practical solutions and industrial applications, still there is a lack of any,
- Training and Continuing Professional Development.

One thing is certain: the shipping industry is undergoing massive change. The “Digital Twin” concept is an example: The ability to reproduce ships digitally, and the use of drones fitted with high-tech cameras will reduce the effort involved in ship maintenance and mitigate safety risks", this was the words of Mr. Knut Ørbeck-Nilssen CEO of DNV GL Maritime on the Maritime Future Summit 2016 in SMM Hamburg. This was the first Summit, which gathers major players and decision makers in shipbuilding and shipping industry of the future. The mainly CEO′s were presented the latest themes and visions of the shipping and shipbuilding of the future of their companies and all of them are based on the idea of the Shipbuilding 4.0, Maritime 4.0, Shipping 4.0. All the speakers presented importance of the collecting and heaving data from the beginning of the design phase till ship delivery and operation in whole life cycle.

4. Shipyard 4.0 - design principles and strategy

The shipbuilding industry has a special attention of the governments, especially in the naval shipbuilding as the leader of the reorganizations and implementation improvements driven by the Shipbuilding 4.0 ideas. The sector of the Navy industry is the driver of development and innovations.

The Shipbuilding 4.0 raises the question of how the shipyards need to be changed, to survive in the market. What added value can be offered to the shipowners, but also how should the

shipyards need to organize the work, in order to survive in the transitional period of transformation and adaptation to the Shipbuilding 4.0, but at the same time survive among shipyards competitors from the Far East and the rest of the Europe. The opportunity lies in the digitization of the shipyard. The key to success is the availability, exchange and processing of relevant data and information overall in the shipbuilding process. This involves one of the most important thing; it is collected Big Data, but also standards, norms, traceability of the process with clear guidelines and control. Full implementation is still a long away, but the Shipbuilding 4.0 is a change of the whole working world, it changes the human society with new job definition and working processes. For the shipyards the digitization is chance for surviving. The most important thing for the shipyard is efficient production processes which are the main competitive factor. Today shipbuilding is characterized by single units or small series production.

Goal to survive is further simplification of the production processes and continuous improvement of the production quality, integrated digitized design, efficient purchasing and lean logistic, high quality of welding processes with the modular production method which pushing upward shipyards. In the situation when the shipyards are preparing the new ship contract, it is very important to design innovative solutions together and in the closer cooperation with the selected bridge-connected suppliers.

For the overall project success is also crucial good cooperation between shipbuilders and shipowners, what brings several benefits: lean, flat point of contact, minimization of the coordination, conflicts and the disagreements are simplified, the risk of loss of the profit is reduced, [18]. With the new close cooperation between the shipbuilders and suppliers, in the very early design phase need to be defined main ship and production systems: energy and fuel saving solutions, main engines and propulsion systems, ship design and hull optimization, machinery, public spaces, technical areas, cabins, deck machinery, but also shipbuilding equipment, surface preparation, welding and preliminary building technology.

During the early definition of the project, the shipyards need to follow green shipping solutions, climate and environmentally friendly solutions and maritime safety technologies which require extensive maritime expertise and knowledge. In the Germany, as the leader of the new industrial revolution innovations, for the shipbuilding sector, the state budget has been increased to 25 million euro for the 2016 year, almost 7.5 million euro more than 2015 year, (Dry dock Magazine, 2016.).

The digitization of the design and ship construction makes the pillars of the overall digitization, which promotes Shipbuilding 4.0, but requires further development of:

- Process optimization,
- Standardization,
- Digital interconnectivity,
- Optimization of information flow,
- Interfacing the material management and information management within the entire supply chain.

The idea of the overall digitization in shipbuilding industry is visible on the Figure 3.

Fig. 3 Digital Future of the Shipbuilding industry, [21].

Availability of the collected digital data from basic design to ships operation in the digital Shipbuilding 4.0 will be essential. Discontinuities in the data flow will affect in loss of profit. Shipbuilders need to prepare the procedures provided by the suppliers to create a standardized, unified, coordinate infrastructure for design, production and maintain the ship. In case of lack of real-time collaboration opportunities for discovery of the design options that could improve a ship capability, accelerate its construction and reduce costs, [21].

5. Shipyards 4.0 - case study/implementation concept proposed methodology

The shipyards in the era of Shipyard 4.0 will use the power of algorithms to rely on their ability to predict the future in the digital world of big data, machine learning and predictive analytic. The shipyard needs to use the algorithms and simulations and their ability to derive from the mass of data produce information that humans can follow and understand. Generally speaking the algorithms allow having knowledge of the future results from the collected data, [21, 23].

The shipyards of the future constantly looking for the new ways to use virtual methods for engineering and commissioning and virtual support. The Smart Shipyard in the era of the Shipyard 4.0 via Cyber-Physical Systems will be organized as integrated, flexible, efficient, green, production process. The real time quality control in self-optimized and autonomous system, [23]. This is especially important for the shipyard there were turned into building special purpose vessels. In the contractual phase, there is a lot of the new requirements for the specific structural needs also adjusted and customized shipbuilding processes and operational conditions, [24]. Usually this period is always too short for the designers and is creating high cost pressure to high demands on the quality. Balancing this act will reinforce in the Shipyard 4.0 by promoting innovative and modern methods that will meet the challenges, [22].

One of the first published results of the Shipyard 4.0 implementation presented as a result of the cooperation between University of Coruña (UDC) and Navantia Spain Navy shipyard. With this cooperation has been designed the Smart Pipe System for monitoring, identification, traceability of the pipes used in the ship construction in the shipyard. The research result shows the implementation of the UHF Radio Frequency Identification (RFID) technology as the foundation of the CPS system in the Shipyard 4.0 era. The presented concept improved the

smarter energy consumption, efficient pipe logistic and shipyard production, usability of the shipyard facilities and real-time yield optimization, [16]. Some of the largest European shipyards from Italy, Spain, Germany, Finland started with the implementation of the Shipyard 4.0 concept. Implementation concept is different in every shipyard according to the present technological level and financial the possibility of the investment in the research and development in this concept.

In this article also have been analyzed the research done on the Faculty of Electrical Engineering, Mechanical Engineering and Naval Architecture in Split, 2016 year, named the project "*INSEN - Croatian innovative company*", [25]. The scientists from the Department of the Industrial Engineering, were researched, which degree of development have the Croatian industry, and what is the level of the industrial development in the respect of the Industry 4.0. This research is very important for the interviewed companies as potential future bridge-building suppliers of the Croatian shipyards. Beside the interviewed companies in the research were also included university experts. The results showed Croatian industrial companies on the level of the *Industry 2.15;* it is visible the long way for the Croatian industrial companies toward the Industry 4.0. The scientists from the Department of the Industrial Engineering started with the design of the "*INSEN - Model of the innovative company*", it represents the Smart, innovative factory adapted to the Croatian industrial environment, and the Croatian industrial way toward to Industry 4.0. With the solid foundation in the Croatian industrial environment dedicated to Industry 4.0, is the possible progress of the Croatian Shipbuilding Industry toward Shipbuilding 4.0.

If the Croatian shipyards want to become the digital shipyards of the future, very important role will be dedicated to the suppliers who will be included in the simulation modeling of the innovative ship system solutions. According to the concept of Shipyard 4.0, a modern shipyard will have an outsourcing ration of more that 80% of the contract value and there is a strong demand for sophisticated interfacing and integration of external sources into the shipyards own project management, [22].

In that respect the interconnection, digitization and integration of the whole industry will have a direct impact on this industrial revolution in Croatian shipbuilding industry.

On the "*GALP - Green and Lead production conference*" held in November 2017 in Zagreb has officially presented a government strategy, for the digitization of the Croatia industry. It was presented "*Digitalizing Impulse 2020 - National platform of the Republic Croatia*" with the strategy for digitization of the overall Croatian society, [26]. Today's reality is present as the *CRO Improve Card 2017* visible on the Figure 4.

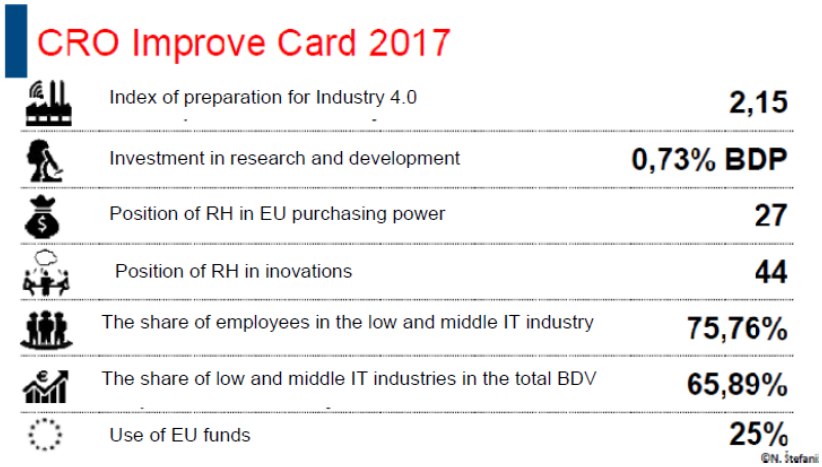

Fig. 4 CRO Improved Card 2017, [26].

Plan for digital transformation of the Croatian society and industry in period from 2017 to 2020 is visible on the Figure 5.

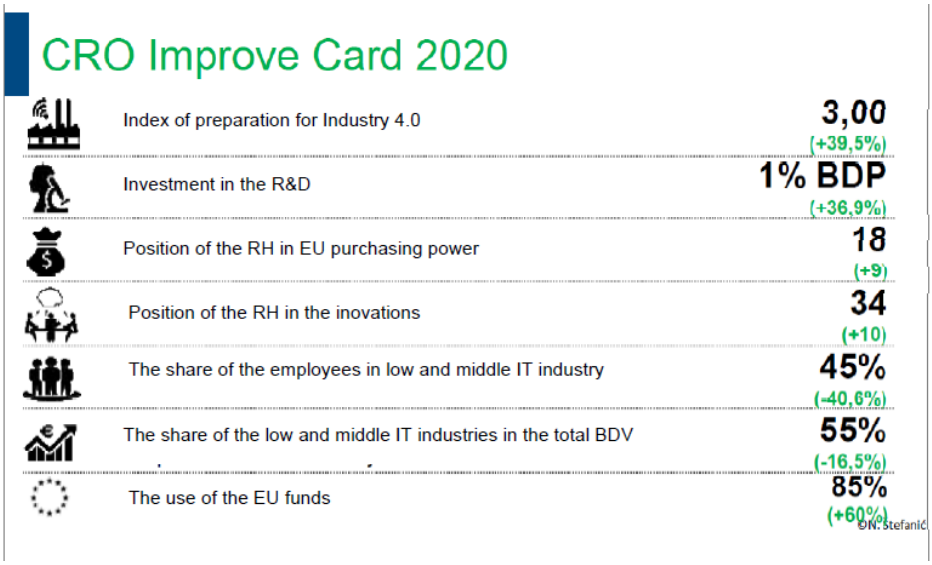

Fig. 5 CRO Improved Card 2020, [26].

What brings about digital transformation and how the change business processes and model are presented on the "*Digital Revolution Conference* "organized by the Croatian Employers Association and sponsored by the Ministry of the Economy, held in February 2018 in Zagreb.

On the conference is presented the plan for the digitization of the Croatian society and the several key goals are presented:

1) Improving the regulatory framework for encouraging innovation and investment in the context of the EU's single digital market,
2) Creating new business models for small and medium-sized businesses,
3) Encourage the development of research and innovation in digital technologies,
4) Developing gigabit networks as the core Internet infrastructure of Things,
5) Cybernetics and data security,
6) Enhance the education of digital skills for all ages,
7) The implementation of Industry 4.0 concepts in selected industry sectors.

This plan for the digitization of the Croatian industry have to include also the shipbuilding industry to stay in race forward Shipbuilding 4.0.

Most of the Croatian shipyards have turned into the building of the special purpose vessels. Croatia has long shipbuilding tradition, good geostrategic position, scientific and education system, and a lot of suppliers which can adopt their production system to the good and strong connection to the shipyards. According to the Croatian Shipbuilding Corporation, the shipbuilding sector is still one of the most important industrial sectors of the Republic of Croatia, by its share in the employment (2%-5% with the subcontractors up to 10%), by its GDP share (0,8%-1,8%) and by the exports (10%-15%), [27]. The Croatian Shipbuilding Corporation (CSC) held in Zagreb was established by the Croatian Government in 1994, as the cooperative organization covering the coordination of the Croatian Shipbuilding Industry on the international shipbuilding market. The main CSC's tasks are to provide expert

monitoring of the restructuring process and modernization program of four largest Croatian shipyards:

"Uljanik" shipyard, "3. maj" shipyard, "Brodotrogir" shipyard and the "Brodosplit" shipyard.

The Croatian shipbuilding industry operates both on domestic and international market and export orientation is the dominant feature.

"Uljanik" shipyard is located in the Pula, founded 1856. From that time from the shipyard were delivered over 200 newbuildings. This shipyard designs, constructs and builds all types of the ships; from the ships for transportation of oil products, bulk cargo, containers, cars, passengers. Last technological rebuilding has been done in 1998. Since then there have been no comprehensive improvements in the shipyard technological production process. The industrial level is abt. 2.15. The number of the employees 2659.

"3. maj" shipyard is located in Rijeka, founded 1892 year. This shipyard designs, constructs and builds all types of the ships; from the ships for transportation of oil products, bulk cargoes, cars. Last technological rebuilding has been done in 1998. Since then there have been no comprehensive improvements in the shipyard technological production process. The industrial level is abt. 2.15. From 2013 year shipyard has become integrated in "Uljanik" shipyard group.

"Brodotrogir" shipyard is located on the island Čiovo, by the Trogir, founded 1944 year. The product range includes tankers, floats, passenger ships, tugs and rescue vessels manufactured for the domestic market or exported. Last technological rebuilding has been done in 1998. Since then there have been no comprehensive improvements in the shipyard technological production process. The industrial level is abt. 2.15. It was privatized in 2013 by the Kermas Energija Company. The number of the employees 341.

"Brodosplit" shipyard, the largest Croatian shipyard is located in the Split, founded 1922 year. They have delivered about 350 vessels, with a total deadweight of over 9 million tons, including many tankers, both panamax and non-panamax, as well as container ships, bulk carriers, dredgers, and passenger ships. 80% of the ships built are exported to foreign contractors. Last technological rebuilding has been done in 1998. Since then there have been no comprehensive improvements in the shipyard technological production process. The industrial level is abt. 2.15. It was privatized in 2013 by the DIV Company. The number of the employees 2300, [27].

The companies analyzed in the article are the Croatian companies dedicated to the design and production of the ship equipment as being: deck machinery, diesel engines, transformers, electric motors, navigation system, loading computer, cranes. The industrial level of the companies are 2.15 still far from the level of the Fourth Industrial Revolution.

The branch of Industry represents a significant source of employment for the shipyards and the small and medium size companies, suppliers as the subcontractors with their operations and the services to the shipyard.

To fulfill all design and production requirement and regulations the new innovative solutions, the sector has to transform into "*integrated digital shipyard*". The pressure to balance high demands on the quality for lower cost, while on the other hand shipyard need to build the ship faster, better, safer with the lowest cost for the shipowners. So it has to be used with the latest advances (robotics, 3D printing, augmented reality of the Industrial Internet of the Things (IIoT)). This new concept has to turn to the shipowners needs, and it is very important that the shipyard is capable to enable the process with the dynamic engineering and flexible, adapting to errors cause by the design and production shipyard process or the suppliers.

The Croatian shipyard will adopt the Shipyard 4.0 model customized for the Croatian specific conditions.

The Shipyard 4.0 model merges the shipbuilding process with the enabling technologies as is:

- Robotic process automation,
- Virtual and augmented reality,
- Virtual modeling and simulation,
- 3D modeling, digital twin,
- Additive manufacturing,
- Big data and analytics,
- Ubiquitous connectivity and The Internet of Things,
- Secure cloud,
- Cyber security,
- Health, safety and environment,
- New materials,
- Artificial Intelligence,
- Autonomous vehicles.

Based on the available results of research and analysis of Croatian shipyards compared to the several European shipyards from Italy, Spain and Germany, Industrial level 3.2 (shipyard experts estimation), which are working on the implementation model of the Shipyard 4.0 concept; in order to achieve the proposed objectives, the following four preliminary phases of the Shipyard 4.0 implementation methodology to be applied, [28, 29]:

5.1. Phase 1: Definition of the problems and the implementation goals

This phase involves the introduction of the shipyard facilities, processes, material and information flow that will be prepared/evaluated, collected for the detail definition of the goals and deadlines.

1. Definition of the problems in the process and causes, it needs to be clearly defined what are the problems of the existing shipyard production process, what are the causes and what need to be improved,

2. Definition of the goals and level of the implementation that need to be achieved, clearly definition of the improvements, what is expected from the implementation of the new Shipyard 4.0 shipbuilding processes,

3. Definition of the responsibilities, deadlines; flow chart with clearly definition of the responsibilities and the implementation time frame deadlines.

As part of this phase are usable different types of the flowcharts, diagrams and modeling and simulation software tools. In the era of the digitized integrated shipyard of the future is visible usage of the huge number of the IT solution dedicated to the specific part of the production process integrated in the Big Data.

The four phases of the proposed implementation methodology are visible on Figure 6.

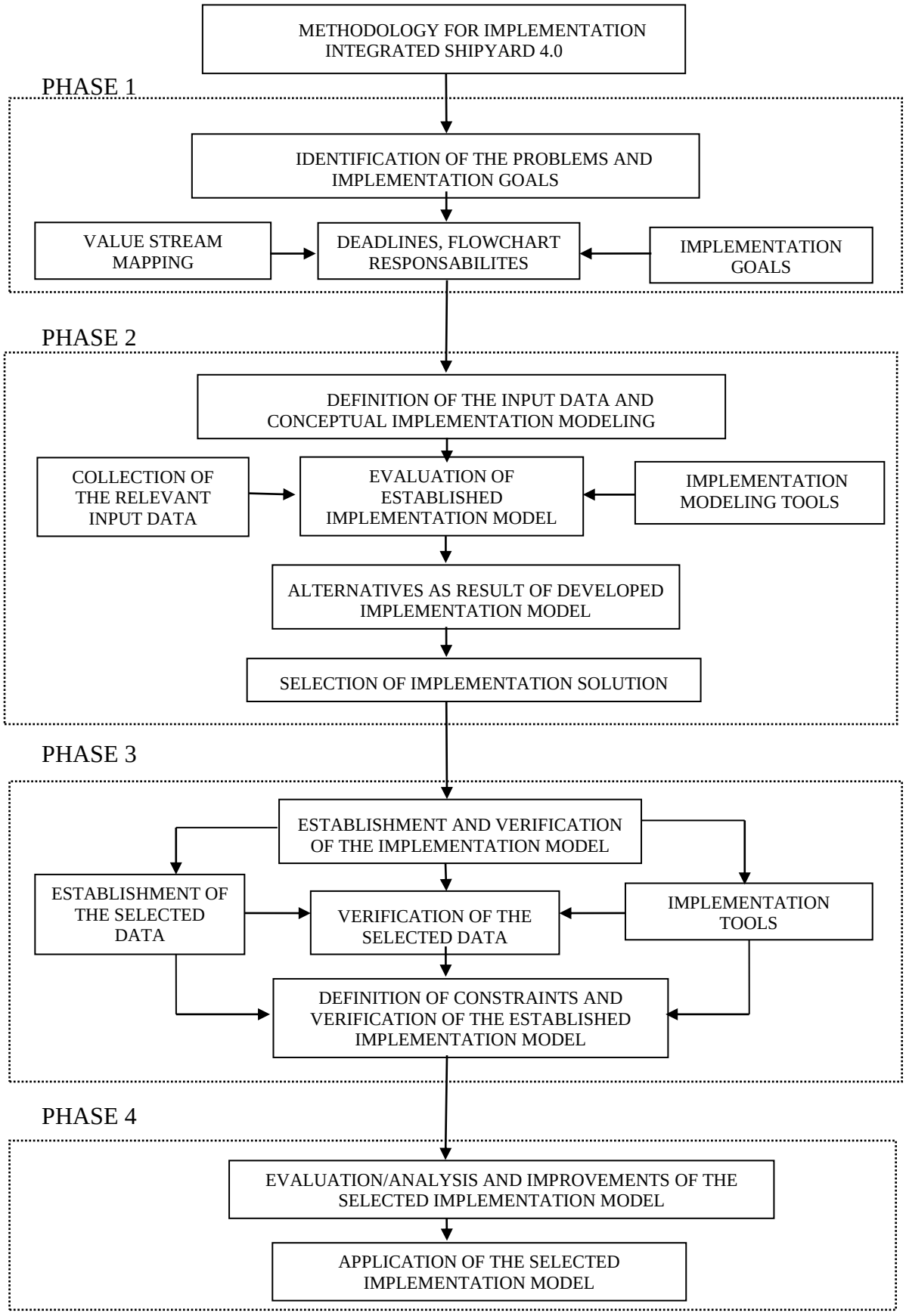

Fig.6 Proposed methodology for the Shipyard 4.0 implementation model

5.2. Phase 2: Definition of the input data and conceptual implementation modeling

The main objectives of this phase are the preliminary design of an implementation model according to the collected relevant input data, evaluation of the conceptual implementation model.

The tasks of this phase are:

1. Definition and preparation of the input data and preliminary implementation model;
2. The preliminary design of the implementation model for the future shipbuilding process, it is started with the design of the digital implementation model for the new shipbuilding process with the selected implementation modeling tools,
3. Evaluation of the alternatives as a result of the developed implementation modeling.
4. Selection of the implementation model/solution.

Method and tools used in this phase is CAD, 3D modeling tools, simulation modeling tools, PLM, flowchart tools.

5.3. Phase 3: Establishment and verification the implementation model

The main objectives of this phase are the establishment and verification of the implementation model of the new shipbuilding process.

The tasks of this phase are:

1. Identification and systematization of the collected data, evaluation of the sorted selected data,
2. Establishment of the selected data and preparation of the implementation tools,
3. Verification of the collected, selected data in the implementation model,
4. Definition of the constraints; elimination of the errors from the implementation model.

Method and tools used in this phase is CAD, 3D tools, simulation modeling tools, PLM, flowchart tools, methods of the decision making.

5.4. Phase 4: Evaluation / analysis and improvements of the selected optimal implementation model.

The main objectives of this phase are the evaluation, improvement of the selected implementation model of the new shipbuilding process.

The tasks of this phase are:

1. Evaluation and analysis of the selected optimal implementation model,
2. Improvements of the selected optimal implementation model,
3. Recalculation and recheck of the functionality of the selected model,
4. Application of the selected implementation model.

The results of the proposed methodology will be visible after shipyard case study implementation as the further research.

Preliminary assessment of the time frame for the proposed methodology application in the one of the Croatian shipyard presented in the Figure 7.

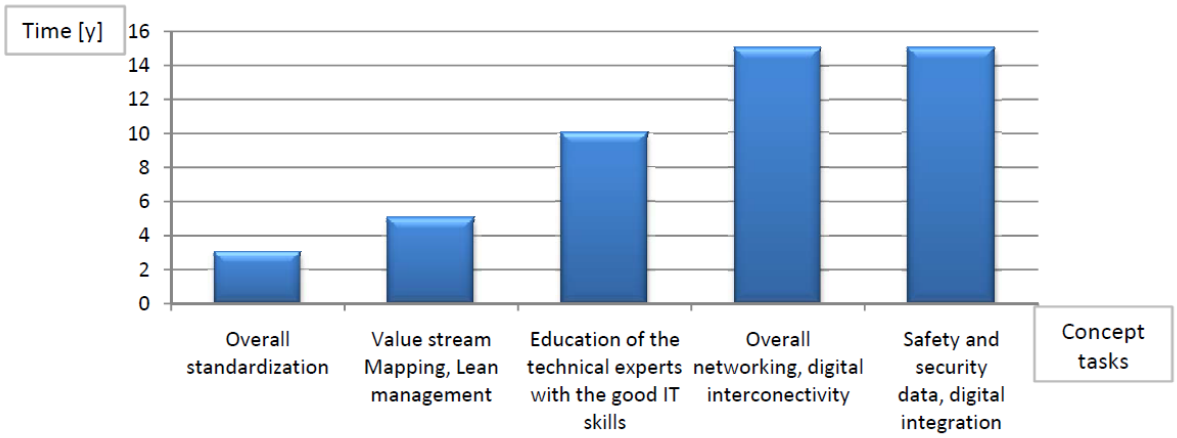

Fig.7 Preliminary assessment, implementation time frame

Preliminary assessment concept items to be applicable in the case study shipyard:

1. Preparation of the shipyard and the shipbuilding standards necessary for the safe flow of data and information,
2. Preparation the Value Stream Mapping of the production process, the Lean management. The shipyard needs to use resources, in the less time with the higher productivity, to have satisfied customer and more satisfied employees. During this production process the analyzed shipyard has already made some steps toward savings the electric energy. Some workshops use the sensors for the automatic turning down the power during the third shift and during the weekends, [28],
3. Strongly raising the level of the knowledge and skills of the employees to work in the digitized industry. As it is currently happening in the car industry, there is a need for the highest level of formal university education. The future shipyard will request to have technical experts with the very good IT skills,
4. Overall, networking and digital connectivity through the whole ship building process from design, purchasing, planning, financing, production by using wireless technologies. Shipyard need to develop new adopted model that will be capable to operate in the digital shipbuilding industry,
5. Safety and security of the exchanged data and information. Digital integration of the overall shipbuilding sector; integration of the shipyards, suppliers, operators, classification societies and port operators. In the interconnected integrated shipyard is crucially had the safe and in time exchanging information.

6. Conclusion

Today, the whole world is working on the fourth industrial revolution, Industry 4.0. All industries searching the possibilities for changes and improvements, so as the Croatian industry with the strategic program for implementation of the digitization of the society and industry. In 2015 year, almost all huge players in the shipbuilding industry started to research the methods for the implementation of this new revolution as the Shipbuilding 4.0.
In the article was presented review of the Industry 4.0 and the way how it is changing the shipbuilding industry as the Shipbuilding 4.0. It was analyzed overall changes in the world shipbuilding industry and finally the changes and preliminary methodology for the implementation of the Shipyard 4.0 implementation model in the Croatia case study shipyard.

For the further research it will be analyzed application of the proposed methodology in the selected Croatian shipyard.

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REFERENCES

[1] Weiser A., 1991, The Computer for the 21st Century, Sectific Ubicomp Paper after Am editing, Scientific American, Vol. 265, No. 3, SPECIAL ISSUE: Communications, Computers and Networks: How to Work, Play and Thrive in Cyberspace, pp. 94-105.

[2] Kagermann. H., Wahlster W., Helbig J., 2013. "*Recommendations for Implementing the Strategie Initiative INDUSTRIE 4.0*", Report Berlin: Industrie 4.0 Working Group of Acatech, Germany.

[3] Drath R., Horch A., 2014. "*Industrie 4.0: Hit or Hype*?" IEEE Industrial Electronics Magazine 8 (2): 56-58. https://doi.org/10.1109/MIE.2014.2312079

[4] Alfredo A., Li Y., Chen W., Zhan Z., 2015. "*Industry 4.0 with Cyber-Physical integration: A design and manufacture perspective*", 21st International Conference on Automation and Computing (ICAC), Glasgow, UK.

[5] Merkel, A., 2015. in Börsenzeitung Die Welt wartet nicht auf uns. Retrieved on https://www.boersenzeitung.de/index.php?li=1&artid=2015070049&titel.

[6] Lee Jay, Hung K., Shanhu Y., 2014. "*Service Innovation and Smart Analytics for Industry 4.0 and Big Data Environment*", Procedia CIRP 16:3-8.

[7] Manhart, K. 2015. "*Potenzial für den Mittelstand. Industrie 4.0 - Die nächste Revolution*?" retrieved on: http://www.tecchannel.de/itstrategie/2077662/industrie_40_die_naechste_revolution/.

[8] VDMA, 2015. German Maritime Industry investing heavily for its future - Chinese shipbuilding important technology partner, Shanghai, China.

[9] Digital Mariner, 2017. "*Shipbuilding 4.0: the digital thread in shipbuilding technology*", Siemens Enthusiast, http:// community.plm.automation.siemens.com.

[10] Kennedy S., 2015. "Made in China 2025", Center for Strategic & International Studies, http://csis.org/analsys/made-china-2025.

[11] Yuyang L., 2014. "Big Data herald era of smart ships", China Economic Net, China.

[12] China State Shipbuilding Corporation (CSSC), 2015. CSSC Developing a Smart Ship for the Future, Shanghai, China.

[13] Business Sweden Tokyo, 2017. "Seizing Industry 4.0 opportunities in Japan", Opportunities & Barriers to implementation of Industry 4.0 in Japan, Stockholm, Sweden.

[14] Hyundai Heavy Industries (HHI), 2015. Hyundai Heavy Industries and Ulsan Metropolitan City Opens Center for Creative Economy & Innovations, Shipbuilding News, Korea.

[15] US Energy Information Administration (EIA). 2017. "*International Energy Outlook 2017*"; U.S. EIA: Washington, DC, USA.

[16] Fraga-Lamas P. at all, 2016. "*Smart Pipe System for a Shipyard 4.0*", Sensors, Spain.

[17] Hughes D. 2016, "Shipping Commits to CO_2 Roadmap", The Business Times, Singapore.

[18] Hribernik K., 2016. Industry 4.0 in the Maritime Sector, SEA, Tokyo, Japan.

[19] Ang J.H.; Goh C., Li Y. 2015, „Key *challenges and opportunities in hull form design optimization for marine and offshore application*", In Processing of the 21st International Conference on Automation & omputing, Glasgow, UK.

[20] Zühlke D., 2005. "*Smart Factory KL, Pioneer of Industrie 4.0*", Technologie - Initiative Smart Factory KL e.V., Germany.

[21] Siemens, 2016. https://www.siemens.com/press/pool/de/events/2016/processindustries-drives, SMM2016, Hamburg, Germany.

[22] Polzer J., 2016. Ship building Activities and Business Potential at North German Shipyards, Turku, Germany.

[23] Hock J., Goh C., Li Y., 2016. "Smart Design in a Smart Production Through-Life and Industry 4.0 Environment", Conference: IEEE World Congress on Computational Intelligence (IEEE WCCI '16), At Vancouver, Canada.

[24] Wang S., Wan J., Zhang C., 2015. Implementing Smart Factory of Industrie 4.0: An Outlook, International Journal of Distributed Sensors Network, Volume 2016, Article ID 3159805.

[25] Veža I., Mladineo M., 2016. "INSEN- Projekt inovativno pametno poduzeće ", FESB, Split, Croatia.

[26] Štefanić N., 2017. "Lean & digitalna tranformacija industrije i usluga", GALP, Zagreb, Croatia.

[27] Croatian Shipbuilding Corporation, 2017. Zagreb, Croatia, */hb.hr/*, Zagreb, Croatia.

[28] Stanić V., Hadjina M., Fafandjel N., 2015. "*The Industry 4.0 concept and it's application in the shipbuilding process*", IN-TECH 2015, Dubrovnik, Croatia.

[29] Stanić V., Fafandjel N., Matulja T., 2017. "*A Methodology for improving productivity of the existing shipbuilding process using modern production concepts and the AHP method*", Brodogradnja publication, Volume 68 Number 3, Croatia.

Nomenclature

The following abbreviations are used in manuscript:

BD - Big Data
CC - Cloud Computing
CPS - Cyber-Physical Systems
CPPS - Cyber- Physical Production System
DT - Digital Twin
IIT - Industrial Internet Consortium
IoS - Internet of Services
IoT - Internet of Things
IVI - Industrial Value Chain Initiative
VDMA - Verband Deutscher Maschinen- und Anlagenbau
5C - Connection, Conversation, Cyber, Cognition and Configuration

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