Operator’s skills and knowledge requirement in autonomous ships control centre

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ABSTRACT

The autonomous ships will be navigating and controlling through the Remote Control Centre (RCC). The purpose of present paper is to identify the certain job requirements, job characteristics, experience requirements of operators in these centers, and it is assumed that two experts or operators (navigation and engine operator) should take charge of the maritime operations of autonomous ships at the RCC. The operators job analysis has been carried out based on the O*Net content model. The results of data analysis showed that the operators of the RCC should have worker requirements such as the ability to use logic, reasoning, thinking and scientific methods and the selection and implementation of appropriate learning strategies. Also experience requirements such as: In-service training, experience in autonomous ships, having a maritime competency certificate and on-side training are important. The navigation operator must be familiar with the passage planning by ECDIS and the principles of electronic navigation. Also, the engine operator must be aware of the knowledge of hydraulic and pneumatic principles and the knowledge of ecology and environmental protection in order to perform his/her duties.

Introduction

There is no doubt that progress and innovation in the maritime industry is happening in parallel with other industries. One of the innovations in the maritime industry is the introduction of autonomous ships. Thus, the growth and diversity of maritime activities have led to an increase in the development of threats, which also affects human elements. These threats may be on issues such as; navigation, collisions avoidance, terrorism, illegal immigration, traffic, pollution, and environmental threats (Cristina, Barsan, and Sutugiu 2012). AS are supposed to be navigated, controlled, and monitored by operators through the Remote Control Centre (RCC). In addition to the weather and environmental conditions, these operators have access to some information about the condition of the ship and its performance parameters. The overall system configuration for Autonomous ships is shown in Figure 1.

According to MUNIN European project, the shore control centre recognises supervisors, captains, engineers, and operators (Lutzhof et al. 2019). Ship owners and shipping companies prefer conventional ships to unmanned ships, because they want to retain the crew, and reduce the volume of work on board, and also use automation in crew offload operations (Ramos, Utne, and Mosleh 2018). Furthermore, changing operations from onboard ship approach to remote control brings new human factors issues (Kim and Mallam 2020). These include skills, abilities, knowledge, and education and training of operators in the RCC. Through job analysis, important information about Worker, Experience Requirements and Job Characteristics can be achieved. In the face of declining seafarers, it will be important to develop competency standards for coastal operators of such vessels and provide relevant training. According to International Convention on Standards of Training, Certification and Watchkeeping for Seafarers (STCW), operators must comply with authorized conditions. New competency standards also need to be considered in the STCW Convention or New Knowledge, Perception and Skills (Brannick et al., 2007). Because the present study is going to identify the skills and knowledge required by the coastal operator, it can play an important role in the development and amending of the STCW Convention in future.

Human resource professionals and consultants describe job analysis as the key process for many human resource functions, such as, employment and performance appraisal. Job description and analysis are essential for any business, so they can ensure that the right people are employed. They also help different companies to assess the competence of job applicants in the organization. Therefore, the issue of the job description and analysis should be done correctly because this accuracy, in turn, affects the quality of...
Figure 1. The overall system configuration for autonomous (Sun et al. 2018).

human resources (Bessen 2015; Smith, Benson, and Hornsby 1990).

Recently, researchers’ and media attention has been attracted towards the impact of technological change on employment, re-needs, and general concepts about the future world of work (Cedefop 2018; World Economic Forum 2016). Technological changes will definitely affect the future needs of the labour market. Recent EU data shows that about 43% of employees adults in the EU labour market have experienced technological change in their workplace over the past five years (Wahlström et al. 2015).

Technological change is taking place in almost all industries. The common goal of all these changes is to improve safety, increase economic profitability, and increase productivity. One of the major technological changes in the maritime industry is the issue of unmanned or autonomous ships. Many companies and institutions that specialise in these types of ships, almost all, agree that the development of these ships will be helpful in providing sustainable, safe, and efficient transportation (Jeanneret and Strong 2003). The human capital in developed and developing countries is considered very important because we of globalization, intense competition, technological development, and innovation. In addition, the business environment is changing rapidly and there are new requirements for staff competencies and new ways to increase productivity.

Thorough understanding of autonomous ships operation and their relationship with the RCC, the job nature and characteristics will be determined and sufficient information achieved. In other words, through this process, it is possible to find out what skills, knowledge, and abilities are required for the operators in the RCC. As a result, Worker and experience requirements and job characteristics will be determined through the job analysis process. O*Net content model can be used for job analysis. This model can provide a lot of information, such as meaningful and reliable information for a wide range of jobs. It also provides valuable information to meet the needs of human resource management, such as; provides job creation, development of job skills standards, determination of qualification conditions, and determination of job opportunities or training needs for employees (Dybvik, Veitch, and Steinert 2020).

To analyse the job, two operators or experts are involved in the operations of the autonomous ships. One will be the navigation operator, which is responsible for all aspects of navigation and monitoring, and the second will be the engine operator, which will be responsible for monitoring, controlling, and troubleshooting the ship’s engine. This assumption is based on the idea that each of the above responsibilities is very broad and that one person cannot be used in the RCC.

A research by Kim & Mallam (Brannick et al., 2007), on Maritime Autonomous Surface Ships (MASS), showed lack of understanding of the consequences of leadership in autonomous shipping. Assessment of the applicability of the current STCW leadership requirements for MASS operations and identification and prioritisation of the leadership competencies were also part of their study. The results showed that the current STCW framework is not entirely relevant to MASS.

Dybvik et al. (Deling et al. 2020) studied the challenges of designing and developing SCCs through semi-structured interviews with the research and industry community. They discussed the tasks, functions and interactions expected in the SCC along with unknown skill requirements of SCC operators. They stated that the skill requirement for operator has remained largely unknown. Although research is currently underway to develop SCC curricula, it has emphasised on learning framework hypothesis rather than the development of a tested and validated curriculum. Undoubtedly, the skills required for SCC operators are quite
different from the skills of traditional seafarers. During the early stages of development, a trained seafarer with the necessary certifications in navigation and watchkeeping should be employed. Operators are trained in the basic skills required for the job only in the legal and regulatory adjustments for SCC competence needs.

Deling, et al. (Mallam, Nazir, and Sharma 2019) have researched on major future challenges related to Maritime Education and Training (MET) in the Marine Autonomous Surface Ship (MASS). They suggested the Knowledge required for updating future MET curriculum as per Table 1.

Lutzhoft, et al. (Ramos, Utne, and Mosleh 2018), in the HUMANE project, examined humans interaction with the technology of autonomous ships in different scenarios with the objective of finding potential gap between current human skills, education and training, and the future of autonomous shipping. They used expert workshops methodology with focus group. They concluded that it is not only the skill thought to be very different from today's skills, but it also includes many contradictory and sometimes demanding elements of abilities that humans do not have, and is unlikely to evolve.

Mallam et al. (Yaghmaie 2003) studied use of autonomous systems and their impact on work and system processes. They identified four main issues of Trust, awareness and understanding, control and training, and work organization, related to the human elements and autonomy in complex safety systems. They argued that, because of automation, future maritime operators (in the SCC) progressively redirect toward supervisory roles, physically separated from sharp-end operations. As different maritime skills have changed with development of technology, traditional maritime skills have become unnecessary and obsolete.

Same as with any other new technology, operation and control of autonomous ships will be associated with some issues. This research studies the operator skills and knowledge requirement in Autonomous Ships Control Centre, with special reference to the job analysis.

**Materials and methods**

To conduct this research, a structured questionnaire is prepared with the main factors were selected from the O*Net content model, but the indicators were collected from both the model and the experts opinions. It consist of five main sections, demographic information, questions measuring perception on workers requirements in the RCC, job requirements (navigation operator), job requirements (engine operator), and experience requirements. The Likert scale was used to score questions. The questionnaire was distributed among statistical samples by sending an email or an independent Google form link.

The statistical population of this study includes university researchers, such as from Delft University, Norwegian University of Science and Technology, Hull University, and Gdynia University. Those researchers have done valuable research on the concept and employment of autonomous ships. The total number of statistical population involved was approximately 128, and based on Cochran's formula, sample size of 96 was calculated.

Data analysis carried out, using Kolmogorov–Smirnov, Friedman, chi-square, Pearson, and Spearman tests. The Kolmogorov–Smirnov test used to check distribution of the data. Since one of the goals of this study is to rank variables, so the Friedman test is used. Spearman and Pearson correlation coefficients also measure the level of significance and linear correlation between two random variables.

The questionnaire validity measured by expert’s opinions. In order to determine the content of the questionnaire, it was distributed among 11 experts in the field of autonomous ships, with 8 feedback received. The validity assessment done be EXCEL. The Content Validity Index (CVI) and Content Validity Ratio (CVR) was calculated.

According to the responses (72.7% of the respondents) to the validity and reliability questionnaire, the minimum reliability value of 0.75 is to be accepted. This means that if the value of CVI and CVR is less than the set acceptance point (0.75), the question should be removed from the questionnaire (Mumford and Peterson 1999).

Internal consistency carried out by measuring reliability of the questionnaire calculated by Cronbach’s alpha test. Table 2 shows the reliability coefficients for 4 variables of the research questionnaire, which are above 0.70, in an acceptable level.
Table 2. The reliability coefficient of the questionnaire variables.

| Variable                   | Number of Questions | Cronbach’s alpha | Questionnaire source                      |
|----------------------------|---------------------|------------------|-------------------------------------------|
| Worker Requirements        | 18                  | 0.896            |                                            |
| Job Requirements (Navigation) | 17                  | 0.704            |                                            |
| Job Requirements (Engine)  | 13                  | 0.822            | Based on the O*Net model and experts      |
| Experience Requirements    | 13                  | 0.826            |                                            |

O*net content model

The occupational information network or O*NET is a classification supported by the United States Department of Labour. The Job Information Network aims to replace the culture of job titles by providing an automated database and a set of tools ready for use to collect, describe, store, and disseminate reliable and professional information (Sanchez and Levine 1999). The latest aspect of O*Net is the use of “multiple windows” or descriptive types of details that can be used for a variety of issues. To facilitate job descriptions across the economy, O*Net developers have selected job descriptors that can be used to describe multiple jobs on specific job traits (Onetcenter.org 2018). Figure 2 shows parts of the O*Net content model.

The O*Net provides meaningful information to meet human resource management needs, such as; provides job creation, development of job skills standards, determination of qualification conditions, and determination of job opportunities or training needs for employees. In addition, the information available on this network can be used to describe job descriptions and groupings (Dybvik, Veitch, and Steinert 2020).

Figure 2. O*Net content model.

Table 3. Data distribution based on the kolmogorov-smirnov test.

| Indicators                     | Distribution parameters | Maximum deviation |
|-------------------------------|-------------------------|--------------------|
|                               | Mean  | S.D    | Absolute value | Positive | Negative | Z. test | P. Value | Sample |
| Worker Requirements           | 4.3236 | 0.5775 | 0.3543       | 0.3118    | 0.2963    | 0.3543   | 0.000    |        |
| Job Requirements (Navigation) | 3.6674 | 0.8048 | 0.3364       | 0.3088    | 0.2692    | 0.3364   | 0.000    |        |
| Job Requirements (Engine Operator) | 3.8622 | 0.7476 | 0.3415       | 0.2613    | 0.2692    | 0.3415   | 0.000    | 96     |
| Experience Requirements       | 4.4023 | 0.5718 | 0.3527       | 0.2960    | 0.3351    | 0.3527   | 0.000    |        |

Results

The number the parameters considered in the study of distribution (average and standard deviation in normal distribution), the absolute value of the maximum deviation, the most positive deviation, the most negative deviation, the statistical value of Z and the significance level (Sig) of the main factors of the research is presented in Table 3.

Worker requirements

Table 4 shows the average, average rank, and standard deviation of the variables. Comparison of the mean of subtests related to worker requirements shows that the highest average (12.47) belongs to the use of logic, reasoning, thinking and scientific methods, and the lowest mean (5.51) belongs to the sub-index of managing ourselves and others times. Also, the amount of chi-square obtained is 296.29, the degree of freedom is 17, the number of samples is 96 and the significance level is 0.000, which is at the error level less than 0.05 (P<0.05). The significance of the Friedman test means that the ranking of worker requirements by experts is meaningful, and experts rank is different from the variables and worker requirements. The Friedman test rankings for indicators of worker requirements shows the use of logic, reasoning, thinking and scientific methods at highest level, which means that according to experts, the use of logic, reasoning, thinking and scientific methods, the most obvious variable in discussing the job requirements. On the other hand, time management of ourselves and others in the RCC is at lowest level, which shows the weakest variable in deciding worker requirements.
Table 4. Ranking the worker requirements based on the Friedman test

| No | Requirement                                                                 | Average | Average rank | S.D  |
|----|-----------------------------------------------------------------------------|---------|--------------|------|
| 1  | Ability to speak and transfer information navigation;                        | 4.427   | 10.21        | 0.4973 |
| 2  | Use of mathematics to solve navigational problems;                           | 3.990   | 7.24         | 0.7608 |
| 3  | Use of logic, reasoning, thinking, and scientific methods;                   | 4.780   | 12.47        | 0.4569 |
| 4  | Ability to learn navigational content;                                       | 4.448   | 10.32        | 0.4999 |
| 5  | Choosing and implementing appropriate learning strategies;                   | 4.573   | 11.53        | 0.4973 |
| 6  | Assessing yourself and others and taking corrective actions;                | 4.302   | 9.22         | 0.4616 |
| 7  | Understanding the reactions of others and understanding their causes;      | 3.990   | 7.15         | 0.5330 |
| 8  | Coordination and Compatibility yourself with others;                        | 4.271   | 9.03         | 0.4467 |
| 9  | Ability to train, serve and assist others;                                   | 4.563   | 11.16        | 0.4987 |
| 10 | Ability to solve complex navigation problems and provide solutions;         | 4.417   | 10.19        | 0.4956 |
| 11 | Design and creation of technology in equipment;                              | 4.292   | 9.13         | 0.6946 |
| 12 | Computer programming, and deployment of tools and software;                 | 4.292   | 9.13         | 0.6946 |
| 13 | Analysis of quality control and Assessment;                                 | 4.135   | 8.02         | 0.8287 |
| 14 | Machines control and operation systems;                                      | 4.573   | 11.45        | 0.4973 |
| 15 | Maintenance of equipment, machines, and systems to troubleshoot and eliminating them | 4.271   | 8.95         | 0.4467 |
| 16 | Assessment and control of systems and the improvement of performance;       | 4.271   | 10.36        | 0.7362 |
| 17 | System analysis and environmental conditions;                               | 4.281   | 9.92         | 0.7064 |
| 18 | Managing ourselves, and others time.                                         | 3.865   | 5.51         | 0.6427 |

Table 5. Ranking of job requirements (navigation operator).

| No | Requirement                                                                 | Average | Average rank | S.D  |
|----|-----------------------------------------------------------------------------|---------|--------------|------|
| 1  | Principles and rules of commerce, international maritime conventions and management knowledge; | 4.438   | 11.72        | 0.7228 |
| 2  | Marine Physics Knowledge;                                                   | 3.615   | 7.04         | 0.4892 |
| 3  | Electronic Principles, Maritime Communication Systems, and Maritime Visual Telecommunications knowledge; | 3.750   | 8.70         | 0.6489 |
| 4  | Principles of coastal navigation and the Dead Reckoning;                    | 4.375   | 12.07        | 0.8367 |
| 5  | Principles of electronic navigation (GPS, ECDIS, AIS, VDR, GMDSS, RADAR) Knowledge; | 4.594   | 12.88        | 0.6254 |
| 6  | Principles of celestial navigation knowledge;                              | 3.406   | 7.40         | 1.2103 |
| 7  | Architecture and marine engineering knowledge;                              | 3.333   | 6.90         | 0.9588 |
| 8  | Voyage planning by “ECDIS” knowledge;                                      | 4.594   | 12.88        | 0.6254 |
| 9  | Cargo work (Loading and Discharging) knowledge;                             | 4.208   | 10.36        | 0.7802 |
| 10 | Environmental science knowledge;                                           | 3.302   | 5.62         | 0.6003 |
| 11 | Computer science knowledge and basic principles of cyber security;         | 3.688   | 8.23         | 0.5678 |
| 12 | Marine Geography knowledge;                                                 | 4.271   | 11.27        | 0.5521 |
| 13 | Construction and Stability of the ship knowledge;                           | 3.594   | 6.69         | 0.6254 |
| 14 | Automation and control systems knowledge;                                   | 3.615   | 7.72         | 0.7014 |
| 15 | Bridge and watchkeeping equipment knowledge;                               | 4.229   | 10.53        | 0.7606 |
| 16 | Marine Meteorology knowledge;                                               | 3.938   | 8.48         | 0.9494 |
| 17 | Fire prevention knowledge;                                                  | 2.708   | 4.51         | 1.0555 |

significance, and the Friedman test results for the job of Engine Operator is similar to Navigation Operator.

Experience requirements

Table 7 shows similar statistics as table 6, but for variables of the experience requirements. In-service training, experience with autonomous ships, holding maritime competency certificate, and onsite Training indicators took the highest average value, and holding personal safety and social responsibility certificate the lowest. The values of the Chi-square with 269.571, the degree of freedom with 12, the number of samples with 96, and the significance level with 0.000, which is at the error level less than 0.05 (P <0.05). In addition, the ranking of experience requirements is meaningful.

Discussion

The universal rapid introduction of innovative technology, science, and knowledge development has affected maritime transport significantly, which resulted in dramatic changes in maritime industry. Almost, the most important organizational element that is facing the industry evolving challenges such as adaptation, promotion, and organisational development is the human capital. Today, leading organizations emphasize on
Table 6. Ranking of job requirements (engine operator).

| No | Requirement                                               | Average | Average rank | S.D  |
|----|-----------------------------------------------------------|---------|--------------|------|
| 1  | Chemistry and material properties knowledge;             | 3.677   | 7.38         | 0.7469|
| 2  | Marine diesel engines knowledge;                         | 3.000   | 3.96         | 0.5804|
| 3  | Electrical engineering Knowledge;                        | 3.598   | 7.53         | 1.0044|
| 4  | Thermodynamics knowledge;                                | 3.698   | 7.53         | 0.9190|
| 5  | Vibration and hydrostatic knowledge;                     | 3.375   | 7.35         | 0.9319|
| 6  | Marine steam boilers knowledge;                          | 3.219   | 5.23         | 1.0281|
| 7  | Ship's electric systems knowledge;                       | 3.625   | 5.61         | 0.7291|
| 8  | Sub-machinery knowledge;                                 | 3.792   | 6.61         | 0.8934|
| 9  | Fuels, lubricants and water knowledge;                   | 3.500   | 5.88         | 0.7678|
| 10 | Pipelines and cooling systems of the ship knowledge;     | 3.500   | 5.88         | 0.7678|
| 11 | Hydraulic and pneumatic principles knowledge;            | 4.010   | 9.03         | 0.8143|
| 12 | Ecology and environmental protection knowledge;          | 4.313   | 9.99         | 0.4659|
| 13 | Fuel injection knowledge;                                | 4.101   | 9.03         | 0.8143|

Table 7. Ranking of experience requirements based on the Friedman test.

| No | Requirement                                               | Average | Average rank | S.D  |
|----|-----------------------------------------------------------|---------|--------------|------|
| 1  | Work experience at sea;                                   | 4.406   | 6.88         | 0.5347|
| 2  | Apprenticeship, experience and training before starting a service; | 4.417   | 6.98         | 0.5743|
| 3  | In-service training;                                     | 4.698   | 8.56         | 0.5051|
| 4  | Having certificate of training related to security duties; | 4.125   | 5.13         | 0.7712|
| 5  | Having advanced medical assistance certificate;          | 4.021   | 5.55         | 0.6955|
| 6  | Having personal safety and social responsibility certificate; | 3.917   | 4.86         | 0.6099|
| 7  | Having other special certifications;                    | 4.271   | 6.52         | 0.6566|
| 8  | Having advanced firefighting certificate;                | 4.448   | 7.10         | 0.5205|
| 9  | Having certificate to work with the GMDSS                | 4.396   | 6.82         | 0.5521|
| 10 | Having certificate to work with the ARPA radar           | 4.438   | 6.91         | 0.4987|
| 11 | Having an experience with autonomous ships               | 4.698   | 8.56         | 0.5051|
| 12 | Having maritime competency certificate                   | 4.698   | 8.56         | 0.5051|
| 13 | Onsite Training                                          | 4.698   | 8.56         | 0.5051|

Therefore, for the purpose of this study the job requirements divided into two roles of navigation operator and engine operator. A navigation operator is someone in charge of management and command in navigation and maritime operations, and an engine operator is someone in charge of operation, evaluation, and troubleshooting of the ship engine at RCC.

Worker Requirements

Worker requirements relate to personality traits, which is achievable through experiences and is useful in performing a large number of tasks. These requirements mean basic and interdisciplinary skills, knowledge, education, training, and practical experience. They ranked, in order of importance, based on expert’s opinions (shown in Table 4). The person at the SCC must legally combine issues related to his/her work to achieve new results and know the right way to think. The next step is to choose and apply appropriate learning strategies. It requires the operator to make best use of the appropriate teaching methods and procedures to acquire relevance knowledge. The ability to control machinery and operate systems is an important factor. On-board ships, all the control and monitoring systems are located in one engine control room. The next factor is the ability of the operator to properly communicate with his/her colleagues and try to improve job performance and efficiency through cooperation. As the next important factor, the worker at the SCC, by learning navigation content, must be able to properly transfer navigation and regional information and receive manoeuvring information from other units in any situation for better decision making. The information quality at the SCC could be a key issue in overall performance and conduct of autonomous ships. Evaluating and controlling systems and improving performance along with efficient exchange of navigation information with other units involved such as PSC, VTS, etc. are the next important indicators. Effective comprehension ability in proper communication with others is very important for the SCC operators. Problem solving ability in complex navigation situations is the other important factor. There are some other factors in worker requirements, less important, and not discussed here. Figure 3 shows the most important worker requirements as prerequisites for employees at SCC.

Job requirements (navigation operator)

Job requirements, as closely related to the job-oriented aspect of the analysis, fall into three categories; general activities of the job, field of work, and organizational field [20]. The features for job requirements of navigation operator are ranked here according to their importance, based on experts’ opinions. According to the

devolution of human resources and pay special attention to the principles of improving the effectiveness and efficiency of educational activities.

Essentially, tow person is supposed to conduct professional operations and handling autonomous ships at the RCC. A navigation operator who is likely to be an experienced shipmaster that in addition to the experience and abilities acquired at sea, he/she has also undergone a series of training courses about these types of ships. The second will be an engine operator who is probably an experienced engineer in charge of monitoring and controlling operation of the ship’s engine.
ranking (shown in Table 5) of the factors for job requirements (navigation operator), it was determined that the operator must first be proficient with the knowledge of passage planning by "ECDIS". Electronic charts are replacing paper navigational charts despite they are still widely being used on conventional ships today. The knowledge of the principles of electronic navigation, in job requirements, is as important as the knowledge of ECDIS. The concept of electronic navigation in the past meant the use of equipment such as DECA, LORAN, and Omega. But since 2006, with the arrival of new equipment such as GPS, DGPS, AIS, and Integrated Bridge Systems (IBS), and etc., it has changed a lot. The next requirement is knowledge of the principles of coastal and dead reckoning (DR) navigation. The next important and effective factor in job requirements is the laws and principles of mercantile knowledge, international maritime conventions and management knowledge. Understanding the effects of existing regulations on the economic viability and quality of international shipping will ensure maritime security, protecting the marine environment and decreasing sub-standard transportation. Knowledge of marine geography is the next effective factor. The person who will be in charge of controlling autonomous ships must have complete information about the seas, oceans and vital passages. This should include public awareness of the environment, geographical climates. The knowledge of cargo work, as a very important issue both in today’s conventional ships and in the ships of future, is the next important factor. The officer in charge of the RCC must have the knowledge of most common types of goods, especially dangerous and hazardous cargo, in addition to proper understanding of basic principles of stowing, loading and discharging. Figure 4 shows most important job requirements for the navigation operator.

**Job requirements (engine operator)**

Similar to navigation operator, study of job requirements for engine operator carried out on the job-oriented aspects of general activities, field of work, and organisational field. Each of these characteristics is ranked according to their degree of importance. The outcome is given in Table 6, which showed ecological and environmental protection knowledge as the most important characteristic. The next most important factor is the knowledge of injector and fuel injection system, which requires the operator to understand its principles of operation and proper troubleshooting thoroughly, in case of emergencies. Knowledge of the principles of hydraulics and pneumatics in creating mechanical forces is the next important indicator. The operator should also have the knowledge of chemistry and the properties of materials. Electrical engineering knowledge, including electrical, electromagnetic, and electronic applications, is the next key indicator. Thermodynamic knowledge, dealing with heat and its relation to energy and work, is another factor that was highlighted by the experts. Other factors fall into the category of job requirements but with lesser degree of importance include knowledge of marine diesel engines, boilers, electric ship systems, fuels, lubricants and water, and knowledge of piping and cooling systems of ships. Figure 5 shows most important job requirements for the engine operator.
**Experience requirements**

These requirements include structured and non-structured experiences such as training, experience, and certifications that can enhance performance. These requirements importance ranking, based on the experts’ opinion, is given in **Table 7**. The experience with autonomous ships was the first major indicator (due to none actual existence of the RCC currently, the related experience means participation in current related projects or researches). Having a seafaring qualification certificate is also an important factor to consider. Although no seafarer can enter the seafaring profession without this certificate at present, employees at the RCC will be eligible to participate in the RCC without this certificate. On-site training (at RCC) is the next factor as this training is a flexible and cost-effective option that allows the organisation to train a small number of employees who need professional on the job training. Training in a real environment, on the job, is more simple and effective in transfer of training and familiarisation with complex systems, than purely theoretical training. In-service training, as another important and key factor, will take place at the RCC, sometime later, after the person is hired. This will familiarise employees, with the new procedures and guidelines, as result of technology advancements. In-service training can upgrade and increase human capacity, and promote efficiency. There are some other factors in this category, but of less importance. They include obtaining certificates of training for security, advance medical assistance, advance firefighting, sea service, basic pre-job training, and personal safety and social responsibility. **Figure 6** shows most important experience requirements for operators in SCC.

**Conclusions**

This research studied the operator skills and knowledge requirement in Autonomous RCC. The operators job analysis has been carried out based on the indicators of the O*Net content model and experts opinions.

The results for workers requirement showed that the person at the RCC should be capable of combine issues related to his/her work, properly be trained, in order, to be able to acquire new and relevance knowledge to control machinery and operate existing systems. The operator must learn to how to improve job performance and effectiveness. In addition to acquiring of engineering knowledge, he/she should learn proper navigation content for better decision-making through improved information exchange.

The quality and ability in communicating navigation information to units, including ports control, PSC, VTS, and other units involved, will highly affects the overall performance and conduct of autonomous ships at RCC.

The results of the job requirements analysis for the navigation operator showed that he/she must be proficient with the knowledge of passage planning by “ECDIS,” principles of electronic navigation. Emphasise on GPS, DGPS, AIS, and Integrated Bridge Systems (IBS), and so on is very important. The knowledge of coastal and terrestrial navigation, mercantile principles and laws, international maritime conventions, and management is essential for navigation.
operator. This improves shipping quality and maritime safety, protection of the marine environment, and decreasing sub-standard transportation. Complete knowledge of the seas, oceans, and vital passages, along with awareness of the environment, geographical climates, marine pollution, coastal management, and preservation of the global ecosystem is essential. The officer in charge of the RCC must have a thorough understanding of most common types of goods with knowledge of basic principles of their stowage, loading and unloading. Other supportive knowledge required for navigation operator are knowledge of ship construction and stability, automation and control systems, marine communications, principles celestial navigation, marine meteorology, management and command of bridge equipment, marine physics, electronic basics, naval architecture and engineering, environmental science, computer science and basic principles of cyber security.

The results for the engine operator showed that knowledge of the injector and fuel injection system is of high degrees of importance, since main propulsion of the ships are using this system. He/she must thoroughly understand the operation principles, and in emergencies, be able to diagnose faults and rectify them. The operator should have enough knowledge about ecology and protection of marine environment. Fluid mechanic is another subject in which the operator must be competent enough to understand hydraulic and pneumatic technologies. Knowledge of chemistry and material science, electronic and electrical engineering is also important for the engine operator. Thermodynamics and hydrostatic knowledge enables the operator to understand production of energy and work from heat. The operator should also have adequate knowledge of traditional means of propulsion and auxiliaries of ships.

According to the result for experience requirements that affect performance, despite the fact that autonomous ships are not practically in operation, some sort of backgrounds on related projects and researches about autonomous ships will be useful for the operator (both the navigation and engine operator) at RCC. Other important necessity is the requirement of holding seafarers’ certificate of competency for employees at RCC. On the job training is considered more effective than theoretical training because it can boost familiarisation with new advanced technology in such a complex systems as well as, understanding of proper new procedures and guidelines. Practical training in real environment will improve transfer of training and fidelity. Other knowledge seems to be required as experience are safety and security, medical assistance, firefighting, and personal safety and social responsibility.

The overall results shows that the role of the operators at RCC is different with that of the traditional seafarers. They are working in a very complex environment and should conduct many operations and activities remotely. The job performance at RCC seems to be associated with higher degrees of risk in early stages of introduction of autonomous ships, same as with any other new technology. The mention requirement for RCC operators for navigation and engine can be combined and be learned as one multipurpose worker, but then the number of workers simultaneously conducting the job is to be investigated. This is very important in terms of preventing fatigue and information overload for the operator. The other important concluding issue is that the requirements for RCC operators should carefully, be taken into account to prepare them for different situations and conditions. These preparations can improve situation awareness and prevent technology-assisted collisions in early states of introduction of new technology.

Although this study did not investigate the cargo management ability of the navigator, and the difference in the ability of the engineer, it is suggested that the conventional training and education system for navigators should be revised to improve such abilities. It requires greater emphasis on the cargo management ability of the navigator which greatly depending on the type of cargo, and the ability of the engineer which is largely depending on the type of propulsion system.

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