Process approach for determining competencies

Ana Gundić[a], Lovro Maglić[b*], Marija Šimić Hlača[b], Livia Maglić[b]
[a] University of Zadar, Maritime Department, Zadar, 23000, Croatia
[b] University of Rijeka, Faculty of Maritime Studies, Rijeka, 51000, Croatia

*Corresponding author e-mail: maglic@pfri.hr

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Abstract
The competencies, as defined in the STCW Convention, are in most part based on traditional shipboard organization, related to common shipboard departments and traditional levels of responsibilities (i.e. management, operational and support levels). Their descriptions mostly refer to the certain task, and are not interconnected with other jobs and tasks. In the future, the strict division between departments and tasks is expected to disappear, or at least to significantly diminish.
In the paper, the results of the two-year research activity are presented. The main goal of the research was to interrelate the on-board processes with competencies required to control and accomplish those processes. Consequently, it requires a process approach implying identification and analysis of critical processes, sub processes, activities, decisions, tasks, and executors. The work processes of the Masters and Chief officers on board LNG carriers and cruise ships have been analysed, and compared with competencies as stipulated in the STCW Code A and B, Model Courses, study programs of the Croatian higher MET institutions, and continuous professional development programs. Results indicate that presently used competence descriptors do not describe competencies up to the required level, particularly as expected in the future working environments.

1. Introduction

A rapid development of technologies used on board ships changes the way the ships are controlled and operated. Anticipated developing trends include further increase of decision-making capabilities in various control units (AI), increased number of different measuring sensors, extensive redundancy of critical systems on board, remote-controlled vessels, and finally gradual introduction of autonomous vessels. Consequently, the concurrent operations of autonomous vessels, remotely controlled vessels and manually controlled vessels are highly probable.
These changes are creating new tasks and challenges for human operators on board. It is beyond any doubt that humans, participating in the shipboard processes, will have to master additional competencies. Presently, the most notable developments are those related to onboard decision-making processes. Rapid development of new technologies and AI-based systems on board ships are followed by continuous reduction of the ships' crews. This causes increased workload, despite the increased level of ships' automation. Finally, these developments change the roles and responsibilities of ships' crews as well as those ashore. At the end, these new forms of control and supervision functions will require respective changes in the legal framework.

Transition to new technologies and ever-increasing complexity of the conventional technologies seems to be a rapid process rather than the gradual one. For example, new MARPOL requirements for sulphur content in marine fuels resulted in increased use of liquefied natural gas (LNG) as fuel. Consequently, new competencies turn out to be required, new certificates are introduced as well as new IMO Model Courses (IMO, HTW 6, 2019).
The most challenging transition will be the introduction of the Marine Autonomous Surface Ships (MASS). According to the present understanding of the capabilities of the autonomous marine systems, IMO divided these ships into four categories (IMO, MSC 99/5/n, 2018):

- Degree one: Ship with automated processes and decision support. Seafarers are on board to operate and control shipboard systems and functions. Some operations may be automated and at times be unsupervised, but with seafarers on board ready to assume control.
- Degree two: Remotely controlled ship with seafarers on board. The ship is controlled and operated from another location. Seafarers are available on board to take control and to operate the shipboard systems and functions.
- Degree three: Remotely controlled ship without seafarers on board. The ship is controlled and operated from another location.
- Degree four: Fully autonomous ship. The operating system of the ship is able to make decisions and determine actions by itself.

It is quite clear that new competencies will be required for crew members (on the MASS vessels of degree one and two) and for shore-based operators who will remotely monitoring and control MASS vessels. The MASS operators will need new competencies, mostly related to control and supervisory systems they will use, but also will need a support from the team members with traditional maritime competencies (Yemao, et al, 2015). At present, regulatory framework as defined by the STCW convention is applicable only to the crewmembers on board and not to operators working in shore-based control centres (Komianos, 2018).
Considering all these factors, it seems that the main role of the ship management in the future will be much more supervision-oriented; decision-making and action execution will be expected only in extraordinary circumstances. The same applies to operators ashore. New roles will require new competencies to be developed, some existing ones to be upgraded, while some presently required will become obsolete.

2. New technologies and effects on required human skills

New technologies implemented and used on modern ships have and will have substantial effects on human competencies.
One of the most easily noticed change is a significant increase of quality and reliability of information. The term “information” here refers to raw information, including raw data generated by the increased number of sensors, metadata (data about data), as well as to real time data (video and audio streams), either requiring human interpretation or not. In general, the quality and reliability of different data streams is constantly improving. Unfortunately, extended availability of information increases the number of correspondents (data users) interacting with the vessel. It is quite common these days that nearly every stakeholder in the transport process wants to have real time information about ship’s movement instead of just using already processed information.

In addition, new types of sensors and measuring equipment offer information previously not available. Consequently, additional competencies are required to process multitude of information and data. In some cases, expert knowledge and experience are required to process the available data and to react as required. Sometimes, there are multitudes of ways to analyse available data. To ease the burden, the AI based systems are eventually introduced. In some cases, the implementation of AI helps, in some cases it only increases the ambiguity, particularly when crewmembers must decide which information is sufficiently reliable and relevant for further actions. In most of the cases, only a part of the available information is needed for the crew to react (Maglic et al, 2016).

In addition, the whole process has become more complex by involving new stakeholders with different legal interests.

As a final point, the main consequences are:

1) significantly increased quantity and quality of information, requiring new competencies, some requiring the knowledge and understanding quite beyond the level of knowledge commonly delivered at traditional MET institutions;
2) transition from individual to collective decision making (teamwork!), as a rule increasing the quality of decisions made, but also requiring much longer time to reach a conclusion (it is particularly emphasized when decision making is shared between ship and shore management);
3) shared responsibilities, mostly because of the extended number of stakeholders (decision-makers), sometimes up to the level that actual responsibility is cluttered;
4) increased dependencies on team members, particularly because increased number of highly complex operation requires the increased number of executors, thus increased probability of underperformance.

It seems that gap between required and actual competencies is recognized by many shipping companies particularly those operating highly sophisticated ships (Gundić et al, 2015). Knowing that digitalization as a process is clearly getting momentum, the remedial actions in respect of missing competencies must be considered at the STCW level. It is important to note that these remedial actions will have to consider also the missing competencies of those ashore, not only shipboard personnel.

3. Competencies

The concept of competencies (as ability to do something successfully or efficiently) was introduced in the 1950s (Mulder, 2014). The main cause was a recognized difference between abilities gained at educational institutions and those needed to perform a job. There is no universally accepted definition of competencies (Dragoo and Barrows, 2016). According to some authors, the competence is a dynamic combination of knowledge, understanding and skills (Caena, 2011). Almost the same definition is used in the STCW Convention according to which a competence consists of associated knowledge, understanding and skills. However, some authors believe that competencies are more than just knowledge and skills. As the competence concept was developing, so were the assigned definitions. For example, (Nanzhao, 2005) considered the idea that competence is a combination of one's capabilities, temper, and talent. That is, a competence consists not only of one's ability to perform demanding tasks, but of one's attitudes too (DeSeCo, O.E.C.D., 2005). Every individual must

be able to use, apply and show awareness, knowledge, skills, and attitude to perform a job effectively (Wahba, 2013). In other words, a competency refers to every distinctive trait, knowledge, skills, and all other qualities of an individual needed to perform a job effectively (University of California, 2012). In a larger sense, a competence represents a combination of cognitive and practical skills, knowledge, motivation, values and ethics, attitudes, emotions, and behaviour that lead to a successfully performed job (Nanzhao, 2005, according to Rychen, Tiana, 2004). It can be summarized that common features for all definitions of competencies are knowledge, skills, and attitudes.

In the STCW Convention competencies are determined according to ship operations (functions) at operational and management level. That led to the classification of competencies that are not clear and precise enough to refer clearly to the unique shipboard process. Another problem is that competencies, as identified in the STCW Convention, are mostly those required on ships commonly trading at the time of the Convention development. At the time technological differences among various ship types and trades were relatively narrow, competencies were relatively easily transferrable, and social relations were relatively simple. Maintaining and upgrading required competencies was relatively simple, usually by attending few short courses or a specific on-board training. In addition, the competencies were mostly perceived as static; working environments were not considered.

Nowadays, technological differences among various ship types and trades are significantly more distant. Because of that, competencies are not easily transferrable, and short courses are not enough, especially for technologically advanced ships (e.g. LNG ships).

As a result, today one can easily recognize obsolete competencies (celestial navigation, still taught in many MET institutions!), but also missing competencies, particularly if highly sophisticated ships are considered (numerous short courses required by companies operating such ships). The list of missing competencies includes especially those associated with the social arena, like those referring to social networks, cyber security, high-tech control, etc. Finally, competencies, as defined in the STCW Convention, refer only to a person, without analysing his/her surroundings.

Based on the mentioned, it is quite clear that competencies should be linked with working processes on board ships as well as with the tools and devices mandatory (or commonly) used aboard.

4. Formalization of the competencies using process approach

Processes on board ships are complex and consist of many system elements. These elements are shipboard organizational units, tools, and devices. An organizational unit[1] can participate in many different processes and vice versa, more organizational units can participate in only one process. In other words, various combinations of organizational units, equipment and processes are possible and existing on modern ships.

Every process on board ships has its measurable goals and objectives, and it can be assigned with appropriate priorities. These objectives refer differently to the main objective of a ship,

[1] An organizational unit implies a person, or a group of people who participate in a process, as it may be appropriate.

that is, to its transport function. All processes, together, affect the realization of the main objective of a ship.

No matter how complex a ship may be, there are several clearly recognized processes on every merchant ship, including (but not limited to):

1) navigation,
2) loading, care for, and unloading of cargo, including embarkation, care for, and disembarkation of passengers
3) safeguarding safety, security, and environmental standards in respect of the vessel, passengers, and cargo
4) maintenance of ship's functionality (propulsion, power management, different services).

Rapid development of technology has changed the crewmembers' role in processes and the way in which the processes are carried out. In addition, new actions and tasks have been developing whereas some actions and tasks are becoming obsolete. As a result, the already existing competencies must be adjusted. Therefore, it is important to:

1) determine how competencies defined in the STCW Convention relate to identified shipboard processes, and
2) redefine competencies to be implementable in different working environments.

To achieve the above mentioned it was necessary to:

1) determine the appropriate method to analyse processes and tasks taking place on ships under investigation,
2) analyse competencies required for most demanding tasks on sophisticate ships,
3) identify commonalities, and
4) compare them with competencies defined in the STCW Convention.

The process analysis (Figure 1) implies the recognition of subprocesses (if they are a part of the process), participating organizational units, decisions to be made within the process, as well as their executors. The number of subprocesses, organizational units, actions, decisions, and their executors within a process determines the complexity of a process.

Most of the shipboard processes take place simultaneously. Some processes contain easily recognizable sequences (subprocesses), repeating from time to time.

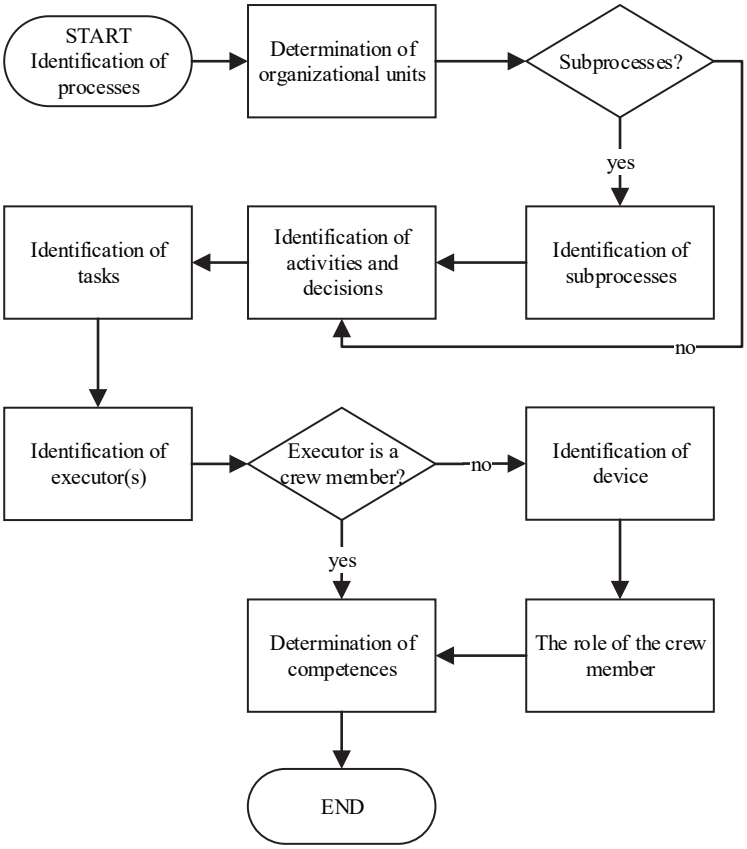

Figure 1 Analysis of a process

The impact of the new technologies can be analysed through their influences on:

1) executors,
2) actions and tasks,
3) decision-making.

Executors of an action within a process can be divided in two groups: crewmembers and devices. Sometimes new solutions will require the same number of executors, sometimes the number of executors might be minimized, or human executors can be completely removed from the loop. In later case, it might mean fewer seafarers, or a significantly changed task list assigned to the crewmember.

Furthermore, the implementation of new technologies can affect the actions within the process. That is, the number of actions (or tasks within an action) may be reduced, the actions and tasks within an action can be done more precisely, time needed to perform an action or a task may be reduced, or new actions may be introduced as well. Finally, the implementation of new technologies can also affect decision-making processes.

The existing determination of required competencies refers only to a person without analysing his/her surroundings or the devices and tools he or she use in the processes. To determine more precisely required competencies, it is necessary to analyse the working environment. Taking into account that decision-making but also execution is often carried out by the teams, the term “competence” should refer not only to the individual but also to the group of people that work together, perform a task together or decide together. That is, the group of people

may have its own competencies. Basic difference between the competence of a group of people and the competence of an individual lies in the fact that knowledge, understanding and skills can be differently distributed within a group, depending on the task they must accomplish.

The analysis of sophisticated ships and their equipment and operations (LNG and cruise ships) revealed a need for more precise descriptions of required generic competencies, too. Generic competencies are defined as transferable, multipurpose knowledge, understanding and skills that an individual acquires and develops in different ways and in different situations (Fung et al, 2007). Today's crew should be able to work in a team, solve problems, analyse more information simultaneously, learn and evaluate, think critically, etc. The results of the two-year research on generic competencies are presented hereafter.

The main goal of the research was to determine to what extent various competencies are present in the STCW Convention, in associated study programs, and in programs of non-formal education. Furthermore, the presence of professional, generic, and other competencies has been estimated. In addition, the analysis includes also sector-specific competencies (those important for various professions within one sector), and cross-sectoral competencies (those used in different sectors according to the European Skill, Competencies, Qualifications and Occupations).

Competencies have been identified estimated according to the total number of topics in a particular STCW table that refer to a certain type of competency. Approach used is shown in Table 1.

Table 1 Example of competence classification

Competence classification in IMO Model Course[2]			
Topic	**Professional**	**Generic**	**Other**
Shifting of bulk cargo by reducing an excessively high GM.	X		
Appropriate action to take in emergency and medical first aid situations involving dangerous goods			X
Effective communication with the port authority		X	
Competence classification in a study program[3]			
Topic	**Professional**	**Generic**	**Other**
Ship's pharmacy	X		
Composition and texture of the human body			X
Competence classification in non-formal programs[4]			
Topic	**Professional**	**Generic**	**Other**
Team development		X	
Bridge watch keeping	X		

The analysis of competencies, determined in the STCW Convention, has been based on the analysis of the respective IMO Model Courses. The IMO Model Courses specify topics that

[2] Competence classification in IMO Model Courses has been shown on the example of topics that refer to Carriage of dangerous, hazardous, and harmful cargo.

[3] Competence classification in a study programme has been shown on the example of the course called Medicine for seafarers.

[4] Competence classification in non-formal programs of education has been shown on the example of a programme called SMS Bridge Resource management. The program is a part of the non–formal programs required on LNG carriers.

are supposed to be a part of the curricula for a particular competence. The results are shown in Figure 2.

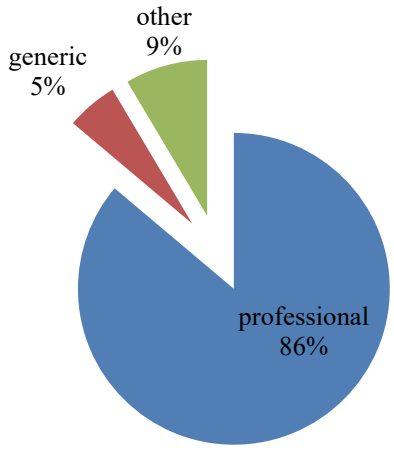

Figure 2 Presence of various competencies in IMO Model Courses

To determine the presence of different competencies, the undergraduate study program "Nautical Studies and Maritime Transport Technology", delivered in Croatia, has been analysed. The program is based on the IMO Model Course, and it includes all topics needed for jobs at management level. Figure 2 shows the participation of different competencies for the undergraduate program under considerations.

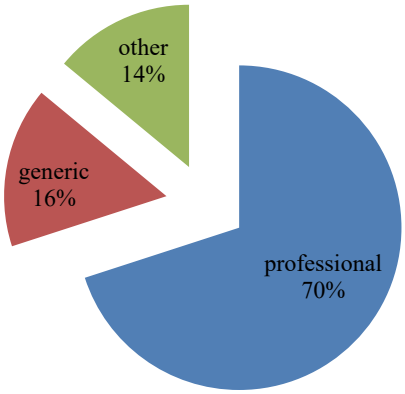

Figure 3 Presence of various competencies in undergraduate program

It has been already emphasized that study programs often do not include all the competencies needed for the job market (Carron, Carr-Hill, 1991), and in many cases are not in accordance with rapid technological development. It is almost impossible to acquire all the competencies needed to perform an on-board job through study programs. It might be assumed that this is the main reason for noticed development of the non-formal education. Non-formal education refers to all programs leading to competencies needed for a working environment (Ainsworth, Eaton, 2010). In maritime education and training, these additional programs may be divided according to their source, i.e. those prescribed by the STCW Convention, and those required by the shipping companies (Gundić et al., 2015). The analysis presented here considered programs required for crewmembers sailing on LNG carriers and cruise ships. These two types of vessels have been chosen because of the specialised equipment and high rate of implementation of the new systems, needed for the safe operations.

The research was divided in two phases. In the first phase, 57 programs required by companies managing 188 LNG carriers, and 41 programs on 12 companies managing 161 cruise ships have been analysed. Since there are no agreed international standards, programs differ in duration, content, and reasons why shipping companies require them.
The second phase focused on duties and responsibilities of masters and officers on board LNG carriers and on-board cruise ships as defined in the available Safety Management Systems.

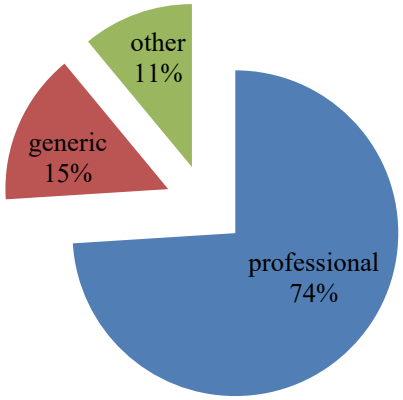

Figure 4 Presence of various competencies in non-formal programs for LNG carriers

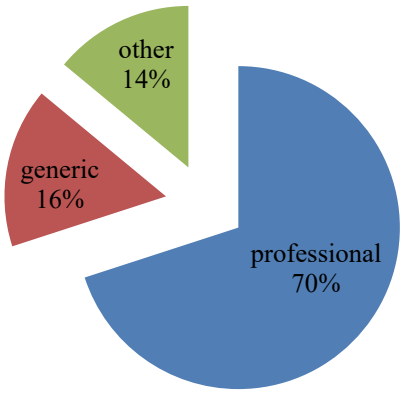

Figure 5 Presence of various competencies in non-formal programs for cruise ships

Research results indicate that IMO Model Courses and the STCW Convention significantly emphasizes topics providing professional competencies. Generic competencies needed to perform a job on board are only partially included. Among those, the mostly present and required competencies are those referring to teamwork and team management.
The analysed study program is based on the respective IMO Model Course, and it includes all topics prescribed by it. The ones that are mostly present in the analysed study program are those that refer to effective communication.
Analysis of non-formal programs revealed again strong focus on professional competencies. Generic competencies mostly present in these programs are teamwork, team management and decision-making.
After being compared with results of analysis of duties and responsibilities of management staff on LNG carriers and cruise ships, it seems that there is a noticeable deficit of several generic competencies. These competencies include teamwork, team management, time

management, decision-making, problem solving, and effective communication, collaboration in multidisciplinary and multicultural teams, critical thinking, teaching and evaluation.
Research revealed generic competencies as a highly important part of the required set of competencies for management level. At the same time, these competencies are not clearly recognized in the STCW Convention and related documents (although several generic competencies are mentioned). In order to ensure the uniform education, at least in part dealing with critical processes, these competencies have to be more precisely described, including the methods of delivering and assessment.

Conclusion

New technologies change the way processes are carried out on board ships. They affect the actions within a process, executors of an action and decision-making processes. Consequently, existing competencies must be upgraded, and new must be developed. It may be concluded that competencies as drafted in the present STCW Convention are not robust enough to be used reliably on high-tech ships.
Moreover, presently drafted competencies do not comply with many working processes on board modern ships, and they are not clear enough. Therefore, new technologies imply development of new competencies and/or the upgrade of the already existing ones, while some traditional competencies may be omitted from curricula.
Traditionally, competencies are tied with an old-style department organization on board. Thanks to the new technologies, these shipboard organization models are not implemented as strictly as they were, with many variations, mostly depending on applied technology and area of trade. Consequently, the so-called process approach for determining competencies has been suggested in this paper.
According to the research results, it is necessary to interrelate competencies with associated processes more strictly. In addition to personal competencies, it will be necessary to define more precisely the collective competencies (in the present STCW Convention the collective competencies, i.e. competencies required and executed by the group of people, are already recognized as teamwork competencies, although not precisely described).
The research results indicate a need for thorough revision of the STCW Convention and related documents; it must ensure precise descriptions of required competencies. In particular, generic competencies are missing, above all those dealing with critical thinking, problem solving, teaching and evaluation, etc. Considering the complexity of the task, it is not reasonable to expect that it can be done only by IMO and maritime administrations. The process needs extensive participation of all involved parties, particularly those providing maritime education and training. In that respect, IAMU, as the most important association of the prominent MET institutions is expected to participate in the process.

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