Application of the expert assessment method in developing a navigation safety system for unmanned vessels

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Abstract. The development of a navigation safety system for unmanned vessels, including port tugs, requires the expert assessment method. This method is applicable when working with risk assessment because there is no reliable statistical data on unmanned shipping. Most companies operating ships have navigation safety systems or safety management systems (SMS), with the exception of shipping companies operating a small tonnage fleet (up to 500 r.t.). These companies have a set of instructions, similar to the SMS. The navigation safety system covers almost all areas of production activities of both the ship and shore segments of the company. The SMS of a shipping company operating the unmanned vessel will require serious refinements compared to the traditional SMS. The development of SMS elements may require the involvement of boatmasters and ship mechanics who know the work of port tugs, as well as researchers who conduct research in the field of unmanned navigation. It is difficult to process the results obtained by experts who combine scientific and practical points; it is necessary therefore to select experts taking into account peculiarities of the SMS and production activities of non-crew port tugs. Thus, one of the main tasks is to combine all the existing opinions and assessments in order to avoid possible inaccuracies, as well as to take into account peculiarities of unmanned port tug operation, depending on production tasks. The term ‘unmanned vessel’ refers to vessels that are operated using unmanned technologies. This article discusses issues of selection of experts that will work with the risk assessment method in the development of a safety system for navigation of unmanned port tugs.

1. Introduction

One of the main issues that arises when a shipping company intends to operate unmanned harbor tugs is the need to develop and implement a new navigation safety system. Services provided by a shipping company include the safe and efficient operation of unmanned harbor tugs. In addition, measures aimed for ensuring and protecting the environment should be taken into account and implemented on the basis of a system ensuring the safe navigation of unmanned harbor tugs. The construction of a rigorous model of the system is impossible due to the lack of sufficient statistical data, a variety of operating factors, their qualitative and random nature, and ambiguity of goals and assessment criteria.

For example, the captain controls the ship on the one-to-one basis. Instructions are transmitted only to the master, who is responsible for their implementation. When carrying out operations in the port, the captain is guided by the Compulsory Port Regulations and navigation documents, instructions from the company's management and dispatching service. The master has an exclusive authority in making decisions to ensure the safe operation of the vessel and contacting the company for assistance. He can make any decisions adequate to the current situation to ensure the safety of the vessel, prevent
environmental pollution and preserve property. These qualities are required for the unmanned harbor tug operator. The expert has to simulate actions in a production situation, starting from the standard protocol of actions.

2. Methods and materials
The purpose of an expert survey is to describe the procedure for conducting an expert assessment. Since the expert analysis can combine several heterogeneous examinations, during which various groups of objects are studied and different methods of assessment are applied, work with experts will be performed both for the expert analysis of the navigation safety system for unmanned harbor tugs, and for each production situation.

The examination includes (Fig. 1) an identification of objects to be assessed; a selection of a criterion for evaluating objects and formulating a proposal that describes this criterion to the expert and allows him to reveal the meaning of his assessments [1].

![Objects of the examination](image)

**Figure 1.** Identification of examination objects to be assessed; selection of a criterion for evaluating objects and formulating a proposal for the situation development.

The selection of experts for an unmanned harbor tug is one of the most intractable tasks. The nature of this task is a human factor. It is not surprising that each of the experts has his own views and understanding of how to solve problems.

The issue includes a number of large-scale, unexplored problems. This means that it is necessary to expand the circle of experts who should form a working group. If it is not possible to find experts who are able to provide an exhaustive conclusion for solving the problem, it is permissible to involve experts from related fields. [4] Since the problem may turn out to be new, there is not enough statistical data; experts are not able to solve the whole problem and take into account its main aspects; therefore, it is necessary to use an extended group of experts. In this case, experts may be navigators holding senior command positions (e.g., a captain) or ship mechanics (a chief engineer) who have sufficient experience of working with these ships. Representatives of the scientific community included in the expert group must have comprehensive knowledge in the field. In this case, an assessment of the competence can be carried out based on the analysis of their publication activity.

In most cases, any research is faced with resource constraints, such as time, financial resources, etc. [1]. Time constraints are most significant, since expert assessments are needed when it is necessary to obtain quick results. It is the lack of time that leads to the narrowing of the circle of experts [5].
Expansion of the circle of experts involves travel, long-distance mail and telephone contacts with geographically remote experts, waiting for one of the potential experts to return from a business trip. The unmanned harbor tug with a remote control system is equipped with azimuthal VRK; tugs with this steering system are more technically adapted for conversion into unmanned harbor tugs.

The unmanned harbor tug operator needs to know features of working with azimuth thrusters. The control system for azimuth thrusters is a separate tracking control system. The control devices are connected to the interface unit (BS, a separate unit or control panel); using the bus cable, they are interfaced with the AT control unit. The control unit ensures smooth and constant steering speed for the throttle control. The principal advantage of the system is smooth and shockless steering of the AT.

An important aspect is the opinion of the scientific community as they directly deal with unmanned technologies.

Therefore, it is necessary to create a group of experts including at least three boatmasters, three ship mechanics and two representatives of the scientific community.

3. Discussion

Ideally, the expert should be an independent and impartial judge. He requires qualities such as competence, erudition, abstract thinking, sociability, and benevolence. Authoritative recommendations and personal acquaintance of the researcher with the expert simplifies the interaction.

But the conditions for selecting experts are rarely ideal. The expert group includes three boatmasters and three ship mechanics who have experience in working with harbor tugs with azimuth propeller-rudder systems and two representatives of the scientific community who have publications on the issue under study.

Depending on the competence of the experts, they need to be ranked.

The potential expert is a researcher (administrator), the head of the process, assesses competence, objectivity and other qualities of all other potential experts, based on test and documentary data.

Based on the assessment, the expert's competence coefficient (rank) is determined.

The degree of familiarity with the issues \( K_\text{z} = 10 \) or more means complete awareness, and \( K_\text{f} = 0 \) means absolute ignorance of the issue; the degree of influence (high, medium, low) of each of the four listed in the table.

| Number | Expert rank arguments | Degree of influence | C |
|--------|-----------------------|---------------------|---|
| 1      | General production experience in working with vessels | High | 0,5 |
| 2      | Experience in harbor tugs with AT | Medium | 0,3 |
| 3      | Diploma | Low | 0,2 |
| 4      | Education | High | 0,5 |
| 5      | Scientific experience (unmanned navigation) | Medium | 0,3 |

\[(1) K_\text{f} = \sum_{i=1}^{N} C \cdot 5,\]

where \( K_\text{f} \) – degree of familiarity with the questions \( \sum_{i=1}^{N} C \) the sum of the rank arguments of the statistical experts, \( N \) – the number of experts, 5 – the number of ranking arguments.
4. Results

Let us provide an example of calculating the rank of an Expert Advisor. The harbor tug captain has 20 years of experience. His experience in working with a tugboat with AT is 10 years, including 5 years as a captain. According to his diploma, he is a coastal voyage captain (up to 500 km). It follows that according to the first three points, he can be assigned 0.5. He has secondary vocational education (0.3). He has no scientific experience – 0.

\[ K_f = (0.5 + 0.5 + 0.3 + 0) \times 5 = 9 \] (Kf = 9). The expert lacks full knowledge, but has a sufficient rank to participate in assessing situations.

The harbor tug mechanic (senior mechanic) has 25-year experience. His experience in working with AT tugboats is 15 years, including 5 years as a senior mechanic. By his working diploma, he is a senior mechanic (over 3000 kW). For the first three points, he can be assigned a grade of 0.5. He has higher engineering education (ship mechanic) – 0.5. He has no scientific experience – 0.

\[ K_f = (0.5 + 0.5 + 0.5 + 0 + 0) \times 5 = 10 \] (Kf = 10). The expert has full knowledge and is of sufficient rank to participate in the assessment of situations.

Representative of the scientific community. He has experience in working on vessels – 5 years (0.3). He has no experience in working with AT tugboats, but has publications on unmanned vessels (0.5). Working diploma – 0. Higher education (water transport) – 0.5 Scientific experience – 0.5.

\[ K_f = (0.3 + 0.5 + 0 + 0.5 + 0.5) \times 5 = 9 \] (Kf = 9). The expert has a sufficient rank to participate in assessing situations.

Representative of the scientific community. General practice, work on ships for 10 years – 0.5. No experience in working with AT tugboats; publications on unmanned – 0.5. Working diploma (captain without restrictions) – 0.5 Higher education (water transport) – 0.5. Scientific experience – 0.5.

\[ K_f = (0.5 + 0.5 + 0.5 + 0.5 + 0.5) \times 5 = 12.5 \] (Kf = 12.5) The expert has full knowledge and a sufficient rank to participate in assessing situations.

5. Conclusion

Many methods have been developed for conducting expert assessments; it is necessary to use them when creating an expert group and select experts. It is possible to work with each expert; he may not know who else is an expert, and therefore expresses his opinion independently of other experts, regardless of their authority. The ability to bring experts together to discuss tasks will reduce misconceptions. The number of experts is fixed; statistical methods of checking the consistency of opinions and averaging them help make informed decisions. But it is possible to increase the number of experts in the examination. There are several methods for processing expert responses, including highly mathematically intensive and computerized ones. [8] An expert survey on the navigation safety system for unmanned harbor tugs is an integral part of obtaining the final product adapted to unmanned vessels, including the selection of experts. The selection of experts is based on the complexity of the problem, education and work experience in the field. It will not be possible to avoid work with experts due to the insufficient amount of statistical data in the field of unmanned shipping.

As shown by the calculation example, the proposed criteria for evaluating an expert make it possible to determine their rank which can improve the quality of expert assessments. In addition, arguments for assessing the rank of experts can be expanded, which can make it possible to more accurately determine the rank of an expert, that is, to take his opinion into account when conducting a general risk assessment.

The group of experts includes people both with practical experience in operating ships, and scientists studying this subject area, which contributes to a more objective assessment of the opinion of experts in a specific production situation.

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