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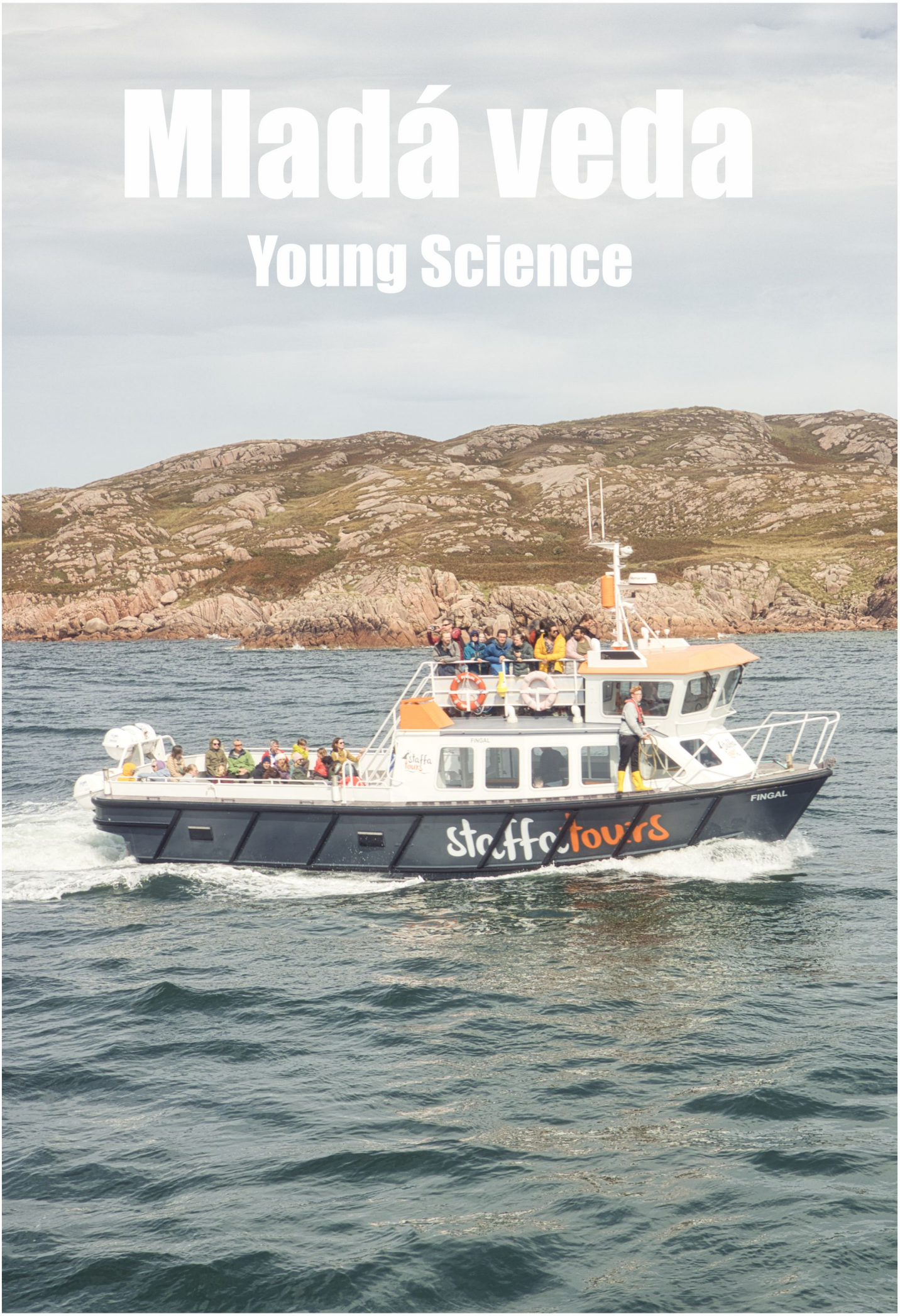

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SIMULATOR ANALYTICS AS A TOOL FOR OBJECTIVE ASSESSMENT OF SHIP CREW COMPETENCIES

SIMULÁTOROVÁ ANALYTIKA AKO NÁSTROJ OBJEKTÍVNEHO HODNOTENIA KOMPETENCII LODNÝCH POSÁDOK

Terézia Debnárová [1]

Autorka pôsobí ako externá doktorandka na Fakulte prevádzky a ekonomiky dopravy a spojov Žilinskej univerzity v Žiline. Vo svojom výskume sa zameriava na problematiku simulačného výcviku lodných posádok, výkonovej analytiky a návrhu adaptívnych výcvikových systémov vo vnútrozemskej vodnej doprave.

The author works as an external doctoral student at the Fakulty of Operation and Economics of Transport and Communications at the University of Žilina. Her research focuses on simulation-based training of ship crews, performance analytics, and the development of adaptive training systems in inland waterway transport.

Abstract

The increasing digitalization of inland waterway transport creates new opportunities for improving the training and assessment of ship crews. Traditional evaluation methods are often based on subjective judgement and limited practical scenarios, which may reduce the objectivity and consistency of competency assessment. Modern navigation simulators generate large amounts of operational and behavioural data that can be used for performance analytics and objective evaluation of crew competencies. This article proposes a conceptual framework for simulator-based performance analytics designed to assess professional competencies of inland navigation crews. The proposed system integrates navigational parameters, reaction times, manoeuvring accuracy, communication procedures, and safety-related indicators into a unified analytical model. The framework also introduces adaptive evaluation principles capable of identifying weaknesses in crew performance and supporting personalized training scenarios. The study highlights the potential of simulation analytics for improving safety, increasing training efficiency, and supporting competency-based education in accordance with current European inland navigation standards and digitalization strategies.
Key words: simulation-based training, performance analytics, crew competencies, inland navigation, navigation safety, adaptive training

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Abstrakt

Rastúca digitalizácia vnútrozemskej vodnej dopravy vytvára nové možnosti pre modernizáciu výcviku a hodnotenia lodných posádok. Tradičné metódy hodnotenia sú často založené na subjektívnom posudzovaní a obmedzenom množstve praktických scenárov, čo môže znižovať objektivitu a konzistentnosť hodnotenia odborných kompetencií. Moderné navigačné simulátory generujú rozsiahle množstvo prevádzkových a behaviorálnych dát, ktoré je možné využiť na výkonovú analytiku a objektívne hodnotenie výkonu posádok. Článok predstavuje konceptuálny rámec simulátorovej výkonovej analytiky určený na hodnotenie odborných kompetencií lodných posádok vo vnútrozemskej plavbe. Navrhovaný systém integruje navigačné parametre, reakčné časy, presnosť manévrovania, komunikačné postupy a bezpečnostné ukazovatele do jednotného analytického modelu. Súčasťou návrhu je aj princíp adaptívneho hodnotenia umožňujúci identifikáciu slabých stránok výkonu posádky a podporu personalizovaných tréningových scenárov. Štúdia poukazuje na potenciál simulátorovej analytiky pri zvyšovaní bezpečnosti plavby, efektívnosti výcviku a podpore kompetenčne orientovaného vzdelávania v súlade so súčasnými európskymi požiadavkami na vnútrozemskú plavbu.

Kľúčové slová: simulátorový výcvik, výkonová analytika, odborné kompetencie, vnútrozemská plavba, bezpečnosť plavby, adaptívny výcvik

Introduction

Digitalization represents one of the most significant transformational elements of contemporary inland waterway transport. Modern technologies enable more efficient traffic management, more accurate navigation, and a higher level of operational safety. Simulation technologies play an important role in this process and are becoming an integral part of professional training for ship crews.

The traditional training model in inland navigation has long been based primarily on practical experience, theoretical preparation, and subjective instructor evaluation. However, current requirements for navigation safety, digital navigation systems, and harmonization of professional competencies create the need for more objective and data-oriented approaches to crew performance assessment.

Modern ship simulators enable realistic simulation of navigational situations, including crisis scenarios, adverse hydrological conditions, and dense traffic environments. One of the major advantages of simulator-based training is the ability to record detailed operational data describing crew behaviour during simulation exercises. These datasets represent significant potential for performance analytics and objective competency assessment.

The main objective of this article is to propose a conceptual system of simulator-based performance analytics for objective assessment of professional competencies of inland navigation crews.

European Requirements for Professional Competencies of Ship Crews

The system of professional competencies in inland navigation is harmonized at the European Union level by Directive (EU) 2017/2397 on the recognition of professional qualifications in inland navigation and Commission Delegated Directive (EU) 2020/12. These documents define minimum requirements for knowledge, practical skills, and operational competencies of crew members.

Particular emphasis is placed on:

- safe vessel manoeuvring,
- radar navigation,
- crew communication,
- emergency response procedures,
- operation within RIS and AIS systems,
- environmental and safety aspects of navigation.

Modern simulators represent an appropriate tool for practical verification of these competencies in a controlled and safe environment. Simulator-based training also enables scenario repeatability and standardized assessment conditions.

Simulator-Based Training and Performance Data Collection

Simulation technologies in inland navigation enable realistic modelling of navigational situations, including hydrological conditions, traffic density, meteorological phenomena, and emergency situations. Training simulators are capable of recording large volumes of operational data in real time.

The most important recorded parameters include:

- vessel trajectory,
- deviation from planned route,
- vessel speed,
- number of course corrections,
- operator reaction time,
- CPA distance,
- correctness of radio communication,
- manoeuvre execution time.

These data enable the creation of a comprehensive performance analytics system that can serve as the basis for objective assessment of professional competencies.

An important advantage of simulator-based training is the possibility of analysing crew performance in hazardous situations without compromising real operational safety. The simulation environment also allows repeated execution of identical scenarios, which increases evaluation objectivity.

Proposal of a Performance Analytics System

The proposed performance analytics system consists of several interconnected components:

- simulation environment,
- operational data collection system,
- analytical module,

- competency assessment module,
- adaptive training system.

Figure 1 – Concept of the Simulator-Based Performance Analytics System
Source: author's own processing

Assessed Competencies and Performance Indicators

The assessment system is based on a combination of several performance indicators.

No.	Competency Area	Description	Assessed Performance Parameters	Example Indicators
1.	**Ship Handling and Manoeuvring**	Ability to safely manoeuvre the vessel in various navigation conditions.	• Deviation from planned track • Number of course corrections • Accuracy of berthing/docking • Stability of the vessel during manoeuvres	• Average cross-track error (m) • Number of heading changes • Berthing deviation (m) • Number of touch contacts
2.	**Radar Navigation**	Ability to use radar equipment effectively for navigation and collision avoidance.	• Reaction time to detected target • Correct use of radar functions • Maintenance of safe distances • Proper interpretation of radar data	• Average reaction time (s) • Number of missed targets • Minimum CPA achieved (m) • Number of radar errors
3.	**Traffic Awareness and Situational Awareness**	Ability to maintain an overview of the traffic situation and anticipate potential risks.	• Detection of critical situations • Time to identify risk • Correct assessment of situation • Decisions in dynamic environments	• Number of risky situations • Time to risk recognition (s) • Number of correct decisions • Number of late decisions
4.	**Communication**	Ability to communicate accurately and according to procedures.	• Correctness of radio communication • Use of standard phraseology • Timeliness of communication • Clarity and completeness of messages	• Number of communication errors • Compliance with phraseology (%) • Delayed communications (s) • Number of incomplete messages
5.	**Emergency Management**	Ability to respond appropriately to emergency situations.	• Time to initiate action • Correct sequence of procedures • Effectiveness of executed actions • Team coordination in emergencies	• Time to action (s) • Number of procedure deviations • Scenario success rate (%) • Number of critical errors
6.	**Navigation Planning and Decision Making**	Ability to plan the voyage and make sound decisions based on available information.	• Quality of route planning • Compliance with navigation rules • Decision accuracy • Adaptation to changing conditions	• Distance to planned route (m) • Number of rule violations • Rate of correct decisions (%) • Number of unnecessary corrections
7.	**Use of Onboard Systems (AIS, ECDIS, RIS)**	Ability to correctly use onboard navigation and information systems.	• Correct use of AIS/ECDIS/RIS • Data input accuracy • Interpretation of displayed data • Timely use of system information	• Number of system errors • Accuracy of entered data (%) • Time to obtain required info (s) • Number of missed alerts

Table 1 – Competencies and Assessed Performance Parameters
Source: author's own processing

Scoring Model Competency Assessment

For objective evaluation of crew performance, a weighted scoring model can be applied.

No.	Evaluation Criterion	Traditional Simulator Training	Adaptive Simulator Training	Expected Benefit
1.	Assessment Approach	Based on instructor judgement and general observation.	Based on objective performance analytics and quantified indicators.	• Increased objectivity • Reduced subjectivity • Consistent evaluation
2.	Scenario Selection	Predefined scenario set for all trainees.	Scenarios dynamically adapted to individual performance and weaknesses.	• Personalized training • Targeted improvement • Higher relevance of scenarios
3.	Data Utilization	Limited use of recorded data, mainly for debriefing.	Comprehensive analysis of operational and behavioural data.	• Deeper insight into performance • Identificaioni of patterns • Data-driven decision making
4.	Feedback	General feedback provided after the training session.	Detailed, metric-based feedback with visualization.	• Better understanding of errors • Faster learning process • Continuous performance monitoring
5.	Objectivity of Evaluation	Dependent on instructor experience and interpretation.	Based on standardized metrics and scoring models.	• Higher reliability • Fair and transparent evaluation • Comparable results
6.	Training Efficiency	Uniform training for all trainees regardless of performance.	Efficient focus on weak areas and competency gaps.	• Better use of training time • Faster improvement • Reduced training costs
7.	Competency Development	Progress depends on general training pace.	Progress monitored continuously with adaptive difficulty.	• Continuous development • Higher competency level • Improved safety performance

Table 2 – Comparison of Traditional and Adaptive Simulator Training
Source: author's own processing

The proposed model enables the creation of a comprehensive performance score and identification of areas requiring additional training.

Adaptive Principle of Assessment

One of the most important benefits of performance analytics is the possibility of implementing adaptive training principles. Based on previous training results, the adaptive system can automatically identify weak areas in operator performance and adjust subsequent training scenarios accordingly.

In the case of repeated problems with radar navigation, the system may generate a higher number of low-visibility or high-traffic scenarios. In situations involving insufficient reaction times, the frequency of crisis situations or complexity of navigational tasks can be gradually increased.

This approach enables personalized training and more efficient development of professional competencies of ship crews.

Discussion

The implementation of performance analytics into simulator-based training represents a significant step toward more objective and data-oriented assessment of professional competencies in inland navigation. The proposed system enables standardized evaluation, reduction of subjective factors, and continuous monitoring of crew performance.

Despite its significant advantages, several limitations remain. Simulator environments cannot fully reproduce all psychological and operational aspects of real navigation. Another important factor is the quality of input data and proper configuration of analytical parameters. Future research should focus on the integration of artificial intelligence, behavioural analytics, and automated adaptation mechanisms into inland navigation training systems.

Conclusion

Simulator analytics represents a promising tool for modernization of professional ship crew training in inland navigation. The combination of simulation technologies, performance analytics, and adaptive principles enables more objective competency assessment, increased navigation safety, and more efficient personalization of the training process.

The proposed concept of a performance analytics system establishes a foundation for further research in adaptive training and intelligent competency assessment systems in inland waterway transport.

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