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Work Domain And Control Task Analysis For Enhanced Fire Control Panels On RoRo Ferries

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Firefighting on Roll-on/Roll-off (RoRo) ferries presents significant challenges, especially with the increasing presence of electric vehicles. To enhance safety and efficiency in maritime firefighting the design of future alarm and control panels should be grounded in a deep understanding of the sociotechnical work system, especially in the light of how common usability issues on ship bridges are (Danielsen et al., 2022). This research adopts a cognitive systems engineering approach (Rasmussen et al., 1994), analysing the affordances and constraints that shape firefighting on such vessels, and the information and control needs for managing firefighting in this setting.

The objective of this research is to gain a deep systems-oriented understanding of firefighting operations on RoRo ferries by applying Work Domain Analysis (WDA) and Control Task Analysis (ConTA) (Naikar, 2013; Rasmussen et al., 1994; Vicente, 1999) The aim is to inform the design of alarm and control panels for firefighting, ensuring they are suitable to the complex task of maritime firefighting. This is similar to the approach by (Lamoureux et al., 2006) where ConTA was used to analyse decision-making processes in tactical planning and response management for naval operations and to generate "design seeds": concepts that can be used to guide the design of new systems or improvements to existing ones.

The research began with observations of firefighting drills conducted on ferries and at training centres. Interviews with multiple stakeholders, including crew members and safety personnel, provided diverse perspectives on firefighting operations. This enabled a detailed mapping of the physical environment and resources such as detection and extinguishment systems, as well as an understanding of organizational aspects like crew training, roles and responsibilities. Gathered data were synthesized into an abstraction hierarchy that models the constraints and affordances impacting work system performance, thus visualizing both physical and abstract components of the firefighting system on RoRo ferries. A Control Task Analysis (ConTA) built on this foundation, to map out and analyse decision-making tasks, and identified crucial work functions and situations, especially from the perspective of bridge officers.

The WDA encompassed elements from the physical layout of the ship to fire containment strategies and emergency response procedures, providing a comprehensive view of the firefighting ecosystem. This multi-layered approach gave an understanding of constraints, capabilities, and functional relationships within the system, and interdependencies between resources and functions, such as the relationship between the fire safety plan and response effectiveness. These types of insights are crucial for the design of future alarm and control panels, ensuring they are developed with a comprehensive understanding of both practical and abstract requirements.

The ConTA revealed central work functions and situations for firefighting on the bridge. Functions included risk assessment, strategic planning, resource management, communication and command, safety and containment measures, and post-incident recovery. Typical situations include initial fire detection, coordination of firefighting efforts, rescue operations, and post-fire management. The ConTA represents information and control needs for the situations. For instance, the bridge officer has an important role in aiding firefighters' wayfinding, i.e.

providing crucial information about fire locations, equipment, and safe pathways, especially in challenging conditions like smoke or power failure.

Table 1. This table summarizes core elements of firefighting activities from the perspective of the bridge officer, showing typical tasks, functions, and situations.

Control task	Work function	Situations
Monitoring & interpreting fire alarms	Analysing alarm signals and visual data for fire verification	Alarm activation, smoke detection, fire progression
Coordinating with Engine Control Room	Strategic collaboration with engineering crew for firefighting	System activation, management of machinery
Coordinating firefighting team	Directing onboard response and resources	Team dispatch, development of containment strategy
Manual firefighting	Guiding manual extinguishing efforts	Initial response, handling small-scale fires
Activating fixed systems	Engaging automated firefighting tools	Large-scale fires, protection of critical areas
Documenting firefighting efforts	Recording firefighting progress and resource utilization	Ongoing efforts, post-incident analysis
Coordinating external parties	Liaising with external services for firefighting assistance	Assistance requests, emergency updates
Ensuring operational continuity	Maintaining ship functions and stability during firefighting	Power and fuel management, flooding

The insights gained from this research exemplify a structured and systems-oriented approach towards safety-critical systems design in complex maritime environments. The research underscores the utility of using ConTA to complement WDA. While WDA offers a systemic perspective by revealing social, organizational and physical constraints as well as resource interdependencies in a compact and visual format, ConTA provides a granular perspective on specific control tasks and decision-making processes required in various firefighting scenarios. It details both data processing activities and knowledge states encountered during decision-making, and also enables analysis of non-sequential movements between these states, described as leaps and shunts in the decision process, which are particularly important when analysing expert performance (Rasmussen et al., 1994). Combining WDA and ConTA creates a comprehensive picture as groundwork for further development of effective and user-centric firefighting systems for maritime environments.

The next phase of this project will use findings from the WDA and ConTA to inform the design of an innovative alarm and control panel system. This system will aim to enhance the efficiency and effectiveness of firefighting operations by supporting rapid decision-making, efficient resource allocation, and communication during maritime firefighting scenarios. However, as also (Lamoureux et al., 2006) point out, where there is potential for automating certain tasks to enhance operator performance, care must be was taken to avoid oversimplifying operator roles which might reduce their ability to handle novel situations.

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