Public summary

Project partner: Rijkswaterstaat
EngD programme: Mechatronic Systems Design, Eindhoven University of Technology

The Netherlands depends on hundreds of locks and movable bridges to keep its waterways accessible and its infrastructure operating safely. As these systems age, Rijkswaterstaat faces a major challenge: modernising critical infrastructure while making better use of limited engineering capacity. Developing control software individually for every structure is costly and difficult to maintain. **My project addresses a key question: how can automatically generated control software become ready for real-world industrial use?**

Rijkswaterstaat is exploring Synthesis-Based Engineering (SBE), which uses formal models to automatically generate supervisory controllers. This can reduce repetitive engineering and support reusable control solutions. However, functional correctness alone is not enough for critical infrastructure. Software must also meet industrial standards, integrate with existing systems, and remain secure, understandable and maintainable.

Working with Rijkswaterstaat, I investigated these challenges using Linne Lock as a real-world case study. I assessed the existing approach against **IEC 61131-3** for PLC programming, **IEC 61512-1 (ISA-88)** for procedural and physical organisation, **ISA-95 (IEC 62264)** for industrial integration, **IEC 62443** and Rijkswaterstaat's **CSIR cybersecurity guidelines** for security, and **ISO/IEC/IEEE 15288, ISO/IEC/IEEE 15289 and NEN 5509** for systems engineering and documentation. These standards provided a common foundation for connecting software quality with industrial needs, including correctness, interoperability, security, traceability and maintainability.

The project delivered three key contributions.

First, I established a clear picture of industrial readiness. By comparing generated PLC code with applicable standards and engineering requirements, I identified existing strengths and areas for improvement. This gives Rijkswaterstaat an evidence-based foundation for prioritising development and moving academic innovation towards practical application.

Second, I improved the connection between formal models and industrial control architecture. I extended the Eclipse ESCET PLC generator with hierarchy-based code generation, allowing the generated software structure to better reflect the underlying model. I also developed a prototype integrating Rijkswaterstaat's standardised procedural states and tasks with existing equipment-level control. This helps bridge academic methods and industrial practice, supporting more consistent and reusable engineering.

Third, I proposed practical improvements to make generated PLC software more compact and informative. By optimising comments and function organisation, the proposed changes have the potential to reduce generated PLC code size by more than 80%, while retaining more useful information with fewer functions. Combined with recommendations for interfaces, communication supervision, fault reporting and cybersecurity, these improvements can make software easier to understand, verify and maintain.

The benefits extend beyond software development. Rijkswaterstaat can use this approach to reduce duplicated engineering effort, preserve specialist knowledge and simplify future renovations. Engineers and maintenance teams can benefit from clearer software and easier troubleshooting. For society, more efficient and dependable infrastructure engineering supports reliable waterway management, shipping and the movement of goods across the Netherlands.

Ultimately, this project brings academic innovation and industrial practice together through a shared foundation of standards. It provides technical improvements, a structured assessment and a practical roadmap towards scalable, maintainable and dependable control systems for the infrastructure on which the country relies.