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Requirements Reuse in Complex European Security Research Projects – A Border Management Perspective

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ABSTRACT

European civil security research most often builds upon a series of interlinked efforts and development work, extending vertically across different funding and work programmes and horizontally across various funding instruments. Requirements reuse may provide a means to benefit from advances made in previous projects and enhance consistency between related equipment and systems. Requirements reuse as part of requirements development may support human systems integration (HSI) by transmitting knowledge or simply repurposing well-defined HSI requirements into the design of new technologies. This paper examines the potential of requirements reuse in EU border management research especially addressing user requirements. We explore our findings from the perspective of HSI that merges the knowledge and skills of different areas of human and organizational factors. The results are based on requirements development processes from seven multiannual EU funded border management projects, in which the authors have conducted research. In our analysis, we identify many factors influencing requirements reuse across separate border management projects. Despite heterogenous practices of requirements development implemented in European projects, the created requirements knowledge base should be utilised in an effective manner. Requirements reuse has multiple benefits and it should be considered more carefully in future when planning new projects.

Keywords: Border management, Border security, Human systems integration, Requirements development, Requirements reuse, Civil security research

INTRODUCTION

European civil security research is typically based on a network of interrelated efforts and development work that spans across different funding programmes and work programmes, as well as various funding instruments. Research outputs at lower technology readiness levels are advanced in potentially several consecutive follow-up projects and adapted to other application areas with similar or similar enough needs and requirements. The funding authority, namely the European Commission, also requires the consideration of the outcomes of preceding and concurrent research, emphasizing the avoidance of duplicate efforts within the same research topics (see European Commission 2022, 2023a for current European civil security research programmes).

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Research and innovation (R&I) in our selected thematic area of civil security, namely border management, forms a broad and multifaceted domain (see e.g., European Border and Coast Guard Agency 2022 for a recent research overview). It encompasses the development of authorities' capabilities in checking persons and controlling the flow of goods to "prevent and address cross-border crime, terrorism and illegal activities, while at the same time facilitating the travels of legitimate passengers". Moreover, border management R&I covers technological development in support of improved border surveillance in various operational environments and maritime security (European Commission 2023b). These activities are performed by different national authorities and jointly with support of the European Border and Coast Guard Agency or other EU agencies.

High heterogeneity characterises EU's external borders as a research space where different regions and Member States are influenced by varying challenges and threats associated for example with irregular migration and cross-border crime (see European Border and Coast Guard Agency 2023 for an overview of current risks). Despite integrating European-level frameworks, such as the Schengen Borders Code (Regulation (EU) 2016/399), individual border management development needs heavily trace back to differing national (and local) policy priorities, political systems, regulatory frameworks, organisational structures, cultures, infrastructure, and environmental conditions. Research consortiums seeking to answer identified needs typically comprise of different-sized businesses, universities, research institutes, standardisation organisations, ministries, national and local authorities, and law enforcement agencies (European Commission 2023c). Practitioners as future technology users are involved in projects to guarantee that the research results match their current and subsequent capability needs (European Commission 2022).

This paper examines the potential of reusing requirements in EU border management research especially addressing user requirements gathered from practitioners (i.e., border management authorities and agencies) and other key stakeholders through participatory methods. Requirements reuse is perceived for example to increase the efficiency and quality of solution development (Lam, McDermid and Vickers 1997). The paper is constructed as follows. Section 2 shortly describes the current state-of-the-art in requirements reuse and how reuse associates with human systems integration (HSI). Section 3 illustrates our methodological approach towards identifying lessons learned in requirements reuse in EU border management projects, while Section 4 analyses and summarises the lessons based on our research background. Section 5 concludes the paper by discussing approaches to requirements reuse in a beneficial and effective manner.

REQUIREMENTS REUSE IN DEVELOPMENT PROCESS AND ITS RELATION TO HSI

One of the main objectives of requirements reuse is to advance design processes and products by better consideration of earlier achievements.

Requirements reuse may provide a means to benefit from advances made in previous projects and enhance consistency between related equipment and systems. (Wiegers and Beatty 2013) Reuse involves the practice of customizing past requirements by adjusting some parameters or attributes, to align them with the specific project's demands (Jankovic and Hein 2022). Requirements reuse may decrease overall development costs and result in fewer defects and rework (Wiegers and Beatty 2013). Increased software system complexity and demand for higher quality are key factors in the software industry's competitiveness with requirements reuse recognized as an effective strategy for improvement (Ivan et al. 2015; Wu 2019).

Reuse can be implemented in different ways, and the methods' practicality largely depends on project objectives. The extent of reuse may vary from individual requirement statements to a set of requirements and their associated design, code, and test elements (Wiegers and Beatty 2013). Certain types of requirements have higher reuse rates than others, such as requirements relating to reliability, maintainability, usability, and security (Palomares, Quer and Franch, 2017).

Requirements reuse has been studied extensively already for a long time (e.g., Lam, McDermid & Vickers 1997; Toval 2002; Montabert et al. 2005; Montabert et al. 2009). For example, Lam, McDermid & Vickers (1997) presented a systematic approach for requirements reuse by classifying ten reuse phases into orthodox and non-conformist categories. Orthodox steps adopt generally accepted reuse principles, whereas non-conformist steps suggest new ways to consider and exploit reuse. In contrast, Benitti et al. (2013) presented an approach for requirements reuse which is based on three pillars: 1) requirement definition models for structuring knowledge to assist reuse, 2) a mechanism to facilitate the selection of patterns, and 3) traceability in creating new requirements from reused requirements. Dilorenzo et al. (2020) focused on use case related taxonomy development noting that it may also enable reusing use case related non-functional requirements and software assets.

Despite identified benefits and efforts to improve reuse, its implementation in projects can remain low. Chernak et al. (2012) studied the reuse of software requirements in the information technology industry showing that the main reason for avoiding reuse is the low quality of available requirements. Most of the respondents were willing to reuse requirements, but less than half of them were actually reusing existing requirements. Although, reuse can enhance the quality of system requirements specifications and lead to benefits like error prevention, improved quality, and reduced project risks, adoption may be limited by a lack of awareness about the reuse processes and concerns regarding its benefits. Moreover, specific project management approaches may limit the implementation of reuse, as it may not be best suited for example for very agile projects (Palomares, Quer and Franch, 2017). Finally, Lam, McDermid and Vickers (1997) found that the perceived similarity in high-level requirements might give an impression of uniformity, but most requirements are intricately tied to detailed designs at a lower level, making them challenging to generalize or reuse.

Requirements reuse as part of requirements development may support human systems integration (HSI) by transmitting knowledge or simply repurposing well-defined Human Factors (HF) requirements into the design of new technologies. From the HSI perspective a key question is to what degree requirements reuse promotes a unified and holistic HSI process that would help organizations to tackle human factors issues systematically throughout the design process. The quality of the HSI process can be assessed, e.g., in terms of accuracy, completeness, consistency, clarity, comprehensibility, usefulness and timeliness of Human Factors products. It is possible that sometimes requirements reuse can enhance the design of high-quality HF products if it results in a compilation of reviewed and generally approved HF requirements. However, it is not self-evident that this kind of 'natural selection' of requirements in which the 'most suitable' requirements have a better chance to survive to the next project will always result in a 'dream team' of requirements and further to an optimal HSI process and high-quality HF products.

Every system related to systems engineering and management contributes to HSI processes, resulting in comprehensive integration of humans, technology, and organizations. Typically, HSI is characterized as a program through which high-quality HF products are created. In this paper, however, it is seen more as a goal-oriented perspective towards which the target projects are aiming rather than a program. This is simply because the projects' activities do not include the development of an explicit and established HSI program.

METHODOLOGY

The paper's results are based on requirements development processes from seven multiannual EU funded border management projects, in which the authors have conducted research implementing HSI approaches. All projects included over fifteen partner organisations indicating dozens of individuals participating systems development and implying a high geographical spread across EU and non-EU countries. The total budgets of the projects ranged from five to sixteen million euros with durations spanning from three to five years. The projects address comprehensively various border management topics from checks on persons, control of goods, border surveillance and maritime security with different technologies and approaches, and they cover three different EU funding programmes for research and innovation starting from the Seventh Framework Programme (FP7) to the present Horizon Europe programme (Horizon Europe). FP7 introduced s*ecurity* a separate, independent theme in European research and innovation funding programmes for the first time (European Commission 2018). Table 1 summarises basic details of each examined project. In the table, practitioners refer to European and national authorities or agencies, such as border guarding, coast guarding or customs organisations. Their main role in the projects is to support requirements development, the organisation of technology field trials and demonstrations, and the evaluation and validation of the results, technological or any other type of key result.

To address our project background and experience in a structured way, we adapted Milton's methodological approach (2010) to lessons learned. Rhodes and Dawson (2013, p. 155) note that authors often differentiate between "when a lesson has been identified and when it has been transferred into a learned lesson". We focused primarily on lesson identification, as this is an explorative paper assembling our key observations and paving the way towards the development of an efficient and effective reuse process particularly for complex European research projects. Milton (2010, p. 17) considers a lesson identified as "a recommendation, based on analysed experience (positive or negative), from which others can learn in order to improve their performance on a specific task or objective".

Table 1. Overview of analysed projects.

Funding programme	Project acronym	Scope	Practitioner geographical coverage
Seventh Framework Programme (2007-2013)	EFFISEC	Development of technologies for novel border control and detection of explosives	Portugal, Romania, Spain
Horizon 2020 Framework Programme (2014-2020)	FastPass	Development of harmonised, automated border control gates	Austria, Finland, Germany, Greece, Romania
	BODEGA	Analysis and design of human factors in border control	Finland, France, Greece, Italy
	ROBORDER	Development of autonomous swarms for border surveillance	Greece, Hungary, Portugal, Romania, UK
	D4FLY	Development of secure document and identity verification technologies for border checks and document issuance	Greece, Lithuania, The Netherlands, UK
	ARESIBO	Development of augmented reality enhanced situational awareness for border surveillance	Finland, Greece, Portugal, Romania
Horizon Europe Framework Programme (2021-2027)	EURMARS	Development of secure, multitasking border surveillance platform for maritime security	Albania, Bulgaria, Cyprus, Romania, Spain, UK

The three-step process for lesson identification includes **1**) review of experience, **2**) analysis of learning points, and **3**) generalisation for future action. Within **step 1**, we examined the planned task level objectives and actual achievements for requirements development. Additionally, we explored through a set of pre-established questions the key issues, success factors and challenges associated with requirements reuse in each project. In **step 2**, the learning points were determined by finding and analysing the root causes to the successes and challenges. In **step 3**, the lesson identification process was concluded with drafting initial recommendations for future directions in requirements reuse.

When reusing requirements across projects, we have often implemented textual copy and subsequent tailoring of former requirements. These represent the most adopted reuse techniques (Palomares, Quer and Franch 2017). Both reused requirements and those defined within ongoing projects were expressed in natural language, specified and documented in case-by-case adopted or modified templates (e.g., Volere Requirements Specification template by the Atlantic Systems Guild Limited), SharePoint based tools or in the form of free text. The requirements were structured according to specific categories also covering usability and user experience. In our case projects, the results of the requirements development processes have been in most cases confidential, so that they are only distributed as deliverables to the members of the research consortium and to the funding authority.

RESULTS

In the process, we identified several lessons to requirements reuse in European border management projects. Within European border management R&I, the high-level needs and requirements are often rooted in the Union's strategic security policy priorities and objectives, while the innovation goals, diverse use cases and environments necessitate thorough processing of dedicated needs derived from specific project practitioners. Table 2 summarises the identified lessons based on our observations and contributions in the selected projects.

Table 2. Summary of identified lessons.

Lessons challenging reuse in border management projects
• To support harmonisation, final requirements are always a compromise
• Reuse may increase the risk of transferring poor requirements across projects
• Requirements reuse requires clearly established quality criteria
• Administration and maintenance of requirements repositories is partner and project dependent
• Considering cost efficient reuse, distinguishing commonalities in heterogenous use contexts may not be practical

As noted earlier in the paper, different authors associate several benefits with requirements reuse in systems development. In general, the requirements development process itself broadens the research consortiums' understanding of the complexities of practitioners' challenges extending beyond project objectives (e.g., by shedding light on decision-making processes or specifying the roles of different users operating at various organisational levels). This is difficult to reach comprehensively at project planning stage before the submission of a proposal to the funding authority. However, the final requirements, documented in project reports and other supplementary formats, such as Excel workbooks, are always a compromise to which the consortium arrived at potentially through several collaborative iteration rounds, also including the prioritisation of requirements. Therefore, the explicit and

tacit knowledge vested within the requirements and within the process itself cannot by fully transferred across projects.

As research consortiums are unique social constructs, including typically only some members from previous projects, potential deficiencies in prior requirements specifications may migrate across projects undetected, because there is no clear process to validate previously defined requirements and assess their quality against novel use cases. Technological advances and changes in relevant regulatory frameworks may also make previously defined requirements outdated. To detect obsolescence in various requirement categories calls for comprehensive expertise, not residing within the project team of a single partner organisation that leads the overall requirements development process.

Although requirements reuse may represent one practical means to respond to the funding authority's preconditions of both utilising the work of previous research and avoiding the duplication of efforts, the selection criteria for reuse may be based on other factors than quality (e.g., technology providers' preferences). Requirements definition acts as a gate in follow-up projects, where technology suppliers try to use the created technology in different operating environments and for different end users.

As requirements specifications in EU border management projects are often confidential, the use of systematic requirements repositories is limited. Instead, documented requirements are stored within dedicated project workspaces that have a finite service life closely linked to overall project duration. For example, project workspaces maintained by the coordinating organisation are often closed some months after the completion of the project. Also, supporting documentation to the requirements development, such as use case descriptions, may be treated as EU classified information posing more severe limitations in reusing requirements across projects (see Council decision 2013/488/EU for further information on the rules for EU classified information).

The case and technology compositions of the projects often seem distinctive, as the consortiums ultimately seek to answer to the specific needs expressed in the funding authority's topic description (at least at the proposal stage to secure funding). The developed systems are multi-technical integrating and embedding software and hardware components and sub-systems of various kind. New systems tested through novel scenarios and use cases in heterogenous practitioner facilities and environments poses major challenges in identifying relevant commonalities between projects from the perspective of requirements reuse. Requirements particularly suitable for reuse, such as maintenance or usability, are rarely emphasized as key development topics in the research project call descriptions.

CONCLUSION

This paper gave a brief overview of identified lessons in requirements reuse within European civil security research, namely in the specific domain of border management. The lessons analysed and summarised provide valuable

insights to potential barriers and challenges in sharing requirements knowledge across European research and innovation projects. Overall, we believe that this initial exploratory work can pave the way towards better utilisation of the research results from former, ongoing, and upcoming projects and security focused operation models.

Despite heterogenous practices of requirements development implemented in European projects, the created requirements knowledge base should be utilised in an effective manner. Requirements reuse can provide multiple benefits, and it should be considered more carefully in future when planning new projects despite of the clear challenges of the implementation domain's security obligations. In an ideal case, previously defined requirements function as a reference against which planned or ongoing projects and their requirements can be compared. Reuse activities should consider special demands and characteristics of the upcoming border management developments and studies. The emergence of novel technologies and the implementation of new solutions also influence how the former requirements should be assessed and utilised. In an optimal scenario, requirements reuse or in some cases reutilisation could be straightforward if the use environments and the practitioners resemble each other between projects. On the other hand, multifaceted differences between Member States and regions and overall confidentiality restrictions pose significant demands on project consortiums as they need to arrive at a sustainable understanding how to utilise existing requirements from previous projects.

The projects were mostly analysed retrospectively with several years passing from their completion, potentially introducing limitations or distortions through historical hindsight to the quality and validity of the lessons identified. Often, post-project reviews are organised at the end or close to the ending of a project (Milton 2010). Future work related to the requirements reuse in border management or civil security projects in general could consider and identify drivers of how to merge e.g., what are the main recognisable indicators in previous requirements that can be applied in defining new requirements or utilising them in the development of future border security technologies. Utilizing machine learning to derive new requirements by reusing existing ones can foster innovative solutions for the future (Do, Browmik and Bradshaw 2020). This might require EU level efforts and guidance to ensure uniform and reusable approach in the security domain.

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