Section E (Item 33): Presentation of research programme for evaluation according to the criterion »Scientific, technological or innovative excellence«

Glossary

AI – Artificial intelligence
API – Application programming interface
BPM – Business process management
CJM – Customer journey mapping
CMMN – Case management model and notation
DMN – Decision model and notation
DPKI – Distributed public key infrastructure
HCI – Human-computer interaction
ICT – Information and communication technology
IS – Information system
IT – Information technology
XAI – Explainable artificial intelligence
ML – Machine learning
PKI – Public key infrastructure
RP – Research programme
SME – Small and medium enterprises
SSI – Self-sovereign identity
SQA – Software quality assurance
UI – User interface
UX – User experience

1. The Research Programme background and vision

With the advent of intelligent solutions, computers will inevitably start performing many tasks that were, until now, reserved exclusively for humans (Enholm et al., 2022). The rapid pace of IS development, in terms of new approaches and services that were not foreseen clearly in the last decade, drives the area into new demands: from a social and business systems perspective, organisations, and their users. The research and development in the area is outreaching increasingly from being a technological and/or organisational enabler, and, instead, becoming the central hub of not only ICT-based services, but also, importantly, digitalisation as understood by the widest possible interpretation.

In the last decade our research and development were focused mainly on efforts on sustainable development of well-designed IS with a high, or at least manageable, internal and external quality. Our past contributions in managing complexity and quality assurance proved to be right and visionary. They addressed challenges, associated with the successful development, deployment, management, operation and acceptance of IT solutions and innovative ICT-based services. However, accelerated development exposed not only tremendous progress, but also the emergence of new issues in the areas, critical to the sustainable IS development with a demand for build-in quality, security and safety, while pursuing cost-effective IT solutions. Some of the enablers for fast ICT solutions and services growth proved to be a high level of automatization (Azad et al., 2023) in major aspects of designing and developing IS, and high volume of data (Sestino et al., 2020), that we can and do store, high processing capabilities, their use in information feedbacks to improve several aspects of the IS development and deployment systematically. In the presented context IS are positioned more than ever in the role of a solid bridge between the ICT (enabling technology), and the business process demands (Plekhanov et al., 2022). Therefore, IS are a crucial enabling component for new business models, with built-in capabilities for highly automated making of informed decisions, and, consequently, enabling users, business, and a wider audience to improve their professional and everyday life. This is why we see our role as an IS research group important, that can, and will, contribute to breakthroughs in **two directions**. The first direction is focusing on enabling data-driven approaches to all aspects of IS development and deployment. As we will demonstrate in the proposal, our research scopes cover a complete pipeline, where informed- and data-driven decisions chain the IS technical aspects with the development and proper employment of intelligent solutions that are built safely and securely with well selected and executed organisational IS development approaches, and, finally, delivering solutions and services that meet the highest user experience standards with the demands of informed decisions in business process digitalisation and management. **The first direction (data-driven decision-making)** is inseparable with the **second direction**, that is going to be crucial in the industry in years to come: **Automated delivery with data feedbacks** as a way of **continuous improvement**. As we can sense, IS delivery is finally becoming more business-driven, which is a situation that we were trying to achieve for years. As a result, data insights will become a built-in component in the automated feedback from the business, process management perspective, to the technical aspects of IS delivery. This has already started to form in terms of approaches and automation, that are spread in the umbrella-like collections of industry-proven best practices, approaches and helper tools (Gartner, 2021): **DevOps** and **GitOps** (bringing together development and operations teams), **NoOps** (minimising the need and interventions of the operations teams), (**Dev)SecOps** (ensuring automated and built-in security and safety), **DataOps** (practices and tools in managing and deploying data pipelines and analytics workflows), **AIOps** and **MLOps** (automated approaches in building ML models from updated data, anomaly detection, etc.), **BizDevOps** (integrating the business development activities into the DevOps processes), and, finally – **XOps**, which aims at the integration of practices that build on the *Ops philosophy, seeking to optimise the software development lifecycle further by integrating additional practices, and aspects, such as the development domain.

The two directions combined (**continuous improvement based on data feedbacks, informed decisions, and automated IS delivery**), that form the long-term vision of our research group are aligned with our mid-term vision. This is in developing, adopting, and advocating a holistic approach to the *sustainable development of intelligent IS, emphasising complexity and quality management*. Unfortunately, the observed industry's focus on AI-based solutions neglects the fundamental issue: Introducing new and (possibly) immature technologies, approaches and tools uncritically might additionally influence the complexity and long-term sustainability negatively. In this context, we would like to stress that the issues and challenges of the past are still (or even more) important to consider and address. Among them, software complexity is probably the most important while developing new intelligent IS. What users perceive as simpler human-computer interaction, requires new development skills, which, in addition, also results in a need for novel approaches and additional complexities. Only carefully balanced methodologies, approaches, paradigms, tools, and algorithms can ensure the sustainable development of high-quality modern IS. For this reason, any research must address the management of complexity, and quality assurance in the design, development, implementation, deployment, and governance of IS holistically. A modern IS recognises and embeds AI techniques as a core operating principle, yet acknowledges and addresses their inherent dangers (Gov.si, 2023; EC-AIWatch, 2023). Summarized, the main vision of the Research Programme supports **continuous improvement** of **sustainable intelligent IS development**, based on **automated delivery** pipelines, and **data feedback,** while handling IS complexity and quality.

We will demonstrate in the next sections how our research directions follow the vision of the "Information system" RP. The **directions**, addressing the main aspects of our research, are broken into a set of coherently **interconnected research scopes** and **objectives**. The presented research methods and timelines outline our further research in a consistent, relevant, and achievable manner, with the considered feasibility of proposed schedule.

2. The Research Programme content

The research will be focused on several interconnected research scopes, that address the RP vision. They spread from advancing technical measures in the research domain to exploring and improving user experience-related issues further. With advancing the scopes of "*IS architectures*" and "*Intelligent systems*" we will support the scope of "*Advanced IS development approaches*" and "*Cybersecurity and privacy*" further, which, in turn will affect "*Quality of user experience*" and "*Process management*". With managing complexity and enabling data feedback, we will advocate informed decisions to be enabled at all levels of IS development and deployment. The birds-eye view on interconnected research scopes is as follows: (1) In the scope of **IS architectures**, research will be directed towards modern information solution architectures and related patterns, including decentralised, cloud-based, big-data, microservice, and serverless architectures; data spaces, data lakes, data lakehouses, modern event-based data management techniques; modern approaches for on- and off-chain data and identity management; (2) The **Intelligent Systems** research scope will, in addition to the well-known issues of ever-increasing volume, complexity and multi-modality of data (with respect to DataOps), address primarily the arising challenges of non-transparent predictive models, unfair AI decisions, the need for highly customised machine learning solutions, high demands on computing power for training machine learning models (considering AIOps), and inefficient deployment of AI models (in accordance with MLOps); (3) **Advanced IS development approaches**, where, in addition to organisational aspects of sustainable IS development, a special emphasis of the research will be on DevSecOps practices, including delivery pipeline automation while ensuring continuous testing, quality assurance with automated dynamic quality gates, enforcing secure code practices, and metrics-based quality assessment to achieve secure and safe IS. The development for and with the help of intelligent cloud-based components will also be addressed partially in this scope; (4) **Cybersecurity and privacy**-related research will largely be congruent with SecOps and will focus on the priority of cybersecurity knowledge and skills to be taught, evaluation of approaches for improving user privacy and security, advancing the scope of modern authentication methods (centralised and decentralised), and advancing proactive and intelligent cyber defence; (5) **Quality of user experience** is the research scope that will focus on new models and methods for exploring UX quality, employing modern advanced intelligent tools and approaches in novel situations, including users with different disabilities, inclusive UX, UX in explainable AI solutions, and advancing patterns for UX in several user interface types; and finally (6) **Process management** is the scope where research objectives will address the dynamic view of modern information solutions, driven by advanced process modelling approaches such as "Customer journey mapping", unstructured processes discovering and modelling, and advancing process mining in organisations.

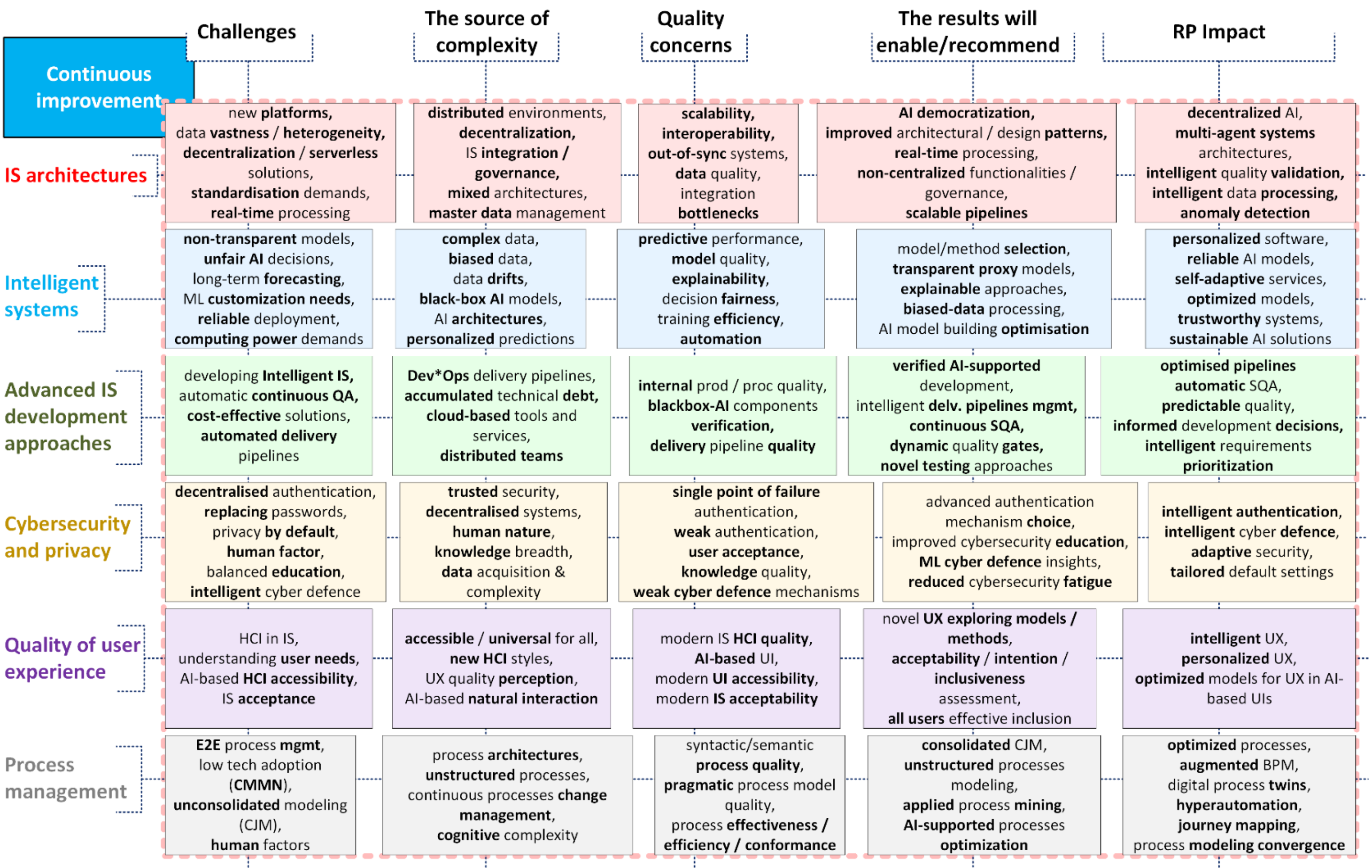

Figure 1: The research scopes in the RP

The presented six interconnected and interdependent research scopes constitute a sound whole, while delivering well-designed and implemented, user- and business-centric secure and intelligent IS in an effective and performant manner. In addition to the intelligent (i.e. data-driven) and domain tailored IS, the research focus in the research group will also address one of the main

IS objectives holistically: supporting decision-making. By incorporating evidence and data-driven approaches in the delivery pipelines, our research will also contribute to the development teams with accurate and time-based information, helping them in making the right decisions in a turbulent environment – i.e. one of the main themes in the research group is also to provide informed decisions to the IS development teams.

2.1 The Research Programme scope comprises six research scopes to fulfil the main vision of the RP and to address the key tasks and operational scopes. In addition to their interconnections, Figure 1 presents an outline of the main **challenges**, the identified **sources of complexity**, the main **quality concerns**, and the main **outcomes** and **potentials**. As we present the c*urrent state* of individual research scopes, outline the *gaps in existing knowledge*, which are assessed as crucial in terms of the main vision of our RP, and *propose original research topics,* we also outline the *planned objectives*. The objectives, when completed, will address the main RP vision holistically.

2.1.1 Research scope: IS architectures. The progress of IS development in the last decade put the software, IS and IT architectures towards new challenges. In addition to the core IS architecture aim (to provide efficient operation, a proven set of functional and non-functional system properties, etc.), the changing IS architecture landscape has many consequences. Decades-long proven approaches to data storage, processing, and retrieval, have been exposed to novel non-functional requirements, that originated from new conceptual, technical and regulatory approaches in modern IT. Traditional distributed architectural styles is in decay, while modern cloud-based, decentralised (Ouyang et al., 2022), microservice-based solutions provide new opportunities, and, consequently, new challenges to be addressed by theoretical and empirical research in order to provide long-term sustainability in IS architecture (Podgorelec et al., 2020 - A).

Originated from modern feature-oriented development practices, one of the main challenges facing modern IT/software architectures is the need for increased agility, scalability, and flexibility. As IS become more complex and distributed, it becomes more difficult to make changes, ensure integration and introduce new features without disrupting it. To follow proven practices and implementing solid architectural styles is becoming even more important in this distributed and connected environment (Gašparič et al., 2020).

A high volume of structured and unstructured data is being produced rapidly (Šestak et al., 2021), processed and stored (in terms of persistent state or persistent change) in on- and off- the blockchain-based ledgers (Turkanović et al., 2018), on cloud-based storage, on-premise datacentres, in various data platform types (Armbrust et al., 2021), and distributed apps (Keršič et al., 2022). Consequently, there are several challenges to be addressed by research in managing modern decentralised AI (Montes & Goertzel, 2019) (objective 1.1), data space governance (objective 1.2), big data pipeline architectures, which include modern data lakes and lakehouses (objective 1.3).

The driver of our further research in the scope will also be patterns of not only modern cloud-based, serverless and decentralized IS (objectives 1.5 and 1.6), but also on enabling mechanisms, such as decentralisation of identity management (Čučko et al., 2022) (objective 1.4), which is crucial in todays distributed IS nature. The driver of our research in the scope of IS architectures is to objectify decision making in developing, evaluating, and managing IS architectures. Therefore, our research objectives, that we will continue to pursue, include novel approaches on modern IS scalability and performance. They include modern data storage concepts, such as event sourcing (objective 1.7), and managing, limiting, exposing, and combining services with API management indirectly (objective 1.8). The objectives of this research scope are as follows:

- *Objective 1.1*: To adopt an improved model for management of **decentralised AI** and related architecture patterns. *['26 – '29]*
- *Objective 1.2*: To develop a model for **data space governance**, based on **decentralised systems** and architectures. *['24 – '26]*
- *Objective 1.3*: To propose and evaluate **big data pipeline architectures** for data integration in **data spaces** and **data lakehouses**. *['24 – '26]*
- *Objective 1.4*: To design an orchestration solution for **identity management** based on **decentralised architecture**. *['24 – '25]*
- *Objective 1.5*: To analyse and classify **architectural patterns** of advanced **serverless architectures**. *['24]*
- *Objective 1.6*: To develop a model for a quality evaluation of **cloud-native microservice solutions**. *['25 – '27]*
- *Objective 1.7*: To define a modern **data storage architecture**, based on **event-sourcing**. *['27 – '29]*
- *Objective 1.8*: To propose approaches of **scalability** and **performance** improvement, based on **API management** and **cloud-native architectures**. *['27 – '29]*

2.1.2 Research scope: Intelligent systems. Applying ML methods and delivering high-quality AI solutions is becoming one of the key activities in IS development. In addition to already accepted issues of ever-increasing volume, complexity and multi-modality of data, the arising challenges are non-transparent models, unfair AI decisions, the need for highly customised ML solutions, high demands on computing power and inefficient deployment of AI models (Paleyes et al., 2022). While we have addressed the challenges of analysing and predicting complex, unstructured data, in large-scale text, visual data and software code successfully (Karakatič et al., 2022), we want to explore proven processing methods with advanced vector embedding data representations (objective 2.1), to simplify the training and to improve ML models with new data and feature engineering methods (objective 2.6) by applying nature-inspired optimisation approaches (Brezočnik et al., 2018). As hybrid ensembles (Vrbančič & Podgorelec, 2022) and tuning of deep neural networks to a specific task are emerging as leading approaches to achieve high predictive performance (Oreshkin et al., 2021), we intend to adapt meta-heuristic methods for hybridisation of AI and ML models (objective 2.2) and assess their potential for artificial general intelligence. We expect that such an approach will also work on the most challenging types of semi-structured data, and improve the long-term predictive performance on multivariate time series significantly (objective 2.3). While such complex models have already demonstrated high predictive performance in controlled environments, these models are also very complex and incomprehensible, making it very difficult or even impossible, to validate the discovered patterns and relationships, to derive insights into the decision-making procedures

(Fister & Fister, 2021) and to deploy them efficiently in a real-world environment (Arrieta et al., 2020). Therefore, we will focus on the research of explainable and fair AI (Colakovic & Karakatič, 2022) models and pipelines (objective 2.4), bringing them closer to domain experts and software engineers (Ooge et al., 2022), by designing intelligent systems engineering techniques for quality assurance throughout the IS lifecycle in a real-world environment (objective 2.5). To approach the goals of Green AI, we will address the reduction of high demands on computing power in training complex ML models with nature-inspired algorithms (objective 2.7). The objectives of the research filed are:

- _Objective 2.1_: To develop and evaluate **hybrid ML methods** for analysing **complex data** and **vector embeddings**. *[‘24 – ‘27]*
- _Objective 2.2_: To design and evaluate **meta-heuristic algorithms** for building and optimising AI & ML models. *[‘26 – ‘29]*
- _Objective 2.3_: To analyse, develop and evaluate hybrid approaches for **training deep neural networks** that improve **long-term forecasting** on time-series data. *[‘24 – ‘25]*
- _Objective 2.4_: To develop, enhance and evaluate the **explainable AI** approaches and **fairness** (Fair AI) of machine learning models and machine learning pipelines. *[‘26 – ‘27]*
- _Objective 2.5_: To design and evaluate intelligent systems **engineering techniques** for quality assurance of **predictive models** in a real-world environment. *[‘26 – ‘28]*
- _Objective 2.6_: To adapt and design new methods for improving the quality of machine learning models with **feature engineering, data processing techniques** and **systems thinking**. *[‘24 – ‘26]*
- _Objective 2.7_: To develop and assess an innovative approach for **reducing computational complexity** in training complex machine learning models with **nature-inspired algorithms** towards Green AI. *[‘27 – ‘29]*

2.1.3 Research scope: Advanced IS development approaches. The modern IS development approaches differ considerably, compared to the organisational and technical aspects of development in previous decades. While traditional development practices were mostly plan-based, focused on detailed requirements and design specifications, today’s pursuit is in rapid development of user-focused, well-engineered, and cost-effective solutions. It relies mainly on automation, cloud services, customer on site, iterative development, and other practices of agile development, such as DevSecOps (including GitOps, DataOps, etc.) with continuous IS delivery pipelines. While short term customer benefits of such an approach in industry are clear (Marnewick and Marnewick, 2022), possible underlying long-term issues (Sumit et al., 2017) of negatively affected quality, accumulated technical debt, unsustainable architectural design, and similar, can, and must, be addressed systematically with appropriate measures. They include appropriate organisational aspects, appropriate practices and supporting tools.

Tool-supported automation in the scope has already been advanced to a level where it is practised on a daily basis. However, with advancements in the AI, novel tools emerged that can help during IS development. Their impact needs further theoretical and empirical validation before they can be employed fully in the IS development. On the other hand, the AI, as a powerful tool in several domains, has raised the development complexity even higher, exposing decades-long practiced and established areas (e.g. software testing, safety by design etc.) to new challenges. In this context, the development of AI-enabled IS needs novel approaches and tools to support activities as common as software testing, predicting IS behaviour in several context-spaces etc. A continuous quality assurance is, therefore, becoming a keystone in both successful development approaches and information solutions and services with high internal and external quality.

The previous work in the research group includes several aspects of IS development, including software quality prediction (Gradišnik et al., 2020) and early-stage research on developing with- and for- AI services. Our research in the scope already addressed quality management, based on systematic testing and metrics (Pavlič et al., 2020, 2021). Therefore, our work will not only continue well established research in the scope, but also investigate deeper the development of IS with AI services (objective 3.1) and employing appropriate approaches and tools, built on AI models, that enable better, and more performant IS development (objective 3.2), e.g. tools in the DevSecOps delivery pipeline. More automated and rapid IS development approaches also create new issues. Our research will focus on further development and adoption of software metrics (objective 3.3) to establish sound and adopted dynamic quality gates as a part of the delivery pipeline. Modern IS testing approaches, especially the ones that verify systems with AI-enabled components, are in the early stages of research. This is why our research group will join the efforts in terms of verifying, adopting, and improving the modern testing approaches in the scope of continuous testing (objective 3.4). Therefore, objectives in this research scope include following:

- _Objective 3.1_: To design and evaluate approaches for developing **solutions with AI-supported services**. *[‘24 – ‘26]*
- _Objective 3.2_: To develop new **AI-based** approaches for supporting DevSecOps **continuous delivery pipelines**. *[‘24 – ‘27]*
- _Objective 3.3_: To develop a model and **adapted metrics** for continuous quality assurance and risk management with **dynamic quality gates**. *[‘27 – ‘29]*
- _Objective 3.4_: To verify modern automated **continuous testing approaches** in the solution delivery pipeline. *[‘26 – ‘29]*

2.1.4 Research scope: Cybersecurity and privacy. The development of ICT, including cybersecurity and privacy, has affected the IS quality (and consequently, trust) directly. Managing the cybersecurity complexity remains one of the biggest challenges for users. Passwords remain the most widely used authentication method, due primarily to their simplicity, ease of implementation, and affordability (Davinson & Sillence, 2014). However, users tend to choose weak passwords, which leads to the development of alternative methods of authentication (Papathanasaki et al., 2022). The analysis, development and evaluation of alternative authentication methods will be one of our research goals (objective 4.1). At the same time, users are faced with many security and privacy decisions. Navigating the endless security in privacy options that users are exposed to on seemingly, every service is becoming overwhelming putting negative pressure on them and causing them to ignore the security/privacy measures altogether (Acquisti et al., 2017). For this purpose, we will analyse and evaluate the different approaches for improving user privacy and security (objective 4.2). Decentralisation has become one of the main tools to combat the lack of trust in a centralised entity, and it is spilling over to authentication mechanisms. Based on the results of our current research (Čučko et al., 2022) on the topic of decentralised and self-sovereign identity (SSI), our aim (objective 4.5) is to design a novel model for mandates and delegation processes, which will be based on SSI principles and aligned with centralised public key infrastructures. The model will use the core IT components and cryptographic primitives already used within both PKI and DPKI. ML and AI have the potential to change the scope of cyber security completely. Early detection of coordinated attacks on cyber systems is a vital part of cyber defence mechanisms (Shaukat et al., 2020). We will analyse and evaluate machine learning models operating on probe data, network equipment logs and the network endpoint events that identify the attack attempt and generate appropriate alerts in real-time (objective 4.4). While all the objectives in this research scope can be tied to SecOps or PrivacyOps, the research related to objective 4.4 has the largest potential for improving the automation of security operations. Meanwhile, cybersecurity competences and skills are becoming more sought after, and the deficit of cybersecurity professionals is massive across the world ((ISC)2, 2022)). We plan to analyse and evaluate the importance of cybersecurity knowledge and skills (objective 4.3). The defined importance of individual cybersecurity knowledge units will support the updating of old and design of new cybersecurity curriculums to produce a competent and well-rounded cybersecurity workforce. Our research in the scope will therefore follow several objectives:

- *Objective 4.1*: To evaluate existing and develop a novel **alternative authentication method**. *['26 – '28]*
- *Objective 4.2*: To analyse and evaluate **approaches for improving user privacy** and **security**. *['26 – '29]*
- *Objective 4.3*: To evaluate the importance of **cybersecurity knowledge and skills**. *['24 – '25]*
- *Objective 4.4*: To analyse and evaluate **machine-learning supported** methods to classify and facilitate **mitigation of coordinated cyber attacks**. *['27 – '29]*
- *Objective 4.5*: To design a novel management model of the **decentralised self-sovereign identity principles**. *['24 – '27]*

2.1.5 Research scope: Quality of user experience. Modern society relies on Human-Computer Interaction (HCI), both in traditional and AI-based applications. Whether a particular technology or its application is adopted, retained, or even abandoned depends largely on the individual or company UX. Therefore, all factors that may play a role in the technology development or while in production should be examined carefully to enable optimal performance. While, generally, we know the main traditional computer-based technologies trajectories of the adoption, this is not the case for fast-growing AI-based technologies. Further research is required not only on intelligent solutions based on AI methods, algorithms and sensor technology that enable the development of devices with human communication capabilities and natural HCI (Šumak et al., 2021), but in HCI and UX as well. Such research will lead to the development of a new generation of intelligent UI improving HCI and the usability of UI (Brdnik et al., 2022). Although there are tremendous efforts to promote digital inclusion to ensure that every individual has access to ICT, our recent research has shown that digital accessibility is still a challenge even in the case of traditional websites (Kous et al., 2021; Kous & Polančič, 2021; Marco et al., 2019). The communication between AI and people with disabilities is, in most cases, still an unexplored research scope. Therefore, the emergence of modern IS and services based on intelligent technologies (e.g. ChatGpt) needs new research to investigate unexplored factors, impacting the adoption and inclusive use of such technologies and services in education, learning, research, project management, software development, etc., and how their use affects the UX in creating learning content, teaching performance, writing research articles, etc. (objectives 5.1, 5.3, and 5.4). Developing user-friendly and accessible solutions also requires conducting end-user testing. Especially for users with disabilities, a user-centred approach is essential to include these users in the process to ensure that the product is usable and accessible for all (Nair et al., 2022). When including users with disabilities into user tests, additional care should also be taken to ensure that the tests are planned and conducted to allow successful and efficient integration of users with disabilities (objective 5.2). While performing HCI research, all precautions related to best practices and regulations regarding research design and privacy must be considered, regardless of the research population (objective 5.3). Further research is also needed in developing and validating solutions that can improve the quality of UX in the use of modern AI-based UI solutions (objectives 5.4 and 5.5). Based on previous experience, an intensive review of references and sometimes unpredictable future technologies, the research objectives are set as follows.

- *Objective 5.1*: To develop and validate new models and methods for exploring the **quality of UX, acceptability** and **continuance intention** of using modern tools and services in different aspects of human lives with **interests in use**. *['24 – '28]*
- *Objective 5.2*: To develop and evaluate **inclusive user-based usability** and **UX testing** methods. *['25 – '26]*
- *Objective 5.3*: To develop and evaluate methods for assessing the **level of inclusive UX** in specific **contexts**. *['28 – '29]*
- *Objective 5.4*: To identify usability and UX challenges in modern **AI based solutions**. *['26 – '29]*
- *Objective 5.5*: To develop and evaluate solutions for **improving the quality of UX and HCI in AI-based UI**. *['27 – '29]*

2.1.6 Research scope: Process management. As part of IS research, the key idea of BPM is improving organisational performance, meaning that BPM's key concerns remain analysis, design, and management of work processes within and across organisations, which often involves the use of information technology (Reijers, 2021). By optimising and aligning these elements, organisations can improve the generation of products or services, such as by speeding up the process, making it more efficient, or reducing its ecological footprint. We plan to address challenges in process management in processes' design and runtime as follows. First, in line with one of the key BPM concerns, i.e., "expansive BPM" (Beerepoot et al., 2023), we plan to continue research in managing process architectures via static (Polančič, 2020) and dynamic (Polančič and Orban, 2023) aspects. We will focus on defining an effective technique for managing complex process architectures and test the effectiveness of process landscape designs empirically (objective 6.1). Secondly, based on experiences gained in the design-science-based specification and empirical investigation of the cognitive effectiveness of notations, we aim to consolidate the »Customer journey mapping« (CJM) technique, and integrate it with business process modelling. CJM has gained significant popularity in recent years, yet remained unstandardised and unconsolidated. Accordingly, we will review present CJM techniques and tools and, upon them, specify a standard visual notation with an underlying meta-model. In addition, we will relate the CJM notation with standard process modelling notations, such as BPMN and Decision Model and Notation (DMN) (Heuchert, 2019)(objective

6.2). Third, due to the continuous and compelling increases in the automation of structured processes, the knowledge and human-intensive (i.e. non-structured, worker-centric) processes have gained popularity in recent years. Accordingly, the Case Management Model and Notation (CMMN) was introduced to standardise the scope. However, recent industrial reports and academic trends indicate that CMMN did not gain momentum. Our efforts will therefore be directed towards identifying the roots of CMMN challenges and proposing improvements in the scope of worker-centric process management (objective 6.3). Fourth, there is an unmet optimization potential in existing business processes, and process redesign has remained mainly a manual, cognitively demanding, time-consuming, labour-intensive, and error-prone task (Beerepoot et al., 2023). Driven by the "hyper-automation" concept, our efforts will be focused on examining the possibilities of how to extend the existing framework for business process optimisation with AI solutions (objective 6.4). Fifth, technical advancements in data science and ML, as well as the third wave of AI, have raised expectations of business transformation (Beerepoot et al., 2023), relying heavily on advanced process mining tools and techniques. Process mining is becoming part of the routines of modern companies (Kerremans et al., 2020), while in our local business environment, it is still underestimated. Accordingly, the goal is to develop and test an evidence-based methodology for business process measurement, evaluation, and optimisation based on process mining of operational data adapted to typical Slovenian enterprises – SMEs (objective 6.5). The research scope objectives are as follows:

- *Objective 6.1*: To design and evaluate a technique for effectively **managing complex process architectures**. *['24 – '26]*
- *Objective 6.2*: To consolidate **CJM** techniques and integrate them with business process modelling. *['26 – '29]*
- *Objective 6.3*: To design and evaluate a modelling technique for effective **worker-centric process management**. *['24 – '28]*
- *Objective 6.4*: To design and evaluate an extended framework for **business process optimisation**. *['28 – '29]*
- *Objective 6.5*: To develop and test a method for **process mining in small and medium enterprises**. *['29]*

3. The methodological approach to the Research Programme objectives

The research programme methodology involves **theoretical** and **empirical research** with practical outlines, including the **inductive and deductive interconnection** of the two levels, to objectify decision-making in developing, evaluating, and managing the quality and complexity of intelligent IS. The programme seeks to contribute to the scope of IS by providing novel methods and solutions to the challenges posed by modern IT approaches and the changing landscape of IS development. We will continue with the methodological approach that *was employed and perfected successfully in the previous periods of RP financing*, whereby most of them are derived from the common research methods from the scientific scope of Computer Science, Information Technology, Software Engineering, as well as Data Science. In addition to fundamental theoretical research, these are also descriptive research and theoretical evaluations, literature and survey review research, empirical methods including construction of models and implementation of prototypes, empirical data-based inductive and deductive research, action research simulations, experiments, case studies and design science research.

Most of our research activities towards previously presented objectives will start with theoretical research (e.g., systematics literature review, conceptual analysis, proposition development) and continue towards descriptive (e.g., surveys, observations), and empirical research (e.g., correlations, case studies, experiments). Systematic literature reviews will be used primarily to assess the current state of research, and to identify the possible reasons for the contradictory findings of the research results. As an example, we will review architectural patterns of advanced serverless architectures, approaches for improving user privacy and security, methods to mitigate coordinated cyber-attacks, and others.

During the central stages of our research, the construction of models and implementation of prototypes will be used to test new approaches and solutions in the fields of IS. Some examples include automated continuous testing approaches, a model for data space governance based on decentralised systems, a method for process mining in small and medium enterprises and others. The research process will be driven based on the concepts of design science, thus data will be gathered through observations, surveys, interviews, as well as possible collaborative processes working with stakeholders. With it, empirical research will typically follow, where we will use empirical methods (e.g. the experimental methods and causal non-experimental methods), validated models and constructs (e.g. performance, acceptance, comprehensiveness and quality) to determine the potential benefits of the proposed results. Systematic or non-systematic empirical data gathering (e.g. with surveys, employing observations and metrics) and accompanied by theoretical evaluations and analysis will be employed as a way to achieve several objectives. Among them are assessing the level of inclusive UX, evaluating the importance of cybersecurity knowledge and skills, validating adapted metrics in dynamic quality gates, evaluating approaches for developing solutions with AI-supported services, evaluating intelligent systems engineering techniques for quality assurance, evaluating the explainable AI approaches, and others.

Finally, to promote our solutions that spread beyond the state-of-the-art, and at the same time, to test the applicability of the proposed solutions, we will use a proof of concept (also with the help of simulations and case studies) and methods implemented in a real environment, where applicable. For example, we plan to construct holistic automated continuous IS delivery pipelines, prototype a data space platform based on decentralised systems and architectures, prototype specific machine learning pipelines to evaluate the concepts of explainable and Fair AI, etc.

4. The Research Programme timetable

By continuing the research work of the last period, the results of our previous work will be upgraded with the novel insights and discoveries. The time plan for working on RP objectives and their achievements over the years is shown in Figure 2. The objectives' interconnection, both within research areas, as well as their interdependence over several areas, is considered in the plan. Typically, the analysis and construction, where applicable, must be at the mature state before the results can lead to, e.g., a novel method, where a previous objective deliverable is an important input or guideline.

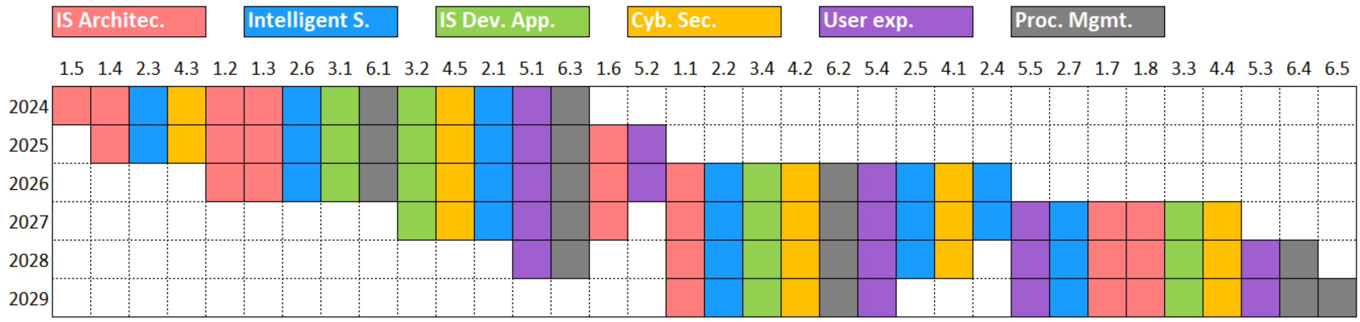

Figure 2: Research Programme time plan – achieving objectives over the years with a target timespan

Examples of intra-scope interconnections are in the cases of objectives 1.5 and 1.6, where we expect that architectural patterns of advanced serverless architectures will play a major role in a model that will be designed for a quality evaluation of cloud-native microservice solutions. Similar interdependencies can also be found while working on objectives 4.5 and 4.4, 2.6 and 2.4, and several others.

An interdependence example, that spread over several areas is in the objective 2.1, that will be finished before the 6.5 starts (the developed and evaluated methods for analysing complex data will be used in newly developed and evaluated process mining methods). Among others, another example is in the case of objective 2.4 (developing, enhancing, and evaluating the explainable AI approaches), that is expected to be on mature level during the work on objective 5.4 (identifying UX challenges in explainable-AI-based IS).

Our time plan is balanced both from the scope- and the programme-perspective in terms of sustainable and evenly distributed efforts over the funding period. The time plan suggests that almost two-thirds of the objectives will be reached before the last year of the funding, giving us the opportunity to finish all objectives on-time, even in the case of unexpected schedule-shocking events.

Based on previous RP funding, the approved funds will cover the foundation work, presented in this proposal. However, to exceed the planned research goals, we will, as usual, continue to seek for additional funds from other institutional, national, and international projects, especially in our collaboration with industry. This is how we will extend the research, and facilitate the transfer of knowledge to industry and society even further.

5. The impact of the RP on the development of new research directions

Research scopes that we address in the RP are very relevant as they tackle important challenges, related to IS. With the further development of digitalisation and the fourth industrial revolution, that drives the transformation to society 5.0, there are new demands being placed on IS in terms of providing data-based solutions to make informed decisions. To do so effectively, several aspects must still be addressed, including performance, usability, reliability, the need to shorten development cycles, reduce costs, and improve development and operation processes, and develop, and validate intelligent IS carefully. The findings of our research, in the form of new methods and approaches, can lead to better quality, efficiency, and capacity of IT-based services. Additionally, they can also contribute to promoting sustainable development of secure, safe and explainable intelligent IT services and solutions.

The RP encompasses several objectives, and its outcomes will also have a significant impact on research scopes beyond IS development. The techniques for collecting, integrating, and analysing data will contribute to the advancement of data-driven decisions in both development activities and for end users also. The objectives, connected directly or indirectly to product and process quality, will contribute to automated testing and quality assurance for and with intelligent components. The methods of data acquisition, integration and analysis of data will contribute to the development of areas of data analytics and machine learning. The developed innovative communication protocols will contribute significantly to the development of the field of Secure Communications and the next generation of social software. The convergence of methods for the modelling and analysis of processes, which will allow an insight into these processes, can play a key role in autonomous management and optimisation of social and business processes. The developed mechanisms for continuous quality monitoring and tested quality assurance models will contribute significantly to the development of services sciences and providing quality services for every person, profession, science and society as a whole.

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Section F (Item 34): Presentation of research programme for evaluation according to the criterion »Potential impact due to the development, dissemination and use of the expected research results«

The Research Programme (RP) concentrates on operational areas that tackle crucial research challenges in the management, design, development, governance, continuous improvement, and deployment of intelligent information systems (IS), which are relevant considering society's digital and green transformation, the fourth industrial revolution, that drives the transformation to Society 5.0. The previous paradigm, known as Industry 4.0, was succes*sful in terms of addressing technical challenges, i.e., the automation and digitalisation of business and technology*. However, the *human factor* was overlooked, consequently, leaving a **gap between technology and sociological, accessibility** and **similar** aspects. **The transition to Society 5.0**, as understood widely, should bring **together the best of the human and machine worlds**. By combining human creativity, empathy, and intuition with the power, efficiency of machines, and possibilities of adopting the applications to users with special needs, this transformative idea fosters collaboration and progress. Through the **integration of novel technological breakthroughs** (e.g., AI, process mining, proactive intelligent cybersecurity, and others), Society 5.0 aims to create **an inclusive and sustainable society** where **innovation thrives**, and **complex challenges are addressed**. This partnership between users and IS holds the potential to unlock new frontiers of advancement and enhance the well-being of all, regardless of locale, age, language, and similar properties. With our RP, we are certain that, while meeting our objectives, **we will contribute to the transformation** directly or implicitly. The presented new demands are being placed on IS in terms of providing data-based solutions that enable informed decisions and establish systematic continuous improvement by employing feedback to the developers and users on all levels of IS. The underlying challenges, beside democratization of technologies, involve improving the performance, reliability, and usability of IS while also reducing development costs and shortening development cycles. The RP aims to produce new methods and approaches to enhance the democratization of technology, quality, efficiency, and capacity of IS and ICT-based services, fostering a sustainable development process for intelligent IS.

The RP core objective remains to manage complexity and ensure **quality** in all phases of the IS lifecycle due to **data feedback** in the context of XOps practices and tools. Artificial intelligence (AI) techniques and tools are considered and applied intensively in all aspects of the RP. As illustrated in Figure 1, the RP objectives are driven by the need of **continuous improvement** in all RP scopes. On the other hand, they **pursue and promote automatic and intelligent informed decisions** because of IS data feedback and its automated delivery. Informed decisions, on the other hand, enable continuous improvement in the field of IS, which connects the loop. Our approach, in addition, while not addressed directly, has a lot of potential impacts, as described in the rest of this section.

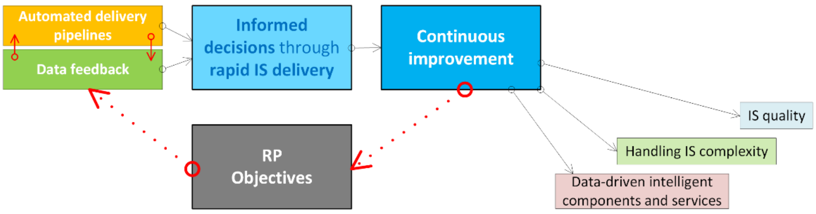

Figure 1: RP Objectives connecting and enabling the loop of continuous improvement.

Impacts on the development of science and the profession

The evolving landscape of IS architecture presents both challenges and opportunities for theoretical and empirical research. Increased demands for agility, scalability, and flexibility have emerged as central challenges facing modern IS architectures. As a result, research in managing modern decentralised AI, data space governance, and big data pipeline architectures, has become crucial to meet these demands. This research aims to **enhance objective decision-making** in developing, evaluating, and managing IS architectures, fostering **long-term sustainability** and **continuous improvement**. Ultimately, it seeks to deliver rapid and **cost-effective** IT solutions, including **multi-agent systems architectures** and a high potential for **anomaly detection**. By addressing the challenges of non-transparent models, unfair AI decisions, and inefficient deployment of AI models, research in intelligent systems is expected to improve the quality and reliability of AI solutions. The development and evaluation of hybrid machine learning methods for analysing complex data and vector embeddings, as well as the design and evaluation of meta-heuristic algorithms for building and optimising AI and machine learning models, can **enhance the accuracy** and **efficiency** of AI solutions. The analysis, development, and evaluation of hybrid approaches for training deep neural networks that improve **long-term forecasting** on time-series data can lead to more accurate and reliable predictions in various domains, including finance, healthcare, and energy. Additionally, the development, enhancement, and **evaluation of explainable AI** approaches and fairness (Fair AI) of machine learning models, and machine learning pipelines can increase the trust of stakeholders and make AI solutions more acceptable in various applications due to **reliable AI models** and, consequently, **sustainable AI solutions**.

By achieving the objectives in the research field of Advanced IS development approaches, researchers will contribute to the development of new and innovative IS **development practices** that can address the challenges posed by the integration of AI in the field. This will have a significant impact on the advancement of science and the profession by enabling the development of **high-quality and efficient intelligent IS** solutions that meet the needs of users and organisations. Informed development decisions, and **intelligent requirements' prioritisation**, are examples of two possible impacts of our RP objectives.

In the research field of Cybersecurity and privacy, the machine-learning supported methods for the classification and mitigation of coordinated cyber-attacks have the potential to **improve the automation of security operations**, making cyber defence mechanisms more effective. The evaluation of individual cybersecurity skills' importance will help focus the education and consequently **impact the future professionals**. The research into decentralised authentication possibilities will potentially shift the focus of the research in the field of authentication, especially where users managing their own identities and controlling their own data is important or desirable. The **intelligent authentication** is a concept that will be enhanced by our work in the RP.

By investigating and analysing the complex and multifaceted aspects of UX, our research aims to enhance our understanding of user needs, preferences, and behaviours, ultimately driving the development of more effective and user-centered solutions. Because the models describe a phenomenon at a theoretical level, we will use or develop appropriate measurements to operationalise and validate the models. Developing and validating innovative models and methods will offer valuable insights for designing **user-friendly and accessible solutions**, thereby promoting technology adoption among end-users. The intelligent, **data-driven approach to the UX** is a current pinnacle that we will contribute to.

By addressing the challenges in Process Management, such as managing complex process architectures, consolidating customer journey mapping techniques, designing effective worker-centric process management, developing an extended framework for business process optimisation, and testing a method for process mining in small and medium enterprises, researchers will contribute to the advancement of the field and provide practical solutions for organizations. In particular, the focus on AI solutions for **business process optimization** and the development of **evidence-based methodologies** for process measurement, evaluation, and optimization based on **process mining of operational data** adapted to typical Slovenian SMEs can have significant implications for the business world. Overall, the research field of process management has the potential to contribute to the development of science and the profession by providing practical solutions for organisations, leveraging technological advancements, and improving communication and collaboration between different stakeholders.

Impacts on economic development

The development of new IS architectures and the increasing complexity and distributed nature of IS have led to new challenges and **opportunities in the IT industry**, which has important economic implications. The shift towards modern **cloud-based**, **decentralised**, and **microservice**-based solutions is creating new opportunities for businesses to offer more efficient and flexible services, which can improve their competitiveness and increase their revenues. **Decentralised AI**, intelligent quality validation, and intelligent data processing are just some of the fields potentially impacted by our work.

Besides, developing **high-quality AI** solutions and **applying ML** methods are becoming essential activities in the field of IS development. By applying ML methods to analyse complex data representations and developing hybrid machine learning methods with meta-heuristic algorithms, AI models can **enhance accuracy**, **transparency**, and **performance**, resulting in better decision-making and **increased efficiency**. We hope to promote **self-adaptive services** and **optimised models** by fulfilling our RP objectives. Advanced and AI-supported IS development approaches have the potential for rapid development of user-focused, well-engineered, and cost-effective solutions which will enable businesses to **remain competitive in the marketplace**. **Automated quality assurance** and optimised delivery pipelines are examples of impacted fields, that have direct impact to the economic development. Developing a novel model for managing decentralised and self-sovereign identity principles could have significant economic implications as it could **reduce the need for centralized identity management systems**, reducing service providers' costs. The research efforts in the quality of user experience can potentially lead to developing more user-friendly and accessible technology solutions, **increasing adoption rates** and potential gains for companies. Optimized models for UX in modern IS user interfaces, that are supported by AI, is the field that our RP is to impact. Developing and testing a method for process mining in small and medium enterprises can help these companies **identify inefficiencies and opportunities** for improvement in their business processes, leading to increased productivity, efficiency, and profitability. In addition, the identified economic impacts of the scope include optimised processes, process digital twins, process model convergence, and as a result, improvements in the **field of hyper automation**.

Impact on social and cultural development

The RP will impact **how people use technology and access information**. The development of intelligent IS and the application of ML have significant impacts on social and cultural development. ML algorithms and AI solutions are becoming increasingly important in various fields, including finance, healthcare, transportation, and entertainment, among others. The research objectives aim to improve the accuracy and efficiency of ML models, address **ethical concerns related to AI decision-making**, and reduce the environmental impact of AI. It also unlocks the possibility of having **trustworthy systems** in a **personalised** manner. The impacts of advanced IS development approaches on social and cultural development may be perceived as indirect but potentially significant. For example, by enabling the rapid development of **user-focused**, cost-effective solutions, these approaches can help organisations to **serve their customers and stakeholders better**. This, in turn, can lead to improved customer satisfaction, increased productivity, and more efficient use of resources, i.e., higher and **predictable IS quality**. The user aspect of cybersecurity and privacy has historically, always been one of the largest issues. The design of novel **authentication methods** and how security settings are presented to the users have a significant potential to change how users **interact and engage with IS**. Especially, decentralised and self-sovereign identity principles can cause a large change in personal data privacy and security, which can lead to increased adoption of new technologies that rely on personal data, such as e-commerce or social media. The work supporting the development of cybersecurity education also has the potential to improve and escalate the growth of human resources that are currently in short supply. However, the possibility to enable **tailored default security** settings and personalized **adaptive security** should not be underestimated, which are the fields that will be affected by our research. As modern society relies heavily on technology, it is essential to ensure that it is user-friendly, accessible, and **inclusive for everyone**, including people with disabilities. Hence, the research field of quality of User eXperience (UX) foresees several impacts on social and cultural development. By including users with disabilities in the testing process, the research could lead to more accessible and inclusive technology, which is essential in promoting digital inclusion. In addition, **inclusive education** is crucial for social and cultural development. By ensuring that the technology used in education is accessible to all students, regardless of their abilities, the research could impact the education system positively. The research field of process management has significant impacts on social and cultural development, as using information technology in process management can lead to the development of new technologies and innovations, which can have a **transformative effect on society**. The consolidation of customer journey mapping techniques and integration with business process modelling can impact society significantly, since it can improve the customer experience of products and services, making them more user-friendly and efficient. This, in turn, can benefit businesses by increasing **customer loyalty and satisfaction**.