The C3-Cloud project is a 4 year Horizon 2020 Research and Innovation Action (total budget of 4,995,000 euros), that started in May 2016, run by a consortium of 12 partners across 7 countries in Europe. C3-Cloud aims to establish an ICT infrastructure to enable a collaborative care and cure cloud for the continuous coordination of patient-centred care activities by a multidisciplinary care team, together with patients and their informal care givers, for multi-morbid conditions. There is an increasing need to organise the care around the patient with the involvement of all stakeholders. As a response to this requirement, the C3-Cloud project aims to achieve high quality integrated care with the support of ICT. More specifically, a Personalised Care Plan Development Platform will allow, for the first time, collaborative creation and execution of personalised care plans for multimorbid patients, through systematic and semi-automatic reconciliation of clinical guidelines. This will be realised with the help of clinical decision support services for risk prediction and stratification, recommendation reconciliation,
poly-pharmacy management and goal setting. Fusion of multimodal patient and provider data will be achieved via C3-Cloud Interoperability Middleware for seamless integration with existing information systems. Active patient involvement and treatment adherence will be attained through a Patient Empowerment Platform. Co-design and 4-layered multi-method multi-stakeholder evaluation will lead to a user-friendly solution. To demonstrate feasibility, pilot studies will focus on diabetes, heart failure, renal failure, depression in different comorbidity combinations. Pilots will operate in 3 European regions with diverse health and social care systems and ICT landscape, which will allow for strengthening the evidence base on health outcomes and efficiency gains.

Work performed from the beginning of the project to the end of the period covered by the report and main results achieved so far

The last three years of the project have resulted in the following achievements:
1. The project management and communications structures have been set up and updated to oversee activities, monitor risks and issues and assure quality.
2. Dissemination of results have continued through various channels, such as website, social media, conferences, workshops and publications.
3. Exploitation plans have progressed further with the refinement of business model canvases for the project and project partners.
4. The design of the technical architecture of C3-Cloud has been completed with co-production between technical and clinical teams throughout software development, testing and deployment phases.
5. Patient pathway and organisational model development and change management for using the tools developed in C3-Cloud have been extensively analysed and guidance developed for new patient pathways and corresponding personalized care plans.
6. The Interoperability Middleware was designed, implemented and has produced three components. The Technical Interoperability Suite enables seamless data exchange between the local care systems and the C3-Cloud components, while the Semantic Interoperability Suite addresses the challenge of heterogeneous clinical data representation formats. Finally, the Security and Privacy Suite has been developed, based on open source toolkits for authentication and authorization of care team members and for ensuring encrypted and auditable data exchange across C3-Cloud software components.
7. The Patient Empowerment Platform (PEP) has been developed as the interface to be used by patients and their informal caregivers. Self-management training materials for increasing patient adherence to care plans have been developed.
8. NICE clinical guidelines for the 4 diseases considered in the project, and in the context of multimorbidty, have been studied. 43 logical flowcharts have been developed that model the clinical recommendations from the guideline text documents. These have been used to develop clinical decision support services. Reconciliation rules for multiple disease combinations have been developed and a drug-drug interaction service has been developed to support care plan development.
9. The Personalised Care Plan Development Platform (PCPDP) care plan management functionalities and the Coordinated Care and Cure Delivery Platform (C3DP) have been completed. These will be used by healthcare professionals to collaboratively develop care plans with the patients.
10. The pilot application has been designed and the deployment requirements of the C3-Cloud High Level Components defined and implemented.
11. All the technical components have been successfully integrated and the C3-Cloud system has been deployed at the 3 pilot sites in Spain, Sweden and UK.
12. Protocols have been developed for the 4 layers of evaluation in the project (e.g. component and application test plans, usability evaluation, etc.). Ethics applications have been obtained successfully for the technology trial of the C3-Cloud system at the pilot sites.
13. Preparation work for the pilot study, the development of standard operating procedures and training materials, as well as recruitment of participants are near completion.

**Progress beyond the state of the art and expected potential impact (including the socio-economic impact and the wider societal implications of the project so far)**

An innovative technical architecture was designed that brings together the different high-level components that make up the C3-Cloud platform – Interoperability Middleware, Patient Empowerment Platform (PEP), Personalised Care Plan Development Platform (PCPDP), Coordinated Care and Cure Delivery Platform (C3DP), Clinical Decision Support Modules. This architecture uses standard-based technologies and the project will contribute to the open source community with the HL7 FHIR-based Audit Viewer sub-component of the Security and Privacy Suite (part of the Interoperability Middleware), clinical decision support services and drug-drug interaction service.

The integration of the C3DP and PEP enables active patient and informal carer participation and easy interaction with the multidisciplinary care team. The potential social impact is enabled the exchange of the personalised care plan with the patient, assignment of questionnaires and daily activities to the patient, patient responses to such assigned activities, patient feedback to assigned goals and activities, and safe messaging between patient and care team. The development of user-friendly software tools contributes to the improved usability for healthcare professionals as well as patients.

C3-Cloud focuses on four major chronic conditions: diabetes, renal failure, heart failure and depression. Relevant NICE clinical guidelines, along with local variations in Spain and Sweden have been analysed and automated by implementing their logic as computable clinical decision support services. More than 230 clinical rules have been implemented as single-disease oriented rules and a further 52 as reconciliation rules. These services are used in the care plan development tools to provide evidence-based guidance to healthcare professionals.

Two innovative questionnaire tools have been developed to describe current organizational models in the three pilot sites. The “System Factor” Questionnaire analyses the system requirements, focusing on promoting and inhibiting factors for system integration and care coordination; while the “Care Coordination Profiles” Questionnaire describes the care coordination components, including actors, activities performed and communication channels.
C3-Cloud Overall Architecture

Clinical Decision Support Modules
- Risk assessment & stratification
- Reconciliation of clinical guidelines
- Detecting & proposing resolutions for multiple treatment plans

Patient Empowerment Platform (PEP)
- Active involvement in personalization of care plan and decision making
- Goals & activities achievement
- Risk monitoring
- Safe messaging with MDT

C3-Cloud Consortium

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