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D7.4 KPI Evolution Report (I to IX) v3

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07/03/2023	0.3	incorporating partners contributions
28/04/2023	0.4	Adding refinements
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Abstract

This is the third edition of the Key Performance Indicators (KPIs), KPIs Evolution report, which is mainly based on surveying the pilots about the expected outcomes of their experiments.

The report includes updated version of pilots' experiment and associated outcomes and **Impact Assessment (IA) KPIs,** as well as the preliminary work with the monitoring tools. Following the vision per pilot, an updated description is reported per Reference Use Case, including primary outcomes and related IA KPIs. In this version, a completely revised version of the **Operational KPIs** and related aggregation tool is also introduced, along with an instrument to monitor the pilots' experiment execution. Both IA KPIs and Operational KPIs are presented as **descriptors** of the overall **ODIN Experiment Framework**.

These KPIs, which include scales and evaluation techniques, were established as part of the WP7 tasks activities in a cooperative and collaborative effort with the pilots.

The Operational KPIs have a specific paragraph to introduce them properly.

Moreover, this report provides a full description of the RUC C together with additional relevant info about the experiments and the technology impact assessment.

Statement of originality

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List of abbreviations

Abbreviation	Explanation
ODIN	“ODIN - Leveraging AI based technology to transform the future of the health care delivery in Leading Hospitals in Europe” - Grant agreement number 101017331
AI	Artificial Intelligence
API	Application Programming Interface
DoA	Description of Action
Dx.x	Deliverable number x(WP number).x(number of the deliverable)
EIP on AHA	European Innovation Partnership on Active and Healthy Ageing
HCP	Health Care Professional
HCW	Health Care Worker
HTA	Health Technology Assessment
IA	Impact Assessment
ICT	Information and Communications Technologies
IoT	Internet of Things
IPJ	Innovative Procurement Journey
IPR	Intellectual Property Rights
KET	Key Enabling Technologies
KER	Key Enabling Resources
KPI(s)	Key Performance Indicator(s)
Mx	Project Month x
NHS	National Healthcare System
R&D&I	Research, Development and Innovation
RUC	Reference Use Case
SME	Small and Middle Enterprises
Tx.x	Task x(WP number).x(number of the task)
UC	Use Case
WP	Work Package

1 About this deliverable

This deliverable, in its third edition, examines how Key Performance Indicators (KPIs) are effectively used as measurable values to show the evolution from the Operational side and the outcomes from the impact side of the ODIN experiments pilot per pilot, and how they will evolve from a more general ODIN Project perspective.

Following the improved version of the pilots' experiment, a proper refinement of the Operational KPIs framework is detailed in terms of indicators and metric collection.

This document is linked to the Deliverables 7.1 (Pilot Studies Use case definitions and Key Performance Indicators (KPIs)), D7.2 (KPI Evolution Report (I to IX) v1) following the D7.3 (KPI Evolution Report (I to IX) v2) and is part of the work done in the different tasks of the Work Package 7 (WP7. ODIN Pilots Design, Deployment, Evaluation and Validation).

Changes in Pilot settings will inevitably reflect a change and evolution in KPIs, as KPIs correctly evaluate how well the experiments are achieving and fulfilling their goals.

1.1 Deliverable context

Table 1 - Deliverable context

PROJECT ITEM IN THE DOA	RELATIONSHIP
Project Objectives	This deliverable is framed in the context of WP7 and contributes directly to the impact evaluation framework the ODIN experiments
Exploitable results	The results of this deliverable will be directly exploited by the technical work packages as well as WP2, WP9 and WP10 related to the open calls.
Workplan	The deliverable will be constantly updated according to the DoA. Our partners will be encouraged to provide constant up-to-date inputs regarding the pilot activities. Pilots' progress in this regard will be monitored and documented.
Milestones	This deliverable is linked to the deployment and running Phases
Deliverables	Related deliverables: D2.2, for the blueprint definition of the pilot needs; D2.3 the catalogue of technology, D7.1 the experiment definition and D7.2 first KPIs report
Risks	Due to the changing nature of hospital contexts, some of the conditions outlined here may change over the course of the ODIN project.

1.2 Summary of key updates and modifications

In table below are reported the list of changes from D7.2

Table 2 - Changes between D7.2 and D7.3

SECTION	UPDATES/MODIFICATIONS
1	Deliverable context
2	Revised introduction
3	Revised description
4	Revised intro for the RUCs definition
4.2	Introducing the Operational and the IA KPIs
5, 6	Revised general IA KPIs
7	RUC C defined
8	Impact Assessment Framework defined
9	Operational KPIs defined
10	Conclusions revised
App. B	Fully revised: Pilots descriptions, (ALL) Pilots' experiments definition, (ALL) defined timelines, (ALL) detailed technology, (ALL) primary outcomes (ALL) re- defined KPIs (ALL but MUL)
App C	Ethical procedures and status updated
App D	Technology assessment and TRL
App E	UML Schema

2 Introduction

Due to the Public dissemination level, some information in this document is already included in D7.1.2 Experiment definition.

For readability purposes as a standalone document, this deliverable includes the necessary forewords, concepts, and descriptions previously included in the earlier editions.

As stated in the DoA, the hospital becomes the primary infrastructure leading towards the necessary evolutions of the Industry 4.0. In fact, one out of three hospitals promoted or planned to adopt particular strategies or policies to implement new technological tools in the last five years. Technology is becoming increasingly prevalent in all parts of the hospital, not just for specific functions such as diagnosis and treatment, but also for managing logistical operations and procedures. Clinical algorithms, patient pathways, decision-assist tools, and optimisation techniques could be created using a combination of clinical skill, patient data, environmental resource availability, and the best available research findings. Evidence-Based Medicine (EBM) changed medicine by relying on the core notion that data-driven processes can significantly improve medicine's effectiveness and safety while keeping costs in check.

This Report Series provides a comprehensive overview of the project status, with a detailed measure of the experiments' evolution pilot per pilot.

This third edition includes the pilots' redefined experiments with the deadlines and their related refined primary outcomes and the related KPIs. The main aim is to demonstrate how these indicators will effectively reflect the evolution of the ODIN experiment framework. For this, a new section, Section 8, has been included about the Operational KPIs.

Future releases we will also include the KPIs defined in the technical work packages, from WP3. Platform integration, Privacy, Security and Trust + knowledge + cognition to WP6. High Level Ecosystem for AI Operations.

This deliverable offers an up-to-date report of the ODIN Experimental Framework. All pilots have thoroughly revised their experiments upon the performed technology assessment. This version includes a full description of the RUC C.

Moreover, this deliverable addresses the comments of the first review report. Specifically, the number of the KPIs and the foreseen primary outcomes for each experiment are reported, and in Appendix D, the technology assessment sheets with the TRL are provided, as requested.

Overall, this report includes 10 sections and 3 appendices: sections 1 and 2 provide the abstract and introduction. Section 3 presents to the reader the framework we build to redefine the use cases (UC) and defining reference uses cases (RUC) and how we co-designed the experiments with the Pilots and all the technical partners. Section 4 introduces the reference use cases. Section 5, 6 and 7 delve into RUCs describing the phases and the goals and, where available, the KPIs, the involved staff, the foreseen technology after the tech assessment. Section 8 shows an overview of Impact Assessment Framework that is being defined. Section 9 reports on the refined Operational KPIs and their current status, and Section 10 presents the conclusions. Appendix A shows the tools used in the co-designing process, the Appendix B reports the Pilots descriptions and the experiments per each RUC they will deploy at the local level. In this version, Appendix B introduces the ODIN Integration within the pilots and what is their main contribution to ODIN. Moreover, Pilots reported the preliminary analysis of the ODIN Strategy for local sustainability. Appendix C includes the Questionnaire about the ethical procedure per pilot and the foreseen timelines. Appendix D presents the technical feasibility assessment performed, and Appendix E includes the UML schema of the architectural components of the project for all the pilots.

3 The ODIN Experiment framework

This section stems directly from the previous one with slight changes only because we followed the same approach.

The ODIN Experiment framework is a federation of case studies aiming to prove the positive impact of the ODIN Key Enabling Resources (KERs), AI, big data, robots, and IoT, on hospitals safety, quality and cost effectiveness.

The starting point is the research and innovation questions here described as the ODIN challenges, in the table below.

Table 3 – ODIN Challenges

Challenges and ODIN answers
Challenge 1. Financial challenges and hospital productivity Data-driven management will enable pervasive data collection, data analytics, real time in-hospital tracing of devices, workers and patients. This will enable optimisation of clinical and logistic processes while reducing the time required to accomplish common hospital tasks and optimise shared resources. Predictive analytic modelling will reveal ways to break down barriers between departments. eWorkers, eRobots, and eLocation will support this optimisation.
Challenge 2. Increase patient and staff safety Advance process for tracing people and medical tools/instruments will help to prevent exposure to risky areas (e.g., infections, electrocution). In case of infection events, ODIN will contribute to the early detection, monitor and intervention measures. The use of autonomous robots will prevent infections. The use of exoskeletons or lifters together with rehabilitation robots will improve the treatment of the patients, while enhancing working conditions of the professionals.
Challenge 3. Logistics, regulatory standards and energy mandates Tracing the real usage of medical locations and goods (e.g., drugs, furniture, medical devices), as well as the path of objects will help optimising internal/external processes, while ensuring the compliance with regulatory standards, facilitation the data exchange and adaptation to new regulations or digital standards.
Challenge 4. Hospital security ODIN surveillance services will contribute to reducing the risk of violence and theft, with support of small-size robots when personnel are not available (i.e., at night), contributing to avoid Mass Casualty Incidents. The use of robots for drugs/objects transportation will provide for more safety when there is a limited number of staff members. Moreover, the employment of block-chain will help facing emerging security issues, such as cyber-security.
Challenge 5. Patient satisfaction (value-based healthcare). Health literacy and patient empowerment will start during the stay in the hospital with the use of robotic assistants that motivate and coach patients, preparing them for self-care after discharge, giving information, entertaining, making teleconferences with family.
Challenge 6. Too many avoidable patient days (reducing unneeded hospital stay). The ODIN platform will enable data collection from patient home/residence in the days after of the discharge, with the use of IoT support services, companions and rehabilitation robots, and cyber assistants. According to literature, these solutions contribute to better planning the transitional care models, preventing delay discharge and reducing readmissions.

Challenges and ODIN answers
Challenge 7. Desire for physician integration but very few employed physicians'. Robotic assistants can support healthcare professionals in non-complex tasks (such as food provisioning), internal and external transport of devices and waste and cleaning related tasks. This will free time for staff-patient interactions.
Challenge 8. Unhealthy community The coordination with smart cities (in terms of air quality, transportation habits, etc) will contribute to create awareness and training campaigns. In case of patients performing transitional care pathway at home, the IoT sensors and the robotics support will enhance the self-care training.
Challenge 9. Poor communication between providers (industry 4.0) A mix of advanced analytical data, tracing devices, people and drugs and targeted interpersonal relations will reduce redundancies in communication and provide optimised communication channels and messages.
Challenge 10. Shortages of physician, nurse and well-trained healthcare professionals. The continuous data exchange and processing optimisation contribute the detection of the lack of training of the different types of staff providing mechanisms to apply the needed training mechanisms. The use of ODIN technologies and interactive tools will support staff and process optimisation.
Challenge 11. Disaster preparedness The COVID-19 pandemic demonstrated the vastness of the number of EU hospitals are not prepared to face disasters. In the past 20 years, EU NHSs have reduced the critical beds in their hospitals (average ICU beds per million inhabitants per EU-Nations cut from 10k in 1990 to 3k in 2020[1]) moving the resulting saved budget to investments in non-hospital health services, in response to demographic challenges. While this is a necessity, these changes cannot be left to empirical attempts, but require EBM reasoning, scientific simulations and holistic approaches, supporting systemic responses from different hospital experts (clinical, technical, managerial), who now still work in silos in the majority of EU hospitals.

These challenges are meant to be deployed by the pilots within the following **areas of intervention**:

- **Enhanced Hospital Workers (eWorkers)**
- **Enhanced Robots (eRobots)**
- **Enhanced Locations (eLocations)**

The areas are defined as follows.

- **Enhanced Hospital Workers (eWorkers)**: The aim is to look into how to provide appropriate technology to hospital staff (such as nurses, porters, technicians, and doctors to improve their abilities and support their daily work. Technology will be employed to relieve workers of the weight of their daily tasks, allowing them to focus on the vital jobs that require all of their human abilities. Wearable technologies will be used to improve their 'senses,' increase their 'connectivity,' speed up their reasoning, and improve their physical traits. We will start with nurses and porters, utilising commercial technologies offered by project partners. Through Open Calls, new healthcare employees and technologies (such as virtual and augmented vision) will be added.
- **Enhanced Robots (eRobots)**: The aim is to automate hospital processes that no longer require humans or can be improved by automatons. These robots will not necessarily be humanoid and will be used in the form of centrally synchronised swarms with some level of

autonomy. ODIN robots will have advanced perception functions (smell, vision, touch, taste, and hearing), extensive connectivity (with other robots, hospital assets, humans, and medical places), advanced AI reasoning capability (both locally and remotely), and task-performability (wheels, arms, hands, etc.). We will initially focus on the distribution of materials (drugs, food, disposables, consumables, and so on), the management of medical devices (e.g., preparing surgical equipment kits), and the facilitation of hospital processes (human navigation, reception, and patient surveillance) during the project. Other hospital processes will be added through Open Calls.

- Enhanced Locations (eLocations): The aim is to instrument medical locations to support hospital activities more proactively. In order to interact with personnel, robots, devices, and other necessary hospital assets securely and effectively, medical places will be improved with sensors (smell, vision, feel, taste, and hearing), technology for communicating with humans (screens, lighting, speakers), and high connection. Furthermore, eLocations will provide real-time data about their underlying technological infrastructures (e.g., power plants, water pipes, air conditioning, medical gases) that are vital for human safety (patients, visitors, and staff), as well as robotics, medical devices, and equipment. Initially, we will concentrate on lower-risk medical settings as part of the study (e.g., reception, diagnostics, laboratories, non-severe patient rooms).Other medical locations will be added through Open Calls.

To understand how the ODIN pilots has to design their experiment to address the challenges we started a co-creation process. In order to achieve a clear UCs definition and an experiment description pilot per pilot the co-creation work has been organised in three methodological steps:

1) The Proposition, Thesis, analysis of the UCs
2) The Deconstruction, Antithesis (or growing)
3) Production, Synthesis of UCs and Reference Use Cases definition

The step 1 was conducted from the beginning of the project during the WP7 meetings and bilateral calls with pilots. The main result of this phase is the template, called “Pilot Journey”, to orient/support the pilots in the preliminary experiment definition of the Step 2.

In the Step 2, from M4 to M7 pilots had to rephrase their own vision about the UCs. For this step different tool have been used:

- A template, from step1, the so-called “Pilot Journey”, administered to all the pilots in order to get their reflections and propositions about their specific needs in relation to each UC
- Focus groups were organised with each UC to discuss their answers to the questionnaires

The results were discussed with all the pilots. Below some excerpts are reported, and the full pilots’ descriptions can be found in Appendix A

These reports highlighted the need to harmonise the experiment descriptions, identifying commonality and stressing specificities.

This led to the Step 3. There were defined three RUCs leveraging on the initial UC description as per DOA and based on the pilots’ inputs to the ODIN UC.

The RUCs are the described in the next section and are the following:

- RUC A Health Services Management, including all the clinical use cases from the DoA, UC3, UC4, UC5, UC6;
- RUC B Devices and Facilities Management, including the UC1 and UC2
- RUC C Disaster Preparedness with the UC7

All the subsequent activities were organised following each RUC group to start defining pragmatic constrains, such as: ODIN partner available technology, Open Call challenges, and external factors.

It was chosen to adopt the WHO navigation diagram used in the "WHO list of priority medical devices for management of cardiovascular diseases and diabetes" (2021). In this publication, the priority medical devices that are discussed, selected and presented are organised by clinical units in a health service provision. The navigation diagram in the figure below represents the range of health-related interventions, from pre-hospital activities to highly specialised tertiary hospital-based care. The diagram has been adapted where the phases represent the departments/units required to perform the different tasks of the selected RUC.

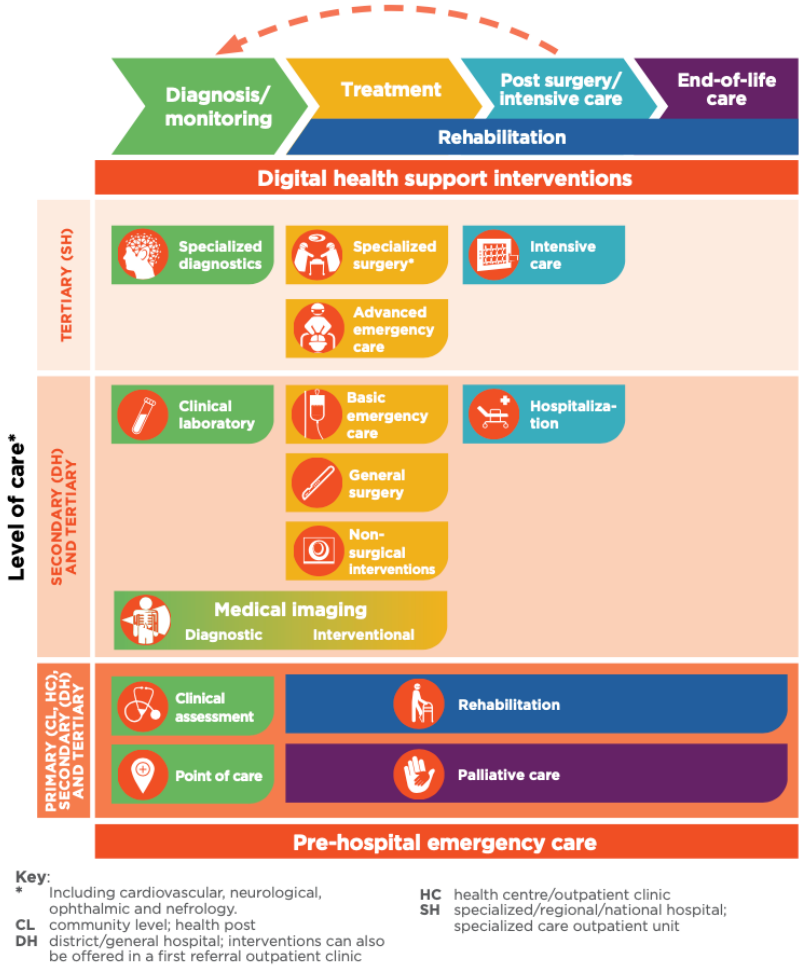

Figure 1 - WHO Navigation Diagram

The phases for each RUC were developed and revised during the workshops, and for each step, the pilots required to specify the Description, Goals / Outcomes, IA KPIs, Technology, and ODIN Contribution, as shown in the pictures below.

The process of KPIs further re-definition is undergoing in the Impact Assessment framework and involves not only the pilots but all the ODIN Partners.

The final goal of this phase is to achieve a **complete framework of indicators (ODIN KPIs journey) from different perspectives: experiment evolution (Operational KPIs), technology deployment (Technical KPIs), impact assessment (IA KPIs).**

3.1 ODIN Pilots

So far in the ODIN Experiment framework at M18 includes the pilots described below.

This list will be updated as the ODIN Open innovation framework will also include new pilots belonging to the running Open Call, from M17 to M19 and starting in M23-M24.

3.1.1 Charité - Universitätsmedizin Berlin, Germany (CUB)

Charité University Hospital has 3,000 beds and 14,000 employees. It is distributed over 4 campuses in the city of Berlin. It is one of the largest hospitals in Europe with a strong focus on excellent patient care and research. The aim is to combine patient care, medical research, education to provide best practice for the future of medical services in Europe.

The sleep medicine centre is part of Charité, linked to the department of pneumology. The sleep medicine centre has 10 beds for patient care and 2 beds for research studies. We have about 3,000 sleep studies in the hospital with polysomnography (sleep recording) per year and about 5,000 home sleep studies (with fewer signals recorded) per year. The staff includes pneumologists, neurologists, ENT physicians, cardiologists, engineers, specialised medical technologists, and nurses.

3.1.2 Medical University of Lodz, Poland (MUL)

Medical University of Lodz (MUL) is a higher state school having over 70 years-long history. With its 5 faculties, 3 teaching hospitals and 80 clinics, 9,500 students, 1,000 foreign students and approximately 1,600 academics, Medical University of Lodz belongs to the leading Polish medical universities. The University is strongly committed to scientific research in a number of health-related disciplines as well as national and international scientific cooperation. The University is considered a leader in the number of scientific publications and citations among medical schools in Poland. In 2022, MUL ranked 9th among Polish Universities, according to national 'High Schools Ranking Perspectives'. MUL's scientists conduct extensive basic and translational research. The Medical University of Lodz has reached the leading position in various research areas, and particularly in patient adherence and healthy ageing. In acknowledgment of these achievements, the Medication Adherence Research Centre (MARC) was founded in 2020 in MUL, headed by Prof. Przemyslaw Kardas.

MUL makes a substantial contribution to the development of the health care system by promoting modern standards of prophylaxis and treatment, and by building long-lasting cooperation with institutions realizing objectives of public health at regional, national and international levels. Last but not least, MUL is strongly committed to Silver Economy. Being formally recognised as the EIP on AHA Reference Site, MUL plays the key role in facilitation of collaboration between academia and industry, in order to transform the demographic challenge into opportunity. Initiating creation of dedicated businesses clusters, MUL is pioneering and helps boosting the local economy.

With its own complete ecosystem of healthcare services, covering full range of healthcare system levels, from primary health centres to tertiary teaching hospitals, MUL is perfectly well-placed for the purpose of testing and implementation of novel health technologies. Serving over 86,000 patients yearly, MUL is also one of the major local healthcare providers, active in each and every area of modern medicine. This potential will be of particular use within the framework of ODIN project.

3.1.3 Hospital Clínico San Carlos, Madrid, Spain (SERMAS)

This pilot is going to take place in Hospital Clínico San Carlos. Three main departments are going to be involved: the Procurement Department, the Cardiovascular Institute and the Innovation Unit.

The Procurement Department is in charge of the supply and logistics distribution of the medical equipment and consumable materials inside the hospital, being a key player in the smooth development of all clinical processes and procedures. This department has transversal action, so the problems we want to tackle affect the performance of the entire hospital.

The Cardiovascular Institute (ICV) represents around 48% of the total hospital's expenditure in medical equipment and consumables. Inside the ICV, the therapeutic areas dedicated to hemodynamic and electrophysiology have high-impact equipment and some of the best-described pathways for consumables provision.

Finally, the Innovation Unit is the hospital team that is part of the ODIN Consortium. It will act as bridge between the ODIN partners and the hospital staff.

3.1.4 Università Campus Bio-Medico di Roma, Italy (UCBM)

Università Campus Bio-Medico di Roma (UCBM) is a young, yet rapidly developing, private academic institution, devoted to undergraduate and postgraduate education and to advanced research also linked with the high-quality healthcare services provided by the Research Hospital of Fondazione Policlinico Campus Bio-Medico (FPCBM). Established in 1992, today the University runs the School of Medicine and Surgery, the School of Engineering, the School of Science and Technology for Humans and the Environment, as well as a PhD programme in "Integrated Biomedical Sciences and Bioethics" and "Science and Engineering for Humans and the Environment". In Italy, UCBM has been systematically top ranked for the quality of the education provided to a selected group of students. The institution has increasing:

i) scientific production per year;

ii) funding raised from competitive sources in Italy, Europe and worldwide (40+ research projects ongoing);

iii) technology transfer activities (16 patents families owned/co-owned and 7 spin-off companies from 2015).

An outstanding network of national and international key scientific and educational partners, including 200+ national and international partners, has been continuously developed and consolidated with specific collaboration agreements over the years.

Within FPCBM, the Geriatrics Unit conducts research activities in the following areas:

i) evaluation of the elderly patient health condition, with particular focus on multidimensional evaluation techniques in various disorders or multimorbidity pattern;

ii) evaluation of respiratory functions, with particular focus on the interpretation of spirometry results in elderly patients; study of diagnosis/prognosis properties of breath volatile organic compounds in the following disorders: heart failure, chronic obstructive bronchitis, obstructive sleep apnoea syndrome, diabetes mellitus, liver diseases;

iii) development and application of remote telemonitoring systems for patients with chronic diseases;

iv) pharmacoepidemiologic and epidemiologic geriatric research.

The Unit research activity can make use of a wide range of equipment for functional evaluations. It also has epidemiologic and statistical competences for the designing, planning, execution and analysis of interventional and observational epidemiological studies.

3.1.5 The University Medical Center Utrecht, the Netherlands (UMCU)

The University Medical Center Utrecht (UMCU) is one of the leading and largest medical centres in the Netherlands and ranks among the best European academic hospitals in international rankings. The core activity of UMCU is to provide healthcare for which special knowledge is required, provide leading research and offer excellent education to students, medical doctors, researchers and other healthcare providers. UMCU has a strong track record in both pre- and clinical research and forges strong links with companies and scientific institutions across the world.

UMC Utrecht's research focusses on six strategic themes, the ODIN projects fall into the Circulatory Health theme. Healthcare is divided over ten divisions, ODIN falls into the Division Laboratories, Pharmacy and Biomedical Genetics division, where the Central Diagnostic Laboratory is located. CDL's translational subunit ARCADIA (Academic Research for Clinical Applications of DIAgnositcs) hosts the Utrecht Patient Oriented Database (UPOD).

Established in 2003, UPOD provides access to the comprehensive and complete electronic health record information of all patients that visited the UMC Utrecht since the 1990's. Overall, 650k individual patients that have been hospitalised were included. UPOD comprises more than 2.4 million individuals, including out-patients. The UPOD group in brief aims to improve clinical diagnostics using routine care data and is involved in efforts to turn the UMC Utrecht into a learning healthcare system.

The UMCU ODIN project members will work in close collaboration with the recently established (2020) UMCU department of Digital Health, which is located in the corporate (permanent) staff.

All projects within the UMCU use case will take place in the strategic theme Circulatory Health. Within this area, UMCU has established a Center for Circulatory Health where a multidisciplinary team sees every patient with a cardiovascular disease. The Circulatory health strategic area includes a long-standing research cohort (Utrecht Cardiovascular Cohort) that already encompasses 13,000+ patients. Combining the Center for Circulatory Health and Utrecht Cardiovascular Cohort efforts has led to the first steps towards transitioning patient care for cardiovascular disease patients into a learning healthcare system. Within this system we are currently developing (clinical decision) support systems. This is where ODIN has its home.

4 Introducing the Reference Use Cases (RUCs)

The above-mentioned hospitals will deploy and run the ODIN experiment framework according to the different case studies described in the following paragraph.

Seven UCs in total, which have been thoroughly discussed in the DoA, were defined for the proper execution of the ODIN project, while taking into account the demands of the participating pilots. In order to best organise the project and address different aims and categories, it has been Reference Use Cases (RUCs) were developed, which cover all of case studies in ODIN. The three major key elements of a hospital are covered by the three RUCs that were chosen, supporting the partners and acting as a high-level guide:

- RUC A, on the health services management:
- RUC B, including goods and devices management
- RUC C, on disaster preparedness, comprehensive of all the previous ones in a disaster management.

The figure below shows the RUCs and Use Cases (UCs) distribution per pilot.

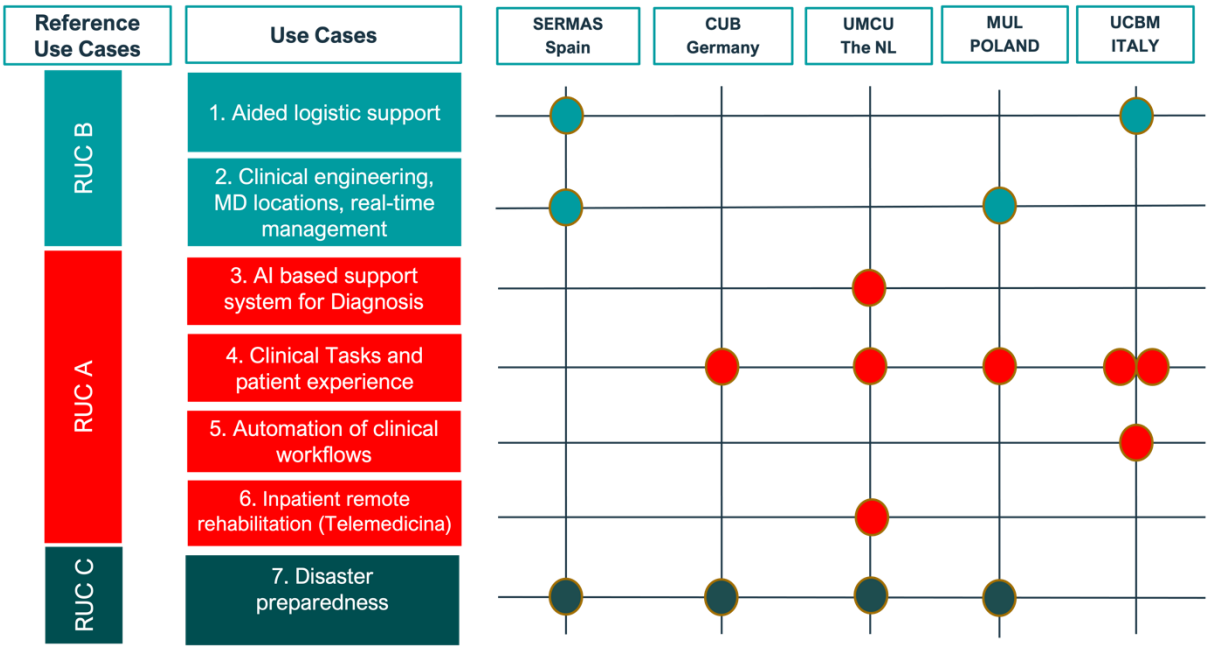

Figure 2 - RUCs - UCs pilots distribution

4.1 RUC A

This reference use case encompasses the use cases focused on the clinical (and diagnostic) oriented activities that the ODIN project will address. Among the use cases, UC4 is considered the most relevant due to the number of pilots that find it significant,, as opposed to the rest of the use cases (UC3, UC5, UC6), which have been identified by only one pilot.

On the one hand, the UC3 "AI-based support system for diagnosis", focuses on the use of AI technologies to optimise the personalised search for the diagnosis considered most effective in each case, serving as a support to healthcare professionals in decision-making, considering probabilities as well as the capacity of available diagnostic modalities.

On the other hand, UC4 "Clinical Tasks and Patient Experience" is the use case with more pilots involved within the RUC A. It aims to reduce the effort that clinical personnel must exert in

therapeutic and diagnostic activities based on ODIN technology. This is intended not only to improve the quality and workflow of clinicians, but also to optimise the comfort perceived by patients during their journey and improve their health conditions.

Likewise, UC5 "Automation of Clinical Workflows" aims to respond/act against the emerging difficulty within workflows, which often follow processes that are not efficient enough. Therefore, this project, taking advantage of workflows and the collection of data and sources, aims to offer a solution by automating clinical research execution processes in order to reduce possible errors.

Finally, UC6 "Inpatient Remote Rehabilitation" focuses on remote patient monitoring covering both patient follow-up and simple and secure communication between patients and the relevant hospital sector. To this end, the ODIN project will deploy an AI system to automatically support patients and help healthcare staff to provide optimised lifestyle monitoring.

4.2 RUC B

This reference use case, related to the managerial area, covers the first two defined use cases (UC1, UC2). It is focused on the improvement, based on ODIN technologies, of the design, programming and execution of hospital logistics, clinical engineering and the management of medical devices.

The first of these, UC1, defined in the DoA as "Aided Logistic Support", has been conceived as the entire process of procurement, storage and distribution of different materials in the hospital environment focusing on activities within the hospital environment that are considered redundant (e.g., transport of consumables). UC1 aims to leverage ODIN technology to optimise all these logistic activities, thus improving working conditions, optimising the working time required by healthcare personnel for certain types of repetitive or risky tasks that do not require their attention, and the efficiency and workflow within the hospital.

In addition, RUC B also includes UC2 "Clinical Engineering, MD Locations, Real-Time Management", which focuses on the management of medical devices with ODIN technologies. This is particularly important as the current lack of real-time information exchange is one of the main causes of adverse events in the hospital environment. The correct functioning and adaptation to this use case will allow not only the optimisation of routine activities but also in supporting RUC C - Disaster Preparedness, which will be discussed in more detail in RUC C - UC7.

4.3 RUC C

This reference use case is focused on the action against possible unforeseen and tragic events that may occur, covering UC7 "Disaster Preparedness". This peculiar RUC has been introduced to prepare and tackle the multitude of difficulties that hospitals had to face during the pandemic and other catastrophes: terror attacks, natural events, and on. For this purpose, ODIN approach and KERs will allow, through different simulations, to contribute to hospital resilient management (e.g., crowd management, security, IPC support) and prepare hospitals for possible future catastrophes, always with the main objective of ensuring safety.

To define the RUC C there have been performed specific workshops and targeted activities with pilots and technical partners. The approach used is similar to the other two and it includes protocols to manage RUC A and RUC B phases during a disaster.

The next sections describe in detail all the RUCs and their related UCs.

5 RUC A: Health Services Management

5.1 ODIN Framework for industry 4.0

The RUC A can be represented as the following process with continuous interactions and feedback from each phase.

The National Health Services strategic planning (https://www.who.int/activities/supporting-national-health-policies-strategies-plans), which identifies needs and gaps, along with requests from the territory where the hospital is located, will be used to create the proper ***admission screening***, an evaluation of the hospital entry points. This phase feeds the ***diagnosis & case study*** where patients enter the path of the identification of a disease by examination of the symptoms. The previous phase is necessary to identify the right ***treatment*** and the subsequent ***monitoring and follow-up***.

This reference use case covers aspects related to the exploitation of ODIN technologies for improving execution of clinical tasks and patient overall experience within the hospital ecosystem. Specifically, it consists of the following phases covering all the clinical workflow, as represented in the picture below, from the patient's admission to the follow-up.

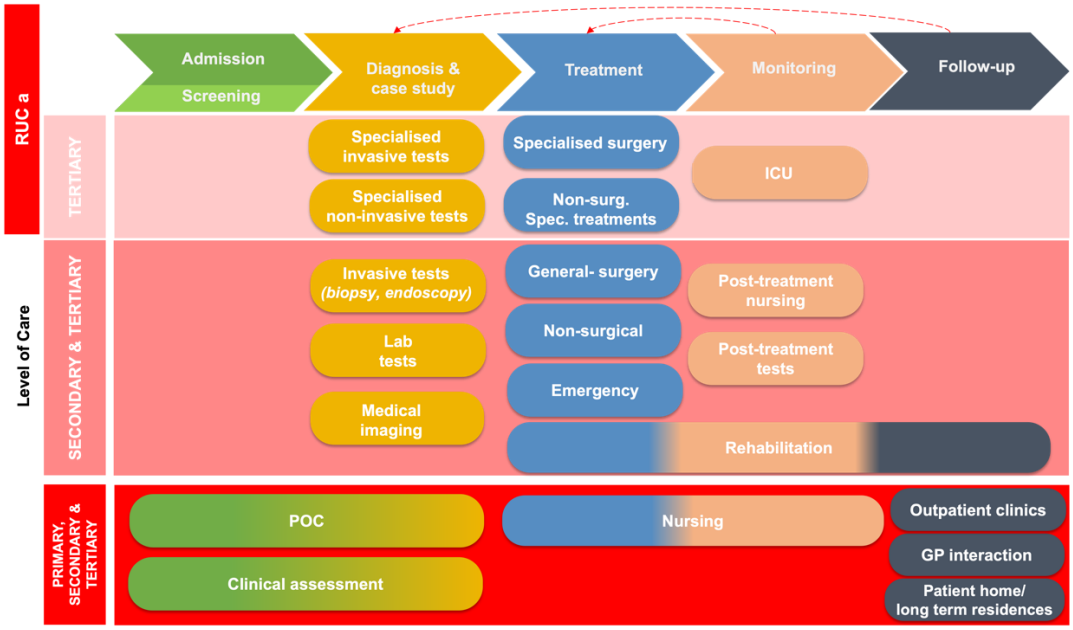

Figure 3 - RUC A Navigation Diagram

5.2 RUC A Phases

As reported in Section 4.1 this RUC includes all of the use cases related to clinical (and diagnostic) activities that will be addressed by the ODIN project. Due to the large number of pilots that believe RUC A2 - UC4 to be relevant, it is regarded as the first use case, in contrast to the remainder of the use cases (RUC A1 - UC3, RUC A3 - UC5, and RUC A4 - UC6), which have only been recognised by one pilot.

On the one hand, the RUC A1 - UC3 "AI-based support system for diagnosis" focuses on using AI technologies to optimise the personalised search for the most effective diagnosis in each case, assisting healthcare professionals in decision-making by taking into account probabilities as well as the capacity of available diagnostic modalities.

RUC A2 - UC4 "Clinical Tasks and Patient Experience," on the other hand, is the use case with the most pilots within the RUC A. Based on ODIN technology, it promises to lessen the effort that healthcare workers must exert in therapeutic and diagnostic activities. This is meant not just to improve clinician quality and workflow, but also to maximise patient comfort and improve their health conditions during their travel.

Similarly, RUC A3 - UC5 "Automation of Healthcare Workflows" strives to respond to/address developing challenges within workflows, which frequently follow inefficient processes. As a result, this project intends to provide a solution by automating clinical research execution processes in order to eliminate possible errors by using workflows and data and source collecting.

Finally, RUC A4 - UC6 "Inpatient Remote Rehabilitation" focuses on remote patient monitoring, including patient follow-up as well as simple and secure communication between patients and the appropriate hospital sector. To this purpose, the ODIN project will implement a robotic component that will automatically support patients and assist healthcare professionals in providing optimal lifestyle monitoring.

Below are presented the phases included in this RUC:

Admission & Screening

This phase refers to all the activities aiming to properly manage the admission of a patient following preliminary assessment of the clinical status.

Diagnosis & Case Study

Delivery of the diagnosis as a confirmation/refusal of the preliminary assessment, after patients undergo specialised exams and assessment. This phase ends with the identification and prescription of the treatment.

Treatment

Execution of the prescribed treatment

Monitoring

Monitoring of the compliance to the prescribed treatment, correctness and risks. According to the output of this phase, adjustment to the treatment can be introduced.

Follow-up

This phase refers to the assessment of the short – terms effectiveness of the treatment. This might also stop the treatment or modify it to reach the clinical goal.

5.3 RUC A Primary Outcomes

This reference use case aims at maximising data-driven decisions and supporting execution of clinical tasks through the adoption of ODIN robotic and IoT platforms.

Admission & Screening

Improving preliminary assessment of the patient's clinical status and optimising the admission process management

Diagnosis & Case Study

Optimising Personalised diagnostic pathway

Treatment

Supporting execution of treatment with a reduction of workers' stress and workload

Monitoring

Implementing a cost-effective monitoring of treatment and generating proper data-driven feedback. During this phase it is necessary to optimise the involvement of the HCW.

Follow-up

Optimising assessment of the short –terms effectiveness of the treatment.

5.4 RUC A IA KPIs (for each phase)

Below are the **high-level IA KPIs** summarised per each phase.

The full experiment descriptions and their locally defined KPIs are reported in Appendix A

Table 4 - RUC A IA KPIs

Phase	KPIs	Measure unit
Admission & Screening	Waiting time before admission	[hours]
	Patients enrolled	[n]
	Early detection of patients at risk	[%]
Diagnosis & Case Study	Time to diagnosis	[days]
	Number of exams for diagnosis	[n]
	Personalisation level	[scores TBD]
Treatment	Adherence to guidelines	[%]
Monitoring	Adherence to prescribed treatment: correct execution, specific KPIs, number of errors	[…]
	Users' acceptance	[%]
	Time that each HCW spends with each patient	[min, h.]
	HCW Stress	[%]
Follow up	Effectiveness of the treatment	[specific KPIs TBD]
	Length of stay in hospital	[days]

Phase	KPIs	Measure unit
	Hospitals visits and re-hospitalisation	[%]

5.5 RUC A Sub Cases

5.5.1 RUC A1 - UC3: AI for diagnosis

Diagnostic trajectories in hospitals and medical centres can become difficult, long, expensive and cumbersome for patients. The objective of this use case is to verify if AI and IoT-driven approach is able to improve the diagnostic pathway by (A) Personalising the diagnostic trajectory of patients based on a priori and post priori probabilities and (B) provide integrated capacity management of the full diagnostic supply chain.

RUC A1 is focused on the second phase of RUC A: Diagnosis.

5.5.2 RUC A2 UC4: Clinical tasks and patient experience

This reference use case includes experiments linked to the exploitation of ODIN technologies for enhancing clinical task execution and patient experience across the range within the hospital ecosystem.

5.5.3 RUC A3 UC5: Clinical workflow

This reference UC aims to implement and validate a workflow-driven solution supporting the automation of the clinical research execution processes. It usually covers all the RUC A phases.

5.5.4 RUC A4 UC6: Telemedicine

Many patients spend unnecessary time in hospitals for monitoring, resulting in higher costs and a higher burden for them. COVID-19 reinforced the value of home telemonitoring services.

According to these needs, this use case aims to implement a home telemonitoring service of clinical parameters integrated with the EHR system to promote the patient's continuity of care.

RUC A4 is focused on the following phases of RUC A: Monitoring and Follow-up.

5.6 Pilots implementing RUC A

Once the reference structure of the RUC A were defined and foreseeable services (RUC A1- A4) were focused on, ODIN pilots described their experiments as a specialisation of these models.

This resulted in the following ODIN RUC A table:

Table 5 - RUC A Pilots implementation

Use Case	Name	Pilot(s)
RUC A1 - UC3	AI for Diagnosis	UMCU
RUC A2 – UC4	Clinical Tasks and Patient Experience	CUB, MUL, UCBM, UMCU
RUC A3 - UC5	Clinical Workflow	UCBM,
RUC A4 - UC6	Telemedicine	UMCU

Tables below summarises for each pilot the different implementation of RUC A. Appendix A reports the details per pilot.

5.6.1 CUB

Table 6 - RUC A - CUB

Use Case	Name	Description	RUC X Phase (s)
RUC A UC 3 & 4	AI Based Support System for Diagnosis & Clinical Tasks and Patient Experience	Validation of Wearables & Automated Scoring of Wearables	Admission & Screening, Diagnosis
RUC A UC 3	AI based support system for Diagnosis	Automated Sleep Scoring of Sleep Studies	Diagnosis
RUC A UC 4	Clinical Tasks and Patient Experience	CERTH Bot Receptionist	Admission & Screening, Monitoring

5.6.2 MUL

Table 7 - RUC A - MUL

Use Case	Name / Description	RUC A Phase (s)
RUC A2 – UC4	Blood transport Robotic transportation of blood samples from the Emergency Department to the Central Lab	All the phases

5.6.3 UCBM

Table 8 - RUC A - UCBM

Use Case	Name	Description	RUC A Phase (s)
RUC A2.1 – UC4	Clinical Tasks and Patient Experience	Monitoring of food assumption to prevent undernutrition	Treatment, Monitoring
RUC A2.2 – UC4	Clinical Tasks and Patient Experience	Rehabilitation to prevent loss of mobility	Treatment, Monitoring
RUC A3 – UC5	Automation of Clinical Workflows	Monitoring of oxygen therapy to prevent hypoxia complications	Monitoring

5.6.4 UMCU

Table 9 - RUC A - UMCU

Use Case	Name	Description	RUC X Phase (s)
RUC A - UC3	AI for Diagnosis	AI tools to improve personalization and efficiency of CVD diagnostic pathways outpatient clinic setting	Diagnosis
RUC A – UC4	Identification of eligible patients for CVD learning	Automatically identify new patients eligible for CVD learning healthcare system	Admission & Screening
RUC A – UC6	Telemonitoring	Post-operative home-tele monitoring of vascular surgery patients.	Monitoring

6 RUC B Devices, Goods, Facilities Management

This RUC was created to enable ODIN technologies to contribute to improving the design, scheduling, and execution of Hospital Logistic, Clinical Engineering, and Medical Device management, starting with the description of UC1 in the DoA.

It includes the phases of material procurement, storage, and distribution (medicines, medical and hotel supplies, meals, linens, waste, etc) part of the logistic management and those phases related to the clinical engineering and medical devices management.

All this processes, e.g., order consumables after using them, transport of objects, refill of ward magazines etc; most of the time need duplication of efforts generating additional, and unnecessary load to the hospital workflows, and extra burden to both administrative and healthcare staff.

This reference use case will employ various combinations of eRobots, eWorkers, and eLocations to optimise procedures, improve healthcare operators' working conditions, and improve hospital efficiency and workflow. This is projected to improve the work of personnel who are primarily responsible for hospital logistic processes (e.g., porters, managers), as well as free up time for healthcare workers (e.g., nurses) by removing them from repetitive, time-consuming, and potentially dangerous jobs.

6.1 ODIN Framework for industry 4.0 hospital logistic management

By approaching RUC B in a similar manner as RUC A, we can build a workflow, which describes the interactions among the different phases and inputs. As per RUC A, all the phases are interconnected and interdependent on each other. The starting points come from the Strategic Management Plan and the gap analysis from the different hospital units. These steps feed the Planning phase where the hospital management is in charge to design and develop what is needed by the next phase the Procurement Stockage. This last phase is dealing with all the necessary activities to acquire good in the hospital context. The next phase is related to the Preparation and Delivery of the acquire good to the final destination / department. Completing this process is the Real Use Monitoring and Management in charge of the follow-up steps after the acquisition

The similar navigation schema of the RUC B can be described as the picture below, where instead of having the levels of care there are the different objects managed by the logistics for the RUC B1 or type of the equipment for the RUC B2 as shown in the figures below:

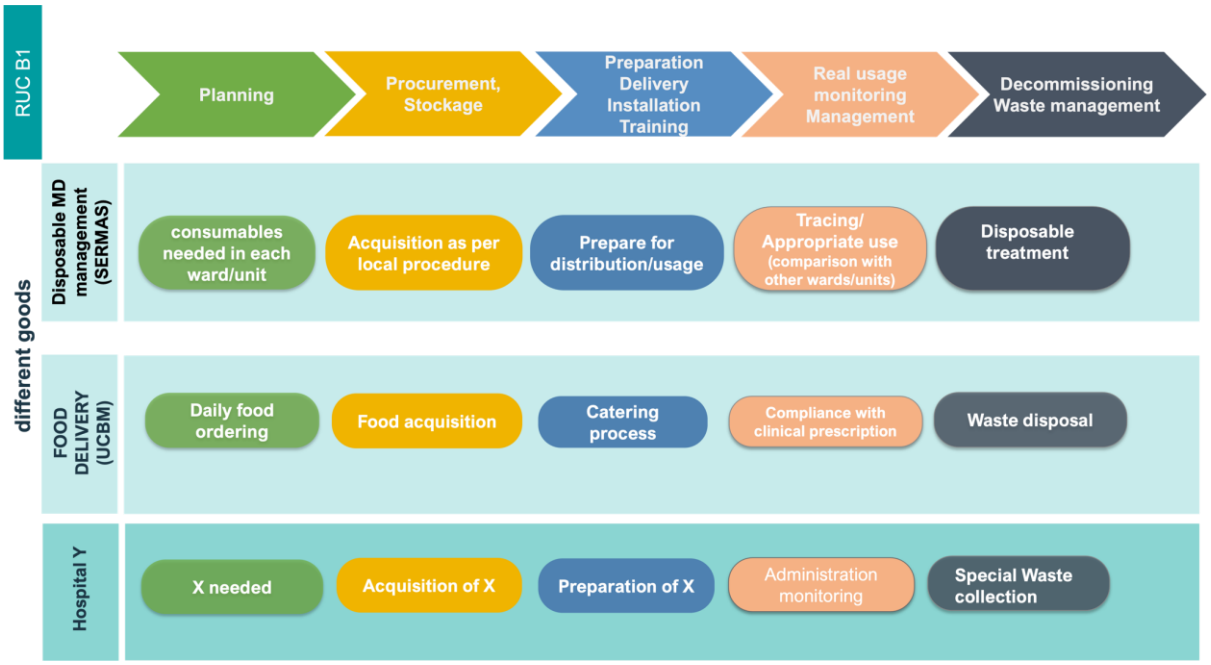

Figure 4 - RUC sub case B1 Navigation Diagram

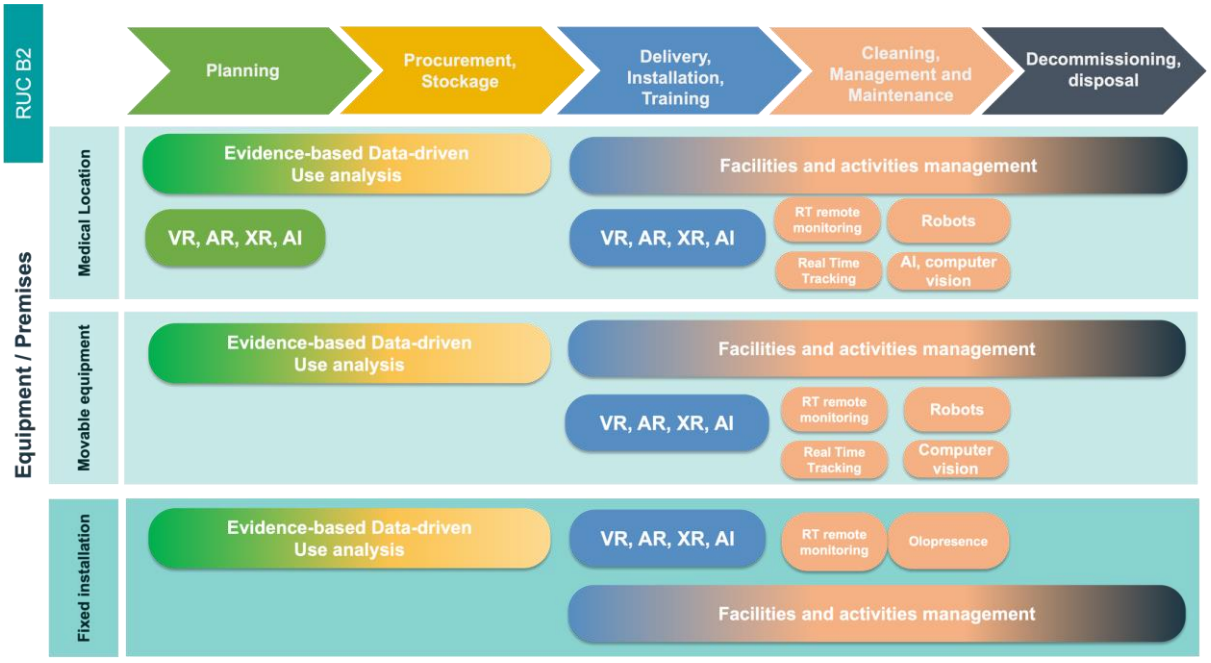

Figure 5 - RUC B2 Navigation Diagram

6.2 RUC B Phases (overall and for each phase)

The first two defined use cases are covered in this RUC, which is relevant to the managerial area (RUC B1 - UC1, RUC B2 - UC2). It focuses on improving the design, programming, and execution of hospital logistics, clinical engineering, and medical device management using ODIN technology.

The first of these, RUC B1 - UC1, has been conceptualised as the entire process of procurement, storage, and distribution of various commodities in the hospital environment, with a focus on operations inside the hospital environment that are considered redundant, as specified by the DoA (e.g., transport of consumables).

The other is RUC B2 - UC2 "Clinical Engineering, MD locations, real-time management," which focuses on the management of medical devices employing ODIN technology. This is especially essential because one of the main causes of adverse occurrences in the hospital environment is the current absence of real-time information transmission. The proper functioning and modification to this use case will allow for the optimisation of normal tasks as well as disaster preparedness, which will be covered in further depth in RUC C - UC7.

Here below, the phases of the RUC are briefly described.

Planning

Planning the changes to medical locations and to the electromedical equipment fleet to respond to health needs, based on evidence from needs assessment, current usage, analysis of faults and recalls, maintenance and real-world data (RWD)

Procurement, Storage

Defining a rational process for acquiring and stocking electromedical equipment

Delivery, installation, training

Planning delivery and installation steps which minimise the impact on the hospital processes. Performing effective and customised training to technical staff and healthcare staff

Cleaning, management, and maintenance

Managing the cleaning of spaces, their assignment to departments and operational units, plan and manage their maintenance.

Managing the maintenance of electro-medical devices with a data-driven evidence-based approach

Decommissioning, disposal

Managing the closure of medical locations and the transfers of activities and technology.

Managing the decommissioning and disposal of medical equipment

6.3 RUC B Primary Outcomes

This reference use case aims at maximising data-driven decisions and evidence-based management of processes.

Planning

Optimising the whole clinical engineering and medical locations management process

Procurement, Storage

Reducing time and maximising equipment availability

Delivery, installation, training

Innovating the way equipment is delivered and put in place, and the training to technicians and health personnel

Cleaning, management, and maintenance

Optimising medical locations and equipment management and maintenance

Decommissioning, disposal

Optimising closures and transfers

Optimising equipment decommissioning and disposal, in particular for fixed devices (e.g. MRI, CT, Radiology, etc.).

6.4 RUC B IA KPIs (for each phase)

Here below are reported the IA KPIs for RUC B summarised per each phase

The full experiment descriptions and the related, locally defined, KPIs are reported in Appendix A

Table 10 - RUC B IA KPIs

Phase	KPIs	Measure unit
Planning	Mean time to problem solution (MTPS)	[hours]
	Costs	[€]
	Operating time	[hours]
Procurement, Storage	Procurement time	[days]
	Backup appliances	[%]
	Storage costs	[€]
Delivery, installation, training	N. of non-conformities [#]	[#]
	Timeliness	[days]
	Training time	[hours]
	Training effectiveness	[scores TBD]
Cleaning, management, and maintenance	Cleanings costs	[€]
	Medical location availability	[%]
	Equipment downtime	[%]

Phase	KPIs	Measure unit
	Maintenance costs	[€]
Decommissioning, disposal	Medical locations closure and transfer time	[days]
	Decommissioning time	[days]
	Disposal costs	[€]

6.5 RUC B Sub Cases

6.5.1 RUC B1 UC1: Aided logistic support

This use case covers all the aspects about the hospital logistics, excluding patient experience part of RUC A

6.5.2 RUC B2 UC2: Clinical engineering and medical locations management

This use case covers aspects related to the exploitation of ODIN technologies for improving the clinical engineering, the management of medical locations and medical equipment.

6.6 Pilots implementing RUC B

Having defined, so far, the RUC B and its sub use cases RUC B1 and B2, ODIN pilots described their experiments as a specialisation of these models.

This resulted in the following ODIN RUC B table:

Table 11 - RUC B Pilots implementation

Use Case	Name	Pilot(s)
RUC B1 – UC1	Aided Logistic Support	SERMAS, UCBM
RUC B2 – UC2	Clinical engineering, MD locations, real-time management	SERMAS, MUL

Tables below summarises for each pilot the different implementation of RUC A. Full detailed pilots' experiments, where available, are reported in Appendix A.

6.6.1 MUL

Table 12 - RUC B MUL

Use Case	Name / Description	RUC Phase (s)
RUC B2 – UC2	Clinical Engineering and Medical Locations Management	All

6.6.2 SERMAS

Table 13 - RUC B SERMAS

Use Case	Name	Description	RUC B Phase (s)
RUC B1 – UC1	Aided Logistic Support	Monitor the use of consumables	Planning Procurement, Storage
RUC B2 – UC2	Clinical engineering, MD locations, real-time management	consumable delivery automation	Delivery, installation, training Decommissioning, disposal

6.6.3 UCBM

Table 14 - RUC B - UCBM

Use Case	Name	Description	RUC B Phase (s)
RUC B1 – UC1	Aided Logistic Support	Logistics of food delivery	Preparation, delivery, installation, training Real usage monitoring Management

7 RUC C Disaster Management

The main focus of this particular use case is to mitigate the risk of potential disasters in the future, with specific emphasis on addressing UC7 "Disaster Preparedness." The COVID-19 pandemic highlighted the many challenges that hospitals faced during a crisis, making it critical to take action to prevent difficulties from arising in the future.

7.1 ODIN Framework for industry 4.0 disaster management

The use of ODIN KERs enables the so-called framework to support hospitals' resilient management to mitigate, prepare, respond and restore in case of disasters. In this project, various simulations will be conducted, this includes managing crowd control, emergency devices management, enhancing security measures, and providing infection prevention and control support. All of these efforts are geared towards ensuring safety and reducing the impact of potential disasters.

To define this RUC C, starting from the WHO Sendai Framework for Disaster Risk Reduction 2015 – 2030 and highlighting all disaster dimensions, we conducted targeted workshops and activities with pilots and technical partners. The preliminary results were the characterisations of the different risks and the schematizations of their management. For this, we adapted the WHO navigation model, as per the other two use cases, with the main difference in mind: the focus on emergency protocols to manage RUC A and RUC B phases during a disaster. The protocols developed in this section are designed to be practical and effective in mitigating the impact of a disaster and will be a valuable resource for hospitals as they prepare for potential future crises.

7.2 RUC C Phases description and Primary Outcomes

The RUC C infographic provides a visual representation of the disaster preparedness flowchart phases. The aim of this reference use case is to help hospitals respond quickly and recover faster from disasters, utilizing state-of-the-art simulations in EBM.

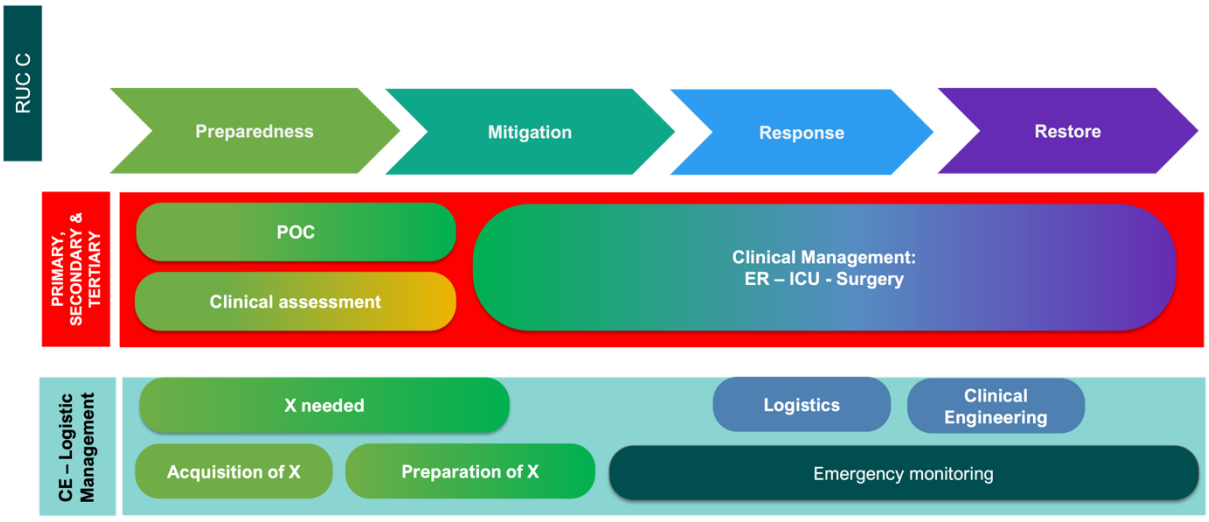

Figure 6 - RUC C Disaster preparedness navigation diagram

This is especially essential because one of the main causes of adverse occurrences in the hospital environment is the current absence of real-time information transmission. The proper functioning and modification to this use case will allow for the optimization of normal tasks as well as disaster preparedness, which will be covered in further depth in RUC C - UC7.

Here briefly described the phases of the RUC.

- Preparedness: The preparedness phase involves activities aimed at enhancing a hospital's readiness to effectively respond to a disaster. Key components of this phase include:
    - Planning and organizing: Developing comprehensive emergency response plans, establishing command structures, and assigning roles and responsibilities to staff members.
    - Training and education: Conducting regular drills and exercises to ensure staff members are familiar with emergency procedures and protocols. Training sessions can cover various aspects like triage, communication, and evacuation.
    - Resource management: Identifying and procuring essential resources such as medical supplies, equipment, and personnel required during emergencies. Ensuring their availability, maintenance, and adequate stockpiling.

  ODIN KER will support data analysis and prediction: AI algorithms can analyse historical data on disasters, patient demographics, and resource utilization to identify patterns and trends. This analysis can help hospitals better understand their vulnerabilities and develop targeted preparedness plans. AI can also facilitate virtual training programs, providing interactive learning experiences to enhance staff readiness. ODIN Platform can assist in optimizing resource allocation by analysing real-time data on person and patient influx, supply levels, and staff availability. This helps ensure efficient utilization of resources during emergencies.
- Mitigation: Mitigation efforts aim to minimize the impact of potential disasters on the hospital and the community. This phase involves:
    - Risk assessment: Identifying potential hazards and vulnerabilities specific to the hospital, analysing their potential impact, and developing strategies to reduce risks.
    - Hazard reduction: Implementing measures to minimize the impact of identified hazards. For example, retrofitting buildings to withstand earthquakes or implementing fire prevention systems.
    - Public education: Conducting community outreach programs to raise awareness about disaster preparedness and promote individual and community resilience.

ODIN KERs can play a significant role in the mitigation phase by:

- Risk analysis: This analysis can help hospitals identify and prioritize mitigation strategies.
- Predictive analytics: AI algorithm can leverage machine learning techniques to predict the likelihood and impact of specific hazards. This allows hospitals to proactively implement mitigation measures and allocate resources accordingly.
- Early warning systems: AI algorithm can integrate with monitoring systems to detect early signs of potential disasters. For example, AI algorithm can analyse

data from sensors to detect anomalies indicating the onset of fires or floods, triggering timely alerts and response actions.

- Response: The response phase encompasses actions taken during and immediately after a disaster to protect patients, staff, and the facility. Key activities include:
    - Activation of emergency plans: Initiating the hospital's emergency response plan, establishing incident command, and activating communication systems to facilitate coordination and information sharing.
    - Triage and medical care: Prioritizing and categorizing patients based on the severity of their injuries or conditions. Providing immediate medical care and initiating treatment as per established protocols.
    - Resource allocation: Effectively allocating and managing available resources to meet the surge in demand during emergencies. This includes staffing, supplies, equipment, and medications.
    - Communication and coordination: Establishing clear communication channels with external agencies, neighbouring healthcare facilities, and other stakeholders to exchange critical information and coordinate efforts.

During the response phase, ODIN KERs can provide critical support in robotics and automation: ODIN-powered robots can be deployed for tasks such as disinfection, delivery of supplies, and logistics management, reducing the exposure of healthcare workers to risks and enhancing overall response capabilities.

- Restore: The restore phase focuses on restoring normal operations and facilitating the recovery process. Key elements of this phase can include:
    - Facility restoration: Assessing the damage to the hospital infrastructure and initiating repair and restoration efforts.
    - Patient care continuity: Ensuring continuity of patient care during the recovery phase. This includes resuming routine healthcare services, addressing any backlog of postponed procedures, and supporting ongoing medical needs.
    - Evaluation and improvement: Conducting a comprehensive evaluation of the hospital's response and recovery efforts. Identifying strengths, weaknesses, and lessons learned to improve future preparedness. Updating emergency plans and protocols based on these findings.

  ODIN KERs can support the restoration phase by:

    - Data-driven recovery planning: AI algorithms can analyse post-disaster data, patient records, and resource availability to assist in developing recovery plans. This helps hospitals optimize resource allocation and prioritize services during the restoration process.
    - Predictive analytics for resource needs: AI can analyse historical and real-time data to predict resource needs during the recovery phase. This allows hospitals to anticipate and address any potential shortages proactively.
    - Intelligent scheduling and optimization: AI can optimize scheduling and resource allocation during the recovery phase, considering factors such as patient demand, staff availability, and operational constraints. This ensures efficient utilization of resources and timely restoration of services.

- Knowledge management: AI-powered systems can facilitate the capture and organization of knowledge and lessons learned during the response and recovery phases. This information can be utilized to improve future disaster preparedness efforts.

7.3 RUC C IA KPIs (for each phase)

Key Performance Indicators (KPIs) for RUC C - Disaster preparedness have to assess the effectiveness and readiness of hospitals in responding to and managing disasters. While the ODIN Pilot are still defining in detail, here are some preliminary defined KPIs descending from the other two RUCs, specifically measured in disaster occurrence.

Emergency Response Time: This KPI measures the time taken by the hospital to initiate a response to a disaster or emergency situation. It includes the time it takes for the emergency response team to assemble, coordinate with relevant stakeholders, and begin implementing the hospital's emergency plan.

Evacuation Time / Crowd management: This KPI measures the time required to safely evacuate patients, staff, and visitors from the hospital in the event of a disaster. It includes factors such as the time taken to mobilize evacuation resources, execute evacuation procedures, and ensure the safe transportation and relocation of individuals to designated safe areas.

Resource Availability and Management: This KPI evaluates the hospital's capacity to effectively manage and utilize resources during a disaster. It includes indicators such as the availability of medical supplies, equipment, and pharmaceuticals, the adequacy of emergency power supply systems, and the efficient allocation and utilization of resources to meet the demands of the disaster situation.

These KPIs provide a preliminary framework for hospitals to assess their disaster preparedness capabilities and identify areas for improvement. By monitoring these indicators, hospitals can enhance their readiness to effectively respond to and manage emergencies and disasters.

Table 15 - RUC C IA KPIs

Phase	KPIs	Measure unit
Mitigation Response	Emergency Response Time	[hours] [days]
All	Costs	[€]
Mitigation Response Restore	Operating time	[hours]
Mitigation Response	Evacuation Time / Crowd management	[hours] [days]
Mitigation Response	Backup appliances	[%]

Phase	KPIs	Measure unit
Restore		
Preparedness Mitigation Response	Resource Availability and Management	[# of available goods]
Preparedness	Training time	[hours]
Mitigation Response	Training effectiveness	[scores TBD]
Cleaning, management, and maintenance	Cleanings costs	[€]
Mitigation Response Restore	Medical location availability	[%]
Restore	Medical locations closure and transfer time	[days]

7.4 RUC C Sub Cases

7.4.1 RUC C1 UC7: Disaster preparedness

This use case covers all the aspects about the hospital preparedness in case of disasters.

7.5 RUC C Pilots' implementation

So far defined the RUC C and its related use case RUC C1, ODIN pilots described their experiments as a specialization of these models.

This resulted in the following ODIN RUC C table:

Table 16 - RUC C - Pilots implementation

Use Case	Name	Pilot(s)
RUC C1 – UC7	Disaster Preparedness	CUB, SERMAS, UMCU

Tables below summarizes for each pilot the different implementation of RUC C. Full detailed pilots' experiments are reported in Appendix A.

7.5.1 CUB

Table 17 - RUC C CUB

Use Case	Name	Description	RUC C Phase (s)
RUC C - UC 7	Disaster Preparedness	Patient monitoring/ Evacuation	All

7.5.2 SERMAS

Table 18 - RUC C SERMAS

Use Case	Name	Description	RUC C Phase (s)
RUC C – UC7	Disaster preparedness	Evacuation flow optimization/ Control of capacity	Preparedness, Response

7.5.3 UMCU

Table 19 - RUC C - UMCU

Use Case	Name	Description	RUC X Phase (s)
RUC C – UC7	Disaster Preparedness	Overview of pathogen carriers for IPD	All

8 Introduction to the Operational Key Performance Indicators (KPIs)

To actively support and monitor the ODIN Experiment Framework the WP Management Team from UoW and UPM defined a set of Operational (OP) KPIs. Related to the evolution of the pilots and the use cases in which they are involved, these OP KPIs support the tracking of the project's progress and enable understanding the status of critical aspects essential for reaching the goals. The OP KPIs also include the identification of required technology, recruitment and training of participants, and incident management. This will allow the identification of any blocking issues that may be hindering a pilot's progress and they will also be helpful to identify which contingency actions and their related mitigation plans to implement. The Operational KPIs are collected monthly as the related reports are generated for each pilot. A Power BI platform is used to facilitate their analysis and representation. This business tool, together with other analytics, will provide a straightforward and dynamic overview of the project's status, pilot per pilot, and use case per use case.

These OP KPIs will soon be completed by the ones defined in the technical WPs.

To build these indicators, we followed an open approach with the pilots and the other partners, and several iterations and workshops. We're testing the first collection.

8.1 The Operational KPIs

In light of the significance of tracking the development of the ODIN Experiment architecture, we made the decision to begin using various analysis methods. One of these is Microsoft PowerBI, which offers an efficient displaying of the experiment's evolution. In order to illustrate the operational perspective, a dashboard has been created. A fresh set of operational KPIs is being validated for this purpose together with each and every RUC/UC. It's worth to mention this is an evolving activity and the KPIs could be refined, added and changed to better portray the ODIN Experimental Framework

We chose PowerBI because of its simplicity to use compared to competing products and its versatility in terms of data preparation and design management. The most pertinent data, such as the status of the RUCs/UCs and the pilots participating, is going to be collected in excel files and fed into the dashboard that has been created.

Any user can explore this dashboard starting with the descriptions of the pilots, the RUCs/UCs that have been implemented, the operational state for each phase, the resources that have been spent, and the defined KPIs. With this method, the most pertinent data is obtained uniformly, making it simpler to manage and monitor the project's status and advancement.

The following sheets represent the Operational KPIs, defined both at global level and the specific ones pilot per pilot, phase per phase.

So far, we have described 28 global indicators and 32 specific indicators for all the RUCs and Pilots.

So far there are 12 for RUC A, 5 for the preparation phase, 5 for the deployment phase and 2 for the running phase; 8 for RUC B, with 4 for the preparation phase and 2 each for the deployment and running phases; last, 8 for RUC C, 5 for the preparation, 1 for the deployment and 2 for the running. All together will show the complete evolution of the RUCs status.

Table 20 – RUC A Global Operational KPIs

RUC A		
Indicator	RUC	Phase
Study protocol	A	Preparation
Ethical approval	A	Preparation
Technology identification/acquisition	A	Preparation
Participant information	A	Preparation
Procurement process	A	Preparation
Technology installation	A	Deployment
Training of medical staff involved in the protocol/supervisors/participants	A	Deployment
Recruitment (HCW)	A	Deployment
ODIN platform integration	A	Deployment
Baseline data collection	A	Deployment
Publication(s) in scientific journals	A	Running
Presentation in scientific conferences	A	Running

Similarly, the table below describes 18 the indicators specific per each and every pilot for the RUC A

Table 21 – RUC A Specific Operational KPIs

RUC A			
Indicator	RUC	Pilot ID	Phase
Approval by the local/hospital administration	A	CUB, MUL	Preparation
Recruitment of participants	A	CUB, MUL	Preparation
Informed consent	A	CUB, UCBM	Preparation
Users in operation	A	CUB	Running
Robots in operation	A	CUB	Running
Services/ AI models in operation	A	CUB	Running
Experiments / protocol finalisation	A	CUB	Running

RUC A			
Indicator	RUC	Pilot ID	Phase
IA KPIs collections	A	CUB	Running
Training of medical staff involved in the protocol/supervisors/participants	A	MUL	Preparation
Data management plan	A, C	UMCU	Preparation
Current and alternative diagnostic pathways description	A	UMCU	Preparation
Data extraction	A	UMCU	Preparation
Deployment of models 1-3	A	UMCU	Running
Validation of the final model	A	UMCU	Running
Launch in clinical workflow	A	UMCU	Running

The next table shows the 8 indicators for RUC B

Table 22 – RUC B Global Operational KPIs

RUC B		
Indicator	RUC	Phase
Study protocol	B	Preparation
Ethical approval	B	Preparation
Equipment (not technology) identification/acquisition	B	Preparation
Technology identification/acquisition	B	Preparation
Training of medical staff involved in the protocol/supervisors/ participants	B	Preparation
Training of medical staff involved in the protocol/supervisors/ participants	B	Deployment
Technology installation	B	Deployment
Publication(s) in scientific journals	B	Running
Presentation in scientific conferences	B	Running

Here below the RUC B specific ones defined so far.

Table 23 – RUC B Specific Operational KPIs

RUC C				
Indicator	UC	RUC	Pilot ID	Phase
RFID tags acquisition	2	B	MUL	Deployment
Recruitment (HCW)	2	B	MUL	Deployment
ODIN platform integration	2	B	MUL	Deployment
Baseline data collection	2	B	MUL	Deployment
RTLS	1	B	SERMAS	Deployment
Test deployment	1	B	SERMAS	Deployment

The next table represents the 8 indicators for RUC C

Table 24 – RUC C Global Operational KPIs

RUC C		
Indicator	RUC	Phase
Study protocol	C	Preparation
Ethical approval	C	Preparation
Technology acquisition	C	Preparation
Participant information	C	Preparation
Procurement process	C	Preparation
Technology installation	B	Deployment
Publication(s) in scientific journals	C	Running
Presentation in scientific conferences	C	Running

The following table reports about the specific OP KPIs for RUC C defined to date.

Table 25 – RUC Specific Operational KPIs

RUC C			
Indicator	RUC	Pilot ID	Phase
Approval by the local administration	C	CUB, MUL	Preparation
Informed consent	C	CUB	Preparation
Recruitment of participants	C	CUB	Preparation
Deployment Area identification	C	SERMAS	Preparation
Monitoring objectives definition	C	SERMAS	Preparation
Data management plan	C	UMCU	Preparation
Data extraction	C	UMCU	Preparation

All the specific OP KPIs are being collected monthly and together with the Global ones will be reported every six months in the D7.2.x series with a full picture.

9 Conclusions

After defining the experiments with clear timelines and applying for mandatory ethical approvals, the pilots thanks to the technology assessment are now in the full deployment phase, dealing with the technology partners and the procurement journey. The goal of this edition was to include the final experiment design at the pilot level, incorporating input from different internal stakeholders to further advance the project's progress and implementation.

This report offers a clear and redefined version of the Impact Awareness KPIs from the pilots' perspective. In Section 8, there is a complete set of Operational KPIs that will allow a well-defined overview of the experiments and the project evolutions.

The next version will include the full Impact Awareness Structure under the HTA Framework to offer a complete impact evaluation of the ODIN experiments, linked to the exploitation dimension of the WP9. It will also include the preliminary analysis of the Operational KPIs after four months running.

Appendix A ODIN Pilots experiments

This appendix describes in detail the full experiments description with the architectural design pilot per pilot. This represents the picture at M24. Each profile includes a pilot description, the experiment definition according to the chosen RUCs with phases, goals, KPIs, and technologies.

A.1 ODIN Technology assessment and TRL

This section reports about the technology assessment performed pilot per pilot with the necessary support of the technological partners of ODIN.

The table below reports the technology provider within the ODIN Consortium, which pilot, the name of the technology / service and the TRL.

Table 26 - Pilots technology providers

Partner Name	Pilots	Main Technology Provided	TRL
CERTH	UCBM	CerthBot robot	TRL6
	CUB	CerthBot robot	TRL6
	CUB	Data analytics platform	TRL6
INETUM	SERMAS	Computer vision algorithm.	TRL4
Forth	SERMAS	AI-based algorithms	TRL6
	UCBM	AI-based algorithms	TRL4
	UCBM	AI-based algorithms	TRL4
	UCBM	AI-based algorithms	TRL5
MYS	SERMAS	RTLS System	TRL6
	MUL	RTLS System	TRL6
	UCBM	RTLS System	TRL6

Partner Name	Pilots	Main Technology Provided	TRL
	UMCU	ORVITAL	TRL6
THL	UCBM	FMS	TRL5
	CUB	FMS	TRL5
SSSA	SERMAS	HOSBOT robotic platform, with smartbox and other ancillary modules	TRL4-5
	SERMAS	HUMAN MODELING ALGORITHMS	TRL3-4
	UCBM	TRANSPARENT ROBOT	TRL4-5
	MUL	HOSBOT robotic platform, with smartbox and other ancillary modules	TRL4-5
PHILIPS	CUB	Federated Learnine pipeline	
UPM		FURHAT	TRL - X
		PEPPER robotic platform	TRL - X

In the following sections are reported the descriptions per each and every pilot.

A.2 CUB - Charité-Universitätsmedizin Berlin, Germany

A.2.1 Pilot Description

Charité University Hospital is one of the largest hospitals in Europe. It has four campuses distributed over the city of Berlin. The Interdisciplinary Sleep Medicine Centre is one of many departments in this institution and it is one of the few facilities in Germany where sleep disorders of all kinds are examined and treated from childhood to old age. The centre includes an outpatient clinic, an inpatient sleep laboratory for all sleep-related problems and all forms of sleep disorders, and an outpatient sleep laboratory within the Charité outpatient health centre for patients with sleep-related breathing disorders. The staff consists of pneumologists, neurologists, ENT physicians, cardiologists, engineers, specialized medical technologists, and nurses.

The constant overall aim of the Charité is to combine patient care, medical research, and education to provide the best practice for future medical services in Europe. As time goes on technology tends to improve and the Charité tries to keep up to date with all the new methods in an effort to provide the best medical service for patients. This aim is in line with the vision of ODIN to improve future medical services for both patients and medical staff. The standard method of improving services at the sleep medicine centre is by implementing experiments where new technology is trialled to see if it can operate to the same level or higher than our current gold-standard equipment.

The main areas of improvement can be characterised into three categories: organisational, environmental, and economic factors. The current approach towards organisation at the inpatient sleep laboratory at the sleep medicine centre is not optimal in relation to the number of patients it treats. The department contains 10 beds to conduct sleep studies using polysomnography (PSG) (12-electrode minimum recording of the whole body) on patients. In addition, it is essential for each patient to spend multiple nights at the sleep centre in order to obtain the most accurate readings so that the sleep technicians can confidently identify a sleep disorder. The main problems that arise here are the waiting list for this treatment is long and that it takes multiple hours to score these sleep recordings, which can be very time-consuming.

A solution to long waiting lists could be to test and validate new technologies that can act as an alternative to the gold standard PSG. This can also be seen as economical and sustainable since these newly emerging devices are relatively cheap and require little energy to operate in comparison to PSG. This is extremely important at this current time since we are currently going through an energy crisis and the cost of living is increasing. Therefore, these new devices could be the future of sleep diagnosis. These studies can be taken one step further by using the raw data in machine learning algorithms to create automated sleep scoring for both standard sleep recordings and new technological devices. Doing so will reduce the efforts of the sleep technicians and provide new

The previously mentioned improvements are not the only focus of the sleep medicine centre. Disaster preparedness is also a concern within the department. As mentioned before, new technology is emerging and it is becoming more feasible to improve areas such as disaster preparedness with up-to-date technology. The standard method of improving these services that are already in place is by implementing experiments trialling new technology to see if they perform better during a potential disaster.

A.2.2 Pilot Experiments

Table 27 - CUB - Experiments

Use Case	Name	Description	RUC X Phase (s)
RUC A UC 3 & 4	AI Based Support System for Diagnosis & Clinical Tasks and Patient Experience	Validation of Wearables & Automated Scoring of Wearables	Admission & Screening, Diagnosis
RUC A UC 3	AI based support system for Diagnosis	Automated Sleep Scoring of Sleep Studies	Diagnosis

Use Case	Name	Description	RUC X Phase (s)
RUC A UC 4	Clinical Tasks and Patient Experience	CERTH Bot Receptionist	Admission & Screening, Monitoring
RUC C UC 7	Disaster Preparedness	Patient monitoring/ Evacuation	Monitoring

A.2.2.1 RUC A UC 3 & 4: Validation of Wearables & Automated Scoring of Wearables

A.2.2.1.1 Description

This use case is based on validating new algorithm-based methods for the diagnosis of sleep disorders. Up until now, overnight in-laboratory PSG is the gold standard in sleep recording. It is a multi-parameter diagnostic tool that monitors various body functions, i.e. brain activity, eye movements, muscle activity, and heart rhythm. However, in-laboratory PSG is labour-intensive, time-consuming, and expensive, which leads to long waiting lists for patients and high costs for the public health system. Manual sleep scoring by sleep technicians imposes a further impediment on the supply of staff given the current shortage in the number of sleep technicians, which is expected to worsen. Thus, reducing the level of burden on health personnel and the use of hospital resources are required.

Wearable sleep monitor devices help to solve these issues. These devices meet the mobility requirements and are simple and lightweight, this allows self-application by the patient at home. However, these methods are to be validated and further developed in terms of validity relative to the PSG as the gold standard. While these wearable devices are already freely available, algorithms behind the automated diagnostic are still to be improved. Furthermore, each wearable device has its own algorithm to calculate sleep disorders which are not available to the public, leaving a black box so to say. By obtaining the raw data from these wearables we will combine all data into a machine-learning algorithm and calculate the average point of where an event was marked. Furthermore, we can create our own algorithm that can accurately score sleep-breathing events automatically with clinically validated data.

The first step is to conduct two internal experiments on the validation of different wearable sleep-tracking devices (Two wearable monitor devices that are worn on the finger, comparable to a ring):

Study 1

Automated analyses are expected to be the future of obstructive sleep apnea (OSA) diagnosis and are likely to become part of the tool in practice for sleep physicians. One such method is based on cardiopulmonary coupling (CPC) analysis, which calculates coupled interactions between heart rate variability (HRV) and respiratory beats (electrocardiogram (ECG)-derived respiration, EDR) to automatically obtain multiple metrics for sleep quality assessment and sleep diagnosis. The latest wearable monitoring device (SleepImage Ring), based on CPC analysis, acquires both plethysmogram (PLETH) and SpO2 signals from a single photoplethysmogram (PPG) sensor. Thus, a software-generated apnea-hypopnea index (AHI) can be calculated by combining CPC output and PPG-derived hypoxic events. Previous research has shown that

accurate automated AHI can be derived from CPC and pulse oximetry from polysomnography (PSG). However, there are no studies that directly demonstrate the diagnostic performance of the SleepImage Ring device in adults with OSA.

This study aims to evaluate the diagnostic capabilities of a wearable monitoring device (the SleepImage Ring device) for OSA in adults using PSG as a reference standard.

Hypothesis:

The SleepImage Ring device will provide high sensitivity, specificity, and predictive values compared to PSG to identify OSA in adults at all thresholds of disease severity.

Protocol:

Overnight sleep recording by PSG and the SleepImage Ring device is planned simultaneously for each study participant.

Objective assessment of OSA severity by PSG used for routine sleep medicine diagnosis. In addition, the finger-worn SleepImage Ring provides objective parameters by which sleep quality, OSA severity, and blood oxygen saturation are recorded. Questionnaires are used for subjective surveys.

Questionnaires:

- ESS (Epworth Sleepiness Scale)
- STOP-Bang questionnaire
- Evening and morning questionnaire

Study 2

For some years now, wearables in the form of watches or rings have promised to determine a hypnogram. It has been proven that the results vary for these watches and that the hypnogram of polysomnography cannot be replaced at present.

Nevertheless, the need is given, because simple and reliable home sleep measurements would significantly expand the diagnosis of sleep disorders and these measurements would then also be good for personal use. They would also have the advantage over polysomnography in that this measurement technique would not interfere.

Some commercial providers, such as "Oura", "SleepOn", and "Circul" offer so-called sleep trackers in ring format or based on an app-based contactless measurement. By measuring oxygen saturation, breathing rate, movement, pulse and activity, these devices evaluate sleep and breathing with proprietary algorithms and create a hypnogram.

Since these applications are very resource-saving and patient-friendly compared to conventional polysomnography, it is of particular interest to verify to what extent the measurements of polysomnography match those of sleep trackers. The quality of the collected parameters and the hypnograms evaluated by the apps of the respective measurement system will be investigated.

Aim of the study:

Primary endpoints: The collected measurement values of the TST and WASO are to be collected and compared with the commercial sleep trackers and polysomnography.

Secondary endpoints: The evaluated hypnograms of the commercial sleep trackers are to be compared with those of the polysomnography.

Hypotheses:

The measurements of TST and WASO collected by the commercial sleep trackers are comparable to those of polysomnography.

The hypnogram produced by sleep trackers is comparable to the hypnogram produced by standard polysomnography.

Protocol:

Overnight sleep recording by PSG and all three devices are planned simultaneously for each study participant.

Objective assessment of OSA severity by PSG used for routine sleep medicine diagnosis. In addition, the finger-worn devices provide objective parameters by which sleep quality, OSA severity, and blood oxygen saturation are recorded.

Protocol for both studies:

- Admission & Screening

Patient screening will be completed initially in the clinical sleep facilities to assure inclusion criteria. The number of patients included in both studies is calculated by means of power calculation for sample sizes. In both studies, ethical applications will be collected prior to data collection. All patients will provide informed written consent about data collection, data analysis and data transfer between cooperation partners.

- Diagnosis

Patients will undergo standardized sleep diagnostic by overnight PSG measurements. Those measurements will be compared to data derived from portable devices.

Following both these studies, we will request and obtain the raw data from the manufacturers of each device and then share the data with another partner in ODIN for machine learning. This is where the algorithm will be created for automated scoring of sleep-breathing events.

A.2.2.2 RUC A UC 3: Automated Sleep Scoring of Sleep Studies

A.2.2.2.1 Description

We are currently in cooperation with Philips and the Kempenhaeghe institute with the goal of improving machine-learning algorithms for the automatic classification and diagnosis of sleep data. In compliance with our ethics guidelines, we will provide Philips with recorded sleep apnoea data from a European database and Insomnia PSG data from a previous clinical trial. Prior to transferring the data, all data must be fully anonymized and from here, Philips will train a model on the data we provide with the hope to have a strong model to successfully diagnose sleep disorders automatically. The way in which Kempenhaeghe is involved is by offering a large dataset of the same kind to improve the training process. By using two different samples removes heterogenous results too. Therefore, it will be more applicable to the wider population, plus Kempenhaeghe already has a data sharing agreement with Philips which makes it much easier to transfer the data.

- Diagnosis

  This is retrospective data training in order to automatically diagnose sleep disorders. Philips plan to create an algorithm that can automatically score prospective recordings following the training.

A.2.2.3 RUC A UC 4: CERTH Bot Receptionist

A.2.2.3.1 Description

We are currently in cooperation with CERTH with the goal of reducing the efforts of nurses on time-consuming tasks by using their robot as a receptionist. Their robot would guide the patients to their rooms and could also detect if the patient falls over or sits down. Either of these functions could be useful in case there was an emergency between reception and the patient ward. It could also indicate that the patient is in bed. The planned experiment is supposed to take place over the course of a few weeks. Here, patients will experience the CERTH bot and will also provide feedback on the usefulness and likeability of the bot. The robot is already highly tested in home environments, but it is important to test it in new environments such as a hospital environment with long corridors. If this proves useful, it could open avenues for transferring patients by robot and nurses can spend more time on more meaningful tasks.

- Admission & Screening

  This use case tends to focus on the admission of the patient, taking the patient from point A to point B.

- Monitoring

  It also monitors the patient whilst reaching the destination, just in case the patient has any problems.

A.2.2.4 RUC C UC 7: Patient Monitoring/Evacuation

A.2.2.4.1 Description

We are currently in cooperation with CERTH with the goal of using new technology to aid in the Charité's disaster preparedness (patient monitoring/evacuation). As it stands, there is no technology in the Charité's sleep medicine centre patient wards that can automatically detect whether a patient is remaining in bed throughout the night, detect intruders, or even detect whether a patient has successfully left the ward during evacuation procedures. However, the patient wards do have cameras installed in them. Therefore, CERTH are willing to implement the CERTHbot technology into these cameras to as a trial to see if this technology can automatically monitor, detect intruders, and if evacuation is successful. The planned experiment is supposed to take place over the course of a few weeks. Here, the technology will be trialled by workers as a pilot or even patients with their consent. The robot technology is already highly tested in home environments, but it is important to test it in new environments such as a hospital. If this proves useful, it could open avenues for more efficient disaster management (faster evacuation and alerting nurses if an intruder is there).

- Monitoring

  Monitors the patient wards and alerts the staff if any of the following occur: patients remain in their room during an evacuation or whether a patient leaves unexpectedly during a sleep recording / if an intruder enters.

A.2.3 Timeline (overall and for each phase)

A.2.3.1 RUC A UC 3 & 4: Validation of Wearables & Automated Scoring of Wearables

The experiment started in November 2022 and will stop in December 2023 with the following timeline:

- Admission & Screening:

  Patient recruitment started as soon as final ethical approval was given.

- Diagnosis (Start approx. 1.02.2023):

  The patient undergoes an overnight recording routine plus self-application of the wearable which is introduced by technical staff.

- Data Sharing (Start as soon as patient data is available, approx.. 01.04.2023):

  Fully anonymise patient recordings and share with partner to test the model with new data once trained.

- Write-up & Dissemination (Approx. 01.07.2023 – 01.12.2023):

  Writing up the final report and disseminating it to all other partners. This will include tying up all loose ends and finalising all aspects of the experiment.

A.2.3.2RUC A UC 3: Automated Sleep Scoring of Sleep Studies

The experiment started in August 2022 and will stop in December 2023 with the following timeline:

- Data Sharing (Start as soon as patient data is available, approx. 01.08.2022)

Fully anonymise patient recordings and share with partner once the data sharing agreement has been signed.

- Diagnosis (Start approx. 01.02.2023 – 11.06.2023)

  After the model has been trained to recognise specific sleep disorders, test model on unseen sleep recordings to see if they accurately detect the correct sleep disorder.

- Write-up & Dissemination (Approx. 01.07.2023 – 01.12.2023)

  Writing up the final report and disseminating it to all other partners. This will include tying up all loose ends and finalising all aspects of the experiment.

A.2.3.3 RUC A UC 4: CERTH Bot Receptionist

The experiment started in March 2023 and will stop in December 2023 with the following timeline:

- Admission & Screening (Start approx. 01.03.2023)

  CERTH bot will be present during admission so that it can take the patient immediately from point A to point B.

- Monitoring (Start approx. 01.03.2023)

  CERTH bot will monitor the patient whilst reaching the destination, just in case the patient has any problems.

- Write-up & Dissemination (Approx. 01.07.2023 – 01.12.2023)

  Writing up the final report and disseminating it to all other partners. This will include tying up all loose ends and finalising all aspects of the experiment.

A.2.3.4 RUC C UC 7: Patient Monitoring/Evacuation

- Monitoring (Start approx. 01.05.2023)

  CERTH bot technology integrated into our cameras in the patient wards: Monitors the patient wards and alerts the staff if any of the following occur: patients remain in their room during an evacuation or whether a patient leaves unexpectedly during a sleep recording / if an intruder enters.

- Write-up & Dissemination (Approx. 01.07.2023 – 01.02.2024)

  Writing up the final report and disseminating it to all other partners. This will include tying up all loose ends and finalising all aspects of the experiment.

A.2.3.5 Technology description

The Validation of wearables & Automated scoring of wearable raw data experiment will use the following technology:

IoT: SleepImage Ring, Oura, SleepOn, and Circul – all of which are rings which measure pulse oximetry. They offer so-called sleep trackers in ring format or based on an app-based contactless measurement. By measuring oxygen saturation, breathing rate, movement, pulse and activity, these devices evaluate sleep and breathing with proprietary algorithms and create a hypnogram.

The Automated sleep scoring of the gold-standard sleep recording experiment will use the following technology:

AI: AI Models to predict sleep disorders – Provide an AI with a large dataset in order to teach it specific characteristics of sleep disorders so that when new prospective data comes in, it can accurately and automatically identify the sleep disorder. Once trained, the AI model should be able to predict the type of sleep disorder without the help of a human if new data is provided.

The CERTH bot receptionist experiment will use the following technology:

Robots: CERTH bot developed and tested by CERTH will be integrated into Charité's sleep laboratory to trial as a receptionist. The robot can learn the hallways and patient wards, so when instructed it can assist the patient to their room. Furthermore, it can lock onto a patient so they will not be lost and can alert staff if they fall.

The Patient monitoring and evacuation experiment will use the following technology:

Robots: CERTH bot developed and tested by CERTH will be integrated into Charité's cameras within the patient wards of the sleep medicine centre to trial as an improved tool for disaster management. It can monitor whether a patient leaves their bed during sleep recording, it can monitor if any intruders enter, and it can also monitor whether a patient has left the ward during evacuation procedures.

The technical architecture of the RUC is provided in the diagrammatic below.

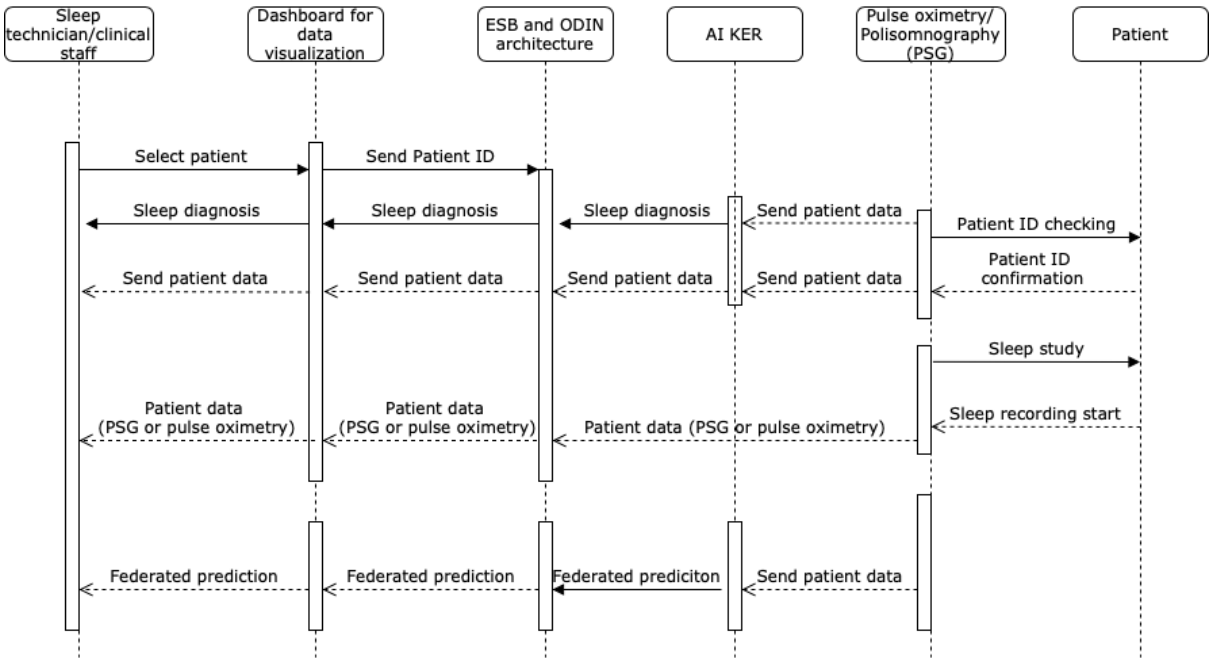

Figure 7 - CUB RUC A2 Sleep disorder management

A.2.3.6Procurement / Acquisition process

The process of acquisition will be through a procurement process / direct buy / technology partnership already in place / other

Wearable devices: Direct buy

AI Models: Technology partnership already in place

CERTH bot: Technology partnership already in place

A.2.3.7 Primary Outcomes (overall and for each phase)

(please refine, improve, detail the Primary Outcomes as from the D7.1 Appendix A. Try to include here the whole value chain and which benefits are expected for each one of them.)

A.2.3.8 RUC A UC 3 & 4: Validation of Wearables & Automated Scoring of Wearables

This use case aims to evaluate the diagnostic capabilities of four wearable monitoring devices for OSA in adults. We will use PSG as a standard reference. If the finger rings' diagnostic abilities are similar to the gold standard PSG, it could be a very helpful alternative for diagnosis. Once this has been confirmed, the raw data will be trained within an AI algorithm in order to produce a single model that can automatically score sleep-breathing events for all four wearable devices.

Admission & Screening

We aim to gather and screen the patients that fit our inclusion criteria in good time. By doing so will allow us to investigate the presence/absence of a sleep breathing disorder. This way we can determine the appropriate course of treatment.

Diagnosis

We aim to collect the finger ring data in a standardised manner in order to produce a clean dataset, which can be easily analysed. Later down the line, this data can be used in a machine learning algorithm with the aim to automatically diagnose future data. Thus, providing us with a new, accurate, and automatic method of diagnosing patients which would not be possible without the help from the partners of ODIN.

A.2.3.9 RUC A UC 3: Automated Sleep Scoring of Sleep Studies

This use case aims to create an AI model that can accurately classify a sleep disorder from a sleep recording (polysomnography and polygraphy recordings).

Diagnosis

Retrospective data collected by Charité and Kempenhaeghe used in a machine learning algorithm could automatically diagnose future sleep data. Thus, providing us with a new, accurate, and

automatic method of diagnosing patients which would not be possible without the help from the partners of ODIN.

A.2.3.10 RUC A UC 4: CERTH Bot Receptionist

This use case aims to reduce the workload of nurses and doctors by using a robot for tasks that can be time-consuming and stop them from completing more important tasks.

Admission & Screening

We aim to display the CERTH bot can take the patient immediately from point A to point B without assistance. Thus, reducing workload whilst completing the task to a high standard.

Monitoring

We aim to display the CERTH bot can monitor the patient whilst reaching the destination, just in case the patient has any problems. This provides total trust in the robot and that the working staff can fully focus on other tasks.

A.2.3.11 RUC C UC 7: Patient Monitoring/Evacuation

We aim to show that the technology provided by ODIN can help improve disaster preparedness at the Charité. This would be done by installing their software into our cameras, it would indicate whether any patients remain in their room during an evacuation or whether a patient leaves unexpectedly during a sleep recording / if an intruder enters.

Monitoring

We aim to show that the CERTH bot technology integrated into our cameras can monitor the patient wards and alert staff if any of the following occur: patients remain in their room during an evacuation or whether a patient leaves unexpectedly during a sleep recording / if an intruder enters. The overall benefit would be that If this proves useful, it could open avenues for more efficient disaster management (faster evacuation and alerting nurses if an intruder is there).

A.2.4 KPIs (for each phase)

Schematic and descriptive

A.2.4.1 KPIs RUC A UC 3 & 4: Validation of Wearables & Automated Scoring of Wearables

Table 28 - CUB RUC A UC3&4

Phase	KPIs	Measure unit	Tool	Notes
Admission & Screening	Patients enrolled: questionnaires (ESS, STOP-Bang questionnaire, Evening and morning questionnaire) and appointment with nurse	Scores and qualitative report	report from nurses	
Diagnosis & Case Study	Patient's adherence	drop-out rate	report from nurses	
	Personalization level	scores TBD	report from nurses	
	Data collection from both studies	Sleep recordings and questionnaires	Finger rings, PSG, questionnaires	
	Diagnosis of sleep breathing disorder from trained AI model	Occurrences of sleep breathing events	Finger ring data trained in AI model	

A.2.4.2 KPIs RUC A UC 3: Automated Sleep Scoring of Sleep Studies

Table 29 - CUB RUC A1 UC3

Phase	KPIs	Measure unit	Tool	Notes
Diagnosis & Case Study	Diagnosis of sleep disorder from trained AI model	Occurrences of sleep disturbing events	PSG data trained in AI model	

A.2.4.3KPIs RUC A UC 4: CERTH Bot Receptionist

Table 30 - CUB RUC A2 UC4

Phase	KPIs	Measure unit	Tool	Notes
Admission & Screening	Patients taken from the meeting point to the patient ward by a robot	Successful number of trips	Report from patient and nurse	…
Monitoring	Monitored throughout the trip from the meeting point to the ward	Number of casualties	The robot alerts the nurse if the patient falls	

A.2.4.4 KPIs RUC C UC 7: Patient Monitoring/Evacuation

Table 31 - CUB RUC C UC7

Phase	KPIs	Measure unit	Tool	Notes
Monitoring	Monitored throughout the night and during evacuation	Number of persons in a room	CERTH bot technology in the already installed cameras	

A.2.5 RUC A UC 3 & 4: Validation of Wearables & Automated Scoring of Wearables

Admission & Screening:

Questionnaires (ESS, STOP-Bang questionnaire, Evening and morning questionnaire) and appointment with nurse - Expected outcome: determines whether a patient is suitable for either experiment.

Diagnosis & Case Study:

Patient's adherence - Expected outcome: determines how well the patient used the devices/ how often

Personalization level - Expected outcome: explains where each device was used on the body and if it needed to be calibrated in a certain way

Data collection from both studies - Expected outcome: we expect a large clean dataset that measures the constructs of interest.

Diagnosis of sleep breathing disorder from trained AI model – Expected outcome: new prospective pulse oximetry data can be automatically classified by model if there is a presence of sleep breathing disorders and the severity.

A.2.6 RUC A UC 3: Automated Sleep Scoring of Sleep Studies

Diagnosis & Case Study:

Diagnosis of sleep disorders from trained AI model – Expected outcome: new prospective sleep recording data can be automatically classified by model if there is a presence of sleep disorders and the severity.

A.2.7 RUC A UC 4: CERTH Bot Receptionist

Admission & Screening:

Patients taken from the meeting point to the patient ward by a robot – Expected outcome: The CERTH bot can successfully take workload from nurses whilst keeping the patient satisfied as an acting receptionist.

Monitoring

Monitored throughout the trip from the meeting point to ward – Expected outcome: The CERTH bot can successfully recognise when a patient falls and can indicate staff instantly.

A.2.8 RUC C UC 7: Patient Monitoring/Evacuation

Monitoring

Monitored throughout the night and during evacuation – Expected outcome: The CERTH bot technology can successfully recognise if an intruder enters/patient leaves during sleep recording/ patient remains in their ward during evacuation. The technology can then notify staff instantly.

A.2.9 Involved stakeholders (overall and for each phase)

A.2.9.1 RUC A UC 3 & 4: Validation of Wearables & Automated Scoring of Wearables

- Admission & Screening
  - Secretary
  - Physicians
  - Nurses
- Diagnosis

Physicians

Nurses

Scientific staff

A.2.9.2 RUC A UC 3: Automated Sleep Scoring of Sleep Studies

- Diagnosis

  IT department

A.2.9.3 RUC A UC 4: CERTH Bot Receptionist

- Admission & Screening

  Nurses

- Monitoring

  Nurses

A.2.9.4 RUC C UC 7: Patient Monitoring/Evacuation

- Monitoring

  Nurses

  Overnight staff

A.2.10 ODIN Integration

A.2.10.1 How you envisage the use of ODIN key enabling resources (KERs), e.g., robots, AI, IoT in this experiment?

We envisage using AI models to automatically score sleep studies for both standard sleep recordings and wearables. The standard sleep recording data we have is retrospective, so once a data-sharing agreement has been created and the data has been fully anonymised, we can send an encrypted hard drive to the partner. This will be then decrypted with a password provided by e-mail and then the data can be used in their AI systems. This is a similar process for the wearable data but first, the data must be collected prospectively. Two separate models will be trained on wearable and retrospective data. From here, the models will have enough information to successfully classify sleep disorders from sleep recordings of the same type. For instance, if a new sleep study measured by PSG were entered into the model after training, the model would be expected to predict what type of sleep disorder is present. By using the ODIN KER (AI models) we will be able to improve the speed of scoring the state-of-the-art recording (PSG) and also the future of sleep recordings (wearable finger rings). Both of these AI models will be integrated into the AI module developments in the ODIN platform. In terms of a timeline, sending over the data will take a few months as anonymization is a long process. It is planned to have the data ready to send by the end of January.

We envisage using the CERTH bot as a receptionist. First, the medical staff will become familiar with the robot and run a mock test to understand the process. Once it is understood, the robot will be integrated into normal working hours with the intention of reducing the workload of medical staff, leaving them with more time to complete other tasks which may not have been possible. We are treating this as a pilot for a hospital and if the implementation is successful and the patients provide positive feedback this will mean our use case implementation can serve as a template for

other hospital departments. To obtain the robot will take a few months, we expect to receive it somewhere between March – April and we plan to test it for 3 weeks.

A.3 MUL (Poland)

A.3.1 Pilot Description

Medical University of Lodz (MUL) is a higher state school having over 70 years-long history. With its 5 faculties, 3 teaching hospitals and 80 clinics, 9.500 students, 1.000 foreign students and app. 1600 academics, Medical University of Lodz belongs to the leading Polish medical universities. The University is strongly committed to scientific research in a number of health-related disciplines as well as national and international scientific cooperation. The University is considered a leader in the number of scientific publications and citations among medical schools in Poland. MUL's scientists conduct extensive basic and translational research. The Medical University of Lodz has reached the leading position in various research areas, and particularly in patient adherence and healthy ageing. In acknowledgment of these achievements, the Medication Adherence Research Centre (MARC) was founded in 2020 in MUL, headed by Prof. Przemyslaw Kardas.

MUL makes a substantial contribution to the development of the health care system by promoting modern standards of prophylaxis and treatment, and by building long-lasting cooperation with institutions realizing objectives of public health at regional, national and international levels. Last but not least, MUL is strongly committed to Silver Economy. Being formally recognised as the EIP on AHA Reference Site, MUL plays the key role in facilitation of collaboration between academia and industry, in order to change the demographic challenge into opportunity. Initiating creation of dedicated businesses cluster, MUL plays a role of pioneer and helps boosting of local economy.

With its own complete ecosystem of healthcare services, covering full range of healthcare system levels, from primary health centres to tertiary teaching hospitals, MUL is perfectly well-placed for the purpose of testing and implementation of novel health technologies. Serving over 86.000 patients yearly, MUL is also one of the major local healthcare providers, active in each and every area of modern medicine. This potential will be of particular use within the framework of ODIN project.

The experiments planned within ODIN are directly linked to the current need of the patients served by MUL. With ageing society of Poland, and rising lack of the workforce in the healthcare system, the use of robotic solutions is more than urgent. This has been particularly emphasized by the novel challenges that come with unexpected plague of Covid-19 pandemics, and war in Ukraine that started in the neighbour country in 2022. Introducing to the hospital settings novel IT-based solutions of e-location, and robotic workers is supposed to overcome current bottlenecks, and make the hospital environment more resistant toward such challenges. Moreover, in a longer run, it will also have a positive economic impact on the hospital sustainability.

A.3.2 Pilot Experiments

(please review and report the pilot table from the D7.1 Appendix A using the WHO Navigation scheme for RUC A and B)

Table 32 - MUL Experiments

Use Case	Name / Description	RUC Phase (s)
RUC A2 – UC4	Blood transport. Robotic transportation of blood samples from the Emergency Department to the Central Lab	All
RUC B2 – UC2	Clinical Engineering and Medical Locations Management	All

A.3.3 RUC A2 - UC4: Clinical Tasks and Patient experience

Intervention envisaged by MUL will adopt a principal objective of helping execution of care and diagnostic procedures with robotic transportation of blood samples from the Emergency Department to the Central Lab.

A.3.3.1 Description (overall and for each phase)

The clinical scenario that corresponds with this objective is the need to help execution of effortful care and diagnostic procedures in elderly patients, e.g. those supposed to be infected by Clostridium difficile bacteria causing potentially life-threatening gastrointestinal infections, at the teaching hospital Emergency Unit. These procedures belong to the daily tasks of nursing stuff. The clinical basis for this is defined by the specific needs of certain clinical specimens (e.g. blood samples), that cannot be carried to the Central Lab with pneumatic post due to their fragility toward shocks. With mobile robotic delivery process, these effortful tasks needing a lot of physical work and staff time will be made easier for nursing staff. Thus, nurses will be less tired, and could be more attentive and focused over higher-level patients' needs, such as e.g. need for social interactions and emotional support in the stressful environment of Emergency Room. In consequence, the use of ODIN technology will have in these patients a positive impact over the quality of life of patients. Enabling elderly patients to be tested, and diagnosed faster, the technology will have a positive effect on their overall wellbeing, as well.

Admission and Screening phase: there is a need for identification of patients with a need for lab test, particularly those which require fast and safe delivery of the specimen to the Central lab.

Diagnosis & Case Study phase: Healthcare providers, especially nurses are struggling with a lot of tasks in Emergency Department (ED). It takes a lot of time and effort to carry the fragile specimens from this environment to the Central lab. This is of particular importance in the ED where the cases are acute and need fast decision making and continuous support. Current gaps include lack of hospital staff (particularly nursing staff), and need for assistance in carrying of fragile samples, just to name the most important ones.

Treatment phase: Currently healthcare professionals in hospitals must often use their precious time to carry fragile samples to the Central Lab in person. Any help in this activities will enable healthcare professionals especially nurses and paramedics to save their time and reschedule their

valuable time to other duties. Current gaps include acute patients, especially unconscious ones, who need continuous help from healthcare staff at the ER. There is a need for new solutions supporting healthcare professionals in securing fast and reliable testing of these patients.

Monitoring phase: Employing robotic solutions is a new idea for Polish hospital staff members. Therefore, there is a need to carefully monitor the performance of this new solution, satisfaction of end-users (nursing staff), safety of the specimens, as well as safety of the other patients in the Emergency Room, in order to secure accumulation of evidence, and better acceptance of similar robotic solutions in future.

A.3.3.2Timeline (overall and for each phase)

The experiment started in February 2023, will end in December 2023 with the following timeline:

Experiment Part I: envisaged for the period February-June, 2023 – involves the use of robotic delivery in secure laboratory environment. In this part, all the phases (i.e. Admission and Screening phase, Diagnosis & Case Study phase, Treatment phase and Monitoring phase) will be simulated, and the robotic system will be verified and fine-tuned, in order to get ready for Experiment Part II.

Experiment Part II: Scheduled for the period July-October, 2023 – involves the use of robotic delivery in real Emergency Department environment, without direct contact with patients. In this part, again, all the phases (i.e. Admission and Screening phase, Diagnosis & Case Study phase, Treatment phase and Monitoring phase) will be employed, and the robotic system will be verified and fine-tuned, in order to get ready for Experiment Part III. Particular care will be taken of making t completely safe for both the staff members and the patients.

Experiment Part III: Scheduled for the period November-December, 2023 – is based on the use of robotic delivery in real Emergency Department environment, with direct contact with patients and staff members. All the phases (i.e. Admission and Screening phase, Diagnosis & Case Study phase, Treatment phase and Monitoring phase) will be included in this Part, and the robotic system will be finally verified regarding its safety and performance, against the pre-set KPIs.

A.3.3.3Technology definition

Overall strategy a cohesive system of screening-execution-monitoring will be secured with the use of relevant digital solutions and interlinked hardware/equipment; robotic carrier (mobile robotic platform provided by Robotnik) equipped with dedicated smart box (provided by SSSA solution)

The technical architecture of the RUC is provided in the diagrammatic below.

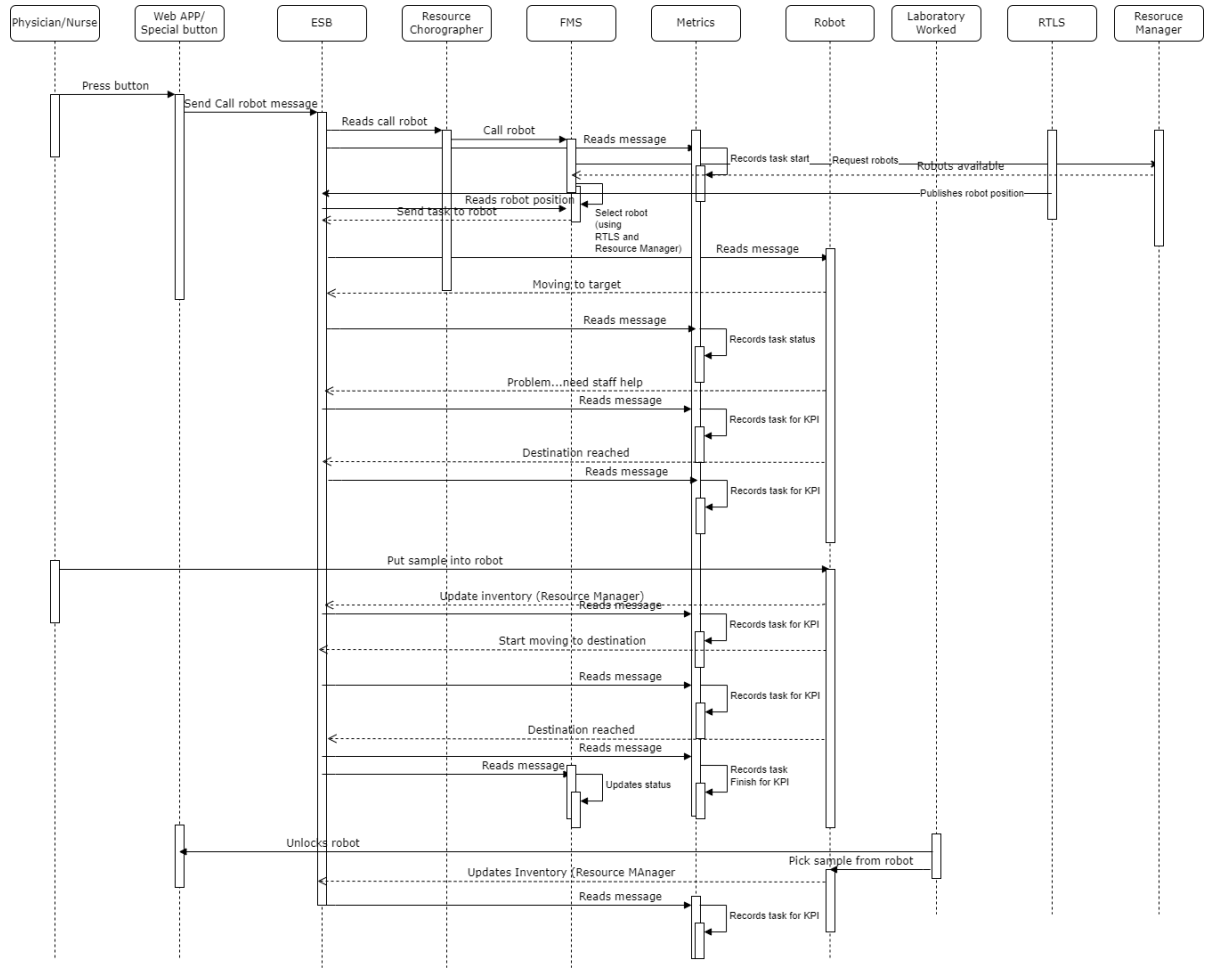

Figure 8 - MUL RUC A2

In details, the experiment will use the following technology:

- Admission and Screening phase: initial screening of the need for specific lab test versus provisional diagnosis (employing HL7/FHIR).
- Diagnosis & Case Study phase: robotic carrier (Robotnik solution) equipped with dedicated smart boxes (SSSA solution); AI component to allow for choosing best path of specimen delivery in potentially crowded environment of Emergency Room
- Treatment phase: same as above
- Monitoring phase: same as above; data storage secured with SQL

A.3.3.4 Procurement / Acquisition process

Current view of the process of acquisition of technology looks as follows:

- robotic carrier (Robotnik solution) is envisaged through technology partnership already in place

- smart box acquisition (SSSA solution) will be through a procurement process being organised according to national regulations and internal regulations as applicable to MUL
- IT hospital infrastructure – will be provided by MUL teaching hospital

A.3.3.5 Primary Outcomes (overall and for each phase)

Overall primary outcome of this Use Case is to help nursing staff in execution of time consuming physical tasks, at the same time improving patient experience and safety in the environment of Emergency Department.

- Admission and Screening phase: early enough identification of the patients with a need for specific lab tests, such as e.g. patients with alerting symptoms, etc.
- Diagnosis & Case Study phase: final and sure validation of the advantage of robotic delivery of blood samples to the Central Lab; along with assessment of time necessary to establish correct preliminary diagnosis in the patient.
- Treatment phase: to replace physical work of nursing staff with robotic solutions.
- Monitoring phase: assess HTA parameters describing performance of robotic solutions, and staff-reported parameters assessing end-users' satisfaction.

AI component being enabled by the ODIN technology is supposed to provide an added value to the performance of this RUC, by making the robotic delivery system more efficient and safer.

Data collected in this RUC are of value for the entire ODIN ecosystem, letting the other RUCs benefit from the library of data of real-life use of the robotic delivery.

A.3.3.6KPI (for each phase)

Table 33 - MUL RUC A2 UC4

Phase	KPIs	Measure unit	Tool	Notes
Admission & Screening	Patients enrolled in the platform	number	[report from platform]	…
	Patients needing specific lab tests	percentage, number	report from platform	
Diagnosis & Case Study	patients with lab tests performed correctly	percentage, number	report from platform	
	average transportation time	seconds	report from platform	

Phase	KPIs	Measure unit	Tool	Notes
Treatment	number of e-robots interventions	Number	report from platform	
	nursing staff satisfaction	Self-assessments	questionnaire	
	safe interventions	percentage	report from platform	
	Costs	Nursing staff time saved	report from platform	
Monitoring	number of e-robots interventions	Number	report from platform	
	nursing staff satisfaction	Self-assessments	questionnaire	
	safe interventions	percentage	report from platform	
	number of errors	Number, percentage	report from platform	
	Costs	Nursing staff time saved	report from platform	

Overall strategy a battery of various parameters will be traced in order to assess solution feasibility, effectiveness and cost-effectiveness.

- Admission and Screening phase: percentage of patients needing specific lab tests, identified at the admission.
- Diagnosis & Case Study phase: percentage of patients with lab tests performed correctly using the means of robotic delivery; average transportation time from ER to Central Lab
- Treatment phase: The variables of interest include: proxy for effectiveness – e.g. number of e-robots interventions, nursing staff satisfaction parameters; proxy for safety – percentage of safe interventions, without technical/medical complications; unobtrusive performance of robotic delivery in real-world environment of Emergency Room; proxy for costs – nursing staff work time parameters.
- Monitoring phase: the same ones as the ones employed in treatment phase, plus parameters assessing effectiveness of solution functioning in stand-by/active mode

A.3.3.7 Involved stakeholders (overall and for each phase)

Involved staff will include target end-users – i.e. mostly nursing staff; as well as researchers involved in designing and executing the tasks (health scientists, IT specialists, etc.)

- Admission and Screening phase: Emergency unit staff - mostly nurses, partly – medical doctors, IT department.
- Diagnosis & Case Study phase: Emergency unit staff - mostly nurses, partly – medical doctors, IT department
- Treatment phase: Emergency unit staff - mostly nurses, partly – medical doctors, IT department.
- Monitoring phase: Researchers – for monitoring, IT department.

A.3.4 RUC B2 UC2 Clinical engineering

This MUL reference use case covers aspects related to the exploitation of ODIN technologies for improving the management of medical locations of medical equipment in the busy environment of the Emergency Department of MUL's tertiary teaching hospital.

A.3.4.1 Description (overall and for each phase)

(please refine, improve the experiment description in general and per phase from the D7.1 Appendix A. When writing the description please include short narratives of how the RUC would work for the main actors involved, it should provide a glimpse of main system functionalities in a narrative and non-technical way).

Planning: this involves identification of core components of medical equipment which are subject to changing location (e.g. ECHO scanner) and are of potential need of emergency use depending on the conditions and provisional diagnosis established in a patient admitted to the Emergency Department. This process will be based on evidence from needs assessment of both staff members and the patients, current usage patterns, analysis of faults and recalls, maintenance and real-world data (RWD).

Delivery, installation, training: Currently, the items of medical equipment being used within the Emergency Department are taken to the room where they will be used by the staff members from their current location. Due to the various needs of individual patients, this location is changing in a consequence. Neither their current location, nor the information on the time of their use is currently traced and recorded in the hospital systems.

In order to change this, previously identified core components of medical equipment will be marked with unique digital identifiers, allowing for their tracing. The technology used for this will secure their safe, resisted and unique identification without any negative consequences for their principal role 9e.g. caused by electromagnetic fields interferences, etc.). Existing infrastructure allowing for in-hospital localisation and navigation will minimise the negative impact of system installation over the performance of the staff in the real-world conditions. Minimal level of technical and healthcare staff training on the system use will be necessary to implement the system.

Cleaning, management, and maintenance: Tagging system applied in order to identify equipment location conforms with relevant cleaning techniques and standards. The use of digitally-enhanced

location system will help better adherence to the relevant cleaning procedures (e.g. UV irradiation).

A.3.4.2Timeline (overall and for each phase)

(please report a detailed timeline)

The experiment started in April 2023 and will stop in December 2023 with the following timeline:

Experimental Phase I: envisaged for the period April-July, 2023 – involves the configuration of the system, training of the staff, and it pilot versification in living lab environment. In this part, all the phases (i.e. Admission and Screening phase, Diagnosis & Case Study phase, Treatment phase and Monitoring phase) will be simulated, within the lab, and the location system will be verified and fine-tuned, in order to get ready for Experiment Part II.

Experiment Part II: Scheduled for the period August-October, 2023 – involves the use of equipment location execution in real Emergency Department environment, however, without direct use in patients. In this part, again, all the phases (i.e. Admission and Screening phase, Diagnosis & Case Study phase, Treatment phase and Monitoring phase) will be employed, and the location system will be verified and fine-tuned, in order to get ready for Experiment Part III. Particular care will be taken of making it able to work among other pieces of equipment, assuring its safety for both the staff members and other pieces of equipment.

Experiment Part III: Scheduled for the period November-December, 2023 – is based on the use of location system use in real Emergency Department environment, for the benefit of patients and staff members. All the phases (i.e. Admission and Screening phase, Diagnosis & Case Study phase, Treatment phase and Monitoring phase) will be included in this Part, and the location system will be finally verified regarding its safety and performance, against the pre-set KPIs.

A.3.4.3Technology definition

(please start from the T7.4 CERTH excel file to describe the technology that will be used, the procurement process, timelines)

Overall strategy a cohesive system of screening-execution-monitoring will be secured with the use of relevant digital solutions and interlinked hardware/equipment; RFID trackers (provided by company identified due to the procurement process) and interlinked AI-guided ODIN solution (being made available by the consortium partner(s))

The technical architecture of the RUC is provided in the diagrammatic below.

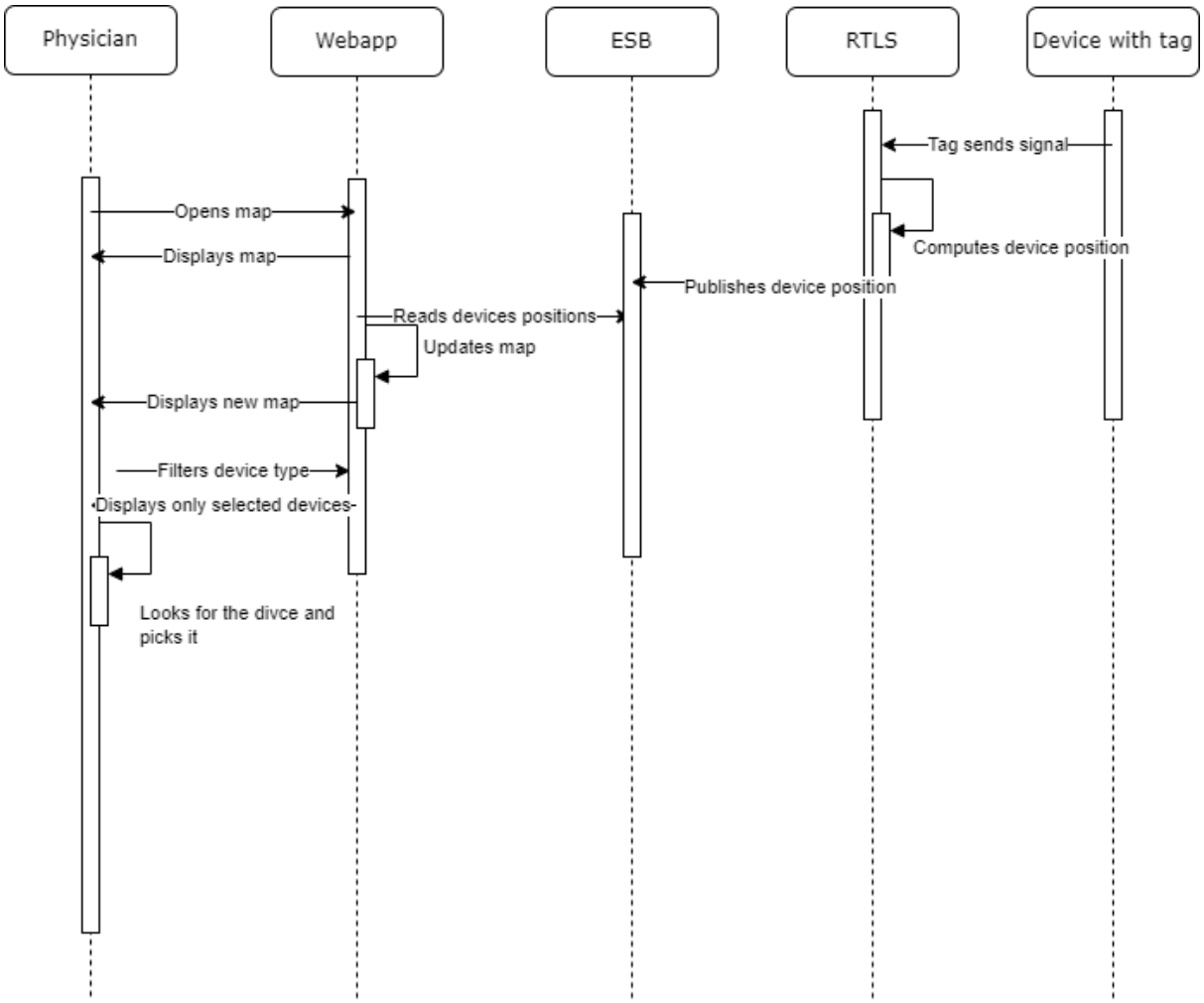

Figure 9 - MUL RUC B2

The experiment will use the following technology:

- Admission and Screening phase: registration of the patient to the ODIN platform
- Diagnosis & Case Study phase: identification of the need to use relevant piece of equipment by medical staff members, which is followed with AI-guided location process showing the staff member where the requested piece of equipment is located, and how to reach it in the fastest way, being informed of the current patient and staff member flow
- Treatment phase: same as above
- Monitoring phase: same as above; data storage secured with SQL

A.3.4.4 Procurement / Acquisition process

Current view of the process of acquisition of technology looks as follows:

- RFID tagging system will be through a procurement process being organised according to national regulations and internal regulations as applicable to MUL
- ODIN platform access is envisaged through technology partnership already in place
- AI module is envisaged through technology partnership already in place
- IT hospital infrastructure – will be provided by MUL teaching hospital

A.3.4.5 Primary Outcomes (overall and for each phase)

This reference use case aims at maximizing data-driven decisions and management of diagnostic and treatment processes in busy environment of Emergency Department, thanks to:

- Optimizing the whole clinical medical locations management process with the use of need-to-solution flow paradigm, starting with the identification of items needing support in their localisation management, through providing operational solution, up to extensive testing and evaluation
- Reducing staff work time, maximizing equipment availability and patient safety.
- Innovating the way the medical equipment is delivered and reused, and the training to technicians and health personnel on the use of the novel system.
- Optimizing equipment cleaning due to shorter time used for location and transportation, and hence, longer time left to e.g. UV irradiation.

AI component being enabled by the ODIN technology is supposed to provide an added value to the performance of this RUC, by making the e-location system more efficient and safer.

Data collected in this RUC are of value for the entire ODIN ecosystem, letting the other RUCs benefit from the library of data of real-life use of the digital location.

A.3.4.6KPI (for each phase)

Table 34 - MUL RUC B2 UC2

Phase	KPIs	Measure unit	Tool	Notes
Admission & Screening	Patients enrolled in the platform	number	[report from platform]	…
	Patients needing specific piece of equipment	percentage, number	report from platform	

Phase	KPIs	Measure unit	Tool	Notes
Diagnosis & Case Study	patients with relevant equipment piece delivered on time	percentage, number	report from platform	
	average delivery time	seconds	report from platform	
Treatment	number of e-locations interventions	Number	report from platform	
	Medical staff satisfaction	Self-assessments	questionnaire	
	safe interventions	percentage	report from platform	
	Costs	Medical staff time saved	report from platform	
Monitoring	number of e-locations interventions	Number	report from platform	
	medical staff satisfaction	Self-assessments	questionnaire	
	safe interventions	percentage	report from platform	
	number of troublesome locations	Number, percentage	report from platform	
	Costs	Medical staff time saved	report from platform	

Overall strategy a battery of various parameters will be traced in order to assess solution feasibility, effectiveness and cost-effectiveness.

- Admission and Screening phase:
  - Number of staff members trained in the location system use
  - Number of episodes of equipment use with and without the use of digitally-enhanced location
- Diagnosis & Case Study phase:
  - number of episodes of equipment use with and without the use of digitally-enhanced location
  - average transportation time from ER to Central Lab
- Treatment phase:

- Number of episodes of equipment use with and without the use of digitally-enhanced location
- Equipment delivery time

- Monitoring phase: the same ones as the ones employed in treatment phase, plus parameters assessing effectiveness of solution functioning in stand-by/active mode

A.3.4.7 Involved stakeholders (overall and for each phase)

(Identify here which are the stakeholders needed to operate this RUC as well as the cohort you target to involve and give a short description on how they will be included in the experiment).

Involved staff will include target end-users – i.e. mostly nursing staff; as well as researchers involved in designing and executing the tasks (health scientists, IT specialists, etc.)

- Admission and Screening phase:
  - Emergency unit staff - mostly nurses, partly – medical doctors;
  - IT department;
  - Technical Managers
  - Health Managers
- Diagnosis & Case Study phase:
  - Emergency unit staff - mostly nurses, partly – medical doctors;
  - IT department;
  - Technical Managers
  - Health Managers
  - Clinical Engineers
- Treatment phase: Emergency unit staff - mostly nurses, partly – medical doctors;
  - IT department;
  - Technical Managers
  - Health Managers
- Monitoring phase: Researchers – for monitoring, IT department.

A.3.5 ODIN Integration

A.3.5.1 How you envisage the use of ODIN key enabling resources (KERs), e.g., robots, AI, IoT in this experiment?

(please describe which ODIN KER technology will be acquired, the process needed and a timeline)

RUC A2 UC4

ODIN will enable fast and effective screening of patients who need an intervention due to the analysis of past patient history catalogue, its execution supported by AI component, data collection, retrieval and analysis.

Admission and Screening phase: Because the number of available eRobots is limited, screening of patients who need help in fast blood specimens' delivery at first place will be necessary. That is why screening tests providing information who should receive eRobots help will be necessary. These screening tests will be provided at the point-of-care thanks to ODIN-enabled battery of screening tests.

Diagnosis & Case Study phase: The screening functionality continuously provided at the point-of-care thanks to ODIN-enabled battery of screening tests.

Treatment phase: use of the eRobot in patients with a need for lab tests, identified due to the screening, monitoring the KPI for treatment in 3 moments: before, during and after intervention, allowing for data collection and retrieval; AI module employed for choosing smart path for the robot in changing environment.

Monitoring phase: allowing for performing an effectiveness and cost-effectiveness study.

At the top of these, several added values will come from integration of this RUC with the ODIN environment, e.g.:

- Use of the ODIN platform will allow to provide interactive education and exercise.
- Data collected in ODIN will allow retrospective analysis of the system performance, trouble shooting, and further education of the staff
- Full access to the data on this RUC implementation, secured with ODIN, can serve as a template for other hospital departments, as well as valuable data for other ODIN partners.

RUC B2 UC2

ODIN will enable fast and effective screening of patients who need an intervention due to the analysis of past patient history catalogue, its execution supported by AI component, data collection, retrieval and analysis.

Admission and Screening phase: Because the number of certain pieces of equipment is limited, screening of patients who need fast delivery of specific equipment at first place will be necessary. That is why screening tests providing information who should be prioritised to get access to equipment are necessary. These screening tests will be provided at the point-of-care thanks to ODIN-enabled battery of screening tests.

Diagnosis & Case Study phase: The screening functionality continuously provided at the point-of-care thanks to ODIN-enabled battery of screening tests.

Treatment phase: use of the e-location in patients with a need for various tests, interventions etc, identified due to the screening, monitoring the KPI for treatment in 3 moments: before, during and after intervention, allowing for data collection and retrieval; AI module employed for choosing smart path for the localised piece of equipment to be delivered in changing environment.

Monitoring phase: allowing for performing an effectiveness and cost-effectiveness study.

At the top of these, several added values will come from integration of this RUC with the ODIN environment, e.g.:

- Use of the ODIN platform will allow to provide interactive education and exercise.
- Data collected in ODIN will allow retrospective analysis of the system performance, trouble shooting, and further education of the staff
- Full access to the data on this RUC implementation, secured with ODIN, can serve as a template for other hospital departments, as well as valuable data for other ODIN partners.

A.4 SERMAS

A.4.1 Pilot Description

This pilot takes place in Hospital Clínico San Carlos. Four main departments are involved: the Procurement Department, the Cardiology Department, the Surveillance and Security Service and the Innovation Unit.

The Procurement Department is in charge of the supply and logistics distribution of the medical equipment and consumable materials inside the hospital, being a key player in the smooth development of all clinical processes and procedures. This department has a transversal action, so the problems we want to tackle affect the performance of the entire hospital.

The Cardiovascular Institute (ICV), represents around the 48% of the total hospital´s expenditure in medical equipment and consumables. Inside the ICV, the therapeutic areas dedicated to Hemodynamic and Electrophysiology have high impact equipment and some of the best described pathways for consumables provision. For these reasons, Hemodynamic and Electrophysiology areas will be the primary location points for executing the pilot. Proving the viability of the interventions in these areas would made easier the scalability of the project to the rest of the hospital.

The Surveillance and Security Service is in charge of managing the human and technical resources available at the hospital in the field of Civil and Property Security, Fire Safety and Emergency response. It is the hospital service devoted to the security tasks. They are responsible for controlling the accesses, people flow, preventing incidents and intervening during emergency situations.

The Innovation Unit is a multidisciplinary team composed of clinicians, pharmaceutics, engineers and a journalist, specialized in hospital innovation. It acts as a bridge between the ODIN partners and the hospital staff, assisting both in the development of the pilot.

A.4.1.1 Pilot Experiments

Table 35 - SERMAS - Experiments

Use Case	Name	Description	RUC B Phase (s)
RUC B1 - UC1	Aided Logistic Support	Monitor the use of consumables	Planning Procurement Storage
RUC B2 - UC2	Clinical engineering MD locations; real time management	Consumable delivery automation	Delivery, installation, training Decommissioning, disposal
RUC C – UC7	Disaster preparedness	Evacuation flow optimization	All

A.4.2 RUC B1 UC1

A.4.2.1 Description (overall and for each phase)

This use case has as objective the development of a dashboard to monitor the use of consumables in the hospital and be able to predict their future procurement. For this pilot, we are going to focus on a single consumable related to the Cardiology service: stents.

- Planning

  The consumable acquisition of the different hospital services needs to be planned in advance. Right now, there is no stock management system implemented in the hospital. The prediction of the needed consumables is done based on historic data, but also on the particular demands of each service according to the procedures that are scheduled for the near future. The historic data concerning consumptions and purchases is sent to the Head of Procurement on a monthly basis in the form of excel/txt files.

  During RUC B1 UC1, a dashboard powered by artificial intelligence (AI) will be developed to analyse the historic trends, spot seasonal patterns and be able to predict the needs of the hospital.

- Procurement and storage

  The same consumable can be purchased from several different vendors. Which vendor is chosen is many times based solely on the preference of individual clinicians. There is currently no objective metric with which to compare the different vendors. For example, the time that elapses between making and order and the product arriving to the hospital is not recorded. In fact, the entire delivery process is transparent to us.

  Furthermore, right now, there is little control over the inventory. The number of units left of each consumable is obtained periodically by counting them by hand. Several persons go through the different storage rooms and count manually the number of items that are stored. Purchase orders are then made in accordance with this counting.

The dashboard will be developed will allow the Procurement Department to compare the performance of the different vendors in a comfortable way. The information about how they work with the hospital will stop being transparent and will start being represented visually. Also, the Head of Department will be able to monitor the number of stents of each type stored in the hospital and where they are located. This will make it easier to distribute stents internally inside the hospital and optimize the procurement, as purchases will only be made when necessary. Also, the reaction time of the Procurement Department will be faster, as the number of stents left can be directly checked by the Head of Procurement at any moment, instead of waiting for the purchase request from the Cardiology Service.

Figure 7. UML diagram SERMAS RUC B1 UC1

A.4.2.2Timeline (overall and for each phase)

The experiment will stop in August 2024 with the following timeline:

- Algorithm development: first version of the algorithm by February 2023.
- Algorithm tuning. Until September 2023.
- Data set batches preparation: Until August 2023. As many batches as necessary will be created to refine the algorithm, taking into account that the estimated time to prepare each batch is one month.
- Hospital implementation: From the beginning of September 2023 until the end of the project.

A.4.2.3 Technology definition

- Planning
  1. The first step is predicting the number of units needed for each stent (historical data analysis) for planning the purchases. The data collected are the historical purchases and consumptions of units, composed of:
     a. Technical aspects of the stents.
     b. Medical records of the patients that receive the stents (hospitalization episodes, comorbidities, etc.).

     For this purpose, AI will be used for the analysis of historical data. At the same time, an interactive dashboard will be necessary (it can be generalised for the logistics RUC B2 - UC2). Also, it will be necessary to have RFID tags on the products to be able to monitor them inside the hospital and gather the information for the dashboard. All the data that will be gathered will feed a data repository that will be accessed by the dashboard.
  2. The next step is to conduct a demand analysis. For this, both the same data types and the same technology will be used.
  3. Another step would be to make a query to verify that a certain product is in stock. To do this we will use the dashboard, which will query the data repository and display the result in a clear way.

4. Alerts will be configured to inform when there is a low number of units for a certain stent type. These alerts will be integrated into the dashboard.

- Procurement and storage
  1. Vendor comparison, selection and optimisation. A section of the dashboard will be designed by the hospital where this step will be analysed (for internal use only). Here, the data regarding the prices, delivery time, errors, etc. will be displayed and studied by the Procurement Department.
  2. To monitor in real-time the number of units available across the different storage rooms, a system composed of RFID tags (attached to the stent packages) and sensors will be used. This information will be stored in the data repository and fed to the dashboard.

A.4.2.4Technology description

The experiment will use the following technology:

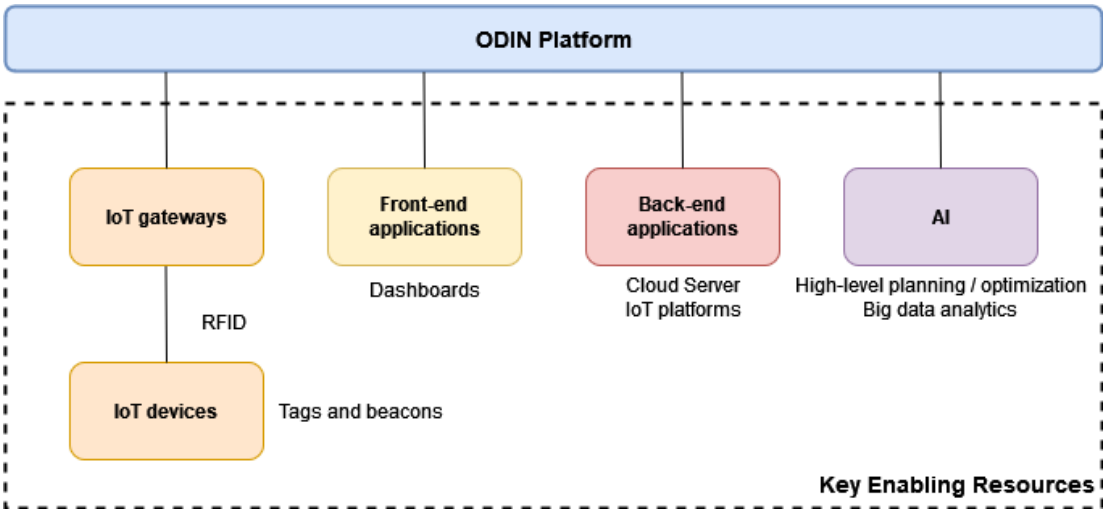

Figure 10 - Pilot's technology

With the following architecture:

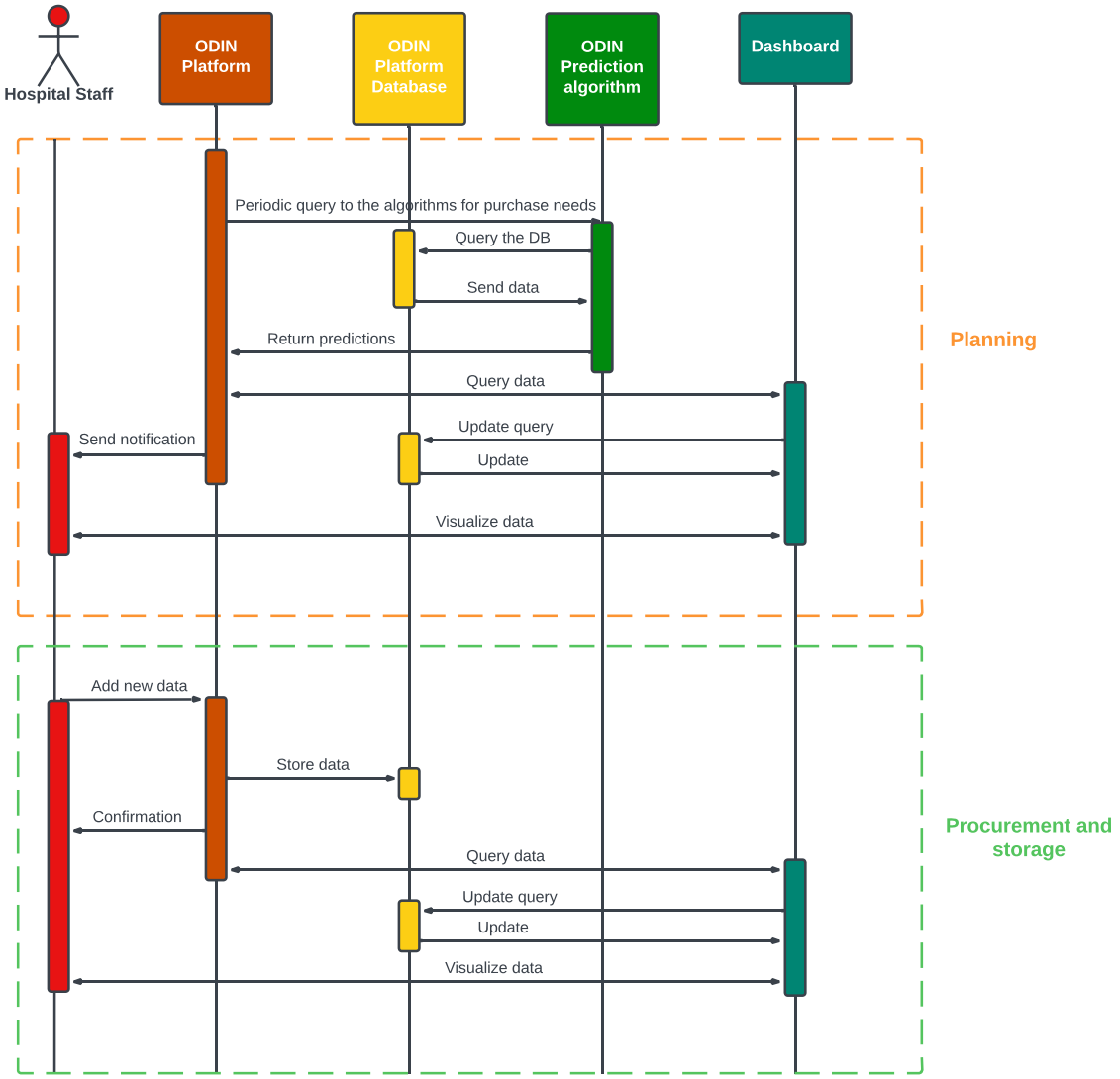

Figure 11 - SERMAS RUC B1

A.4.2.5Procurement / Acquisition process

A direct procurement process, currently underway, will be made to another ODIN consortium partner (MYS) for the acquisition of RFID tags and IoT gateways.

At the same time, a direct purchase will be made for an Internet installation to support the project in the hospital.

The rest of the technologies used are integrated within the ODIN platform. Therefore, a service is already offered and no procurement is required.

A.4.2.6 Primary Outcomes (overall and for each phase)

This reference use case aims at maximizing data-driven decisions and evidence-based management of processes.

- Planning

  The main goal would be to improve stock management: number of units, time, costs… We want to be able to predict accurately the number of units needed for each stent. It would also be interesting to know, when considering buying a new stent type, if there is already one with the same specifications already in the catalogue, to make the purchase process more efficient.

  The ODIN technology will make this phase possible thanks to 1) the AI module necessary to make predictions about the future hospital stent needs and 2) the interactive dashboard that will facilitate information analysis and decision making.

- Procurement and storage

  In terms of procurement, the objective would be to be able to select vendors based on objective metrics: clinical outcomes associated to a certain consumable, number of delays, number of errors, delivery time, cost… It would also be interesting to optimize and homogenize the catalogue of consumables. Having the same item from different brands is not necessary nor efficient.

  Concerning storage, the objective would be to have registered how many units are left of each item automatically. That is, to know in real time when new units of a certain consumable are stored in the storage room and when they are retrieved.

  In this phase the ODIN technology will be necessary to 1) dump all the information into the dashboard and 2) implement the RFID real-time location system to track the stents.

A.4.2.7KPI (for each phase)

Table 36 - SERMAS RUC B1 UC1

Phase	KPIs	Measure unit	Tool	Notes
Planning	Difference between number of consumable units predicted as needed and real needs	[%]	[report from platform]	
Procurement, storage	Vendors' evaluation: • Difference in clinical outcomes • Delivery time • Delivery delays	Evaluation metrics: • [% of readmissions] • [hours/days] • [%] • [%]	[report from platform / dashboard]	

Phase	KPIs	Measure unit	Tool	Notes
	• Delivery errors • Costs	• [€]		
	Number of stents stored in the storage room	[# units]	[report from platform / dashboard]	

- Planning
  - Difference between the number of consumable units predicted as needed and the real needs [%]. This KPI should give us a metric with which to evaluate the performance of the AI algorithm. The predictions of the algorithm need to be at least as good as the current manual method and, if possible, much closer to the real needs of the hospital.
- Procurement, storage
  - Objective metrics to evaluate the different vendors [scores]: These metrics will allow us to have an objective and quantitative basis from which to compare the different vendors and filter out those with less score. That way, we will be able to reduce the complexity of the Procurement Department catalogue and simplify their day-to-day tasks. Some potential metrics are:
    - Difference in clinical outcomes [% of readmissions]: This KPI will measure the impact each stent model has in the patient prognosis. If the same stent model is available from different vendors, then the model associated with better clinical outcomes should be kept and the rest, discarded. This should be done to both improve the patient care and simplify the stent catalogue.
    - Delivery time [hours/days], delays [%] and errors [%]: Measuring these metrics will allow evaluating the different vendors and selecting the ones who perform the best, resulting in a more efficient procurement process.
    - Costs [€]: Measuring the costs is a key element in deciding which stent vendors should be prioritised, as the Cardiovascular Institute represents around 48% of the total hospital's expenditure in medical equipment and consumables.
  - Being able to measure the number of stent units stored in each storage room [# units]: Knowing where the different units are stored will allow to see if there is a correct relationship between the stents that are being marked as consumed and the number of units that are really being consumed. It will also help to distribute the stents in a more efficient way.

A.4.2.8 Involved stakeholders (overall and for each phase)

The involved stakeholders for this reference use case spans from technical staff to healthcare personnel, clinical engineers, manufacturers and ODIN technical partners.

- Planning

- Procurement Department: They provide part of the data necessary to develop the algorithm and contribute with their knowledge to the design of the dashboard. They also are responsible for using the dashboard during its implementation. In particular, the Head of Procurement is the person involved in the RUC and the one which will use the dashboard.
- Innovation Unit staff: They gather and anonymize the data from the Procurement Department and the rest of the hospital sources. They process the data and send it to the ODIN Consortium. They act as an intermediary between the Procurement Department and the ODIN Consortium. They will guide the Procurement Department in the use of the dashboard.
- Wardens: They are responsible for counting the number of stents stored in the storage rooms. During the RUC they will check if the number of units available according to the dashboard matches the actual volume stored in each storage room.
- ODIN technical partners (MYS, FORTH): They will provide the necessary technology (AI, dashboard, RFID tags, sensors...) to be able to carry out the RUC. They will also teach the Procurement Department how to use the dashboard.

- Procurement and storage
  - Procurement Department: They are responsible for using the dashboard during its implementation. They will determine if the predictions made by the algorithm are accurate and if the vendor list can be reduced with the information provided by the dashboard.
  - Innovation Unit staff: They will act as intermediaries between the ODIN Consortium and the Procurement Department. They will guide the Procurement Department in the use of the dashboard and transmit its feedback to the ODIN technical members to adjust the dashboard.
  - Wardens: They check that the number of units available according to the dashboard correspond with the units stored in each storage room. This information will be key to evaluate the performance of the dashboard and adjust it if necessary.
  - Nurses: They will play a similar role to the wardens. They will be the ones taking the stents from the storage rooms and their actions should be displayed in the dashboard.
  - ODIN technical partners (MYS, FORTH): They will provide the necessary technology (AI, dashboard, RFID tags, sensors...) to be able to carry out the RUC. They will also teach the Procurement Department how to use the dashboard.

A.4.3 RUC B2 UC2

A.4.3.1 Description (overall and for each phase)

This use case has as objective the use of a robot to automatically transport consumables from the storage room to certain destination. For this pilot, we are going to focus on the same consumable as in RUC B1 UC1 (stents) and have chosen as delivery location the Haemodynamic Room.

- Delivery, installation, training

At the present moment, stents are both manually retrieved and taken to the room where they will be used. Stents are withdrawn from the storage rooms without this action being registered. There is no information about the moment a stent leaves the storage room or when it arrives to its destination. There is no control over the item journey inside the hospital.

Although the action of withdrawing stents from the storage room is not recorded, information about which items have been used is indeed registered. That is, if a stent is withdrawn from its shelf and not used, it could be placed back in that shelf or simply kept at the Haemodynamic Room for a later use. However, if the item has been used, that is registered in a database, since that information is used to justify costs and plan procurement.

During RUC B2 UC2, a robot will be installed in the hospital to take care of the stent transport. Thanks to it, it will be possible to monitor the journey of the stent as it moves inside the hospital. Also, the robotic system will feature some sensors to detect if a stent is introduced in the robot or removed from it. That way, we can have a more precise control over the inventory.

- Decommissioning, disposal

  The packaging of the stents that have been used is returned to the storage room, where one person has to manually enter the stent code in a database. This action registers the item as used. Afterwards, the packaging is discarded.

  The robotic system will be able to register when an item has been used by placing its package in a special compartment. That way, the decommissioning process can be automated.

A.4.3.2Timeline (overall and for each phase)

The experiment will stop in August 2024 with the following timeline:

- Installation of the IoT environment in a temporary area within the hospital: From January 2023 until March 2023. This area is not the final placement of the robot but a safe place for an initial validation. This phase includes the installation of an internet network and the configuration of a cloud server. It is envisaged that there may be small delays.
- Robot installation and testing: From February 2023 until March 2023.
- Robot validation: March 2023
- Staff training: From February 2023 until June 2023.
- Final installation of the IoT environment: From July 2023 until August 2023.
- Hospital implementation: September 2023.

A.4.3.3Technology definition

- Delivery, installation, training

  1. Autonomous navigation towards the assigned locations. HOSBOT's robotic system is able to autonomously navigate across different rooms to deliver its load to the desired location. It is able to avoid obstacles and react to a dynamic environment.
  2. Delivery of consumables with the HOSBOT system or through the smartboxes (as stand-alone units) to the destination point. The full transport system is composed of the robot (which navigates the environment and transports the rest of the components), a rack

(which contains the smartboxes and has the interface from which to give instructions to the robot) and the smartboxes (which store the load and detect if an item enters or leaves them). The rack is the component which connects the entire system. It is a structure where the robot can attach itself to and that can store three smartboxes. The rack comes with a tablet that is used to give the robot instructions and interact with the smartboxes. Finally, the smartboxes are containers which are able to detect when an item is placed or removed thanks to the use of RFID tags. The smartboxes can also be undocked from the robot to allow a worker to manually transport the load.

Figure 12 - RUC B2 technology

3. Real position monitoring through RFID tags and RTLS integrated into the smartboxes. A real-time location system will be used to follow the stents as they travel through the hospital inside the smartboxes thanks to some gateways placed along the trajectory of the robot.
4. Autonomous navigation and/or manual handling back to the storage room for power charging and consumable management. The user will be able to order the system to navigate back to its charging station and connect itself to it to recharge.

Decommissioning, disposal

1. Register used goods. One of the smartboxes will be used to store the packaging of the used stents. Once the smartbox detects that the packaging is introduced (thanks to a RDIF tag) it will send this information to a data repository where the stent will be marked as consumed.
2. Manually coding and tracking of items (same as above).

A.4.3.4Technology description

Here below is described the results of the technology assessment to find the best match between the catalogue and the pilot's needs

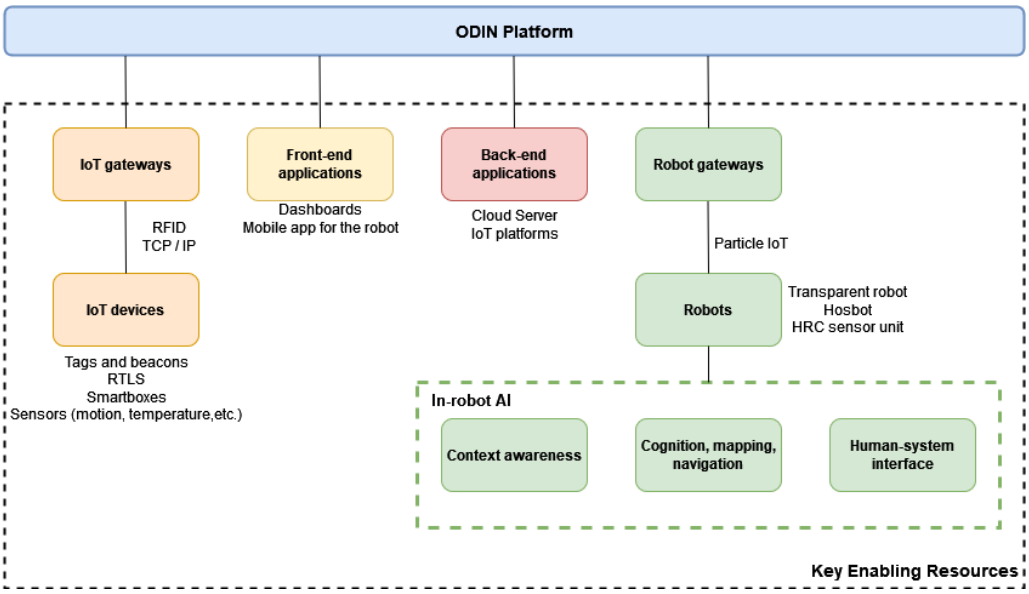

Figure 13 - SERMAS Technology used in RUC B2

This can be described with this architectural schema:

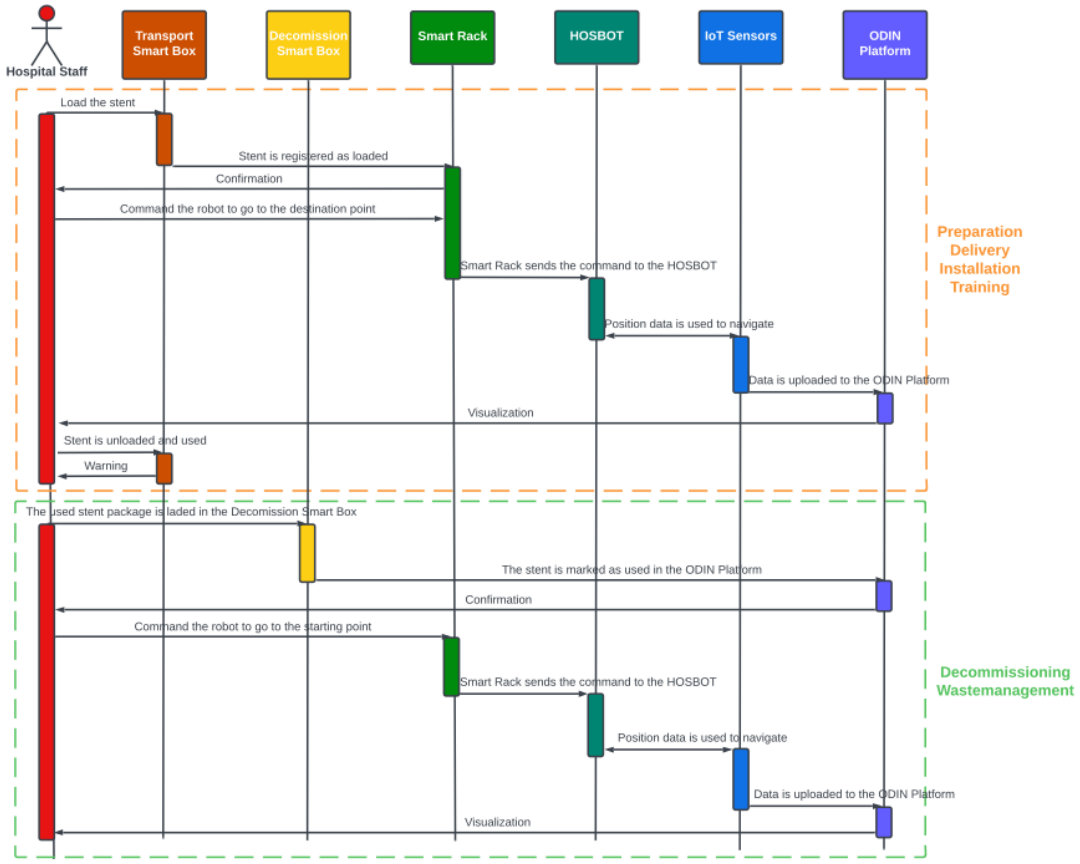

Figure 14 - SERMAS RUC B2

A.4.3.5Procurement / Acquisition process

A direct procurement process, currently underway, will be made to another ODIN consortium partner for the acquisition of RFID tags and IoT gateways (MYS).

For the robot, funds will be arranged with the consortium member (SSSA) providing the robot for shipment to the hospital.

At the same time, a direct purchase will be made for an Internet installation to support the project in the hospital.

The rest of the technologies used are integrated within the ODIN platform. Therefore, a service is already offered and no procurement is required.

A.4.3.6 Primary Outcomes (overall and for each phase)

This reference use case aims at maximizing data-driven decisions and evidence-based management of processes.

- Delivery, installation, training

  The goal would be to measure when an item leaves the storage room and when it reaches its destination point. If the item has not been used, we want to know when it is returned to the storage room. This is key to being able to have control over the inventory.

  The ODIN technology will facilitate this phase thanks to 1) the RTLS that will track the stents along their journey inside the hospital and 2) the smartbox, which is able to register when the stent is introduced inside it and when it is removed.

- Decommissioning, disposal

  The main goal would be to automatize the process of registering used goods. If possible, avoiding taking their packaging back to the storage room.

  The smartboxes will allow us to achieve this goal, as employing one of them specifically for disposing used goods will allow us to identify which items have been used.

A.4.3.7KPI (for each phase)

Table 37 - SERMAS RUC B2 UC2

Phase	KPIs	Measure unit	Tool	Notes
Delivery, installation, training	Number of stents: • Manually retrieved • Correctly delivered	• [%] • [%]	[report from platform / dashboard]	

	to target destination • Units returned to storage room • Units delivered but not used	• [%] • [%]	
	Delivery time	[mean, median, standard deviation in seconds]	[report from platform / dashboard]
	Feedback from the clinical staff	[score]	[questionnaire]
Decommissioning, disposal	Monthly time saved	[hours]	[report from platform / dashboard]

- Delivery, installation, training
  - Number of consumable units:
    - 1) Manually retrieved [%]: The percentage of stents that are manually retrieved from the storage room from the total of stents used. This figure will allow us to see if the robotic delivery system is being used by the staff or if they prefer to transport stents the traditional way.
    - 2) Correctly delivered to the target destination [%]: The percentage of stents that the robotic system delivers to the Haemodynamic room without failures. It will inform us of the quality of the performance of the robot.
    - 3) If not used, returned to the storage room [%]. This KPI will inform us of the percentage of stents that are stored at the Haemodynamic room. It is important because those stents may not be taken into account when planning a new purchase.
  - Consumable delivery time [mean, median, standard deviation in seconds]: These metrics will inform us of the speed of the robot. The delivery time should be as fast as possible (as long as it is safe for the robotic system and the staff) and, ideally, with low variability times.
  - Number of units delivered but not used [%]. This KPI will provide information about the stents that are requested but not used. Looking for patterns among the stent models that are returned without being used might help RUC B1 UC1 objective of simplifying the stent catalogue.
- Decommissioning, disposal

- Monthly time saved by automatizing the process [hours]. This KPI is key to see if this feature of the robotic transport system is worth having. Even if the system can automate some tasks, at the end of the day it should make the job easier for the staff and increase the efficiency of the hospital.

A.4.3.8 Involved stakeholders (overall and for each phase)

The involved staff for this reference use case spans from technical staff to healthcare personnel, clinical engineers, manufacturers and ODIN Consortium members.

- Delivery, installation, training
  1. Procurement Department: The Procurement Department will be able to see (thanks to RUC B1 UC1's dashboard) when a stent has been used and how many units are left. This information will allow them to make more efficient purchases.
  2. Innovation Unit staff: The Innovation Unit will be in charge of supervising the deployment of the robotic transport system, training the staff in its use and addressing the different issues that might appear.
  3. Wardens: They will be responsible for loading with stents and commanding the robotic transport system.
  4. Nurses: They will be responsible for loading with stents and commanding the robotic transport system.
  5. ODIN members: They will supply the technology (MYS, SSSA, INETUM) and train the staff (SSSA) on its use.
- Decommissioning, disposal
  1. Procurement Department: Same as in the previous phase above.
  2. Innovation Unit staff: Same as in the previous phase.
  3. Wardens: They will be responsible for placing the used items in the corresponding smartbox for the system to register them as used.
  4. Nurses: They will be responsible for placing the used items in the corresponding smartbox for the system to register them as used.
  5. ODIN members: Same as the previous case.

A.4.4 RUC C UC7

A.4.4.1 Description (overall and for each phase)

This use case has as objective he use of an image supervision and geographical location system to achieve the automation of current internal processes for managing emergency situations within the scope of the building's Self-Protection plan:

- Improving of the evacuation plan and management of evacuation flows.
- Control of capacity and avoidance of unnecessary crowds.

Due to its strategic location (proximity to the university centre and several of the city's main communication routes) and the hospital complexity in terms of clinical specialties, the hospital is included in the list of critical infrastructures of the city of Madrid (which also includes airports, train stations, the Bank of Spain and the parliamentary headquarters). Critical infrastructure designation will become effective in the next 2 years. Being a critical health infrastructure means, among other things, that safety levels must be optimal to ensure adequate clinical care in the event of catastrophes or disasters such as terrorist attacks, pandemics, fires, landslides, floods, etc.

In addition, the architectural barriers of the Hospital have a negative impact on the vertical evacuation plan. In a peak hour 10.000 people are inside the hospital premises. Current monitoring and communications systems are not robust enough for assuring a fast evacuation.

A.4.4.2 Timeline (overall and for each phase)

The experiment will stop in August 2024 with the following timeline:

- By April-May 2023 it is expected that the tender for the necessary equipment will be completed and the installation will take place.
- Once the security cameras are installed (the installation of which will not exceed one month), images will be captured until the end of the project.
- By September 2023 it is expected that the artificial intelligence algorithms will be implemented and the first results will be collected.
- The next step will be to implement the geolocation system for medical equipment. This is expected to be implemented by February 2024 and tested before August 2024.

A.4.4.3Technology definition

The installation of a system integration and decision automation platform is proposed for study, which encompasses different necessary security subsystems (CCTV, 3D geolocation, fire detection, public address system, intrusion, etc.) to achieve the indicated objectives. In the market there are different providers, such as DESICO, which has software for the supervision, control and interrelation of the systems necessary for the development of the pilot and which we know for its integration capabilities. It is a highly customizable and scalable system, being able to add own or third-party modules.

As a fundamental part of the security platform, a CCTV system is proposed that uses analytics and artificial intelligence to provide the data to the system, such as those of the AVIGILION brand.

The main characteristics of this system must be:

- Open platform, based on client server architecture.
- Interface oriented to the use of analytics and artificial intelligence.
- Search by appearance: Based on a powerful artificial intelligence engine, and that allows to start an investigation to efficiently locate people, vehicles or objects based on their description thanks to the metadata received from the cameras connected to it.
- Platform ready to work in conjunction with cameras with embedded artificial intelligence and efficiently process events of interest in real time.

- Focus of Attention Interface, which allows a change in the operation in control centres ignoring routine or worthless aspects, to present to the operator what only matters at all times.
- Failsafe architecture that provides a robust system against power or network failures.
- Full integration with third party cameras.
- Unusual motion detection: The analytics will be able to learn how objects in the scene usually behave and allow searches for unusual events.
- Motorized zoom managed from the Video Management System (VMS) software itself.
- Automatic or manual focus from the VMS software itself.
- Independently configurable day focus and night focus with illumination threshold auto focus switching.
- Easy-to-use video management that optimizes the way security professionals manage and interact with high-definition video.
- High-Definition Network Video Recorders (NVR). The proposed system should allow the balancing of cameras between the NVRs in the event of a failure of one of the recording NVRs.

Geolocation

The integration of 3D geolocation programs would allow us to manage gauges, flows and, through detector arches at the entrances, the system would allow the protection and monitoring of patients and objects using RFID tags or bracelets. Market study pending.

A.4.4.4Technology description

The experiment will use the following technology:

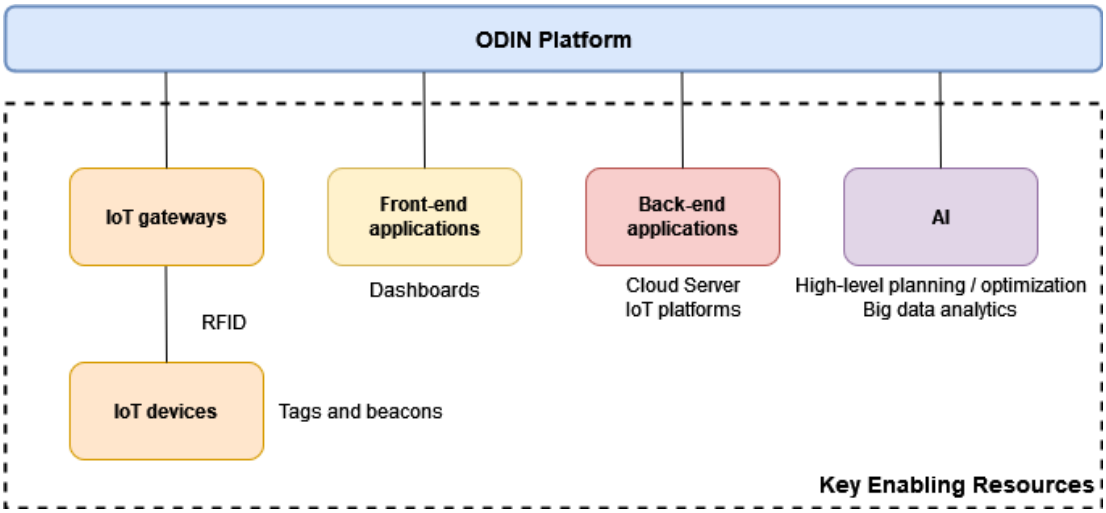

Figure 15 - Pilot's technology

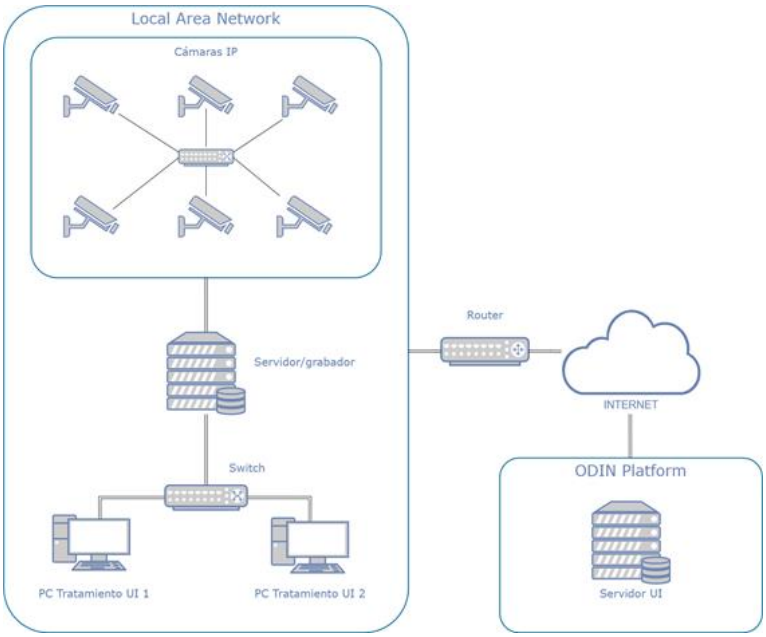

Figure 16 - Pilot's technology

The above technology can be summarised in the following architectural schema:

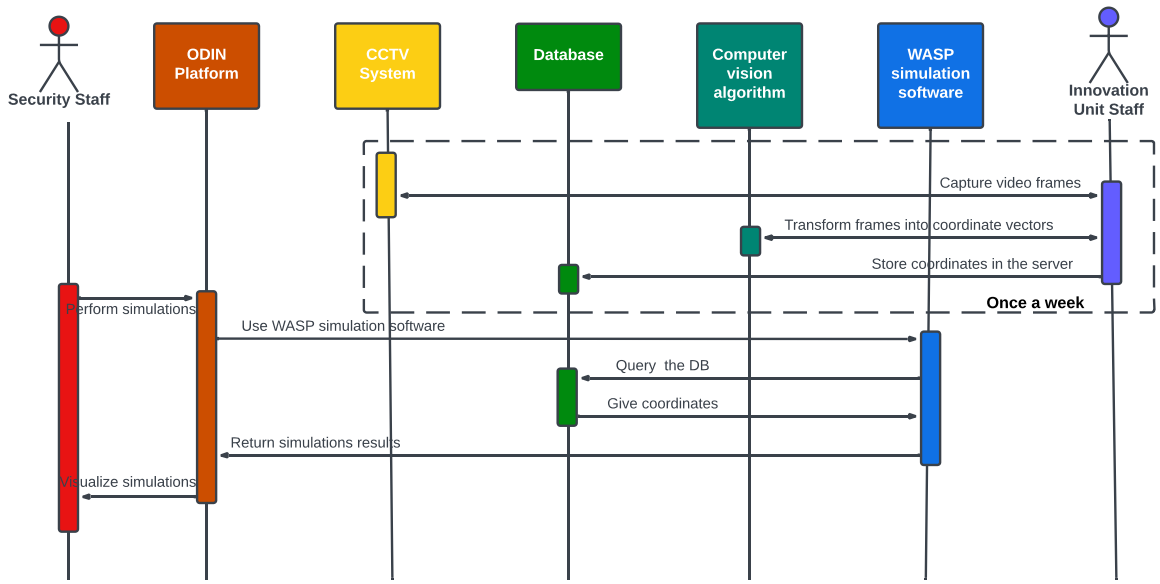

Figure 17 - SERMAS RUC C UC7

A.4.4.5Procurement / Acquisition process

A direct procurement process will be made to another ODIN consortium partner (UoW) for the acquisition of Warwick Apollo Semantic Platform (WASP), an ontology that is specific for Medical Locations.

At the same time, a direct purchase will be made for an Internet installation to support the project in the hospital.

A public tender process is underway for the installation and purchase of a CCTV system to monitor the pilot area.

The rest of the technologies used are integrated within the ODIN platform. Therefore, a service is already offered and no procurement is required.

A.4.4.6Goal (overall and for each phase)

The main objective of this use case is to improve the Hospital's capacity to react to disasters (natural, technical or human) in terms of its architectural design characteristics, its capacity to monitor the activity carried out inside and its capacity to anticipate such events. Specifically, the aim is to improve the HCSC's current Evacuation Plan.

To this end, the following actions are proposed:

"Real-time monitoring of the flow of people and virtual simulation of the trajectory of this flow in emergency situations":

1. Management of evacuation flows, establishing alternative routes depending on the location of the incident.
2. Capacity control and avoidance of unnecessary crowds: Knowledge of the number of people by delimited sectors and the distance between them.
3. Identification of erratic or accidental movements of people.
4. Control of portable medical equipment.

A.4.4.7KPI (for each phase)

Table 38 - SERMAS RUC C UC7

Phase	KPIs	Measure unit	Tool	Notes
	Reduction of evacuation time	[%]	[report from platform / dashboard]	
	Identification of new evacuation routes	[# number of routes]	[report from platform / dashboard]	
	Identification of critical points or bottlenecks in evacuation	[# number of points]	[report from platform / dashboard]	
-	Reduction of response time to unusual behaviour of people	[%]	[report from platform / dashboard]	

Response time reduction in emergency situations	[%]	[report from platform / dashboard]
Reduction of the time to locate/move specific equipment	[%]	[report from platform / dashboard]

The expected impact being:

- Reduction of evacuation time [%]. This KPI will allow us to measure the impact that the new evacuation protocol had in terms of the speed.
- Identification of new evacuation routes [# number of routes]. It will give us information about how well the system is able to adapt to a dynamic scenario.
- Identification of critical points or bottlenecks in evacuation [# number of points]. It will be used to compare the different evacuation routes and to see if the system correctly identifies the optimal one.
- Reduction of response time to unusual behaviour of people [%]. This indicator serves to measure the efficiency, in terms of speed, of the response time to these incidents.
- Reduction of response time in emergency situations [%]. This KPI will allow us to measure the impact that the new system has had in terms of the speed in which the security protocol is activated when compared to the current response time.
- Reduction of the time to locate/move specific equipment [%]. This KPI will allow us to measure the impact that the new system has had in terms of the speed in which the equipment is located/moved during an emergency situation when compared to the current time.

The expected result is to have an integrated system that monitors and simulates the flow of people and equipment in emergency situations, thus improving evacuation plans in the event of a disaster and improving evacuation times.

A.4.4.8 Involved stakeholders (overall and for each phase)

1. Surveillance and Security Service. They will receive the results of the use case as well as having access to the images captured by the security cameras. All of this with the objectives of 1) protecting the integrity of the users and workers during their stay in the hospital facilities, 2) protecting the material goods and values placed at the disposal of the Centre, 3) establishing the human and technical means that allow for immediate intervention in the event of an emergency by the Centre's staff and external assistance in the event of fire.
2. Innovation Unit staff. Responsible for the coordination of the different agents involved as well as the management of the purchase and installation of the necessary equipment. They will also be responsible for the implementation of the algorithm provided by the ODIN consortium (INETUM) in order to anonymise the images.

3. Property management. Management of the Hospital's fixed assets, property transfer and donation actions, and the management and control of the register of spaces. Responsible for the management of the spaces where the cameras are to be located, including the supply of plans for the project.
4. ODIN members. Responsible for supplying the necessary technology (MYS, INETUM) (with the exception of the video surveillance system).

A.5 UCBM - Università Campus Bio-Medico di Roma, Italy

A.5.1 Pilot Description

Università Campus Bio-Medico di Roma (UCBM) is a young, yet rapidly developing, private academic institution, devoted to undergraduate and postgraduate education, advanced research, and third mission. Established in 1992, today the University runs the School of Medicine and Surgery, the School of Engineering, the School of Science and Technology for Humans and the Environment and hosts PhD course in Bioengineering, Applied Sciences and Intelligent Systems, Integrated Biomedical Sciences and Bioethics, Sustainable Development: Environment, Food and Health and the National PhD in Artificial Intelligence – area: Health and Life Sciences and National PhD in Robotics and Intelligent Machines – area: Robotics and Intelligent Machines for healthcare and wellness of persons. The University hosts 51 multidisciplinary Research Units. In Italy, UCBM has been systematically top-ranked for the quality of the education provided to a selected group of students. The institution has increasing: i) scientific production per year (more than 900 papers, 4500+ ISI cumulative impact factor in 2021); ii) funding raised from competitive sources in Italy, Europe and worldwide (70+ research projects ongoing in collaboration with large companies and SMEs); iii) technology transfer activities (18 patents families owned/co-owned and 8 spin-off companies from 2015). An outstanding network of national and international key scientific and educational partners, including 200+ national and international partner, has been continuously developed and consolidated with specific collaboration agreements over the years.

UCBM has devolved at the end of 2021 the Policlinico Universitario Campus Bio-Medico business unit to the Fondazione Policlinico Universitario Campus Bio-Medico (FPUCBM). FPUCBM is a not-for-profit institution pursing the aim of protecting and promoting the human person in the field of healthcare, training, scientific research and innovation in the biomedical and health fields, both clinical and translational. From January 1st 2022, all clinical activities as well as clinical and translational research are carried out by FPUCBM. It is hosting 60 Research Operative Units and 10+ laboratories. Scientific production of the researchers of FPUCBM includes 700 papers in indexed journals with 3000+ normalized cumulative impact factor. At the present FPUCBM has more than 15 research active projects (40% as coordinator) funded under competitive calls and commissioned research contracts and more than 100 active clinical trials (profit). From January 2022, more than 45 projects under competitive calls have been submitted and are currently under evaluation.

Within FPUCBM, the Geriatrics Unit conducts research activities in the following areas: i) evaluation of the elderly patient health condition, with particular focus on multidimensional evaluation techniques in various disorders or multimorbidity pattern; ii) evaluation of respiratory functions, with particular focus on the interpretation of spirometry results in elderly patients; study of diagnosis/prognosis properties of breath volatile organic compounds in the following disorders:

heart failure, chronic obstructive bronchitis, obstructive sleep apnoea syndrome, diabetes mellitus, liver diseases; iii) development and application of remote telemonitoring systems for patients with chronic diseases; iv) pharmacoepidemiologic and epidemiologic geriatric research. The Unit research activity can make use of a wide range of equipment for functional evaluations. It also has epidemiologic and statistical competences for the designing, planning, execution and analysis of interventional and observational epidemiological studies.

A.5.1.1 Pilot Experiments

With reference to the selected UCs, the planned experiments at UCBM are overviewed in Table 39.

Table 39 - UCBM – Experiments.

Use Case	Name	Description	RUC A Phase (s)
RUC A2.1 – UC4	Clinical Tasks and Patient Experience	Monitoring of food assumption to prevent undernutrition	Treatment, Monitoring
RUC A2.2 – UC4	Clinical Tasks and Patient Experience	Rehabilitation to prevent loss of mobility	Treatment, Monitoring
RUC A3 – UC5	Automation of Clinical Workflows	Monitoring of oxygen therapy to prevent hypoxia complications	Monitoring
RUC B1 – UC1	Aided Logistic Support	Logistics of food delivery	Preparation, delivery, installation, training Real usage monitoring Management

A.5.2 RUC A2.1 UC 4: Clinical Tasks and Patient experience – Monitoring of food assumption to prevent undernutrition

A.5.2.1 Description (overall and for each phase)

Undernutrition is a highly prevalent condition in older hospitalized patients and associates with an increased risk of prolonged hospitalization and mortality. Inpatients usually present undernutrition, which is promoted by an energy expenditure exceeding energy intake, and/or micronutrient-related undernutrition (i.e. lack of important vitamins and minerals). Nutritional support is effective in improving body weight, fat and fat-free mass, hence a timely recognition of an unbalance between energy expenditure and intake is pivotal to minimize the risks of adverse outcomes. Although there exist formulas to easily predict the energy expenditure of hospitalized patients, the

estimation of energy intake requires to quantify food assumption, a burdensome activity for nurses, that is performed only in a selected population, leading to an underestimation of patients at risk for undernutrition.

Furthermore, undernutrition recognizes several causes but one of the most common is dysphagia, a condition that increases the risk of pulmonary aspiration and aspiration pneumonia. Screening is therefore crucial at hospital admission, particularly in older patients.

- Admission and Screening (screening of patients at risk of undernutrition and dysphagia): Acute diseases requiring hospitalization increase the risk of undernutrition, an independent risk factor for morbidity and mortality, particularly in the older and more frail adults. Indeed, these individuals, aside a higher energy expenditure due to the multimorbidity, experience a lower energy intake due to the loss of appetite, dental disorders and cognitive impairment that affect their ability to feed autonomously. One of the most common causes of undernutrition is dysphagia, a difficult swallowing increasing the risk of pulmonary severe complications. Screening of dysphagia and undernutrition is therefore mandatory in all patients at admission and is usually performed by nurses and doctors. Several questionnaires and tests are available in the literature, among which it is worth to cite the 3-oz water swallow test for dysphagia and the Mini Nutritional Assessment for undernutrition. Patients that are considered at risk are then addressed to a specialized evaluation to confirm the diagnosis.
- Diagnosis/Case Studies (diagnosis of undernutrition and dysphagia and diet prescription): Once patients have performed screening tests and result at risk of dysphagia and undernutrition they undergo a specialized assessment which is performed by the nutritionist and speech therapist (or otorhinolaryngologist), respectively. Nutritionists evaluate patient weight and body composition (e.g. bioimpedance analysis or DeXa scan), estimate energy expenditure using predicting formulas (e.g. Harris-Benedict, Angelillo-Moore, etc.) and calculate food intake using food intake diaries. Speech therapists evaluate vocal cords using and endoscope and quantify the risk of aspiration using coloured boli. Once the diagnosis has been confirmed, specialists prescribe the treatment, which mainly consists of speech exercises and detailed diet (i.e. calories, consistency, etc.).
- Treatment (meal assumption): Meal is delivered by nurses and healthcare providers and respects the nutritionist and speech therapist indications in terms of consistency and calories. This helps to get the required energy intake and to minimize the risk of pulmonary aspiration.
- Monitoring (compliance with clinical prescription): Nurses and doctors daily overview whether and to which extent patients are feeding, quantifying the food assumption. Errors, as well as no willingness to accomplish the prescription are detailed and reported to the specialist. Patients are motivated to follow their prescription.
- Follow-up (check for improvements in reducing undernutrition): Specialists reassess patients during hospitalization in order to evaluate the goodness of fit to their prescription and patient short-term improvements, if any. This allow to stop the treatment in case the problem is solved or to modify the schedule of exercises or diet to reach the goal.

A.5.2.2Timeline (overall and for each phase)

The experiment started in March 2023 and will stop in July 2023 with the timeline reported in Table 40.

Table 40 - UCBM RUC A2.1 UC4 - Timeline.

Task	M25	M26	M27	M28	M29
Preliminary functionality tests in UCBM laboratory					
Tests on healthy subjects at UCBM					
Tests on selected geriatric patients at FPUCBM for preliminary validation					
Full experiments on geriatric patients at FPUCBM					

A.5.2.3Technology definition

Within this UC, a mobile robot (TIAGo and possibly CERTHbot) will reach the patient, recognize her/him (camera + bar code) and check the consistency with the prescribed daily diet and the delivered meal. After that, the robot monitors the patients (camera and possibly wearable sensors) to assess the meal consumption in terms of quantities and estimated calories (AI algorithm), also analysing possible coughs events based on saturation measurement (oximeter). The workflow is briefly reported in Figure 18.

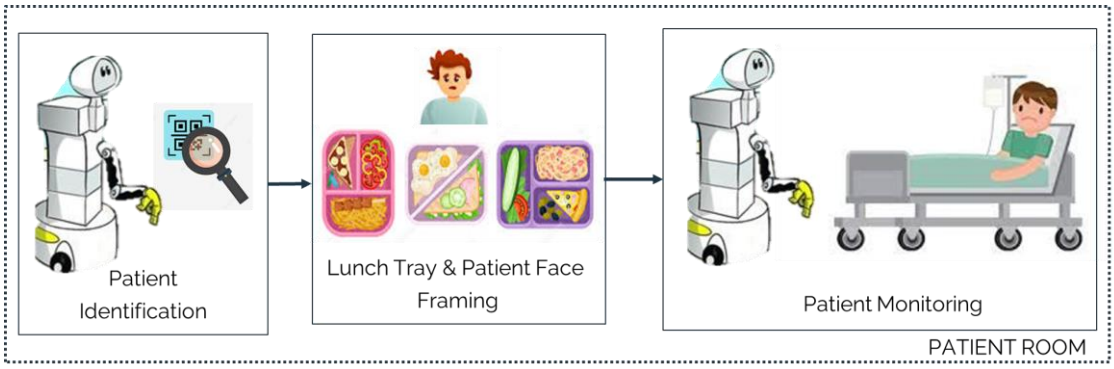

Figure 18 - RUC A2.1 overview.

It's architectural schema is the following:

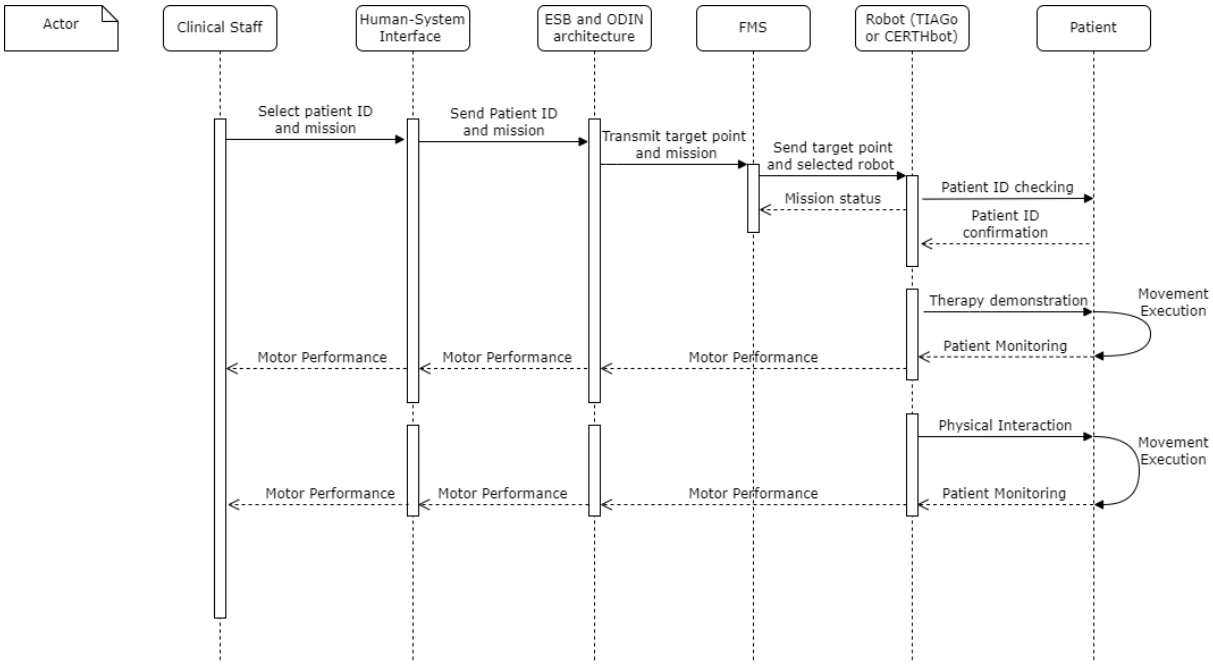

Figure 19 - UCBM RUC A2.1

A.5.2.4Procurement/acquisition process

It is not necessary to acquire any additional technologies except for oximeters able to exchange data with TIAGo robot.

The technologies for this UC include:

- TiAGo robot: already available at UCBM
- CERTHbot: already available at CERTH
- Wearable and environmental sensors (RGB-D camera, Heart Rate and Respiration Rate sensors): already available at UCBM (wearable sensors possibly not used, if not needed)
- Oximeter: acquired (to be integrated in the acquisition software)
- AI software modules: under development in the ODIN consortium (WP5+WP6)
- Barcode/Tag module for patient/meal matching: barcode already available; Tag module to be developed within the ODIN consortium if needed

A.5.2.5 Primary Outcomes (overall and for each phase)

- Admission and Screening (screening of patients at risk of undernutrition and dysphagia): The goal is to identify patients at risk of dysphagia and undernutrition to refer to a further specialized assessment.
- Diagnosis/Case Studies (diagnosis of undernutrition and dysphagia and diet prescription): The goal is to diagnose dysphagia and undernutrition to allow a timely intervention to minimize complications (e.g. aspiration pneumonia, low of muscle mass, low of exercise capacity, etc.).

- Treatment (meal assumption): The goal is to reach the required energy intake to avoid weight and muscle mass loss, to minimize the risk of aspiration and treat dysphagia. The use of the TIAGo robot is expected to identify problems of undernutrition and avoid complications.
- Monitoring (compliance with clinical prescription): The goal is to verify that patient is following correctly the diet prescribed in order to timely modify the intervention. We aim at monitoring meal assumption that normally is not performed in the normal clinical routine. An accurate monitoring can provide the patient with several benefits and robotic intervention can reduce the time spent by healthcare operators in monitoring patients.
- Follow up (check for improvements in reducing undernutrition): The goal is to verify the overall efficacy of the treatment for nutrition improvement and swallowing and stop it in case of solution or to redefine the prescription to improve its effectiveness.

A.5.2.6KPI (for each phase)

Only treatment and monitoring phases will be interested by the use of ODIN technologies.

Table 41 - UCBM RUC A2.1 UC4 KPIs

Phase	KPIs	Measure unit	Tool	Notes
Treatment	Energy intake	[kcal]	TIAGo camera with AI algorithm	
	Percentage of assumed macronutrients	[%]		
Monitoring	Correctness of head position while eating	[rad]	Kinect camera with algorithm for skeleton reconstruction	
	Time spent consuming the meal	[min]	TIAGo text-to-speech module	The patients interact verbally with TIAGo
	Number of oxygen desaturation events detected throughout the meal	[#]	Oximeter connected with TIAGo	Indicator of severe aspiration

A.5.2.7 Involved stakeholders (overall and for each phase)

- Admission and Screening (screening of patients at risk of undernutrition and dysphagia): Doctors and nurses.
- Diagnosis/Case Studies (diagnosis of undernutrition and dysphagia and diet prescription): Nutritionists and speech therapists (or otorhinolaryngologists).
- Treatment (meal assumption and speech exercises): Doctors and nurses.
- Monitoring (compliance with clinical prescription): Doctors and nurses.
- Follow up (check for improvements in reducing undernutrition): Doctors and nurses.

A.5.3 RUC A2.2 - UC4: Clinical Tasks and Patient experience – Rehabilitation to prevent loss of mobility

A.5.3.1 Description (overall and for each phase)

World Health Organization defines rehabilitation as "a set of interventions designed to optimize functioning and reduce disability in individuals with health conditions in interaction with the environment". From a general point of view, motor rehabilitation aims at recovering patient motor skills following an injury, trauma and/or pathology and can involve both upper and lower limbs. In case of elderly, rehabilitation aims recovering the highest possible level of self-sufficiency (specially to carry out activities such as eating, dressing, washing, moving from bed to chair, going to the bathroom, checking the function of the bladder and intestine) and avoid loss of mobility.

Moreover, the importance of movement in elderly patients, while not being among the priorities in the acute phase of any disease, should not be underestimated because the restoration of motor functions becomes problematic, complex and sometimes completely impossible. Hospitalized patients may have reduced mobility and potential consequent risks and can strongly benefit from rehabilitation in terms of active mobilization and motor recovery.

Admission and Screening (screening based on risk of reduced mobility): The admission phase is focused on the screening of hospitalized patients with possible long time of reduced mobility and potential consequent risks with the final aim to avoid prolonged bed rest syndromes.

Diagnosis/Case Studies (motor assessment and rehabilitation prescription): The rehabilitation treatment is preceded by an evaluation phase of the patient, which is fundamental for both the therapist/nurse and the patient, as it allows the identification of the treatment to be performed and, at the same time, validated clinical scales are generally administered, in order to assess the state of the patient at the beginning and at the end of the rehabilitation treatment, in order to guarantee a targeted treatment outcome. This phase ends with identification of rehabilitation exercises (bed mobilization, sit-to-stand exercises, bed positioning and repositioning, stand, short walk, ADLs, etc.) and the prescription of the exercises to be performed with passive and/or active mobilization, potentially in an autonomous way.

Treatment (in-hospital rehabilitation): During the rehabilitation treatment, the patient is asked to perform exercises aimed at improving mobility. The recovery of the muscular characteristics from the structural and functional point of view is a long and difficult process, which can last even a few months. For collaborative patients, the treatment is active and the patient is able to (at least

partially) autonomously move or support himself/herself, with or without the assistance of a physiotherapist. For uncollaborative patients, the treatment is passive and the presence of the physiotherapist, who guides the execution of the task, is strictly necessary.

Monitoring (monitoring of compliance prescription, correctness, and risks): The aim of this phase is to monitor the patient in performing physical exercises and verify their correctness, compliance with prescription and risks of injuries. During the rehabilitation treatment it is necessary to optimize the involvement of the physiotherapist, who should support the patient's movement only when strictly necessary and, if not, favour the patient's autonomous movement in order to guarantee the maximum effectiveness and autonomy of the treatment. In the worst case, the therapist monitors the subject and encourages him to carry out the assigned motor task correctly.

Follow up (short-term post-rehabilitation assessment): The aim of this phase is the motor assessment and the valuation of benefits of mobilization, in order to evaluate of effectiveness of rehabilitation treatment in short term.

A.5.3.2Timeline (overall and for each phase)

The experiment will start in August 2023 and will stop in January 2024 with the timeline reported in Table 42.

Table 42 - UCBM RUC A2.2 UC4 - Timeline

Task	M30	M31	M32	M33	M34	M35
Preliminary functionality tests in UCBM laboratory						
Tests on healthy subjects at UCBM						
Tests on selected geriatric patients at FPUCBM for preliminary validation						
Full experiments on geriatric patients at FPUCBM						

A.5.3.3 Technology definition

Within this UC, a mobile robot (TIAGo) will reach the patient, recognize her/him (camera + bar code), will retrieve the prescribed physical rehabilitation exercises to be performed and will demonstrate them to the patient. After that, the robot monitors the patient (camera and possibly wearable sensors) to assess the motor performance (AI algorithm) and provide physical support if needed to complete the motor task (robotic arm). The workflow is briefly reported in Figure 20.

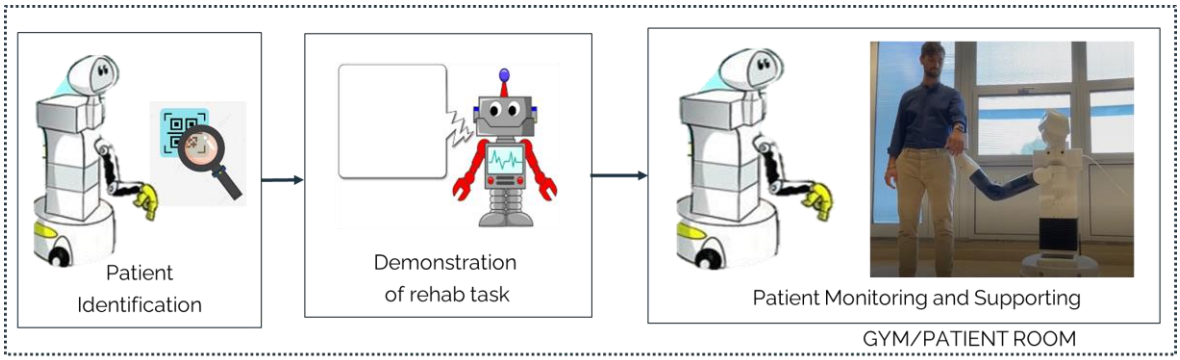

Figure 20 - RUC A2.2 overview

Its architectural schema is the following:

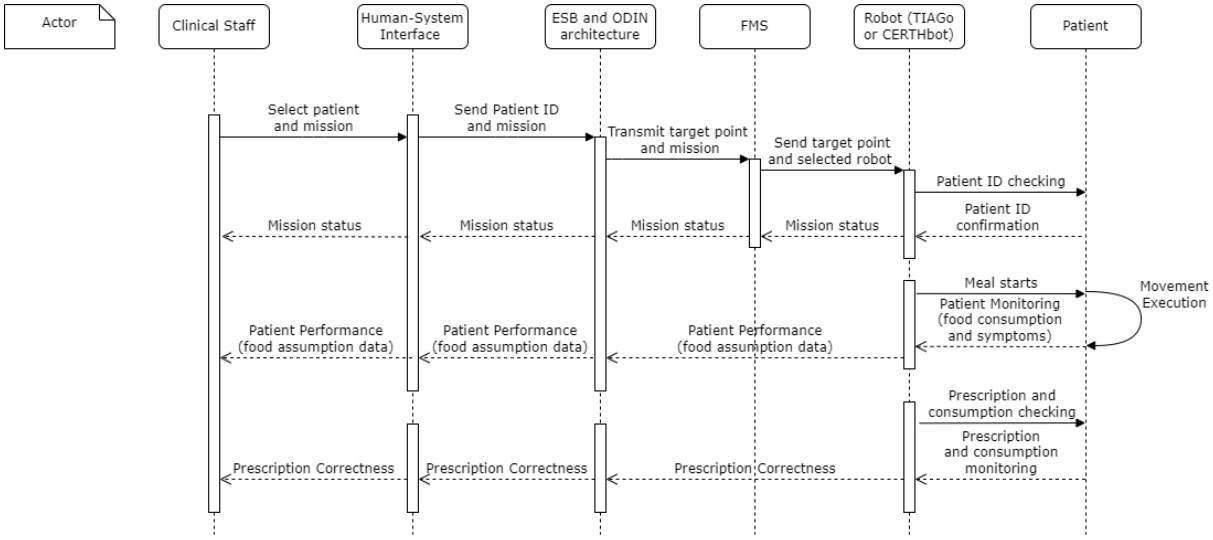

Figure 21 - UCBM RUC A2.2

A.5.3.4Procurement / Acquisition process

It is not necessary to acquire any additional technologies.

The technologies for this UC are already available/will be developed within the ODIN consortium.

- TiAGo robot: already available at UCBM
- Wearable and environmental sensors (RGB-D camera, EMG sensors, Heart Rate and Respiration Rate sensors): already available at UCBM (wearable sensors possibly not used, if not needed)
- AI software modules: under development in the ODIN consortium (WP5+WP6)s
- Barcode/Tag module for patient matching: barcode already available; Tag module to be developed within the ODIN consortium if needed

A.5.3.5 Primary Outcomes (overall and for each phase)

- The objectives of the treatment are many, including certainly the recovery of flexibility and range of motion, the recovery of strength and muscle tone and mass, the reduction of pain, risk of blood clot formation, the improvement of fitness and balance.
- Admission and Screening (screening based on risk of reduced mobility): The goal of this phase is to identify hospitalized patients at risks of mobility loss that require to perform (possibly autonomously) rehabilitation exercises.
- Diagnosis/Case Studies (motor assessment and rehabilitation prescription): The objective of this phase is to collect the greatest number of relevant clinical information, to exclude the presence of contraindications for the rehabilitation treatment, to confirm the initial diagnostic hypothesis, identify risk factors, preserve and possibly improve the original motor functions and avoid loss of exercise capacity in bedridden patients secondary to acute diseases.
- Treatment (in-hospital rehabilitation): The goal of the treatment phase is to improve patients' mobility and reduce consequences of limited mobilization, providing continuous support to rehabilitation with reduced involvements of the clinical staff.
- Monitoring (monitoring of compliance prescription, correctness and risks): The goals of monitoring phase are the continuous assessment of the adherence to the prescription for each task, providing an effective feedback and prompting of the patients to correctly execute the assigned task.
- Follow up (short-term post-rehabilitation assessment): The aim of the follow up phase is to check the motor functions of the patient, to estimate the benefits and the efficacy of rehabilitation in comparison with his/her initial condition.

A.5.3.6 KPI (for each phase)

Table 43 - UCBM RUC A2.2 UC4 KPIs

Phase	KPIs	Measure unit	Tool	Notes
Treatment	Presence/Absence of immobilization-related lesions	[#]	Clinical operators	
	Percentage of function preservations (trunk control)	[%]		
	Time spent in performing autonomous exercises	[min]	TIAGo + Kinect	
	Number of vocal robotic interventions	[#]	TIAGo	

Phase	KPIs	Measure unit	Tool	Notes
	Number of physical robotic interventions	[#]		
Monitoring	Success rate	[%]	TIAGo + Kinect	
	Execution time	[min]		
	Number of repetitions	[#]		
	Number and type of errors	[#]		
	Number of requests to stop the therapy	[#]		
	Number of anomalous movements from the patient	[#]		

A.5.3.7 Involved stakeholders (overall and for each phase)

- Admission and Screening (screening based on risk of reduced mobility): Physician and nurses.
- Diagnosis/Case Studies (motor assessment and rehabilitation prescription): Specialist in physiotherapy.
- Treatment (in-hospital rehabilitation): Physiotherapist and nurses.
- Monitoring (monitoring of compliance prescription, correctness and risks): Physician, physiotherapist and nurses.
- Follow up (short-term post-rehabilitation assessment): Specialist in physiotherapy.

A.5.4 RUC A3 - UC5: Automation of Clinical Workflows - Monitoring of oxygen therapy to prevent hypoxia complications

A.5.4.1 Description (overall and for each phase)

Respiratory failure is a syndrome in which the respiratory system is unable to correctly perform gas exchange: arterial blood oxygenation and carbon dioxide elimination. It is possible to recognize two types of respiratory failure basing on the underpinning mechanism: lung failure, or type I failure, when ventilation, and thus carbon dioxide elimination, is preserved but the impaired lung function leads to hypoxia, and pump failure, or type II failure, when ventilation is impaired (i.e. neurological and/or muscle and/or chest disorders) and hypoxia develops together with hypercapnia. In the first case the therapy is the supplementation of oxygen through different devices according to the severity and patient's characteristics, in the latter ventilation is needed. Hypoxia and hypercapnia are usually symptomatic (i.e. confusion, dyspnea, etc.), however older

patients are often asymptomatic or develop geriatric syndromes, like delirium, which are totally nonspecific, delaying the diagnosis and increasing the occurrence of complications.

- Admission and Screening (screening of patients requiring oxygen): Acute respiratory failure is one of the leading causes of hospitalization in geriatric patients, particularly during the COVID-19 pandemic. Hypoxia consists in the lack of arterial blood oxygen to deliver to peripheral tissues for the production of energy and increases the risk of complications, even severe. Symptoms of hypoxia may attract the attention, however older patients may be totally asymptomatic or have nonspecific reactions that can delay the diagnosis and therapy.
- Diagnosis/Case Studies (patient assessment and oxygen therapy prescription): Once the patient is considered at risk of respiratory failure, it is mandatory to confirm the diagnosis and classify the underpinning mechanism to timely start the required treatment, which entails oxygen supplementation in case of lung failure and ventilation in case of pump failure. Furthermore, the diagnosis of respiratory failure compels to search the disease responsible for the organ failure to start a treatment. Symptoms and signs are pivotal, but additional investigations (e.g. imaging, echocardiography, etc.) help to address the diagnosis.
- Treatment (in-hospital therapy): Once the diagnosis has been confirmed and the type of respiratory failure identified, oxygen therapy or ventilation is prescribed. Prescription is performed by hospital doctors and takes into account several aspects other than blood gas analysis. Oxygen can be supplemented through nasal prongs, venture mask or high-flow nasal cannula and the treatment can be prescribed during the whole day or only during the night according to patient needs.
- Monitoring (monitoring of compliance with prescription and correctness of therapy): Once oxygen therapy has been prescribed, the correctness of the therapy and patient's compliance should be monitored. Indeed, older patients, particularly those with dementia or with hospital-induced delirium, do not perform the therapy correctly and are less compliant, reducing the benefits of the therapy and increasing side-effects. It is therefore mandatory to check that oxygen supplementation is ongoing and that it is performed with the correct device and for the right time to foster healing.
- Follow up (short-term assessment): Oxygen supplementation is not a causative therapy, and its prescription is aimed only at avoiding the risk of developing hypoxia complications until the causative disease has been treated. It is therefore clear that patients should be regularly evaluated to define whether respiratory failure has improved, worsened or resolved to timely stop or increase/decrease the treatment.

A.5.4.2 Timeline (overall and for each phase)

The experiment will start in February 2024 and will stop in June 2024 with the timeline reported in Table 44.

Table 44 - UCBM RUC A2.2 UC5 - Timeline.

Task	M36	M37	M38	M39	M40
Preliminary functionality tests in UCBM laboratory					
Tests on healthy subjects at UCBM					
Tests on selected geriatric patients at FPUCBM for preliminary validation					
Full experiments on geriatric patients at FPUCBM					

A.5.4.3Technology definition

Within this UC, a mobile robot (TIAGo and possibly CERTHbot) will reach the patient, recognize her/him (camera + bar code) and check the consistency between the prescribed therapy and the delivered one. After that, the robot monitors the patients (camera, oximeter, fluximeter and of needed wearable sensors) to assess the correctness of the therapy, e.g. in terms of oxygen flux and mask position (AI algorithms). The workflow is briefly reported in Figure 22.

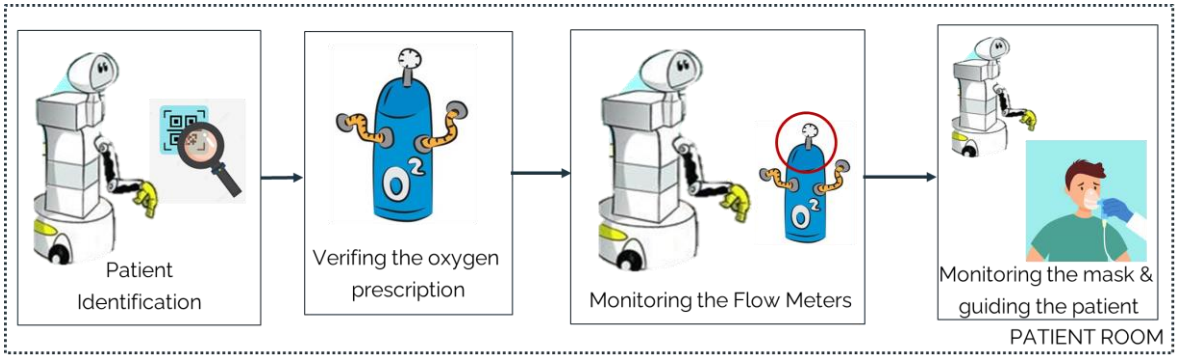

Figure 22 - RUC B1 overview.

Followed by its architectural schema below:

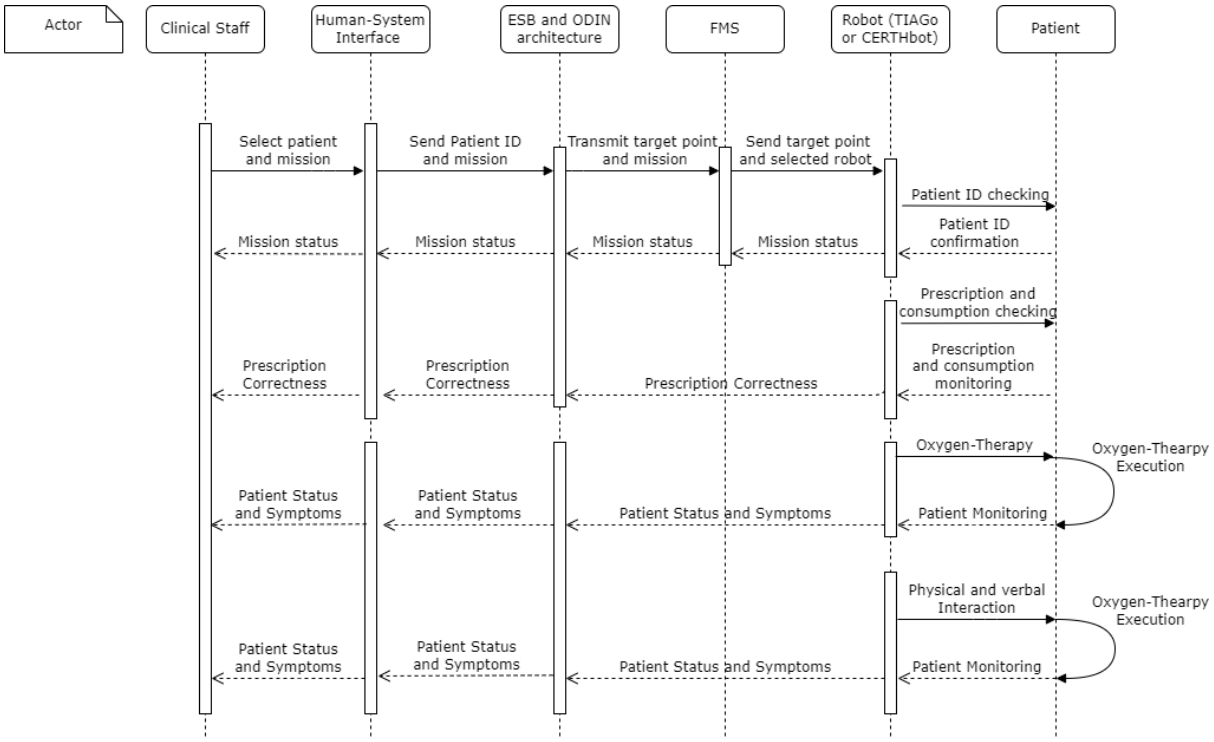

Figure 23 - UCBM RUC A3

A.5.4.4 Procurement / Acquisition process

It is not necessary to acquire any additional technologies.

The technologies for this UC are already available/will be developed within the ODIN consortium.

- TiAGo robot: already available at UCBM
- Wearable and environmental sensors (RGB-D camera, Heart Rate and Respiration Rate sensors): already available at UCBM (wearable sensors possibly not used, if not needed)
- Oximeter: acquired (to be integrated in the acquisition software).
- Flowmeter: acquired (to be integrated in the acquisition software).
- AI software modules: under development in the ODIN consortium (WP5+WP6)
- Barcode/Tag module for patient matching: barcode already available; Tag module to be developed within the ODIN consortium if needed

A.5.4.5 Primary Outcomes (overall and for each phase)

Admission and Screening (screening of patients requiring oxygen):

Prompt identification of patients at risk of respiratory failure.

Diagnosis/Case Studies (patient assessment and oxygen therapy prescription):

Diagnosis of respiratory failure, classification and stratification of severity.

Treatment (in-hospital therapy):

Oxygen supplementation according to patient's needs.

Monitoring (monitoring of compliance with prescription and correctness of therapy):

Prompt identification of scarce compliance to oxygen therapy and/or erroneous supplementation.

Follow up (short-term assessment):

Identification of patients that have recovered from those who still need oxygen and reassessment of oxygen needs.

A.5.4.6 KPI (for each phase)

Table 45 - UCBM RUC A2.2 UC5 KPIs

Phase	KPIs	Measure unit	Tool	Notes
Monitoring	Device correctness	[Boolean]	TIAGo camera	
	Air flow	[l/min]	Flowmeter	
	Fraction of oxygen	[%]		
	Therapy duration	[min]	External camera	
	Correct device positioning	[Boolean]		
	Correct therapy duration	[min]		
	Number of robotic interventions	[#]	TIAGo	
	Oxygen saturation	[%]	Oximeter connected with TIAGo	

A.5.4.7 Involved stakeholders (overall and for each phase)

- Admission and Screening (screening of patients requiring oxygen): Doctors, nurses and caregivers.
- Diagnosis/Case Studies (patient assessment and oxygen therapy prescription): Doctors.
- Treatment (in-hospital therapy): Doctors.
- Monitoring (monitoring of compliance with prescription and correctness of therapy): Doctors, nurses and caregivers.
- Follow up (short-term assessment): Doctors.

A.5.5 UCBM RUC B1 - UC1: Aided logistics support – Logistics of food delivery

Hospital foodservice is complex and can be considered as one of the most complicated systems in the hospitality sector with many interrelated factors. The layout of hospital wards, often at considerable distances from the kitchen, adds an additional logistics burden, and as a consequence, a long stream of possible delays between production, service, delivery and consumption. The goals of a hospital foodservice are to provide inpatients with nutritious meals that are beneficial for their recovery and health, and also to give them an example of healthy nutrition with menus tailored to patients' specific health conditions. When meals are carefully planned and customized to meet patients' specific needs, and when patients consume what they are served, these goals can be considered as achieved. Meal consumption by inpatients is related to nutritional status and satisfaction with the foodservice, along with other factors such as health status, medical conditions, appetite, the eating environment and dentition. It is widely recognized that food and other aspects of foodservice delivery are important elements in patients' overall perception of their hospital experience and that healthcare teams have a daily commitment to deliver appropriate food to patients. Moreover, among many difficulties that can potentially arise in the phase of meal distribution, the patient-meal match is an issue that can both burden clinical staff and also have negative effect on patients' care and experience.

This UC will address the problem of improving the process of delivering the right meal to the right patients (food delivery process in the following sub-sections) based on the clinical prescription and on the daily special requests.

- Planning (food ordering): Any hospital menu planning and food-based criteria aims to ensure that differing dietary needs are catered for and thus maximizing opportunities to ensure nutritional needs can be achieved. Hospital menu requirements are informed by assessment of local patient population needs which require to be regularly reviewed. The hospital menu typically provide for breakfast, lunch, and evening meal and can include two additional substantial snacks throughout the day. It enables the range of energy and protein requirements of patients to be met i.e. 'nutritionally well' and 'nutritionally vulnerable'. Effective menu planning is essential to meet the dietary and nutritional needs of the hospital population and requires the collection of a wide range of information and input from numerous groups. Before considering menu planning or development of a recipe database, menu planning groups need to consider the wider issues that can affect patient food choice and hence food intakes. Gathering of information about the differing dietary needs of different hospital patient groups can help menu planners develop an appropriate food service that is in a form that is familiar to patients.
- Preparation, delivery, installation, training (food delivery process): Meal distribution represents a repetitive and elementary task that burdens nurses and healthcare workers but is not free of risks. Indeed, the delivery of food to allergic patients can lead to adverse and even severe events, and the delivery of food to patients fasting for a procedure can raise the costs for the healthcare system. Most of the activities related to food delivery must be carried out at least twice a day, to ensure lunch and dinner for each hospitalized patient, as well as breakfast and a possible afternoon snack. Moreover, the perfect synchronization of all the involved resources (not just human: from dieticians to cooks, from drivers to bedside delivery operators) is absolutely necessary. In this context, there are different aspects from a logistic point of view that can be optimized to make a critical service such as that of hospital catering contributing to the improvement of patient health.

- Real usage monitoring management (compliance with clinical prescription): The monitoring of food assumption can have different final aims: i) to check for the proper nutrition of patients; ii) to identify compliance with clinical prescription; ii) to identify possible needs of changes of the patients' diet; iii) to provide feedback on the food planning and delivering; iv) to identify possible food waste. A wide literature has been produced on all these different topics; anyhow, the focus of the UCBM UC is to compare the diet prescription with the actual delivery of the food. This aspect is also strictly related to the activity carried out within the RUC A2.1 (Monitoring of food assumption to prevent undernutrition) where the aim is to check possible problems of undernutrition.

A.5.5.1Timeline (overall and for each phase)

The experiments will run in parallel to the ones of RUCA2.1.

A.5.5.2 Primary Outcomes

Planning (food ordering):

Menu planning groups need to: i) recognize the often complex needs of specific patient populations to be cared for including 'nutritionally vulnerable' patients and those on specialised therapeutic diets; ii) provide a choice of foods for individuals who require or would benefit from following a diet based on 'healthy eating' principles enabling them to meet their nutritional requirements; iii) ensure provision is made for a choice of foods for individuals with poor appetites or increased requirements to enable them to meet their nutritional requirements; iv) ensure that the dietary needs of individuals who follow diets for cultural or religious reasons are met (e.g. vegetarian diet, vegan diet). It is important to remember that the menu should be reviewed and updated regularly in order to continue to meet the dietary needs of a potentially changing hospital.

Preparation, delivery, installation, training (food delivery process):

The objective of this phase of the UC is to introduce technologies to:

- Monitor and support the delivery of the right meal to the right patient (to avoid any issues related to specific prescriptions or diet constraints);
- Improve safety for patients during food assumption (to prevent risky assumption of wrong dangerous food);
- Improve working conditions of the healthcare operators (to re reduce the time spent in checking meal-patient correspondence and possibly adopt corrective actions);
- Increase hospital efficiency and workflow (to avoid time loss and inefficiencies due to erroneous meals delivery).

The intervention not only directly impact on patient health but also will soothe the burden for nurses and healthcare workers.

Real usage monitoring management (compliance with clinical prescription):

The goal of this phase, at least in the UCBM UC, is to verify the compliance of the food assumption with clinical prescription. This is also strictly related with the goals presented in the RUC A2.1 of UCBM, where a timely intervention on undernutrition is targeted. This phase is strictly interwoven with the previous one and technology/KPIs, presented hereafter, will be shared among the two phases.

A.5.5.3KPI (for each phase)

Table 46 - UCBM RUCB1 UC1 KPIs

Phase	KPIs	Measure unit	Tool	Notes
Preparation, delivery, installation, training (food delivery process)	Success rate in verifying patient-meal matching	[%]	TIAGo camera	
Real usage monitoring management (compliance with clinical prescription)	Success rate in delivering food (right food to the right patient)	[%]	TIAGo camera	
	Number of warnings detected by robotic platform	[#]	TIAGo and its software module	

A.5.5.4Technology definition

A robotic system will deliver the meal to the patient checking the congruity between patient records on the meal and that on patient bracelet. Moreover, the robotic platform verifies the correspondence between the assigned meal and patient's special requests (allergies, pathologies, daily needs, etc.). The robot is also able to deliver the meal and check the percentage of correct intake by providing alerts (if necessary). The system needs to be equipped with:

- Navigation capabilities to reach the bed of the correct patient;
- Multisensory system and intelligent algorithms for patient recognition;
- AI capabilities to monitor food assumption (shared with UCBM RUC A);
- Communication system to provide alerts to the healthcare staff.

A.5.5.5Procurement / Acquisition process

It is not necessary to acquire any additional technologies.

The technologies for this UC are already available/will be developed in the ODIN consortium.

More in detail, the following hardware/software modules will be adopted for this UC:

- TiAGo robot: already available at UCBM
- AI software modules: under development in the ODIN consortium (WP5+WP6)
- Barcode/Tag module for patient matching: to develop in the ODIN consortium

A.5.5.6Involved stakeholders (overall and for each phase)

- Preparation, delivery, installation, training (food delivery process): Doctors, nurses.

- Real usage monitoring management (compliance with clinical prescription): Doctors, nurses.

A.5.6 ODIN Integration

A.5.6.1 How you envisage the use of ODIN key enabling resources (KERs), e.g., robots, AI, IoT in this experiment?

We envisage the use of ODIN KERs as solutions to improve patients' care in three different conditions representative of the clinical practice in the Geriatrics Unit and also to reduce the effort of clinical operators during time-consuming or demanding and wearing tasks.

Technologies will be acquired based on what reported in the previous sections. Mostly robotic solutions will be adopted (TIAGo by UCBM, CERTHbot by CERTH), integrated with AI algorithms developed within the project (food assumption and oxygen therapy monitoring by FORTH) and also supported by IoT (transparent robot by SSSA, environmental cameras by UCBM) and software for the coordination of robots (fleet management system by TWI). All the KERs will be linked to the whole ODIN platform.

Our UCs implementations will serve as a proof of concept for demonstrating technology-aided efficient improvements in the care of geriatric inpatients. The adopted solutions, demonstrated at UCBM, anyhow, will be also possibly generalized and adapted to other hospitals and or to different units and patients.

A.6 UMCU

A.6.1 Pilot Description

The University Medical Center Utrecht (UMCU) is one of the leading and largest medical centers in the Netherlands and ranks among the best European academic hospitals in international rankings. Core business of UMCU is to provide healthcare for which special knowledge is required, provide leading research and offer excellent education to students, medical doctors, researchers and other healthcare providers. UMCU has a strong track record in both pre- and clinical research and forges strong links with companies and scientific institutions across the world.

UMC Utrecht's research focusses on six strategic themes, the ODIN projects fall into the Circulatory Health theme. Healthcare is divided over ten divisions, ODIN falls into the Division Laboratories, Pharmacy and Biomedical Genetics division, where the Central Diagnostic Laboratory is located. CDL's translational subunit ARCADIA (Academic Research for Clinical Applications of DIAgnositcs) hosts the Utrecht Patient Oriented Database (UPOD).

Established in 2003, UPOD provides access to the comprehensive and complete electronic health record information of all patients that visited the UMC Utrecht since the 1990's. Overall, 650k individual patients have been included that have been hospitalized. Including out-patients, UPOD comprises more than 2.4 million individuals. The UPOD group in brief aims to improve clinical diagnostics using routine care data and is involved in efforts to turn the UMC Utrecht into a learning healthcare system. The UMCU ODIN project members will work in close collaboration with the recently established (2020) UMCU department of Digital health, which is located in the corporate staff.

All projects within the UMCU use case will take place in the strategic theme Circulatory health. Within this area, UMCU has established a Center for Circulatory Health where a multidisciplinary team sees every patient with a cardiovascular disease. The Circulatory health strategic area includes a long-standing research cohort (Utrecht Cardiovascular Cohort) that already encompasses 13,000+ patients. Combining the Center for Circulatory Health and Utrecht Cardiovascular Cohort efforts has led to the first steps towards transitioning patient care for cardiovascular disease patients into a learning healthcare system. Within this system we are currently developing (clinical decision) support systems. This is where ODIN has its home.

A.6.2 Pilot Experiments

Table 47 - UMCU - Experiments

Use Case	Name	Description	RUC X Phase (s)
RUC A - UC3	AI for Diagnosis	AI tools to improve personalization and efficiency of CVD diagnostic pathways outpatient clinic setting	Diagnosis
RUC A – UC4	Identification of eligible patients for CVD learning	Automatically identify new patients eligible for CVD learning healthcare system	Admission & Screening
RUC A – UC6	Telemonitoring	Post-operative home-tele monitoring of vascular surgery patients.	Monitoring
RUC C – UC7	Disaster Preparedness	Overview of pathogen carriers for IPD	All

A.6.3 RUC A UC 3: AI for diagnosis

A.6.3.1 Description (overall and for each phase)

The right treatment starts with the right diagnosis. Diagnostic trajectories can be straightforward, short and inexpensive, but in specialised medical centres can become difficult, long, expensive and cumbersome for patients. Most diagnostic pathways are well defined within protocols, and this implicates simplicity. However, patients that are referred to the UMC Utrecht Cardiovascular health centre (= cardiovascular outpatient clinic) can be referred by general practitioners or other medical specialists in secondary or tertiary care.

Cardiovascular diagnostics can be broad, as atherosclerosis, the underlying culprit disease, can manifest itself in multiple ways. Especially in patients that present with atypical complaints, this can result in a series of diagnostic tests before a diagnosis is given. At the same time, some diagnostics are redundant (e.g. sometimes MRI or angiography can replace CT, yet MRI is more expensive and angiography is more invasive) for some specific patients and diagnostic modalities can replace each other. Furthermore, choices are made based on availability of diagnostic tools. This availability can be in terms of whether or not a specific machine is available in a hospital, but

also in terms of whether the agenda indicates availability of the machine within a certain period of time, or even in terms of where the machine is within the hospital. This leads to inefficient diagnostic pathways.

The above culminates into the following conclusion:

in the UMC Utrecht Cardiovascular health centre, diagnostic pathways for complicated diagnostic problems are not Personalised and the location and availability of diagnostic tools are not considered in planning.

For this use case, we want to include patient characteristics, location and availability of the diagnostic devices to make the diagnostic process in the UMC Utrecht Cardiovascular health centre more efficient. We will start with the diagnostic process in patients that visit the cardiovascular surgery department, as these patients vary the most in terms of patient characteristics, diagnostic trajectories and diagnostic modalities used.

- Diagnosis

  Once the patient has been referred to the UMCU cardiovascular surgery department, it is needed to determine what kind of diagnostic tests the patients should undertake. This can be determined by evaluating the patient characteristics (Personalising the diagnostic process). Thereafter, using data on the availability and the location of the medical devices within the hospital, we can make the diagnostic workflow more efficient, as it enables prioritisation within the workflow. For example; if a patient requires both an ECG and an MRI, but the ECG is further away than the MRI and only available in an hour, we could advise the patient to first take the MRI and later-on the ECG.

A.6.3.2 Timeline (overall and for each phase)

The experiment started in January 2023 and will stop in August 2024.

This experiments takes place in one of the phases only (diagnosis). However, within the experiment we start small and are planning to gradually expand the model.

First, we will build a model to predict the kind of diagnostic test needed solely based on the patient characteristics. Then, we will add the availability of the diagnostic modality to the model, based on agenda data from the electronic health record (EHR). Thereafter, we will incorporate the location of the modalities by using the data coming from the IoT sensors/tags, enabling us to determine and prioritise the diagnostic workup. At last, we will incorporate alternative pathways, in which some diagnostic modalities are replaced by others, if possible, and if it would make the diagnostic workup more efficient.

Preliminary timeline:

- Ethical approval: July 2022
- Description of current and alternative diagnostic pathways: June 2022 – December 2022
- Model 1: January 2023 - April 2023
- Model 2: May 2023 – August 2023
- Model 3 : September 2023 – January 2024
- Evaluation/validation of the final model: February 2024 – August 2024

A.6.3.3 Technology definition

The experiment will use the following technology: IoT (eLocations)

The objective is the optimization of the diagnostic workflow of patients visiting the vascular surgery department. In particular, the idea is to automatically match the diagnostic needs within clinical procedures, the availability and location of diagnostic modalities, such as, echocardiography, MRI and CT scans to identify the optimal (most efficient) workflow of devices usage based on their availability and location in the hospital, for each patient. Considering device locations and diagnostic needs, an automated algorithm should be able to provide the physician of information on the most efficient diagnostic pathway.

This can be described by an architectural perspective as below:

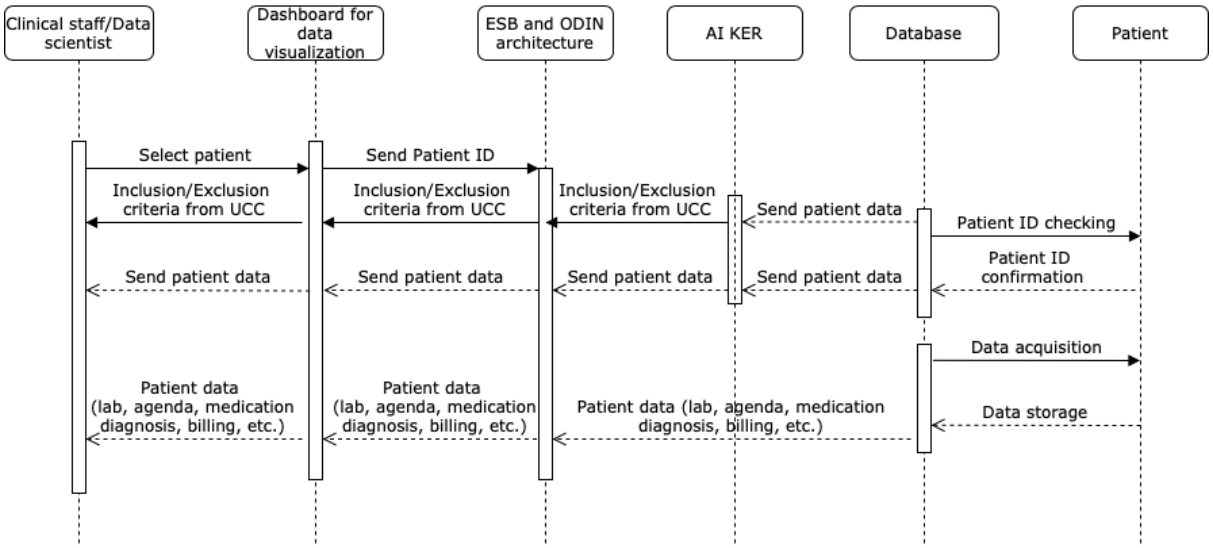

Figure 24 - UMCU - RUC A Patient management

A.6.3.4Procurement / Acquisition process

The experiment will need the following technology to be acquired: sensors, tags, gateways

The process of acquisition will be through a procurement technology partnership already in place. Currently the IT department of the UMCU is establishing a network of sensors, tags and gateways that enabling localisation and availability of medical devices and other modalities. At the moment of writing, several discussion have taken place. This ODIN use case could be used as a clinical use case for the IT department. Therefore, further acquisition will not be needed.

We have also discussed the use of the IoT technology of MYSPHERA. We could, if possible, use both for comparison purposes or to complement one another. The possibilities are to be discussed in the coming weeks. We will come back to this as soon as possible.

A.6.3.5 Primary Outcomes (overall and for each phase)

Diagnosis

To make the diagnostic workflow more efficient by;

(1) Personalising the diagnostic process, and

(2) including location and availability of the medical devices.

A.6.3.6 KPI (for each phase)

Table 48 - UMCU RUCA1 UC3 KPIs

Phase	KPIs	Measure unit	Tool	Notes
Diagnosis & Case Study	Time to diagnosis	[days]	Measured by validating the model against manual planning done in 2019	-

Diagnosis

Time to diagnosis (in days). We expect to decrease the time to diagnosis, as by including the location and availability of the devices, we will be able to suggest a more time efficient diagnostic workup/planning. Furthermore, we will also determine the diagnostic tests needed based on patient characteristic, making the diagnostic process more personalised.

A.6.3.7 Involved stakeholders (overall and for each phase)

- **Diagnosis**

  IT department: The IT department will help us during the experiments by setting up the whole IoT landscape. They will put the sensors/tags on the medical devices needed and provide the data from those devices.

  Datamanagers: The UPOD datamanagers will be involved during the entire process. They will provide us the necessary data from the electronic health records to build the model. In addition, the IT department will send the data from the sensors/tags to the datamanagers.

  Physicians, nurses and administrative staff will be consulted to plot the current diagnostic pathway and underlying assumptions, and, in addition, possible alternative pathways.

A.6.4 ODIN Integration

A.6.4.1 How you envisage the use of ODIN key enabling resources (KERs), e.g., robots, AI, IoT in this experiment?

The experiment will use the following technology: IoT (eLocations).

IoT will be used to find the location of medical devices used for diagnostic purposes within the hospital and check the availability of the device. Using demographic data, clinical data and data on availability of physicians and devices from the electronic health records in combination with the data from the IoT devices we will develop a model that is able to predict the most efficient (and personalized) diagnostic workflow.

Timeline: We will not need the data from the IoT sensors for the first two models (as indicated under the paragraph “Timeline”). However, we will need the data for the development of Model 3, which we plan to work on from September 2023 onwards. Therefore, the sensors, tags and gateways need to be in place before September 2023.

Our use case implementation can serve as a template for other hospital departments.

A.6.5 RUC A UC 4: Clinical Tasks and Patient experience

A.6.5.1 Description (overall and for each phase)

Cardiovascular risk management has since the Framingham risk score was published been established as the best way to manage cardiovascular risk. The Framingham risk score has since then been updated and refined into cardiovascular risk management guidelines, that each physician needs to follow when treating at-risk patients. These guidelines include measuring blood pressure and BMI, draw blood to perform laboratory testing including lipid levels, assessing cardiovascular history and family history and behaviour such as smoking and physical exercise. We know that cardiovascular risk management attainment is generally poor, i.e. not all patients that are entitled to it, get it.

Therefore, the UMCU initiated a cardiovascular learning healthcare system (LHS) to improve uniform assessment and registration of cardiovascular indicators in all patients referred to the UMCU that are entitled to cardiovascular risk management (e.g. for cardiovascular evaluation, either because they are at risk for cardiovascular disease (primary prevention) or because they already got it (secondary prevention). Within this LHS, we regularly assess fields in our electronic health record system where the above risk factors need to be filled in (laboratory results, measurements, etc.). To close the LHS loop, each department received monthly feedback reports consisting of feedback on data quality and completeness so they can improve their cardiovascular risk management attainment and provide better care according to state-of-the-art guidelines that benefit the patients.

However, these reports only include this valuable information for the patients that are included into the LHS. Currently, these patients are manually included into the LHS by medical staff and research nurses. They screen appointments and referral letters in outpatient clinics for diagnoses and measurements that indicate cardiovascular risk. However, this identification method is very time-consuming and has proven to be unsustainable. For example, during the COVID-19 pandemic, inclusion of patients into the LHS stopped completely, as it dropped on the priority list. There was no time or resources left to include patients into the cardiovascular LHS. Additionally, after evaluation we saw that a lot of patients that actually should have been included into the LHS

were missed because of time constraints/non-structured data that is not easily visualized in the EHR is needed to identify them. A patient selection based on simple rule-based methodology and structured data (e.g. appointment codes/billing codes) is will still miss patients and make our cardiovascular risk management suboptimal, which is not right for patients.

Therefore, we would like (1) to develop a patient selection tool for the cardiovascular LHS which includes the appropriate patients based on structured and unstructured routinely available electronic health record data. We then want to (2) provide reports to the treating physicians including visualizations and data quality feedback of the cardiovascular risk profile of their patients in order to close the LHS loop.

Screening

This use case only falls in the screening phase. Patients that visit outpatient clinics for cardiovascular evaluation for the first time will be included in the LHS based on structured and unstructured routine care electronic health record (EHR) data. Of these patients, baseline cardiovascular risk management indicators are extracted from the EHR and the completeness thereof is reported back to physicians through dashboards, aiming to improve the quality of care.