This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement Nº 101017331

D7.2- KPIs Evolution Report M12

Deliverable No.	D7.2	Due Date	28/02/2022
Description	This deliverable starts the public reporting about the KPIs definition and evolution, including those from the technical WPs.		
Type	Report	Dissemination Level	PU
Work Package No.	WP7	Work Package Title	ODIN Pilots Design, Deployment, Evaluation and Validation
Version	1.0	Status	Final

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History

Date	Version	Change
15/01/2022	0.1	First structure draft
28/02/2022	0.2	Elaborating KPIs definitions
15/03/2022	0.3	first draft
15/04/2022	0.4	incorporating pilots' contribution
25/04/2022	0.5	final draft for peer review
30/04/2022	1.0	final version

Key data

Keywords	KPIs, Impact assessment, outcomes
Lead Editor	Silvio Pagliara (UOW)
Internal Reviewer(s)	MUL, SSSA, AMIENS

Abstract

This is the debut issue of the KPI Evolution report, which is based on surveying the Pilots about the expected outcomes of their experiments.

It will report on KPIs as quantitative values that illustrate (or dispute) how well ODIN is fulfilling its core objectives every six months, and it will be available to the public domain.

Within the activities of Tasks 7.2 and 7.3, as well as a cooperative and collaborative effort with the Pilots, the Key Performance Indicators (KPIs), comprising scales and evaluation methods, were established.

Statement of originality

This deliverable contains original unpublished work except where clearly indicated otherwise. Acknowledgement of previously published material and of the work of others has been made through appropriate citation, quotation or both.

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1 About this deliverable

This document will examine how Key Performance Indicators (KPIs) are effectively employed as measurable values, as well as how well each Pilot experiment achieves its goals. This Report Series will give the impact of the ODIN Platform as well as the Pilots' experiments execution from a broader and ODIN Project perspective. This document is linked to the Deliverables 7.1 and is part of the work done in Tasks 7.2 and 7.3.

Changes in Pilot settings will inevitably reflect a change and evolution in KPIs, as KPIs correctly evaluate how well the experiments are 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	Milestones will be shared with the relevant consortium members and pilots' managers in order to update the document.
Deliverables	Related deliverables: D2.2, for the blueprint definition of the pilot needs; D2.3 the catalogue of technology, D7.1 the experiment definition
Risks	Due to the changing nature of hospital contexts, some of the conditions outlined here may change over the course of the ODIN project.

2 Introduction

Due to the Public dissemination level, this document will report some info already included in D7.1

As stated in the DOA, the hospital becomes the primary infrastructure leading towards the necessary evolutions of the Industry 4.0. One out of every three hospitals has promoted or planned to adopt particular plans to implement new technological tools in the last five years. In fact, technology is becoming more prevalent in all parts of the hospital, not just for particular functions like diagnosis and treatment, but also for managing and logistical operations and procedures. Clinical algorithms, patient pathways, decision-assist tools, and optimization 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 deliverable provides a public report about the evolution of the ODIN experiments through the measures of the KPIs. This report in the future releases will also include a deep analysis of KPIs defined in the technical work packages, from WP3 to WP6.

This document reports in section 3 how we worked with the Pilots and the other Partners to gather the necessary info. Section 4 briefly reports about the use cases (UC) and the reference use case (RUC) of the ODIN project. Section 5 and 6 report the KPIs per RUC and per Pilot. Appendix A reports the KPIs per Pilot experiments.

3 The ODIN Experiment framework

The ODIN Experiment framework will be based upon a federation of case studies aiming to prove the safety, efficacy, and cost-effectiveness of AI, big data, robots, and IoT Key Enabling Technologies (KER). for improving hospital safety, productivity, and quality. As well as All the experiments are meant to address one of more of the 11 ODIN Challenges as defined into the DOA, and reported in the table below.

Table 2 – 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 optimization of clinical and logistic processes reducing the time required for common hospital tasks and optimizing shared resources. Predictive analytic modelling will reveal ways to break down barriers between departments. eWorkers, eRobots and eLocation will support this optimization.
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 enhance 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 optimizing 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 reduce the risk of violence and theft, supported by small-size robots when personnel are not available (i.e. night), contributing to avoid Mass Casualty Incidents. The use of robots for drugs/objects transportation will contribute to 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, playing, make teleconferences with family.
Challenge 6. Too many avoidable patient days (reducing unneeded hospital stay) 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 task. 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 optimize communication channels and messages.
Challenge 10. Physician, nurse and well-trained healthcare professionals shortages The continuous data exchange and processing optimization 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 optimization.
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 where 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) in order 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'll 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 those 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 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 so that they can 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 be able to 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.

This premise led to the co-creation process with the pilots in order to achieve a clear Use Cases 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 organized with each UC to discuss their answers to the questionnaires

The results were discussed with all the pilots. Below are reported some excerpts, the full pilots' descriptions are in the Appendix A

From these reports emerged the necessity to harmonise the experiments description finding commonalities and highlighting specificities.

This led to the Step 3, and there were defined three Reference Use Cases leveraging on the initial UC description as per DOA and based on the pilots' inputs 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 – Reference). In this publication, the priority medical devices that are discussed, selected and presented are organized by clinical unit 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 specialized 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

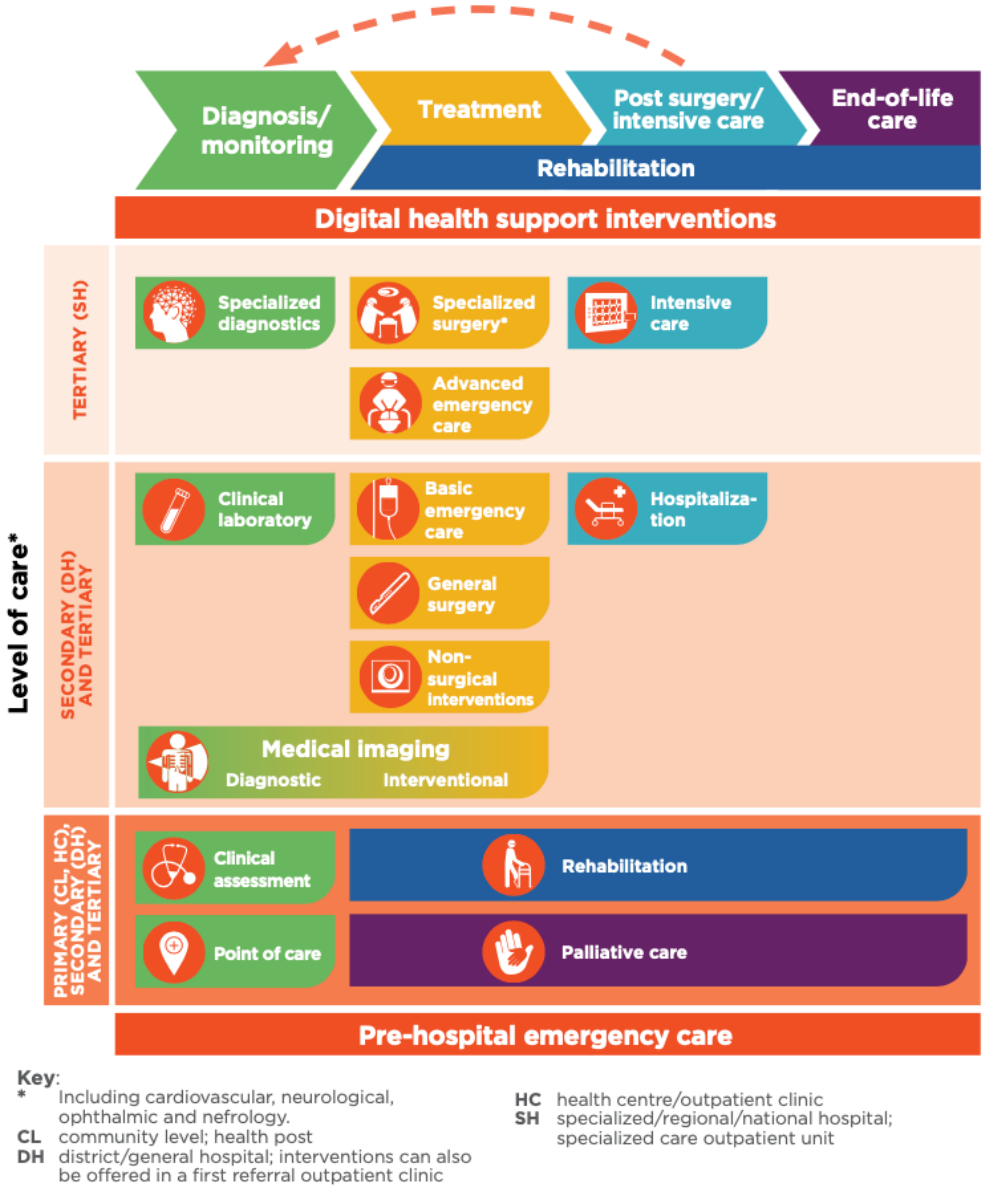

Figure 1 - WHO Navigation Diagram

During the workshops, bilateral and technical meetings were defined and refined the phases per RUC and per each phase Pilots had to define Description, Goals / Outcomes, KPIs, Technology, ODIN Contribution, see 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.

4 Introducing the Reference Use Cases (RUCs)

For a correct execution of the ODIN project, considering the needs of the pilots participating in it, a total of seven use cases were defined, which have been explained in detail within the DoA. Considering these and the objectives and categories covered by each of them, in order to optimise the organisation of the project, it has been chosen to introduce Reference Use Cases (RUCs) overarching all the case studies to be included in ODIN. The selected RUCs include three different key aspects of a hospital, providing support to the partners involved and serving as a high-level guide:

- RUC A, about the health services management,
- RUC B, including goods and devices management
- RUC C, 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.

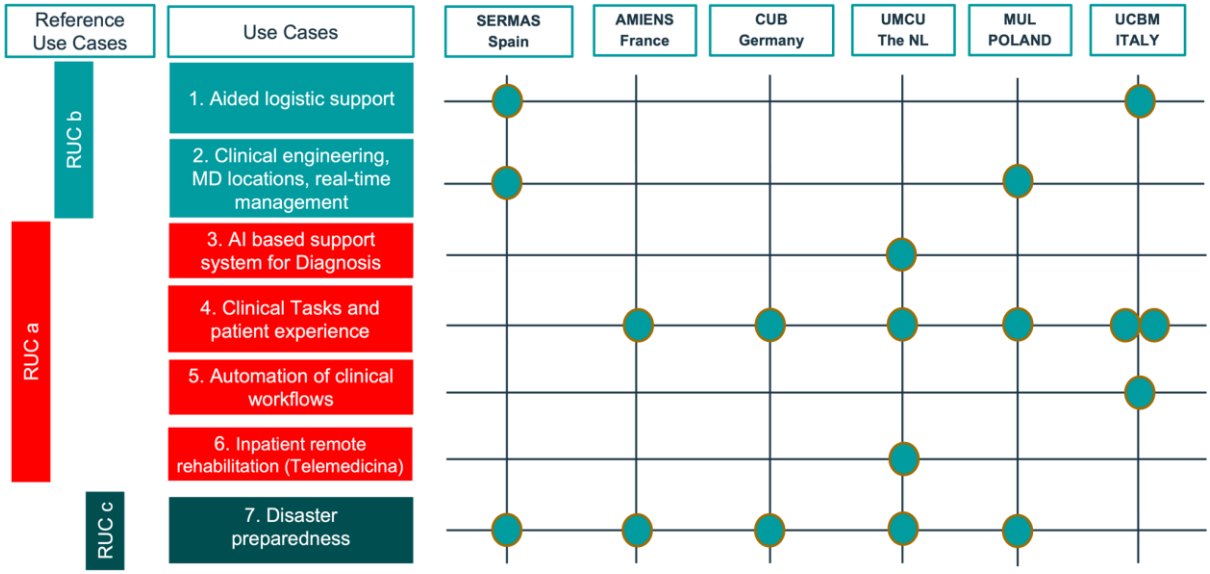

Figure 2 - RUCs - UCs Pilots distribution

4.1.1 RUC A

This reference use case encompasses the use cases focused on the clinical (and diagnostic) oriented activities that this ODIN project will address. Under this approach UC4 is considered the relevant use case, due to the number of pilots that find it relevant, 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 optimized lifestyle monitoring.

4.1.2 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 optimize all these logistic activities, thus improving working conditions, optimizing 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 using 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 disaster preparedness, which will be discussed in more detail in RUC C - UC7.

4.1.3 RUC C

This reference use case is exclusively focused on the action against possible catastrophes that may occur in the future, covering UC7 "Disaster Preparedness", due to the multitude of difficulties that hospitals had to face because of COVID-19. For this purpose, using ODIN technology, different simulations will be carried out 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.

RUC C will be defined after the complete description of the RUC A and RUC B because it will include protocols to manage all their phases during a disaster.

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 needs and the gaps come from the National Health services strategic planning (https://www.who.int/activities/supporting-national-health-policies-strategies-plans) these combined with the requests from the territory where the hospital is located will design the appropriate assessment of the hospital entry points, here called ***admission screening.*** This step feed the ***diagnosis & case study*** where patients enter the path of the identification of a disease by examination of the symptoms. This step 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.

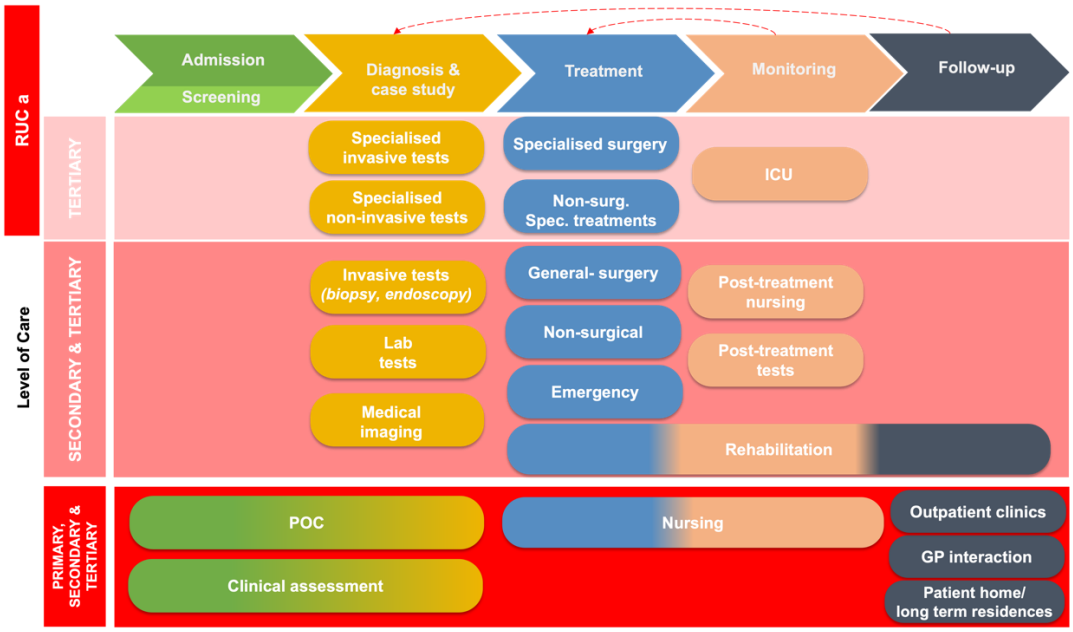

Figure 3 - RUC A Navigation Diagram

5.2 RUC A Phases

This reference use case 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 the first use case, as 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.

Here below 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 they undergo specialized 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 also might stop the treatment or modify it to reach the clinical goal.

5.3 RUC A Goals (overall and for each phase)

This reference use case aims at maximizing 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 optimizing the admission process management

- Diagnosis & Case Study

  Optimizing personalized 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 optimize the involvement of the HCW.

- Follow Up

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

5.4 RUC A KPIs (for each phase)

Here below the KPIs summarised per each phase

Table 3 - RUC A KPIs

Phase	KPIs	Measure unit
Admission & Screening	Waiting time before admission	[hours]
	Early detection of patients at risk	[%]
Diagnosis & Case Study	Time to diagnosis	[days]
	Number of exams for diagnosis	[n]
	Personalization 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	HCW Stress	[%]
Follow up	Effectiveness of the treatment	[specific KPIs TBD]
	Length of stay in hospital	[days]
	Hospitals visits and re-hospitalization	[%]

5.4.1 RUC A Sub Cases

5.4.1.1 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) personalizing 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 focused on the second phase of RUCA: Diagnosis.

5.4.1.2 RUC A2 UC4: Clinical tasks and patient experience

This reference use case covers experiments relating to the exploitation of ODIN technologies for improving execution of clinical tasks and patient overall experience within the hospital ecosystem.

This is the most comprehensive reference use case, that can be differently specialized as concerns the involved RUC A phases.

5.4.1.3 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.

5.4.1.4 RUC A4 UC6: Telemedicine

Many patients spend unnecessary time in hospitals for monitoring leading to higher costs and a higher burden for the patient. COVID-19 reinforced the value of home tele monitoring service.

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

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

5.4.2 Pilots implementing RUC A

Once defined the reference structure of the RUC A and focused the services that are foreseen (RUC A1- A4), ODIN pilots described their experiments as a specialization of these models.

This resulted in the following ODIN RUC A table:

Table 4 - RUC A Pilots implementation

Use Case	Name	Pilot(s)
RUC A1 - UC3	AI for Diagnosis	UMCU
RUC A2 – UC4	Clinical Tasks and Patient Experience	AMIENS, CUB, MUL, UCBM, UMCU

RUC A3 - UC5	Clinical Workflow	UCBM,
RUC A4 - UC6	Telemedicine	UMCU

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

5.4.3 AMIENS

Table 5 - RUC A - AMIENS

Use Case	Name / Description	RUC A Phase (s)
RUC A2 – UC4	Neurosurgical theatre	Treatment Follow Up

5.4.4 CUB

Table 6 - RUC A - CUB

Use Case	Name / Description	RUC A Phase (s)
RUC A2 – UC4	Sleep disorders	Diagnosis, Treatment, Follow Up

5.4.5 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

5.4.6 UCBM

Table 8 - RUC A - UCBM

Use Case	Name / Description	RUC A Phase (s)
RUC A2 – UC4	Monitoring of food assumption to prevent malnutrition	All the phases
RUC A2 – UC4	Rehabilitation to prevent loss of mobility	Treatment, Monitoring, (Follow up ?)
RUC A3 – UC5	Monitoring of oxygen therapy to prevent hypoxia complications	Monitoring (Follow up?)

5.4.7 UMCU

Table 9 - RUC A - UMCU

Use Case	Name / Description	RUC A Phase (s)
RUC A1 - UC3	AI for Diagnosis AI tools to improve personalization and efficiency of CVD diagnostic pathways outpatient clinic setting	Diagnosis
RUC A2 – UC4	Identification of eligible patients Automatically identify new patients eligible for CVD learning healthcare system	Admission & Screening
RUC A4 – UC6	Telemonitoring Post-operative home-tele monitoring of vascular surgery patients	Monitoring, Follow up

6 RUC B Devices, Goods, Facilities Management

This Reference Use Case 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

Approaching this RUC similarly to the RUC A, we can build a workflow describing the interactions among the different phases and inputs. As per the RUC A, all the phases are interconnected and interdependent 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 stage is dealing with all the necessary steps 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:

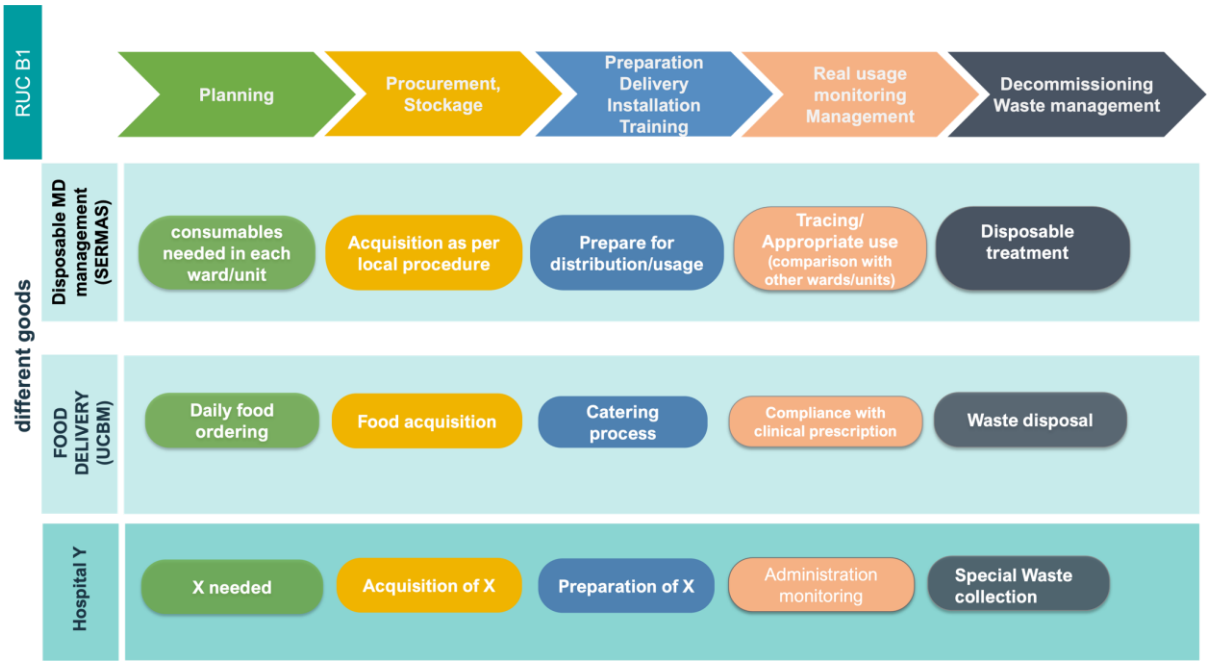

Figure 4 - RUC B1 Navigation Diagram

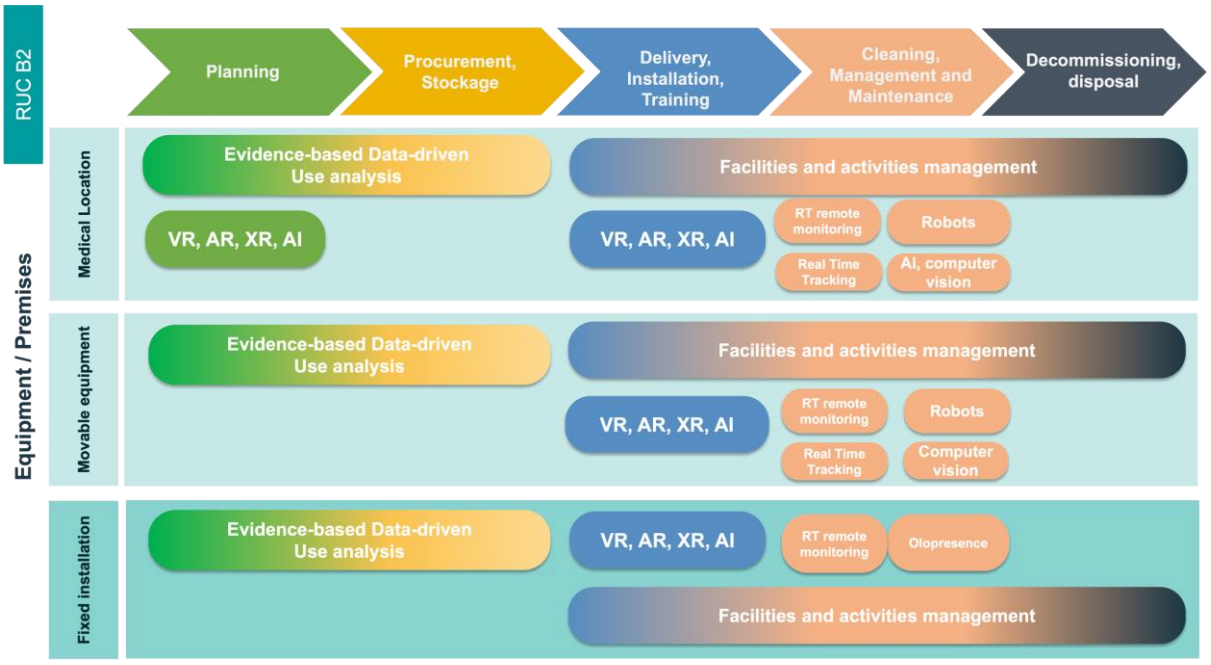

Figure 5 - RUC B2 Navigation Diagram

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, RCU 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 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.

- 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 minimize the impact on the hospital processes. Performing effective and customized 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 Goals (overall and for each phase)

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

- Planning

  Optimizing the whole clinical engineering and medical locations management process

- Procurement, Storage

  Reducing time and maximizing 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

  Optimizing medical locations and equipment management and maintenance

- Decommissioning, disposal

  Optimizing closures and transfers

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

6.4 RUC B KPIs (for each phase)

Here below the KPIs summarised per each phase

Table 10 - RUC A 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

So far defined the RUC B and its sub use cases RUC B1 and B2, ODIN pilots described their experiments as a specialization 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 summarizes for each pilot the different implementation of RUC A. Full detailed pilots' experiments, where available, are reported in Appendix A.

6.6.1 SERMAS

Table 12 - RUC B SERMAS

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

6.6.2 UCBM

Table 13 - RUC B UCBM

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

6.6.3 MUL

Table 14 - RUC B - MUL

Use Case	Name	Description	RUC B Phase (s)
RUC B1 – UC1	Aided Logistic Support	Real time management of blood samples	Preparation, delivery, installation, training

7 Conclusions

This deliverable introduced to the preliminary ground to design and implement the ODIN Impact assessment framework. This report included the defined KPIs both from RUC and the Pilots' perspective. Its aim is to realise tools to actively monitor and support the ODIN experiment execution including the KPIs from all the technical Work Packages.

We gave a general definition to which each pilot will detail in the experiment design and implementation. Here described there are the impact assessment KPIs that will help to measure the local impact of each experiment and draft the overall impact of the ODIN project.

Starting from the next issue we will introduce and describe in detail the adopted tools and indicators to also support and monitor the operational aspects of each pilot.

This will give a full picture of the ODIN experiments.

Appendix A ODIN Pilots experiments

In this appendix are briefly reported the experiments pilot per pilot, the goals and the KPIs so far defined

Next issues of this report series will include the KPIs from the technical WPs together with the overview of the ODIN impact assessment framework

Here below the experiment description per Pilot

A.1 AMIENS

A.1.1 Pilot Description

Amiens University Hospital and its robotics' institute GRECO are a leading player in robotics surgery. Robotics' surgery remains difficult to evaluate regarding laparoscopic surgery. We are lacking clinical, operational, and real-life data to push forward the knowledge of robotic surgery and measure its impact on care pathway, patient's outcomes, or operating room efficiency. New IA, big data solutions are today available in the OR to crack "this Blackbox effect" and get access to new set of indicators to better understand the robotics surgery outcomes and improve its utilization and performance.

A.1.2 Pilot Experiments

Table 15 - AMIENS - Experiments

Use Case	Name	Description	RUC A Phase (s)
RUC A2 – UC4	Clinical Tasks and Patient Experience	Optimize spine cord patients' involvement and remote follow-up	All the phases

A.1.3 RUC A2 UC4

A.1.3.1 Description (overall and for each phase)

This use case, primarily focused on patients undergoing spine cord surgery, is based on getting patients to receive the necessary personalized educational material about their disease to improve their knowledge and involvement. On the other hand, it aims to minimize the stay of these patients once they are operated, facilitating and optimizing their remote follow-up, thus reducing the level of burden on health personnel and the use of the hospital resources required.

- Admission & Screening

  This first phase describes the process of digitizing the hospital's care pathway (focused on spine cord), while correctly enrolling patients on a remote follow-up platform. It is also intended to include different specific and personalized education materials in order to improve the patients' level of knowledge and involve them in their care from the early stages of the disease.

- Diagnosis

Once the patients have been registered on the platform, their profile is evaluated in order to propose a personalized educational program prior to surgery.

- Treatment

  Patients are already hospitalized for their corresponding spine surgery and following an ERAS (Enhanced Recovery After Surgery) protocol. To both improve the practices employed so far, minimize hospitalization time and develop one-day surgery, it is planned to continue the follow-up of these patients at home, through a digital platform and a virtual nurse.

- Monitoring

  The rehabilitation care plan for each patient is monitored while, in parallel, data is collected and analysed in real time. Thanks to an approved clinical algorithm it will be possible to support the medical team in their tasks, and a virtual nurse will take over a triage activity to prevent the physician from being overwhelmed by the number of patient alerts, notifications or messages.

- Follow-up

  Finally, in this last phase, patients at home are followed remotely by their HCP (Health Care Provider). Also, in order for the virtual nurse to be able to identify and avoid risks of complications and manage alerts, each patient must answer a series of specific questions and share real time.

A.1.3.2 Goal (overall and for each phase)

This reference use case aims to reduce the patients' hospitalization (post-surgery) and optimize their enrol to the platform, as well as their remotely follow-up from home.

- Admission & Screening

  Correctly enrol patients on the platform.

- Diagnosis

  Identify patients' characteristics in order to personalize their education plan.

- Treatment

  Optimization of the patient's hospitalization while applying the ERAS guidelines.

- Monitoring

  Accelerate the rehabilitation process and minimize the possible risks of post-operative complications.

- Follow-up

  Improve patients experience while they are remotely followed in their home.

A.1.3.3 KPI (for each phase)

- Admission & Screening

  Patients enrolled in the platform [number]

- Diagnosis

Patient's adherence

Evaluation of the patients' engagement

- Treatment

  Length of stay

  Same day entry

- Monitoring

  Rehospitalization rate

  Number of alerts

- Follow-up

  Satisfaction level [%]

A.1.3.4 Involved staff (overall and for each phase)

- Admission & Screening

  C-Suite
  IT department
  Secretary
  Physicians
  Nurses
  Neurosurgery manager

- Diagnosis

  C-Suite
  IT department
  Secretary
  Physicians
  Nurses
  Neurosurgery manager

- Treatment

  -

- Monitoring

  Secretary
  Physicians
  Nurses
  Neurosurgery manager

- Follow-up

  IT department
  Secretary
  Physicians
  Nurses
  Neurosurgery manager

A.2 CUB

A.2.1 Pilot Description

Charité University Hospital has 3.000 beds and 14.000 employees. It is distributed over 4 campuses in the town 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 in order to provide best practice for the future of medical services in Europe.

The sleep medicine centre is part of Charite, 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 5000 home sleep studies (with fewer signals recorded) per year. The staff includes pneumologists, neurologists, ENT physicians, cardiologists, engineers, specialized medical technologists and nurses.

The sleep centre cooperates with the department of medical informatics for applying interoperability and eRobots

A.2.2 Pilot Experiments

Table 16 – CUB - Experiments

Use Case	Name / Description	RUC A Phase (s)
RUC A2 – UC4	Sleep disorders	Diagnosis, Treatment, Follow Up

Sleep disorders are a medical problem with a very high prevalence. Therefore, this use case is addressed in three separate groups. All the same problems with different diagnosis and different severities and viewed from different angles.

Group A: many patients come to the hospital and seek for help because of their sleep disorders. There are sleep disorders because of stress and too short or too little sleep. There are sleep disorders caused by intrinsic problems such as sleep related movement disorders (restless legs syndrome) or sleep related breathing disorders (sleep apnea). The consequence of all sleep disorders is unrefreshed sleep with consequences for daytime functions.

Group B: some patients come to the hospital because of any other problems, but they have a sleep disorder in addition, and they are not aware of this additional sleep disorder. Typically, the additional sleep disorder causes complications when the patient is diagnosed and treated with his first line problem. It is well studied, that surgery and anesthesia have two times more delirium and two times longer hospital stays if the patient has a sleep disorder in addition to the problem for which he or she is seeking surgical help.

Group C: in addition, sleep disorders are also a high problem among employees in health care. Nurses, doctors, decision makers have to work in day and night shift and often suffer from sleep problems. Many health care employees sleep to little or at the wrong time of the day. With too little sleep, more errors are made during the work. There may be small errors, just caused by

longer reaction times and there may be false decisions, because lack of concentration or simply because of being too tired.

A.2.3 RUC A2 – UC4 Clinical Tasks and Patient experience

A.2.3.1 Description (overall and for each phase)

Admission and Screening (screening of patients at risk for sleep disorders):

Acute diseases requiring hospitalization increase the risk of sleep disorders. This risk is an independent and often neglected risk because most medical observations and investigations are done during daytime. No investigations are done during sleep, even if sleep and its restorative functions are a very important part of health and recovery from any disorder.

Diagnosis/Case Studies (diagnosis of sleep disorders):

The diagnosis of sleep disorders is defined and explained by the International Classification of Sleep Disorders Manual. This manual exists in its third edition, the ICSD-3. The classification defines 67 different sleep disorders, all with different degrees of severities and many with different diagnostic instruments. This classification will be transferred in a category by its own in the new ICD-11. The classification of sleep disorders distinguishes six major groups which are (a) insomnia, (b) hypersomnia, (c) sleep related breathing disorders, (d) sleep related movement disorders, (e) circadian sleep-wake schedule disorders, and (f) parasomnias. Beside these groups, there are also secondary sleep disorders, these can be induced by drugs or medications, these can be induced by mental problems or mental, psychical, or neurological disorders, and can be induced by other medical conditions.

Treatment (medical device treatment and medical drug treatment and behavioral interventions):

The treatment of sleep disorders is oriented to their origin. Patients with insomnia may receive drugs or cognitive behavioral therapy (CBT-I), or relaxation advice, depending on the severity and how chronic the problem is. Patients with sleep apnea may receive a CPAP device, or an APAP device or a BPAP device or a mandibular advancement device or a hypoglossal nerve stimulation by implantation. This depends on the severity and the specific complications / comorbidities accompanying sleep apnea. Patients with sleep related movement disorders receive medical drugs. Patients with hypersomnia receive specific drugs to increase their wakefulness. A sleep hygiene advice is often useful in mild cases of sleep disorders. This depends heavily on the severity assessment and the result of the medical interview with a sleep doctor (somnologist).

Monitoring (follow up of sleep problems):

Nurses and doctors overview patients not only during daytime but also during nighttime. Nurses and doctors will receive additional training that a considerable number of disorders and problems are caused during sleep and that they need to monitor patients also during the nighttime. Patients will be educated that their problems occur not only during daytime, which is the traditional focus of medical care, but may have their origin at nighttime during sleep when they are not conscious of their conditions.

Follow up (of sleep disorder):

Once a sleep disorder is diagnosed, it requires little effort to take care of a follow up. Questionnaires and specific tools, like smartwatches or wearables can help to monitor sleep disorders with very reasonable effort long-term and even at home when the patient left the hospital again. This allows an optimization of medical care and treatment.

A.2.3.2Goal (overall and for each phase)

Admission and Screening (screening of patients at risk for most common sleep disorders):

The goal is to identify patients at risk of sleep disorders. The most common groups of sleep disorders are insomnia and sleep related breathing disorders. The third group in terms of prevalence is sleep related movement disorders. Still secondary sleep disorders are very common and should be recognized. However, they do not need an extra recording and treatment.

Diagnosis/Case Studies (diagnosis of insomnia and sleep apnea):

The goal is to diagnose insomnia and sleep apnea to allow a timely intervention and to minimize complications (e.g., longer duration of hospitalization, complications during anesthesia, staff problems, etc.).

Treatment (meal assumption and speech exercises):

The goal is to treat the sleep disorder in a way that reduces daytime consequences. Many sleep disorders are chronic conditions. There the goal is to minimize daily impact and make the patient aware of his or her condition and means to deal with it.

Monitoring (compliance with clinical prescription):

Because most sleep disorders are chronic conditions a follow up monitoring is required. A good treatment is only achieved if a good adherence to treatment is reached. This needs an acceptance of the condition and a training with the device or the regular drug usage.

Follow up (check for improvements in reducing undernutrition):

The goal is to verify the overall efficacy of the treatment for sleep improvement and improvement of daytime performance with full concentration and readiness for work again.

A.2.3.3KPI (overall and for each phase)

Admission and Screening (screening of patients at risk for sleep disorders):

The screening is based on the following stepwise approach:

- Medical interview for sleep disorders in terms of too little or unrefreshing sleep with dedicated standardized questionnaires
- Recording of sleep with oximetry or sleep apnea testing or actigraphy, or movement monitoring depending on the result of the questionnaires
- In case of suspected sleep disorders, a sleep testing in the sleep laboratory with cardiorespiratory polysomnography.

Diagnosis/Case Studies (diagnosis of sleep disorders):

Diagnosis considers the following variables:

- Number of days in hospitalization
- Number of days for sick leave and doctor visits
- Number of accidents at work or in traffic.

Treatment (daytime impairment):

The treatment effects are observed at work capacity during daytime. Number of naps and number of accidents, reaction time are important treatment markers.

Monitoring (compliance with sleep disorder treatment):

To monitor the compliance with clinical prescription, i.e., the proper use of CPAP or other medical devices or with sleeping drugs can be considered:

- Oxygen saturation during the night
- Respiration during the night
- Number of awakenings during the night
- Time to fall asleep and sleep duration
- Time in different sleep stages and number of arousal events
- Number of naps during daytime

Follow up (check for improvements in reducing malnutrition):

To assess the improvement after the treatment the following indicators can be considered:

- Body weight and composition (fat- and fat-free mass);
- Energy expenditure;
- Energy intake;
- Cough and oxygen desaturation.

A.2.3.4 Involved staff (overall and for each phase)

Admission and Screening (screening of patients at risk for sleep disorders):

Doctors and nurses.

Diagnosis/Case Studies (diagnosis of sleep disorders):

Somnologists at cardiology, pneumology, otolaryngology, pediatrics, geriatrics, neurology, psychiatry.

Treatment (drug and medical devices):

Doctors and nurses.

Monitoring (compliance with clinical prescription):

Doctors and nurses.

Follow up (check for improvements in reducing daytime impairment):

Doctors and nurses.

A.3 MUL

A.3.1 Pilot Description

Table 17 - 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

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 ono 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.

A.3.2 Pilot Experiments

Table 18 - MUL - RUC A

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. stroke survivors, 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 help 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. 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 ER 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 these 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 future better acceptance of similar robotic solutions.

A.3.3.2 Goal (overall and for each phase)

Overall goal 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 chest pain, abnormal INR level, 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.

A.3.3.3 KPI (overall and for each phase)

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.3.3.4 Involved staff (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.

Diagnosis & Case Study phase: Emergency unit staff - mostly nurses, partly – medical doctors.

Treatment phase: Emergency unit staff - mostly nurses, partly – medical doctors.

Monitoring phase: Researchers – for monitoring.

A.3.4 RUC B2 UC2 Clinical engineering

A.3.4.1 Description (overall and for each phase)

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 tertiary teaching hospital.

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).

Decommissioning, disposal: Not applicable to MUL RUC B – relevant medical equipment items are in the continuous use in the Emergency Department.

A.3.4.2 Goal (overall and for each phase)

This reference use case aims at maximizing data-driven decisions and management of diagnostic and treatment processes in Emergency Department.

Planning: 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

Procurement, Storage: Reducing staff work time, maximizing equipment availability and patient safety.

Delivery, installation, training: 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.

Cleaning, management, and maintenance: Optimizing equipment cleaning due to shorter time use for location and transportation, and hence, longer time left to eg. UV irradiation.

A.3.4.3 KPI (for each phase)

- Delivery, installation, training

  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

  Equipment delivery time

- Cleaning, management, and maintenance

Daily number of whole cycles of equipment cleaning per item

Monthly time saved to the staff members due to the use of system

A.3.4.4 Involved staff (overall and for each phase)

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

- Planning
  - Technical Managers
  - Health Managers
  - Hospital epidemiology managers
- Delivery, installation, training
  - Clinical Engineers
  - Manufacturers
  - Emergency Department Megamenu
  - Healthcare staff (nurses, physicians)
- Cleaning, management, and maintenance
  - Technical Managers
  - Clinical Engineers
  - Hospital epidemiology unit staff

A.4 SERMAS

A.4.1 Pilot Description

This pilot is going to take place in Hospital Clínico San Carlos. Three main departments are going to be involved: The innovation Unit, The Procurement Department and The Cardiology Department.

The Procurement Department is on 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 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.

A.4.2 Pilot Experiments

This pilot will deploy the experimentations within the RUC B as the detailed in the table below:

Table 19 -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

A.4.3 RUC B1 UC1

A.4.3.1 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 their future procurement. For this pilot, we are going to focus on a single consumable related to the Cardiology service.

- Planning

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

- Procurement, Storage

  The same consumable can be purchased from several different vendors. Which vendor is chosen is many times based solely on the preference on 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.

  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 by hand the number of items that are stored. Purchase orders are then made in accordance with this counting.

A.4.3.2 Goal (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 consumable. It would also be interesting to know, when considering buying a new consumable, if there is already one with the same specifications already in the catalogue, to make the purchase process more efficient.

- Procurement, 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.

A.4.3.3 KPI (for each phase)

- Planning

  Difference between the number of consumable units predicted as needed and the real needs [%]

- Procurement, Storage

  Objective metrics to evaluate the different vendors:

  Difference in clinical outcomes [% of readmissions]

  Delivery time [hours/days]

  Delivery delays [%]

  Delivery errors [%]

  Costs [€]

  Being able to measure the number of consumable units stored in each storage room [# units]

A.4.3.4 Involved staff (overall and for each phase)

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

- Planning

  Procurement Department

  Innovation Unit staff

Wardens

- Procurement, Storage

  Procurement Department

  Innovation Unit staff

  Wardens

  Nurses

A.4.4 RUC B2 (UC2): Clinical engineering and medical locations management

A.4.4.1 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 UC1 and have chosen, as delivery location for the consumable, the Haemodynamic Room.

- Delivery, installation, training

  At the present moment, consumables are both manually retrieved and taken to the room where they will be used. Consumables are withdrawn from the storage rooms without this action being registered. There is no information about the moment a consumable 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 consumables from the storage room is not recorded, information about which items have been used is indeed registered. That is, if an item is withdrawn from its shelf and not used, it could be placed back in that shelf or simply kept at the destination 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.

- Decommissioning, disposal

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

A.4.4.2 Goal (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.

- 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.

A.4.4.3 KPI (for each phase)

- Delivery, installation, training

  Number of consumable units 1) withdrawn from the storage room, 2) correctly delivered to the target destination and 3), if not used, returned to the storage room [%]

  Consumable delivery time [seconds]

  Number of units delivered but not used. Are the clinician procedure petitions realistic? [%]

- Decommissioning, disposal

  Monthly time saved by automatizing the process [hours]

A.4.4.4 Involved staff (overall and for each phase)

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

- Delivery, installation, training

  Procurement Department

  Innovation Unit staff

  Wardens

  Nurses

- Decommissioning, disposal

  Procurement Department

  Innovation Unit staff

  Wardens

  Nurses

A.5 UCBM

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 provision of high-quality healthcare services with the Research Hospital. 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 PhD 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 UCBM, 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 Department 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.5.2 Pilot Experiments

This Pilot will develop the experiments in two RUCs according to the following tables:

Table 20 - UCBM Experiments

Use Case	Name	Description	RUC A Phase (s)
RUC A2 – UC4	Monitoring of food assumption to prevent malnutrition		All the phases
RUC A2 – UC4	Rehabilitation to prevent loss of mobility		Treatment, Monitoring, (Follow up ?)
RUC A3 – UC5	Monitoring of oxygen therapy to prevent hypoxia complications		Monitoring (Follow up?)

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

A.5.3 RUC A2.1- UC4: Clinical Tasks and Patient experience – Monitoring of food assumption to prevent undernutrition

Malnutrition 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 malnutrition (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, malnutrition 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.

A.5.3.1 Description

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 malnutrition. 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 malnutrition 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 and speech exercises):

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. Besides, patients perform speech exercises.

Monitoring (compliance with clinical prescription):

Nurses and doctors daily overview patients while performing their exercises to ascertain that they are consistent with the prescription, in terms of quality and quantity. Likewise, they 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.5.3.2 Goal (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 and speech exercises):

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.

Monitoring (compliance with clinical prescription):

The goal is to verify that patient is correctly following the exercises and the diet prescribed in order to timely modify the intervention.

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.5.3.3 KPI (overall and for each phase)

Admission and Screening (screening of patients at risk of undernutrition and dysphagia):

The screening is based on the following two tests:

- 3-oz water swallow test for dysphagia;
- Mini Nutritional Assessment score.

Diagnosis/Case Studies (diagnosis of undernutrition and dysphagia and diet prescription):

Diagnosis considers the following variables:

- Body weight and composition (fat- and fat-free mass);
- Energy expenditure;

- Energy intake;
- Cough and oxygen desaturation.

Treatment (meal assumption):

The treatment based on energy intake (calories) and percentage of macronutrients.

Monitoring (compliance with clinical prescription):

To monitor the compliance with clinical prescription, i.e. the proper food assumption the following variables can be considered:

- Correct head position while eating;
- Meal intake time (minutes);
- Number of coughing events and oxygen desaturation events per meal.

Follow up (check for improvements in reducing malnutrition):

To assess the improvement after the treatment the following indicators can be considered:

- Body weight and composition (fat- and fat-free mass);
- Energy expenditure;
- Energy intake;
- Cough and oxygen desaturation.

A.5.4 RUC A2.2 - UC4: Clinical Tasks and Patient experience – Rehabilitation to prevent loss of mobility

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"*[1]. 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.

A.5.4.1 Description

Admission and Screening (screening based on risk of reduced mobility):

[1] https://www.who.int/news-room/fact-sheets/detail/rehabilitation.

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.5.4.2 Goal (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 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.5.4.3 KPI (overall and for each phase)

Treatment (in-hospital rehabilitation):

Indicators on the effectiveness of the treatment can include:

- Absence of immobilization-related lesions (e.g. bedsores);
- Function preservations (e.g. trunk control);
- Time spent in autonomous exercises.

Monitoring (monitoring of compliance prescription, correctness and risks):

To monitor the proper execution of exercises, the following indicators related to the performance of each motor task can be considered:

- Success rate;
- Execution time;
- Number of repetitions;
- Number and type of motion errors;
- Number of requests to stop the therapy;
- Number of anomalous movements from the patient;
- Time that each HCW spends with each patient.

A.5.4.4 Involved staff (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.5.5 RUC A3 - UC5: Automation of Clinical Workflows - Monitoring of oxygen therapy to prevent hypoxia complications (UCBM)

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, dyspnoea, 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.

A.5.5.1 Description

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.5.5.2 Goal

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.5.5.3 KPI

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

During monitoring, the following indicators can be considered to check the compliance with the prescription and the correctness of the therapy:

- Success rate in properly executing the therapy in terms of:
  - Type of device (nasal prongs, venturi mask or high-flow nasal cannula);
  - Air flow;
  - Fraction of inspired oxygen (FIO2) – from 21% to 100%;
  - Therapy duration (e.g. 24 hours, night, during exercise);
- Time of mask usage with respect to total therapy time;
- Number of robotic interventions.

A.5.5.4 Involved staff (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.5.6 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 [REF]. 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 [REF]. 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.

A.5.6.1 Description

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 provides 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.5.6.2 Goal (overall and for each phase)

Planning (food ordering):

Menu planning groups need to: i) recognise 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.5.6.3 KPI (overall and for each phase)

Preparation, delivery, installation, training (food delivery process) and real usage monitoring management (compliance with clinical prescription):

Some indicators of success of the delivery process can include:

- Success rate in verifying patient-meal matching;

- Success rate in delivering food (right food to the right patient).

A.5.6.4 Involved staff

Preparation, delivery, installation, training (food delivery process) and real usage monitoring management (compliance with clinical prescription):

Doctors, nurses.

A.6 UMCU

A.6.1 Pilot Description

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. 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 Centre 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 Centre 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

This Pilot will develop the experiments within the RUC A according to the following table:

Table 21 - UMCU Experiments

Use Case	Name	Description	RUC A Phase (s)
RUC A1 - UC3	AI for Diagnosis	AI tools to improve personalization and efficiency of CVD diagnostic pathways outpatient clinic setting	Diagnosis
RUC A2 – UC4	Identification of eligible patients for CVD learning	Automatically identify new patients eligible for CVD learning healthcare system	Admission & Screening
RUC A4 – UC6	Telemonitoring	Post-operative home-tele monitoring of vascular surgery patients.	Monitoring, Follow up

A.6.3 RUC A1 - UC3: AI for diagnosis

A.6.3.1 Description (overall and for each phase)

Diagnostic phase

The right treatment starts with the right diagnosis. Diagnostic trajectories can be straightforward, short and inexpensive, but in specialized 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 upon 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 personalized and the location and availability of diagnostic tools are not considered in planning.

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.

A.6.3.2 Goal (overall and for each phase)

To make the diagnostic workflow more efficient by (1) personalizing the diagnostic process, (2) including location and availability of the medical devices.

A.6.3.3 KPI (overall and for each phase)

Decrease in time to diagnosis. We will measure this KPI by validating the diagnostic model against manual planning done in 2019 (i.e. before covid-19).
Patient satisfaction scores are not part of the KPI.

A.6.3.4 Involved staff (overall and for each phase)

To plot the current diagnostic pathway and underlying assumptions, we need PAs, doctors and administrative staff. UPOD data managers are consulted to help build a script/syntax to select the eligible data from the EHR. Finally, we need to consult with the IT department to get access to IoT data for the diagnostic tool. We have involved all staff already in the project.

A.6.4 RUC A2 - UC4: Clinical Tasks and Patient experience

A.6.4.1 Description (overall and for each phase)

Screening 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.

A.6.4.2 Goal (overall and for each phase)

To develop an AI-based system that, based on extractable data from the electronic health record (EHR) automatically identifies new patients that are eligible for CVD learning healthcare system and creates reports for the LHS.

A.6.4.3 KPI (overall and for each phase)

- We want to measure the percentage of (rightfully) included patients into the LHS by answering the following questions:
    - Did we include all eligible patients into the LHS?
    - How many did we miss and why?

  Measured by, for example, validating the to be developed patient inclusion model against historical data. The model should at least identify all patients that were manually included into the LHS at that time. Results from this validation could then be used to improve the model.
- Increase the monthly number of inclusions into the LHS. Measured by comparing the monthly inclusion rates with the monthly rates of 2019.

A.6.4.4 Involved staff (overall and for each phase)

Nurses and doctors of all participating departments of the UMCU are involved. They will need to provide us with the information needed to be able to select the correct patients for the LHS. For example, by pointing us towards structured and unstructured data that are able to identify of patients (-patient groups) that they want us to include into the LHS. This will be an iterative process.

UPOD data managers are consulted to help build a script/syntax to select the eligible patients from the EHR.

A.6.5 RUC A4 - UC6: Telemedicine

A.6.5.1 Description (overall and for each phase)

Many patients spend unnecessary time in hospitals for post-operative monitoring purposes leading to higher costs and a higher burden for the patient. COVID-19 helped to implement the concept of telemonitoring into the UMCU. However, telemonitoring hasn't been implemented yet for all. Patients that had a carotid endarterectomy in which blood pressure needs to be monitored multiple times a day to prevent major post-operative complications (e.g. cerebral hyper perfusion syndrome) could benefit from telemonitoring and are currently monitored while admitted to the hospital. The UMCU already has a telemonitoring app (e-Health, Luscii) to monitor blood pressure in high risk obstetric patients that need blood pressure monitoring and otherwise would visit the

obstetrics outpatient clinic 3 times a week. This application could potentially be also useful in vascular surgery patients. However, obstetric patients are usually younger tech-savvy patients whereas vascular surgery patients are considerably older. Furthermore, the at-risk pregnancy is different from post-operative monitoring in terms of risk. Therefore, we would like to establish a workflow that incorporates remote monitoring of patients with mitigated remaining risks and trains both nurses and patients to use and adhere to the monitoring protocols.

A.6.5.2 Goal (overall and for each phase)

- Expanding our (already used by the obstetrics department) telemonitoring platform to enable post-operative home-monitoring of vascular surgery patients.
- Establishing a workflow that accurately mitigates remaining risks, incorporating training of patients and nurses to use and adhere to the monitoring protocol using the app.

A.6.5.3 KPI (overall and for each phase)

- Ease of use / usability. Measured by enrolling vascular surgery patients into a clinical study with the monitoring device and app. We will measure the usability and patient experience using a survey. Possible answers will be given using a Likert-scale.
- Usability of the workflow and the device, measured by interviewing doctors/nurses/patients.

A.6.5.4 Involved staff (overall and for each phase)

- UPOD data managers to extract data from the EHR. UPOD is a large patient database containing all data from the electronic health record (EHR) of all patients in the UMCU.
- nurses and doctors will need to be involved to increase the adoption and adherence of the technology
- nurses and doctors to help monitor the values obtained from the home monitoring devices
- PhD candidate (Anna) and/or research nurse and/or master student to set up a clinical study and include 100 patients