



TORNADO

Deliverable D2.1

End-user requirements - first version



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Abbreviations

Abbreviation	Explanation
AMR	Autonomic Mobile Robot
BEST	MCC Best Value LTD
FM	Foundation Models
HKP	Hankamp Gears B.V.
HRC	Human Robot Collaboration
HRI	Human Robot Interaction
O	Objective
ROS	Robot Operating System
SLAM	Simultaneous Localization And Mapping
SME	Small and Medium Enterprise
SRA	San Raffaele S.p.A.
UC	Use Case
WP	Work Package



Executive Summary

This document outlines the first version of the end-user requirements (D2.1) for the TORNADO project. The three diverse use cases (UCs) are set in: a gear manufacturing company, a palliative care ward and a supermarket distribution center. D2.1 has been developed within the framework of Work Package 2 (WP2) – Use Case Requirements and Pilot Studies, it will be used throughout the project to ensure that the solutions developed align with the end-users' requirements.

The primary objectives were to identify case-specific and cross-cutting challenges, conduct a technical analysis of each working environment and define user profiles in line with a human-centered design approach. Each use case UC revealed unique operational challenges, such as managing deformable objects in confined industrial spaces (UC1), integrating robots into sensitive healthcare environments (UC2) and recognizing varied waste types in a high-throughput distribution center (UC3). Despite these differences, several overarching issues were identified, including human–robot interaction, communication, unpredictable human behavior, task assignment and the classification of users and objects. These common challenges provide a basis for designing solutions that can be applied across industries.

A structured technical analysis was conducted for each UC through a standardized questionnaire, resulting in detailed documentation of system needs in terms of safety, navigation, perception and ergonomics. Comparative analysis of these findings informed the initial definition of minimum platform requirements, forming the basis for further development in future work packages.

Additionally, preliminary user profiles were developed to ensure alignment with human-centered design principles and promote user acceptance. These will be further refined in future stages to improve our understanding of user interaction and attitudes towards robotic systems.

Overall, this deliverable lays the groundwork for the TORNADO platform by linking end-user requirements to specific technical specifications and design objectives. It also facilitates alignment between the requirements phase (WP2) and the development phases (WPs 3–6), ensuring that the platform is shaped by real-world needs and ethical considerations. Future activities will validate and refine these requirements through testing and field evaluations, resulting in finalized specifications in deliverables D2.2–D2.6.

1. Introduction

1.1. Purpose statement

This document begins by outlining the overall approach and key decisions taken when identifying end-user requirements. Particular attention is paid to technical and user-centric considerations that form the basis of the solutions currently under development. The content is organized into five main sections and one annex.

- 1. Introduction – Provides the purpose of D2.1
 - 2. Methodology – Explanation of the used methodology
 - 3. Use case identification – Context explanation
 - 4. Requirements analysis – In depth analysis of the requirements
 - 5. Summary and outlook – Summarizes the purpose and expected outcomes of D2.1
- Appendix 1 – Complete requirements analysis questionnaires

1.2. Intended readership

This document is intended for both TORNADO consortium members and external project stakeholders. It aims to provide the project consortium and stakeholders with an overview of the context in which the three different Use Cases (UCs) take place, as well as the defined end-user requirements. The purpose of this is to ensure that the consortium members have sufficient background knowledge to develop the most suitable solutions for the UCs and ensure that the foundation models are aligned with the UC requirements and similar situational contexts.

1.3. Contribution to WP2 and project objectives

The aim of the end-user requirements as part of the WP2, is to gain insight in the context of the UCs and their respective requirements. By identifying concrete real-world scenarios, the first objective would be to drive and provide direction to the technical developments of the TORNADO project. The second objective would be to demonstrate the final project results.



1.4. Relation to other WPs and deliverables

This initial version of the end-user requirements will form the basis of the final version and support various activities, such as specifying pilot scenarios, planning and executing pilot activities, and the accepting and evaluating systems. These activities will be documented in deliverables D2.2 to D2.6.

The requirements will guide the implementation of actions across the three main TORNADO R&D axes:

1. **Safe Robot Planning, Navigation, and Manipulation** – The end-user requirements support activities related to task planning, simultaneous localization and mapping (SLAM), and communications (deliverables D3.1 and D3.2), as well as navigation, manipulation, and safety management (deliverables D3.3 and D3.4).
2. **Adaptive AI and Self-Adjusting Cognitive Pipelines** – The requirements also support the development of adaptive artificial intelligence and flexible cognitive mechanisms, as described in deliverables D4.1 and D4.2.
3. **Advanced Robotic Perception and Human-Robot Interaction (HRI)** – They further support actions focused on audiovisual perception, human awareness, and HRI (deliverables D5.1 and D5.2), as well as human factors analysis (deliverable D5.3).

In addition, the end-user requirements guide the design and integration processes, including overall system architecture, robot development and integration, cloud infrastructure integration, and Beyond-5G network integration. The upcoming deliverables D6.4 and D6.5 will document continuous integration efforts.

2. Methodology

The development of the requirements presented in this document was based on a structured approach consistent with the WP2 methodology described in the Grant Agreement. Starting from direct observation of operational contexts and the active involvement of end-users, technical, environmental, and organizational data were collected to precisely define the tasks to be automated or supported by robots. The requirements definition followed the principles of Human-Centered Design, integrating considerations of acceptability, impact on workflows and ethical and regulatory aspects. Each requirement was then mapped to the technological capabilities envisaged in the subsequent WPs and to the overall objectives of the project, thus ensuring a direct alignment between actual needs, technical development and expected results.

Due to the different areas in which the UC partners are active (manufacturing, healthcare and food/logistics) it is necessary to establish a common ground on how to align the UCs without losing the uniqueness of each UC. Therefore, in this first version of end-user requirements analysis, the following actions have been executed:

- Identification of problems/challenges and tasks for each UC.
- Technical analysis of the working environment.
- Definition of the end-user profiles as part of the human-centered design principle.

In task “T2.1 - End-user requirements”, the UC specific aspects and functional requirements will be identified and presented in “D2.1 - End-user requirements - first version”. In task “T2.2 - Pilot scenario definition”, the identified UC tasks will be more closely linked to the technical requirements relevant to the research partners when developing new solutions, and these will be presented in “D2.2 - End-user requirements – final version”.

2.1. Task identification

Each UC partner conducted field observations and interviews with key stakeholders, and completed detailed technical questionnaires. This work gathered information on environmental constraints, eligible automation tasks, and end-user profiles. Photographic documentation, floor plans, videos, and physical measurements of the operational environments were used to support this work, as required by the activities of WP2.

Specific activities that could benefit from the support of AI-based robotic systems were identified through direct discussions with the partners involved in each UC. The following were taken into consideration: operations that were already performed manually but were characterized by a high physical load, repetitiveness, or ergonomic complexity; and tasks presenting limitations for traditional robotic applications, such as the manipulation of deformable objects, the recognition of highly variable contexts, or the autonomous navigation in densely human-populated environments. The partners provided lists of priority tasks, describing the operating conditions, technical constraints, and user interaction requirements for each UC. This process enabled us to define a set of representative tasks for each UC to guide the development, integration, and validation of the project's technologies. Each UC partner has been asked to compile a list of tasks that could benefit from the assistance of AI and robotics. This involves:

- Knowledge transfer/lack of knowledge
- Ergonomic aspects

- Repetitive/boring tasks
- Currently challenging aspects for standard robot applications

2.2. Technical analysis

The technical analysis was conducted to understand in detail the characteristics and operational requirements of each application context, thus translating end-user needs into functional specifications and design constraints for the robotic system. Each UC partner completed a structured questionnaire, covering environmental parameters (lighting, noise, temperature), physical and dimensional characteristics of the spaces, types of objects to be manipulated, and safety conditions to be respected. This data collection was supported by visual materials such as photographs, floor plans, and videos, which provided a precise documentation of workflows and human-environment-machine interactions. The analysis also considered potential interference with other ongoing activities and the operational variability typical of each context, thus providing a solid basis for defining realistic requirements, compatible with the technological capabilities envisioned by the TORNADO project.

2.3. Human-centered design

Humans are involved in all three UCs, and, especially for the healthcare UC, a more user centered approach was considered necessary. Due to positive past experiences, it was decided to include Human-Centered Design in all UCs, ensuring that human factors would be adequately included in the project, as outlined in the GA. This led to considering, in addition to technical aspects, the acceptability of the technology, the impact on workflows, and the overall quality of the user experience. In the healthcare use case (UC2), this translated in the integration of empathetic interaction, security, and privacy. In the industrial use cases (UC1 and UC3), priority was given to human-robot collaboration scenarios that improved ergonomics and minimized disruptions.

The requirements thus gathered were then correlated with the technological capabilities envisioned in the research and development activities of WP3–WP6, regarding navigation, manipulation, perception, cognitive planning, and connectivity. Performance requirements were defined, aligned with the project's objectives and metrics, and the needs common to the three UCs were summarized in a set of cross-platform requirements that will guide the technical integration of the TORNADO system.

Finally, all requirements involving the collection or processing of personal data were subjected to a preliminary ethical review, in accordance with the provisions of WP1. For UC2, the issues of privacy, informed consent, and clinical data protection, in accordance with the GDPR and the AI Act, were specifically addressed, while for UC3, regulations on food safety and contamination prevention were taken into account.

This methodological approach ensures that the requirements are relevant, achievable, and compliant with ethical and legal constraints, that technological development is effectively driven by real needs, and that subsequent validation activities can meet both the functional objectives and the project's social and ethical commitments.



3. Use case identification

This chapter focuses on the context in which the UC takes place, the end-users of the system, the (sub)tasks that pose multiple challenges for traditional robotic systems in this context. It also considers how these (sub)tasks contribute to the goals of the UC owners and TORNADO project, as well as the performance requirements.

It takes into account the guidelines and priorities set out in the Grant Agreement to ensure consistency with the project's overall objectives, while allowing for adaptation based on the results achieved and the actual implementation conditions. Where applicable, features considered to be of strategic interest are also included, and these may be subject to further evaluation during the project.



3.1. UC1 - Manufacturing & Assembly

3.1.1. UC1 context

Hankamp Gears (HKP) is a gear manufacturing company based in Enschede, the Netherlands. HKP can be described as an 60 FTE SME with a typical High Mix Low Volume production. Throughout the entire production process a high degree of automation is in place. One department that lags behind in the automation developments is the shipping department. The shipping department is one of the most challenging and dynamic departments within the gear manufacturing company. Challenging as the robot should be able to handle small and lightweight gears (>5mm and weighing a few grams) up to big heavy gears (Ø400mm and 10 Kg of weight) in small (25 pcs.) and semi small batches (150 pcs.). This means that the robot should possess fine motor skills and “sensing” abilities in combination with strength, to handle the different types of gears properly.

Currently, available solutions like magnetic grippers are either not strong enough or may cause damage to the gears. Furthermore, the shipping department is a dynamic department, with heterogeneous traffic during the day, ranging from people walking to pallet trucks and forklifts that move around to deliver the required products. This means that the robot should be aware of its environment, not obstructing others and be able to maneuver in areas with a limited or reduced passageway, where currently available autonomous vehicles are not able to move through due to safety regulations. Moreover, the intervening layers between products pose a unique challenge. These so-called ply-sheets, being deformable and resistant to manipulation by automated systems, require meticulous manual handling by company workers. This task not only adds to the workload but also demands sustained attention to detail, further highlighting the intricate nature of these operations.



Figure 1 – Overview of the shipping department at Hankamp Gears

3.1.2. UC1 end-users

The robot platform will interact with the people who work in or visit the shipping department. To gain a better understanding of these groups, the following have been identified as the primary contact groups, each with their own characteristics:

- HKP shipping department employees
- HKP other departments employees
- External visitors (customers, suppliers, etc.)
- Parcel delivery drivers.

Table 1 – Primary HKP user characteristics

HKP employees department		
Demographics	Age	16-50
	Education	Secondary vocational education
	Language	Dutch (native) English (sufficient)
	Physical condition	Good
	Cognitive condition	Good
	Chronic conditions	None
	Sensory limitations	None
Technical	Computer skills	Basics
	Programming skills	None
	Attitude towards technology	Hesitant / Open to new technology.
	Frequency of robot contact	All day
	User type	Primary user
Typical activities	Distribution of incoming material/goods (with pallet truck/ forklift);	
	Visual product inspection & counting parts before shipment	
	Making product sets	
	Laser engraving	
	Wrapping products in a protective cover	
	Putting products in cardboard boxes	
	Preparing shipping documents	
	Contact with parcel delivery drivers	
	Distribution of outgoing goods (with pallet truck/ forklift)	
Job characteristics	High amount of physical labor	
	A lot of walking activities	
	Processing multiple jobs per day	
	Frequent use of ERP system	

Table 2 – Secondary HKP user characteristics

HKP employees other departments		
Demographics	Age	16-67
	Education	Secondary vocational education – Academic education
	Language	Dutch (native) English (sufficient)
	Physical condition	Good
	Cognitive condition	Good
	Chronic conditions	None
	Sensory limitations	None
Technical	Computer skills	Basics - Good
	Programming skills	None
	Attitude towards technology	Hesitant / Open to new technology
	Frequency of robot contact	A few times a day / week
	User type	Secondary user – Is able to familiarize with the implemented solution
Typical activities	Bringing goods for outsourced activity (with pallet truck)	
	Bringing finished goods (with pallet truck)	
	Crossing shipping department to reach the office or workshop	

Table 3 – Secondary external user characteristics

External visitors		
Demographics	Age	21-70
	Education	Secondary vocational education – Academic education
	Language	Dutch (native) English (sufficient)
	Physical condition	Unknown
	Cognitive condition	Good
	Chronic conditions	Unknown
	Sensory limitations	Unknown
Technical	Computer skills	N/A
	Programming skills	N/A
	Attitude towards technology	Hesitant / Open to new technology
	Frequency of robot contact	Incidental
	User type	Secondary user – Is not able to familiarize with the implemented solution
Typical activity		
Crossing shipping department to reach the office or workshop (always under supervision of a HKP employee)		

Table 4 - Secondary external user characteristics

Parcel delivery drivers		
Demographics	Age	18-50
	Education	Secondary vocational education
	Language	European
	Physical condition	Good
	Cognitive condition	Good
	Chronic conditions	Unknown
	Sensory limitations	Unknown
Technical	Computer skills	N/A
	Programming skills	N/A
	Attitude towards technology	Unknown
	Frequency of robot contact	Incidental
	User type	Secondary user – Is not able to familiarize with the implemented solution
Typical activity		
Entering confined space of the shipping department (shipping desk)		

3.1.3. Task identification

The main task of the robot platform in UC1 will be to support the shipping employees with their daily activities.

To break down the main task into manageable blocks that address multiple challenges for traditional robot systems, the following subtasks have been identified and will be addressed via the robotic system operation during the TORNADO project:

- The robot must be able to grasp large and heavy gears from the transportation crates and support the human workers by placing them on a table (Human-Robot Collaboration).
- The robot must be able to grasp large and heavy boxes that need strapping, put them onto the strapping machine and execute strapping action (Autonomous task execution).
- The robot must be able to pick up small and delicate gears from (form-fit) blisters without damaging the product (Fine motor skills).
- The robot must be able to make product sets together with a worker and manipulate (grasp, orient, and place) correctly the deformable ply sheets (that vary in shape and deformation) in-between the gear layers (Human-Robot Collaboration & programming by doing).
- The robot must be able to start a simple conversation with a truck driver (HRI).



3.1.4. Expected key contributions

At this stage of the project, the TORNADO project is expected to demonstrate how the next evolutionary step in human-robot collaboration will look like in a challenging and dynamic manufacturing and assembly environments, such as the shipping department of a gear manufacturing company.

The expected key contributions are:

- Supporting employees with daily tasks that involving physical (lifting heavy gears) or cognitive strain (boring and repetitive tasks) on a higher cognitive level than current robot systems do (O1, O2 & O3).
- Improved human-robot communication (assigning tasks/ programming of the system, a simple conversation in a different language, etc.) enabling a more intuitive interaction between the use and the system (O3.3, O3.4, O3.6).
- A system that can handle unforeseen circumstances faster and more safer than currently available systems in navigation, manipulation, perception and safety when handling objects (O1.1, O1.5, O1.6, O2, O3.1 & O3.8).
- Improved anticipation of human behavior in a human-centric environment (contextual understanding, adaption to different users and their behavior) enabling a more intuitive user experience (O3.2, O3.3, O3.6 & O3.7).

3.1.5. UC1 performance requirements

For UC1 the following performance requirements have been defined:

1. Reducing the number of lifting actions performed by the shipping employees per day.
2. Reducing the required programming skills to program the robot. Currently, a sufficient knowledge of the programming language and flow is required before a robot can be programmed.
3. Enable foreign truck drivers to start a simple conversation in English or German with the robot.
4. Reduction of gripper swap actions. Current grippers are only suitable for a limited range of dimensions & weights.
5. Improving object recognition under standard factory lighting conditions.
6. Improving maneuverability in narrow spaces. Currently a path width larger than 1,5m is required.

3.2. UC2 – Healthcare & Assistance

3.2.1. UC2 context

San Raffaele (SRA) is a Hospice Ward based in Cassino, Italy. The hospice is dedicated to the care of patients in the advanced stages of the disease, no longer susceptible to active therapies for curative purposes. In this context, the goal is not to prolong life, but to alleviate suffering and improve the residual quality of life, respecting the dignity, preferences and comfort of the patient and the patient's family.

The presence of a robot in such a delicate context introduces unique challenges in terms of acceptability, empathy, safety and respect for human time and space. However, it can offer important support through a series of assistive, communication and monitoring functions that relieve staff from repetitive tasks and promote more continuous interaction with the patient, even in the temporary absence of the human operator.

The robot will be integrated into the clinical environment to perform specific and defined tasks, combining elements of passive monitoring and light physical interaction. The robot interacts mainly with patients, nurses, doctors and family caregivers, in different ways. The following subtasks have been deemed of main interest, although some (such as bag monitoring) involve critical issues in terms of visual perception, reliability and privacy, and will be the subject of controlled experimentation.

These activities will form the basis of patient-robot interaction in a real-world setting and will be validated in collaboration with the clinical and technical teams.



Figure 2 – Areas of interest for robotic navigation and interaction

3.2.2. UC2 end-users

The robot platform will interact with a variety of people working or staying at the SRA palliative care unit. To gain a better understanding of these groups, the following have been identified as the primary contact groups, each with their own characteristics:

- SRA patients
- SRA caregivers
- SRA medical doctors
- SRA nurses

During the pilot, only mannequins will be used to replace patients in interactions with robots. The definitions provided here serve to describe the real framework for a complete user requirements definition and for guiding future implementation.

Table 5 - SRA user characteristics

SRA patients		
Demographics	Age	10 - 100
	Education	From “No formal education” to “Postgraduate”
	Language	Italian
	Physical condition	From moderate to severe limitation
	Cognitive condition	From normal to severe impairment
	Chronic conditions	
	Sensory limitations	From normal to severe impairment
Technical	Computer skills	variable
	Programming skills	none
	Attitude towards technology	variable
	Frequency of robot contact	From occasional to daily
	User type	Primary user
Typical activities	Daily basic activities (eating, hygiene, resting, pharmacological therapy, sleeping), social interactions with caregivers, relatives, and healthcare staff, possible participation in psychological or recreational support activities.	
Job characteristics	not applicable	

Table 6 - SRA caregivers characteristics

SRA caregivers		
Demographics	Age	20 to 80
	Education	From “No formal education” to “Postgraduate”
	Language	Italian
	Physical condition	Good / Moderate limitations
	Cognitive condition	Normal
	Chronic conditions	From no chronic illness to moderate
	Sensory limitations	From no limitation to moderate limitation
Technical	Computer skills	variable
	Programming skills	Generally none
	Attitude towards technology	variable
	Frequency of robot contact	From episodic to daily
	User type	Secondary users – they will be involved in the use of the implemented solution
Typical activities	Psychological and emotional support to the patient, accompanying the patient during visits or transfers within the facility, acting as intermediaries in communication between the patient and healthcare personnel, monitoring the patient informally, managing practical matters related to the patient's stay.	

Table 7 - SRA staff characteristics

SRA medical doctors		
Demographics	Age	28 - 65
	Education	Postgraduate (University degree in Medicine and Surgery with specialization in oncology or geriatrics)
	Language	Italian, English (basic to good)
	Physical condition	Good
	Cognitive condition	Good
	Chronic conditions	Not relevant
	Sensory limitations	Generally none
Technical	Computer skills	Good to advanced
	Programming skills	none
	Attitude towards technology	Generally good with focus on safety
	Frequency of robot contact	Few times per day
	User type	Primary user
Typical activity	Diagnosing, prescribing, monitoring, coordinating with nurses, communicating with patients and caregivers, reviewing data, participating in ethical and decisional discussions	

Table 8 - SRA nurses characteristics

SRA nurses		
Demographics	Age	25 - 65
	Education	Graduated
	Language	Italian, English (basic to good)
	Physical condition	Good
	Cognitive condition	Good
	Chronic conditions	Not relevant
	Sensory limitations	Generally none
Technical	Computer skills	variable
	Programming skills	none
	Attitude towards technology	Generally good with focus on safety
	Frequency of robot contact	Few times per day
	User type	Primary user



3.2.3. UC2 task identification

The following tasks have been identified for UC2 and will be investigated during the TORNADO project:

- The robot must be able to make a distinction between the role of doctors, nurses, patients and caregivers, based on visual criteria (clothing, badge, position) and adapt its behavior towards the specific role.
- The robot must be able to verify whether the people who remain in the patients' room are authorized, promoting patients' safety and privacy.
- The robot must be able to visually recognize the level of liquid in the urinary bag and warn the staff when it approaches the critical threshold (1500 ml), avoiding the risk of overflow and improving patients' comfort.
- The robot must be able to detect the residual level of the infusion liquid and warn the staff when it is close to exhaustion (about 100 cc), avoiding unwanted interruptions in therapy and reducing the nursing workload.
- The robot must be able to provide a clear and structured summary of the patient's main actions (e.g. requests, filling out scales, preferences), making them accessible to the healthcare team and the caregiver.
- The robot must be able to accompany caregivers or visitors to a specific area of the department (e.g. patient's room, exit), improving reception and orientation.

These functionalities represent a balance between technical complexity and perceived utility. Their validation will be the result of a joint evaluation between clinical and technical partners. The goal is not only to demonstrate what a robot can do, but to understand how and to what extent it can be accepted and meaningfully integrated into healthcare settings.

3.2.4. UC2 expected key contributions

At this stage of the project, TORNADO is expected to demonstrate how a cognitive robotic system can be sustainably and acceptably integrated into a clinical context involving high human sensitivity, such as a palliative care department.

The main expected key contributions are:

- Support to healthcare personnel through the autonomous monitoring of non-critical parameters (e.g. IV level, urinary bag) and the automation of simple but repetitive tasks (delivery of objects, notifications), freeing up time for activities with high clinical and empathy value (O1.1, O1.6, O2 & O3).
- Detection and synthesis of patient-robot interaction, useful for improving continuity of care, communication between teams and understanding the patient's subjective experience (O3);
- Mediation between patient, caregiver and structure, thanks to the robot's ability to adapt its behavior and accompany family members within the department, through simple interaction (O3.2, O3.3, O3.4, O3.6, O3.7 & O3.9).
- Support the analysis of the limits and opportunities of HRC in fragile contexts.
- Definition of contextual technical constraints (distance, volume, privacy) as a prerequisite for acceptability.
- Stimulation of ethical and operational reflection on the use of robotics in places of palliative care.

3.2.5. UC2 performance requirements

For UC2 the following performance requirements have been defined:

- Ability of the robotic system to adapt its behavior based on the role of the detected person (doctor, nurse, patient, caregiver), consistently with the clinical context and without evident perceptual ambiguity.
- Ability of the robot to detect unexpected or unrecognized presences in the room, activating appropriate behavior (e.g. notification, discreet warning), without interfering with privacy or creating discomfort.
- Ability of the robot to visually detect the filling of the bag and activate a warning in cases where the level exceeds a clinically defined critical threshold, compatible with the limits of visibility and ambient light.
- The system's ability to detect the approaching end of the infusion and notify nursing staff sufficiently in advance, limiting false positives and delays.
- The system's ability to aggregate and communicate in an understandable way a summary of the patient's activities via the robot (e.g., interactions, completed stairs, preferences), useful for nurses, physicians and caregivers to improve daily monitoring.
- The robot's ability to safely and clearly guide a visitor or caregiver to a destination within the department (e.g., patient room, waiting room), managing unexpected events and maintaining a reassuring interaction.

3.3. UC3 – Distribution & Waste Management

3.3.1. UC3 context

MCC Best Value (BEST) is a wholesale chain for independent retailers and food service operators. The UC will take place in the distribution center situated in Inofita, Greece. The facility handles most of the goods for the store chain. The environment is active and unpredictable, with workers walking or driving forklifts and pallet trucks. Packaging waste often ends up on the floor, and tasks like product sampling or quality checks can be requested at any time. Products come in different sizes and shapes.

An Autonomous Mobile Robot (AMR) will be deployed in the facility and specifically in the Produce Storage Area to support daily operations by assisting with quality checks and collecting recyclable packaging waste.

Challenges: The AMR will operate in a dynamic environment where workers and forklifts move constantly, and tasks such as product sampling are requested at any time. The AMR must safely navigate the space, without obstructing human workers, respond to human instructions and handle recyclable material.

There is a constant flow of incoming fresh goods, fruits & vegetables on cartons and pallets that typically leave recyclable packaging waste on the factory floor, which are dynamically and unpredictably generated.

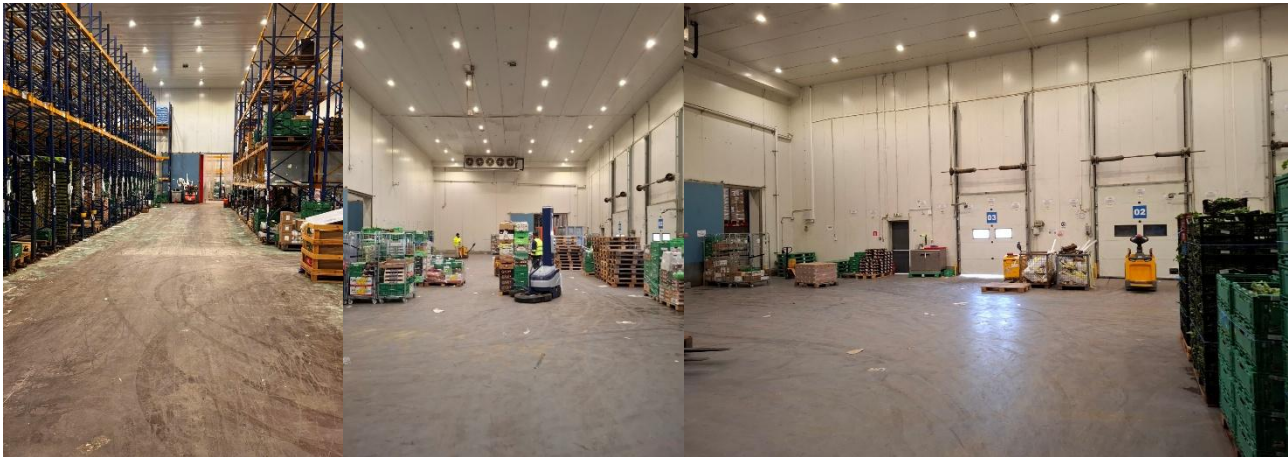


Figure 3 – Overview of the warehouse and Produce Receiving Area at MCC Best Value

3.3.2. UC3 end-users

The robot platform will interact with the various people who work at or visit the distribution center. To gain a better understanding of these groups, the following have been identified as the primary contact groups, each with their own characteristics:

- BEST employees produce storage area
- BEST other employees in the Distribution Center
- External Visitors

Table 9 - Primary BEST user characteristics

BEST employees produce storage area		
Demographics	Age	18-67
	Education	Secondary Level
	Language	Greek native English basic
	Physical condition	Good
	Cognitive condition	Good
	Chronic conditions	None
	Sensory limitations	None
Technical	Computer skills	Basic
	Programming skills	None
	Attitude towards technology	Hesitant- Positive towards new technology
	Frequency of robot contact	All day
	User type	Primary user
Typical activities	Reception of fresh goods	
	Quality control	
	Storage of fresh goods	
	Keeping the area clean and tidy	
Job characteristics	High amount of physical labor	
	A lot of walking activities	
	Processing multiple jobs per day	

Table 10 - Secondary BEST user characteristics

BEST other employees in the Distribution Center		
Demographics	Age	18-67
	Education	Secondary or Third Level Education
	Language	Greek native English basic or up to fluent
	Physical condition	Good
	Cognitive condition	Good
	Chronic conditions	None
	Sensory limitations	None
Technical	Computer skills	Basic to Good
	Programming skills	None
	Attitude towards technology	Hesitant- Positive towards new technology
	Frequency of robot contact	Incidental
	User type	Secondary user- able to familiarize with the implemented solution
Typical activities	Working in other departments of the Distribution Center like office employees or any other employee that won't be in direct contact with the robot, but may find himself in the same area with the robot	

Table 11 - Secondary external user characteristics

External Visitors		
Demographics	Age	18-67
	Education	Secondary or Third Level Education
	Language	Greek native English basic or up to fluent
	Physical condition	Unknown
	Cognitive condition	Good
	Chronic conditions	Unknown
	Sensory limitations	Unknown
Technical	Computer skills	Unknown
	Programming skills	Unknown
	Attitude towards technology	Hesitant- Positive towards new technology
	Frequency of robot contact	Very Limited
	User type	Secondary user, not able to familiarize with the implemented solution
Typical activity	Entering the area and maybe moving around it	



3.3.3. UC3 task identification

The following tasks have been identified and will be investigated during the TORNADO project:

- The robot must be able to check the floor of the Produce Storage Area for damaged products, (liquid) spills and alert the staff with the exact location to clean up.
- The robot must be able to assist the staff in the Produce Receiving Area by checking the quality of incoming fruits and vegetables.
- The robot must be able to receive instructions from the staff wearing orange vests in the Produce Receiving Area.
- The robot must be able to check product quality using its camera.
- Define quality of the received goods according to the specs for each product.
- Upon definition of quality of the products, send a report to the Quality Control Department informing them about their condition/quality.
- Receive goods from the staff in Produce Receiving Area and deliver them to nearby Quality Control Department.
- The robot must be able to collect recyclable materials from the floor and dispose of them properly.
- Detect materials on the floor and identify the recyclable materials (wood, plastic, and paper).
- Upon detecting recyclable material, the robot will collect it and place it in its carry-on basket, sorting items by material type (wood, plastic, paper).
- When the carry-on basket is defined as "full" the robot will not pick-up any other material.
- When the basket is defined as "full" the robot will move to the Recyclable Deposit Area to empty the basket.

3.3.4. UC3 expected key contributions

At this stage of the project, the TORNADO project is expected to demonstrate how it can support the Distribution Center workers with repetitive and time-consuming activities, allowing the employees to work in a more productive and efficient manner.

The expected key contributions are:

- Workers will not need to check the designated area for damaged products, themselves but will be notified when the robot detects one (O1.1, O1.3, O1.6, O3.2, O3.4, O3.6, O3.7 & O3.8).
- Assistance with the Quality Assurance process during the reception stage. If necessary, the product will be delivered to the Quality Control Department, enabling workers to continue their duties without wasting time walking back and forth (O1 & O2).
- Assistance with the Quality Assurance process for stored goods, including sampling and delivering products with quality issues to the Quality Control Department (O1 & O2).
- Supporting the workers with the collection and disposal of recyclable materials. This task is currently done by workers, so human resources will be allocated more efficiently (O1, O2 & O3).



3.3.5. UC3 performance requirements

For UC3, the following performance requirements have been defined:

1. Detecting generic obstacles and avoiding them.
2. Recognizing authorized personnel and exclusively receive instructions from them.
3. Detecting damaged products and providing the exact position to the staff.
4. Correctly defining the quality of the fruits and vegetables.
5. Receiving products and delivering them to the Quality Control Department.
6. Sending data to the staff.
7. Detecting recyclable materials on the floor and classifying them by type (wood, plastic, paper) to enable proper sorting and disposal.
 - Picking up the material and safely placing it in the basket.
 - Defining when the carry-on basket has no more available space.
 - Moving to the Recyclable Deposit Area and placing the recyclable material sorted by material type.



4. Requirements analysis

This chapter summarizes the results of the requirements analysis for each UC, based on observations, interviews, and technical assessments conducted during the initial phase of the project. The goal is to translate the operational and organizational needs identified in real-world contexts into functional specifications and technical constraints that will guide the development and integration of the TORNADO robotic platform.

For each UC, the requirements related to human-robot interaction, operators' skills and characteristics, navigation, manipulation, and perception are described, along with those common to multiple contexts, thus identifying both specific characteristics and common elements useful for defining the platform's transversal requirements. This analysis provides a structured basis for guiding the activities of subsequent WPs, ensuring that the developed solutions are realistically implementable and consistent with the intended use conditions. The complete analysis can be found in

Appendix 1: Technical Requirements Analysis.

4.1. Analysis of robot functionalities needed for UC1

4.1.1. HRI - Setup for validation & verification

To significantly increase acceptance of the developed technologies for UC1, it is essential to pay sufficient attention to the HRI of the system. With traditional robot systems, HKP employees miss feedback on what the system is doing and is going to do. Giving input is also quite cumbersome through unintuitive interfaces. Ideally, HKP employees would prefer to interact through speech or a wearable device, as environmental noise can sometimes be high. Overall, there is a need for a more intuitive HRI. Therefore, as well as being technically functional, the HRI also needs to be perceived as reliable and advantageous by operators, thereby supporting productivity, safety, and work quality. This will be validated by meeting the defined performance requirements.

Necessities

- Defining how the operators want to assign tasks to the system, whether through gestures, speech or other communication methods.

4.1.2. Navigation - Setup for validation & verification

The shipping department roughly measures 224m² with a minimal pathwidth of 0,8m and the average transport distance is between 0 and 5m. The workspace is organized with 2 fixed tables and multiple fixed warehouse storage racks. The products that pass through the shipping department are placed on pallets on the ground and their position on the floor changes daily.

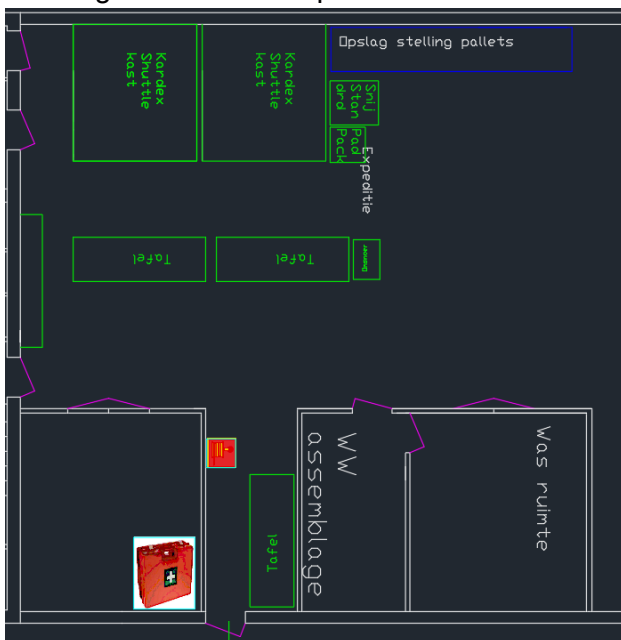


Figure 4 – Map of the shipping department at Hankamp Gears

Necessities

- 2D/3D lidar mapping of the work area
- Videos and RGBD images of the complete navigation area.

4.1.3. Manipulation – Setup for validation & verification

The products that need to be grasped are:

Table 12 – UC1 product specifications

	Gears	Oil Paper	Foam wrap	Cardboard box
Length	Ø5mm up to Ø400mm	Up to 1,5m	Up to 1,5m	Up to 500mm
Width	Ø5mm up to Ø400mm	Up to 0,5m	Up to 1m	Up to 500mm
Height	5mm up to 300mm	0,5mm	5mm	Up to 500mm
Weight	5 grammes up to 10 kg	5 grammes up to 500 grammes	5 grammes up to 500 grammes	200 gram up to 1kg
Fragility	Scratches easily	N/A	N/A	N/A
Shape retention	Solid	Limp	Limp	Semi solid

Necessities

- Photos of the objects that need to be recognized.
- Gripper must have a minimal payload of 10kg.
- Robot arm must have a minimal reach of 500mm.
- Robot arm must have a minimal lifting capacity of 10 kg excluding gripper weight.

4.1.4. Perception - Setup for validation & verification

For this UC, extra attention has to be paid to the perception of the working environment, due to the limited maneuvering space and pallets that vary in height. It is necessary for the robotic platform to be aware of itself and ensure that it will not bump into anybody or anything in its surroundings.

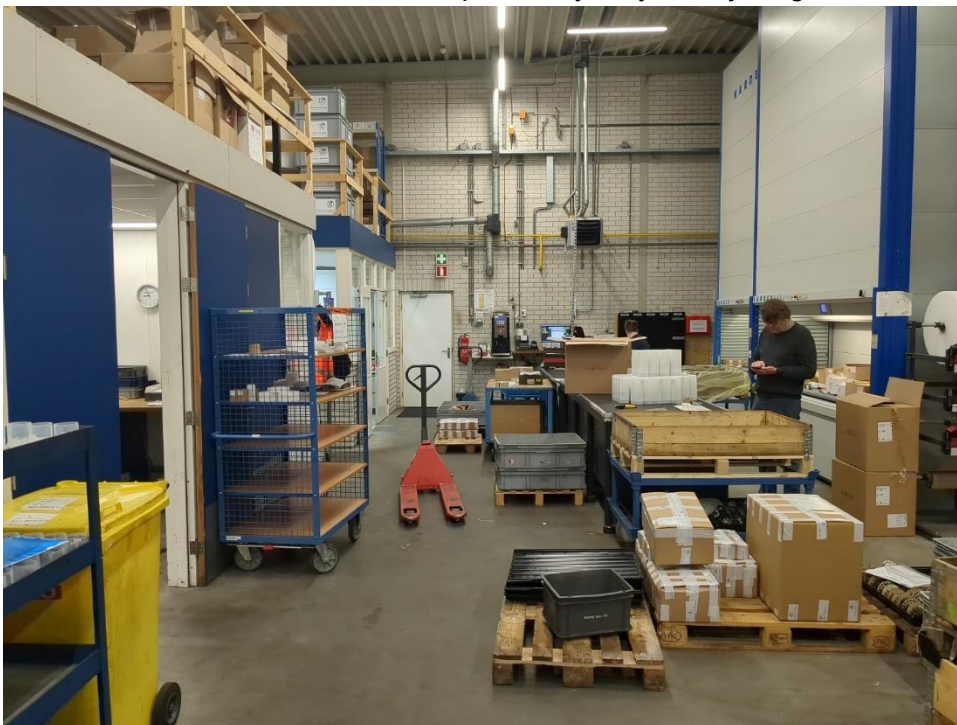


Figure 5 – Example of a variety of obstacles in the shipping department



4.2. Analysis of robot functionalities needed for UC2

4.2.1 HRI - Setup for validation & verification

HRI plays a central role, as the implementation environment is a palliative care unit, where sensitivity, empathy, and clear communication are essential. The interaction model must be designed to respect the emotional state, privacy, and dignity of patients and their families, while ensuring that healthcare personnel consider the robot as a reliable and non-invasive support tool. The requirements presented in this section focus on the robotic system's ability to recognize and adapt to different user roles, respond appropriately to verbal and non-verbal stimuli, and operate fully integrated into a human-centered workflow. The goal is to ensure that the robot not only performs assigned tasks but also integrates seamlessly into the interpersonal dynamics and routines of the clinical setting.

Necessities

- Defining how the operators want to assign tasks to the system whether through gestures, speech or other communication methods.
- Photos of the clothing that need to be recognized.



4.2.2 Navigation - Setup for validation & verification

For UC2, the navigation area includes the corridor of the palliative care unit and the room where the robot has to interact and collaborate with the patient, the medical professionals and the caregiver, and it has to manipulate the objects. The robot will have to adapt its navigation to overcome people's movements and avoid collisions. Moreover, the robot will be able to accompany or guide people in this area.

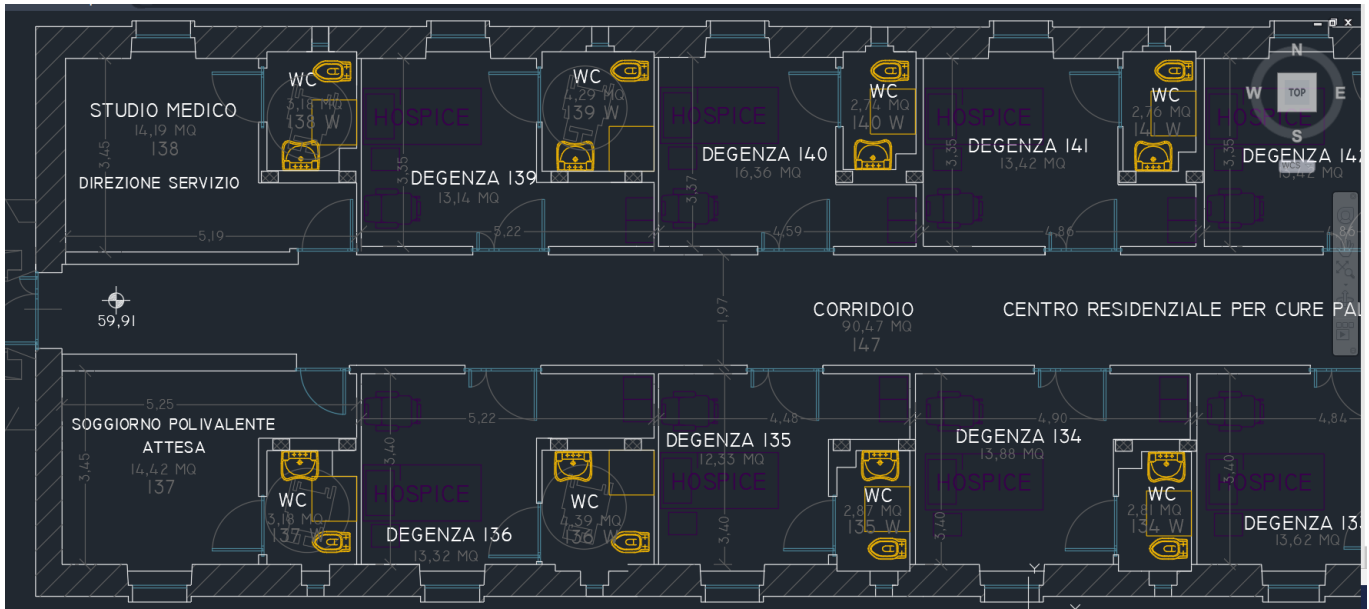


Figure 6 – Map showing a section of the hospice department at San Raffaele

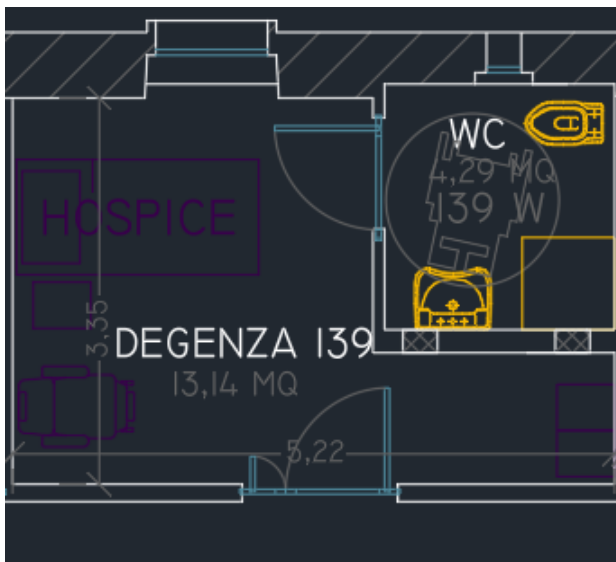


Figure 7 – Detailed view of a typical patient room at San Raffaele

Necessities

- 2D/3D lidar mapping of the work area.
- Videos and RGBD images of the complete navigation area.

4.2.3 Manipulation - Setup for validation & verification

The products that need to be grasped are:

Table 13 – UC2 product specifications

	Water bottle	Mobile phone/ TV Remote	Empty iv drip bag
Length	Ø60 mm	160 mm	300 mm
Width	Ø60 mm	75 mm	170 mm
Height	200 mm	8 mm	10 – 20 mm
Weight	0.5 kg	0.2 kg	0.05 kg
Fragility	Deforms under high force	Scratches easily	Deforms under own weight
Shape retention	Semi solid	Solid	Limp

Necessities

- RGB images and point cloud data of the objects that needs to be recognized.
- Grasping points of the objects to be manipulated.
- Gripper must have a minimal payload of 1 kg.
- Robot arm must have a minimal reach of 700 mm.
- Robot arm must have a minimal lifting capacity of 2 kg, excluding gripper weight.

4.2.4 Perception - Setup for validation & verification

The robot requires perception sensors in order to operate effectively within the palliative care unit. These sensors enable the robot to navigate the environment, interact with patients and caregivers, collaborate with healthcare professionals, and manipulate objects safely and efficiently. The sensors will be strategically positioned in different parts of the robot based on the specific requirements of each task.

Different types of sensors will support various activities, including navigation, interaction, collaboration, and object manipulation. The list below outlines the minimal amount of sensors required:

- Sensors: One force and torque sensor in each robot arm.
- Lidars: One 2D lidar and one 3D Lidar.
- Cameras: RGBD camera from an ego centric point of view, one RGBD camera in the front and one RGBD camera in one of the wrists of the robot arms.



4.3. Analysis of robot functionalities needed for UC3

4.3.1. HRI - Setup for validation & verification

HRI is essential to ensure the system can operate in a dynamic logistics and production environment, characterized by the constant presence of operators, forklifts, and goods handling. The robot must be able to quickly recognize authorized personnel, correctly interpret instructions provided, and respond efficiently, minimizing the risk of interruptions or slowdowns in operations. The requirements described in this section focus on the system's ability to integrate into daily workflows, communicate clearly and intuitively, and maintain fluid interaction even under complex operating conditions or with multiple interlocutors simultaneously. The goal is to ensure that the HRI is not only technically functional but also perceived as reliable and advantageous by operators, supporting productivity, safety, and work quality, as will be validated via the satisfaction of the defined performance requirements.

Necessities

- Defining how the operators want to assign tasks to the system (whether through gestures, speech or other communication methods).
- Photos of the clothing that need to be recognized.

4.3.2. Navigation - Setup for validation & verification

The area included in the yellow frame (Produce Receiving Area) is where the fresh goods are received from the suppliers and Quality Control takes place. The goods are then stored in the area with the green frame (Produce Storage Area). The area where the recyclable materials will be disposed is shown in orange and is part of the Produce Receiving Area.

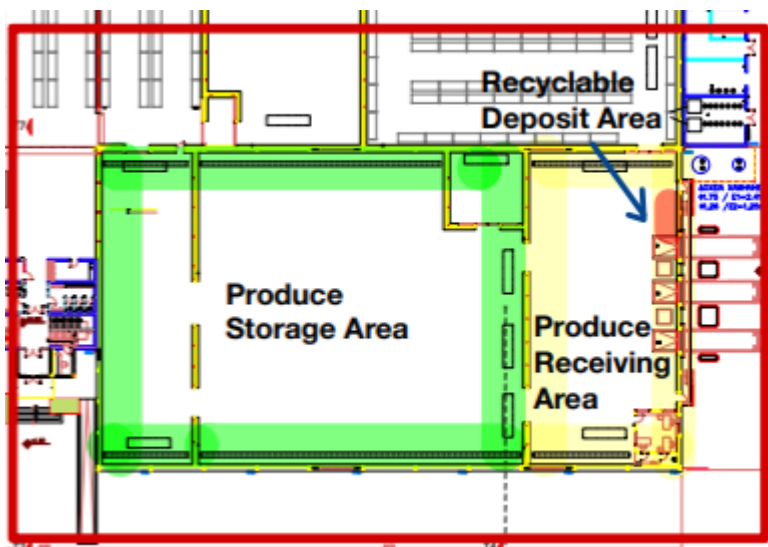


Figure 8 – Map showing the produce storage and produce receiving area at MCC Best Value

Necessities

- 2D/3D lidar mapping of the work area.
- Videos and RGBD images of the complete navigation area.



4.3.3. Manipulation - Setup for validation & verification

Table 14 – UC3 product specifications

	Recyclable waste	Apples	Oranges	Tomatoes
Length	50 - 1000 mm	77-87 mm	75-85 mm	>50mm
Width	50 – 1000 mm	77-87 mm	75-85 mm	71-85 mm
Height	50 - 500 mm	77-87 mm	75-85 mm	71-85 mm
Weight	0,005 -5kg	0,07 – 0,3kg	>0,18kg	>0,2kg
Fragility	Depends on the waste type. In general their shape and size is irregular	Deforms and bruises easily under low force	Deforms and bruises easily under low force	Deforms and bruises easily under low force
Shape retention	Depends on waste type	Limp	Limp	Limp

Necessities

- RGB images and point cloud data of the objects that need to be recognized.
- RGB images of good & damaged products that need to be recognized.
- Grasping points of the objects to be manipulated.
- Gripper must have a minimal payload of 5 kg.
- Robot arm must have a minimal reach of 1 mm.
- Robot arm must have a minimal lifting capacity of 5 kg excluding gripper weight.

4.3.4. Perception - Setup for validation & verification

The AMR for UC3 needs to be equipped with various perception sensors in order to be able to perform defined tasks in a safe and secure way:

- Lidars: One 3D Lidar for navigation and two 2D Lidars for safety functions of AMR platform.
- Camera: One RGBD forward-facing camera on the AMR platform and one RGBD camera near gripper on the end of robotic arm.



4.4. Platform requirements

To combine the individual UC requirements together into cross-UC platform requirements, the different requirements were compared resulting in the following list of minimal requirements:

Minimal requirements

- Omni directional drive for increased maneuverability
- 3D view to map its surroundings at least in the direction of travel
- 3D view to increase the probability of picking up goods in the right orientation
- A human machine interface to communicate with its surroundings
- Possibility to add additional sensors
- Wi-Fi and RJ45 connection (internet connection)
- Emergency stop at least at the AMR
- Robot Operating System (ROS)
- At least one 6 DOF robot arm
- 3D lidar (navigation)
- 2D lidar (safety)
- Stereo camera at platform
- Stereo camera on the robot arm
- UC specific gripper design
- Corresponding dimensions and weight for good maneuverability in designated areas
- Operating temperature minimal range: 0 to 40 °C
- Maximum width: 800 mm (usual door width is 800 mm)

4.4.1. Computation

Requirements

- Perception sensors will run on internal and external CPUs and GPUs.
- Foundation models will run on an external GPU with at least 48 GB memory (for example RTX 6000).
- Real-time manipulation: kernel and connection to robot.
- For Sound & Language Manager Module (if On-AMR (edge)):

Table 15 – Sound & Language Manager Module specifications On-AMR

Area	On-AMR (Edge) – Minimum (SLOW)	On-AMR (Edge) – Recommended	Notes
CPU	6 cores (x86_64 or ARMv8), ≥ 2.0 GHz	8–12 cores, ≥ 2.4 GHz	Concurrency: 1–2 audio streams
GPU / NPU / TPU	Optional; if CPU-only, use int8/int4 models and streaming	NVIDIA Jetson Orin NX (≈ 70 TOPS) or RTX A2000-class	Needed if you want local LLM (e.g., DeepSeek-R1-Distill-Qwen-1.5B) to stay $< 1-2$ s
RAM	16 GB	32 GB	Buffers for ASR streaming
Storage	128 GB SSD	512 GB NVMe	
OS / Runtime	Ubuntu 20.04/22.04 LTS (64-bit), Docker 24+, Python 3.10+	Same + NVIDIA CUDA	Containerized microservices
Middleware	ROS 2 (Humble/Irons), gRPC or WebSocket for streaming, REST for control	Same	ROS-agnostic API facade for partners
Networking	Ethernet OR Wi-Fi 6/6E; LTE/5G optional	Ethernet OR Wi-Fi 6/6E; LTE/5G optional	Round-trip target to cloud < 100 ms
Audio I/O	4–8 mic array, 16–48 kHz, ≥ 60 dB SNR	Same	USB or similar mic array; far-field optimizations
APIs (our solution)	/asr/stream (PCM16 16 kHz), /nlp/parse (NER/SRL), /sentiment, /spk/verify, /esc (sound events), /dialogue/respond, /tts/synthesize	Same	

- For Sound & Language Manager Module (if cloud/API):

Table 16 – Sound & Language Manager Module specifications cloud/API

Area	Cloud/API – Minimum (SLOW)	Cloud/API – Recommended
CPU	4 vCPU	8–16 vCPU
GPU / NPU / TPU	Optional	T4/A10/A100-class GPU for LLM/ASR burst
RAM	16 GB	32 GB
Storage	50 GB	200 GB
OS / Runtime	Linux x86_64, Docker + NVIDIA CUDA	Same
Middleware	REST/gRPC ingress with TLS	Same
Networking	Public cloud or on-prem	Same
Audio I/O	—	—
APIs (our solution)	Same	Same

4.4.2. Batteries

Requirements

- Sufficient battery capacity or a connection to plug in a permanent power supply.
- The battery of the mobile base can also support the robotic arm.
- Possibility to power external devices at 12V and 24V.

4.4.3. System communication

Requirements

- **Edge Gateway**
 - FIWARE-based communication system standardizing robot–HMI–cloud communication.
 - Provides APIs, data aggregation, and routing.
 - For the communication among the components, the edge gateway supports technologies such as Wi-Fi, optional 5G.
- **Network Infrastructure**
 - Wi-Fi (baseline): reliable communication for all robotic tasks.
 - Private 5G (optional): provides deterministic low-latency paths for time-critical operations.
 - Private 5G requires that each Use Case (UC) obtains the necessary government-issued licenses. Robotic platforms require additional hardware to enable 5G connectivity.
- **Robot-Edge Communication**
 - The FIWARE-based edge gateway serves as the central hub, aggregating and managing all robot data.
 - Wi-Fi provides reliable bandwidth for telemetry, sensors, actuators, and camera data.
 - Optional private 5G enables deterministic, low-latency communication and enhanced reliability for critical operations.
- **Edge-HMI Communication**
 - Operator HMI devices communicate with the FIWARE edge gateway via the private network (Wi-Fi or optional 5G) for monitoring and control.
 - Low-latency communication shall allow human-in-the-loop interaction with minimal perceptible delay.
- **Edge-Cloud Communication**
 - The edge gateway connects to the cloud infrastructure primarily via Wi-Fi.
 - Optionally, a private 5G link may be used for enhanced reliability and deterministic low-latency communication.
 - If the cloud is external, the communication shall traverse the Internet using a secure VPN tunnel to ensure confidentiality and integrity.
- **Near Real-Time Communication**
 - Robotic platforms' onboard PCs shall support deterministic real-time control loops at approximately 1 kHz update rate to ensure precise and stable operation.
 - Communication between the robotic platforms and the edge gateway shall maintain low latency and minimal jitter to support reliable autonomous operation.
- **Security**
 - End-to-end post-quantum encryption.

4.5. Discussion of end-user requirements

In this first version of the end-user requirements the emphasis lays on:

- Identification of problems/challenges for each specific UC.
- Technical analysis of the working environment.
- Defining the user profiles as part of the human-centered design principle.

Identification of problems/challenges

Since the three UCs' companies operate in three entirely different market segments, it was expected that some of the core problems would be UC-specific. For example, for UC1, a gear manufacturing company, handling deformable objects in a highly dynamic environment with limited space to maneuver poses a crucial problem. For UC2, which takes place in a palliative care ward, the introduction of a robot into a human-only environment presents unique challenges. For UC3, a Supermarket distribution center, the difficulty lies in recognizing different types of waste and spills and defining the quality of incoming goods.

However, some problems transcend the individual UCs.

- Human-robot interaction
- Human-robot bilateral communication
- How to react to "unpredictable" human actions
- How to program/assign tasks to the system
- Manipulation of soft deformable objects
- Recognizing and classifying task-related parts/products
- Recognizing and classifying users to ensure the right tasks are offered to each user

These UC transcending problems matter due to the variety of companies, because if they occur in these three companies, they most likely also occur in others as well. Therefore, addressing these problems solves not only the problems for the individual UC companies, but also those for future integrations in other companies and market segments.

Technical analysis of the working environment

Each UC filled out a technical requirements analysis questionnaire which focused on a variety of topics. Starting with the general characteristics such as working area and UC description, it gradually moved onto system details like HRI, product specifications and finally to system relevant inputs such as safety, navigation and perception. This resulted in three documents detailing the characteristics specific to each UC. After analyzing the individual documents, the UC owners and the research partners involved compared all three documents. This was done to identify commonalities between the three different UCs, in order to define the minimal platform requirements as discussed in paragraph 0. This forms the starting point upon which the other WPs will build the TORNADO platform.

Defining the user profiles

While the first version of the end user requirements places a strong emphasis on identifying problems in each UC and analyzing the technical aspects of the UCs, this also identifies the users of the system for each UC. The aim is to outline these users and their relation with the robot. To ensure a high degree of acceptance during the pilot sessions, the final version of the end-user requirements will further investigate the users and their attitude towards robots.

5. Summary and outlook

This first version of Deliverable D2.1 systematically collected and organized end-user requirements for the three TORNADO project use cases (UCs). This process enabled us to document the operational context of each partner, identifying the functional needs relating to specific manipulation, navigation, perception and human-robot interaction tasks, as well as the environmental, ergonomic and ethical constraints influencing the implementation of advanced robotic solutions.

For each UC, we identified the expected contributions and performance requirements in line with the Grant Agreement guidelines. It should be noted, however, that these will need to be further quantified, validated, and adapted to real-world operating conditions if necessary. Common elements also emerged across the three scenarios, enabling us to define an initial set of cross-platform requirements to guide the development and technological integration of subsequent work packages.

This work also provided an opportunity to strengthen the connection between the requirements gathering and analysis phase (WP2) and the development activities planned in WPs 3–6, thereby ensuring that the design and integration of the TORNADO platform are guided by concrete, measurable needs. At the same time, focusing on human-centered design aspects and ethical and regulatory implications lays the foundation for the sustainable and acceptable adoption of robotic technologies in various application contexts, particularly in highly sensitive settings such as palliative care. In the next phases, the requirements outlined here will be explored and validated further through controlled experimentation, laboratory testing and field evaluations. These activities will enable us to refine and consolidate the specifications, update the performance requirements, and verify the technical and operational feasibility of the proposed solutions. The aim is to produce the final versions of deliverables D2.2–D2.6, providing a clear, shared and tested overview of the functionalities of the TORNADO platform, ready for implementation and evaluation in the real-world contexts of the three UCs.

Appendix 1: Technical Requirements Analysis

UC1 – Hankamp Gears

1. General Descriptions		
Company Name	Hankamp Gears B.V.	
Location (City/ Country)	Enschede, The Netherlands	
Date (DD/MM/YYYY)	3-2-2025	
Questionnaire filled by:	Name/Surname	Pim Siahaya
	Affiliation	Project manager Automation & Digitalization
Provide a brief description of the working area:	Shipping department, highly dynamic due to a lot of movement by people, pallet trucks and forklifts but also frequently changing of pallet locations available products, etc., concrete floor without coating	



Provide a photo of the working area:



Provide a brief description of the use-case:

Manipulation of gears (small/ light & large / heavy) and deformable ply-sheets handling

Provide a brief description what needs to be improved/ what is the aim of the robot implementation?:

A mobile collaborative robot with dexterous loco-manipulation skills that is able to grasp and handle a wide variety of small and varying sized gears and handling of deformable ply-sheets of different sizes at the shipping department



Provide a brief description of the sub-tasks (if applicable):	a) pick up small and delicate gears from (form fit) blisters without damaging the product; b) grasp larger and heavier gears from the transportation crates and support the human workers by placing them on a table (where the worker can prepare the gear for transport; c) make product sets together with one of the workers; d) manipulate (grasp, orient, and place) correctly the deformable ply sheets (that vary in shape and deformation) in-between the gear layers. e) counting the amount of gears that are being shipped as an extra check
What could be the main contribution of TORNADO? Please specify e.g., full automation of a process, HRC, learning from humans, etc.)	Advancement in the dexterous loco-manipulation skills of collaborative robots by incorporating techniques among others vision, machine learning, etc.





2. Interactions & Expectations

Users						
Which users are involved with the robot, how often and does this happen direct or indirect?	User	Age	Education	Language	Frequency of contact	Contact type
						Direct
	- Employees shipping department	30-50	Secondary vocational education	Dutch/English	Always	End user
	- Other employees entering the shipping department	16-67	Secondary vocational education upto Academic education	Dutch/English	Daily	Bystander, who is able to familiarize with the robot
	- External visitors	21-70	Secondary vocational education upto Academic education	Dutch/English	Incidental	Bystander, who is unfamiliar with the robot
	- Automation/Maintenance engineer	21-67	Secondary vocational education upto Academic education	Dutch/English	Incidental	Expert who is technically familiar with the robot
	- Software developers	21-67	higher vocational education upto Academic education	Dutch/English	Incidental	Expert who is technically familiar



						with the robot
Which sub task involve human - robot interactions?	Intervention 1 - Learning by doing when the human shows the activities that need to be executed					
	Intervention 2 - Communication between robot and employee when the employee and the robot collaborate handling heavy gears					
	Intervention 3 - When the employee and robot work together to create product sets					
	Intervention 4 - Interaction between the human and robot when the human or robot needs to pass					
	Intervention 5 - When a human intervenes with the robot in case of error handling					
Are there activities which are not allowed to be done by the robot?	No, in general not.					
Should the robot be able to work unattended?	Yes	Partially				No
	X					
Human to Robot						
How do you want to program the robot?	Programming by demonstration	Programming by guidance	Block based programming	Traditional programming	Other:	
	X					
How do you want to give an assignment to the robot?	Through speech	Through hand gestures	Through a wearable	Through push buttons	Other:	
	X	X	X			
How do you want to be able to interfere with the robot if	System error handling	Through speech	Through hand gestures	Through a wearable	Emergency button	Other:



something goes wrong (not life threatening)?	X	X	X	X		
Robot to human						
How should the robot confirm it understood the assignment?	Through facial expression	Through speech	Through a wearable	Through text	Through light/ sound signals	Other:
	X	X	X	X	X	
How should the robot respond when the assignment is done?	Through facial expression	Through speech	Through a wearable	Through text	Through light/ sound signals	Just stop
	X	X	X	X	X	
How should the robot make clear what it is doing or going to do next?	Through facial expression	Through speech	Through a wearable	Through text	Through light/ sound signals	
		X	X	X	X	
How should the robot respond if something goes wrong?	Through facial expression	Through speech	Through a wearable	Through text	Through light/ sound signals	Just stop
		X	X	X	X	
Should the robot be able to start a conversation/ social talk?	Not, required but it would be cool					
What is the aim of the conversation?	Asking truck drivers how they can be helped in Dutch, English, German or Polish and giving basic answers and in worse case informing the operator to help					
Expectation management						
	Flawless system	System with minor flaws	System with major flaws	Proof of principle		

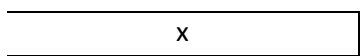
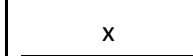
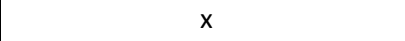
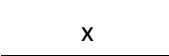
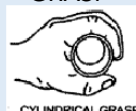


What level of maturity do you expect from the robot programming module		X				
What level of maturity do you expect from the object recognition module	Flawless system	System with minor flaws	System with major flaws	Proof of principle		
			X			
What level of maturity do you expect from the conversation module	Flawless system	System with minor flaws	System with major flaws	Proof of principle		
			X			
What level of maturity do you expect from the error handling module	Flawless system	System with minor flaws	System with major flaws	Proof of principle		
		X				
What level of battery life do you expect from the robot system	>8 hours	8 hours	4 hours	<1 hour		
		X				



3. Components to be handled				
How many different components and assembled parts are handled in the respective sub-task?	Depends on the shipping task, from 2 to 10 components.			
This is about the number of different shapes that must be handled. Two components with the same shape or a component that is handled several times are counted only once. Example subprocess "assembly of a shaft": The shaft is picked up and two identical ball bearings are mounted = shaft + ball bearing = 2 components are handled."	Product (Gears, many variants) Oil paper Anti rust spray Foam wrap Cardboard wrap Cardboardbox Pallet			
What is the min-max component weights that are handled?	Min. [Unit: kg]		Max.	
Add up the weight of the products, packaging and filling material if they are handled jointly. Otherwise rate the component with the highest weight.	0,005		10	
What is the min.-max. dimensions of the component that are handled?	Min. (L x W x H) [Unit: mm]		Max. (L x W x H)	
Add up the height of the products, packaging and filling material if they are handled jointly	5x5x5		500x500x500	
How fragile are the components? Are components susceptible to optical or functional impairments?	Highly fragile, Impairment due to careless handling	Impairment due to the application of a small force	Impairment due to the application of a high force,	Solid (no impairment due to force application)
	x	-	x	x
	Comment			



	 The gears are solid but can be scratched easily The paper, foam and cardboard can be easily damage when applying high forces or improper handling				
Do the components retain their shape despite the application of process forces? Do the parts deform solely due to the influence of gravity or weight forces?	Limp Deformation under low force	Deformation under force	Deformation under high force	Solid	
					
	Comment				
	Gears are solid Some cardboard/plastic blister deform under (high) force Paper and foam wrap deform under low force				
Can the components be gripped easily? Are there clearly defined surfaces for gripping?	CYLINDRICAL GRASP  CYLINDRICAL GRASP	TIP  TIP	HOOK or SNAP  HOOK or SNAP	PALMAR  PALMAR	SPHERICAL  SPHERICAL
					
	Comment				
	All products can be grasped easily main diffculty lies in the varianion in shape, size, weight and way of packing				
	In general all products are oil/ grease free				



How slippery the components are while grasping?			
Are the components statically positioned? Are they placed on a moving conveyer or similar? In the latter case, what is the speed range of the conveyer?	Statically positioned		
Are the 3D models of the components available? (e.g., product CAD)	YES	NO	
	X		
	Comment (If yes, please provide the name of S/W)		
	T.b.d.		
What is the typical lot size? (i.e., number of parts per lot)	Min. (L x W x H) [Unit: mm]	Max. (L x W x H)	
	100pcs. 5x5x5	50pcs. 500x500x500	

4. Navigation /transportation					
What is the min.-max. transportation distance between pick/place locations?	Min. [Unit: m]			Max.	
	0			5	
What is the min.-max. load weight to be transported?	Min. [Unit: kg]			Max.	
	0,005			10	
Are there static and/or dynamic obstacles (including humans) on the path of transportation?	Static			Dynamic	
	x			x	
	Comment (If there are static ones, is it possible to construct a map of the environment or is the environment dynamically changing?)				
	There are 2 tables standing in the middle of the area and it is possible to construct a map of the environment				
	Flat ground	Slopes	Stairs	Cabling	Rails



What is the ground level condition along the task trajectory? (explain the details; roughness, inclination, material, height, falls, even/uneven, change in the height of the flooring.)	x			x	
	Comment				
	Concrete floor, no coating, sometimes cables are temporarily lying on the floor for water or electricity (shouldn't be run over)				
What is the best way of transporting a component in workplace?	Via robot gripper at all times (light and easily graspable objects)	Manual loading on mobile based, robotic transportation, and manual unloading	Collaborative loading on mobile based, robotic transportation, and collaborative unloading	Autonomous loading on mobile based, robotic transportation, and autonomous unloading	
	x				
How often this transportation task is performed? (Choose one, and put a number)	Minute	Hour	Day	Week	Month
		5			
	Comment				
In what speed the transportation is performed?	Very Slow	Slow	Medium Speed	Fast	Very Fast
			x		
	Comment				
	Walking speed so +/-5km/h				
What is the minimum clearance of the transportation path?	Width [Unit: mm]			Height [Unit: mm]	
	800mm (pallet width)			5000	
Are there static markers on the floor or ceiling? (In case of the use of markers for navigation)	YES			NO	
				x	
	Comment (If no, can we place markers in the workspace, otherwise?)				



	Yes, markers can be placed			
	Operator	Crane	Carrier	etc.
	x	x	x	-
Explain how pick/place operations are performed?	Comment			
	Depends heavy parts without pallet are handled by crane or forklift, heavy parts with pallet are handled with the pallettruck/ forklift and all goods below 25kg's can be done by the operator			
Is the path of transportation always the same?	YES		NO	
			x	
	Comment (If yes, is the direction defined (forward/backward or lateral)?)			
	No position of pallets change, people are walking also in that area so during the day a transportation path may change slightly			
Are maps or other relevant data (system layout CAD) available?	YES		NO	
	x			
	Comment (If yes, please provide the name of S/W)			



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A CAD drawing is available



Are there any restricted areas (where robots can't pass through)?

Yes, the entrance door for the truck drivers

Sketch the spaghetti chart (operators' paths in the workspace)



5. Manipulation					
What are the maximum force levels for the manipulation tasks?	Max 25 kg's				
At which speed are the manipulation tasks performed? Pieces/minute? (in Human Scale)	Very Slow	Slow	Medium Speed	Fast	Very Fast
				6 pcs/minute	
	Comment				
How much is the maximum Cartesian translation/rotation displacement at endpoint (operators' hand)?	Translation [Unit: mm]		Rotation [Unit: deg]		
	300		+90 and -90		
Does this process need the modulation/tuning of robot Cartesian impedance during the execution of the task?	YES		NO		
	Comment				
What is the worst state of orientation that currently occurs in the respective subprocess?	Precise order		2D Mixed	3D Chaotic	
				x	
	Comment				
How often this manipulation is performed? (Choose one, and put a number)	Minute	Hour	Day	Week	Month
		30			
	Comment				
In which direction the task (assembly, mounting) is performed?	Straight line from side		Straight line from above		Not a straight line / other (specify)
					x
	Comment				
	Combination of slight rotation and linear movement				
	<0.5mm		≥0.5 and <1mm		≥1mm Other (specify)



What range describes the tolerance limits of the sub-task?			x	
	Comment			
	The most difficult one is to fit gears in a plastic tube which is slightly larger (3mm clearance) then the gear itself			
What is the feeding orientation of manipulation objects?	Random	Arranged in a layer	Arranged in fixture	
		x		
	Comment			
	Depends a little bit on the type of product most are stacked in blisters, some are lying on a pallet and some have formfit blisters.			
Are there repetitive actions in this subprocess? If yes, what is the execution frequency?	Yes		No	
	x			
	Specify the frequency			
	1 per minute			
Are there any constraints on the working range of the robot? Please specify				
Are there actions in which large-range changes in postures over the course of the task (e.g. walk to crawl, bend, stand, sit, etc.)? If yes, how these	Yes		No	
			x	



actions are combined with the motion in interaction (with objects, environment or both).

Mainly standing



6. Human Perception and Tracking

Can a human skeleton be observed by an external camera?
(e.g., obstacles such as desks may block the view)

Yes, but a desk and other people can block the view

Wearable Suit

Ground-mounted camera

Ceiling-mounted camera





Which human pose tracking technology seems to be most suitable?	x				x	
	Reason?					
	The least amount of interference by other people walking in the same area					
How mobile is the human during the execution of the task? Can force-plates or sensor-insoles be used to measure ground reaction forces?	At the moment rather mobile, most likely sensor insoles are the best solution					
Can wearable sensors such as EMG electrodes be attached the human body? Explain what body parts would be engaged in sensory measurements.	Emg electrodes can be used, for back, armmuscles, leg muscles					
How many people will be working in the same task? Is multi-person tracking required?	2 max.					
How predictable and repeatable are the human movements?	Quite predictable as multiple products of the same order have to be prepared for shipment					
What is the maximum size of the workspace that can be tracked?	Length [Unit: m]		Width		Height	
	5		3		5	
	Comment					
Is the measurement of interaction forces needed? How?						
How are the lighting (source, brightness, color temperature, direction) conditions?	Source	Brightness		Color temp.	Direction	
	LED				From ceiling to the ground	
	Comment					



Is the human wearing any fixed equipment in which sensors could be embedded? Working boots, helmet, etc.	Working boots, sometimes an exo skeleton
Is a wearable metabolic system (face mask, heart rate chest belt) compatible with the work tasks?	Could be
Explain the environment around the worker; dirt, moisture, noise level(dB), magnetic interference and radio interference (objects, materials and other wireless systems).	Just noise and wifi



7. Item perception				
How is the lighting condition for the visual perception? (source, brightness, colour temperature, direction)	Source	Brightness	Color temp.	Direction
	LED			From the ceiling to the ground
	Comment			
What is the variability of the components to be detected through vision? This is to understand if template matching algorithms can be used effectively.	One type only	Few distinguishable types	High variation and high mix	
		x	x	
	Comment			
	Within one order a few items are used, between the different orders a high variation and high mix is possible			
How dynamic is the working environment for the sub-task?	Structured environment	Semi-structured with minor variability	Highly dynamic and varying scenes	
		x		
	Comment			



How much is the position tolerance (are parts exactly in the same place and orientation?)	<0.5mm	≥0.5 and <1mm	≥1mm	Other (specify)
			x	
	Comment			
	Entirely depends on the geometry of the product			
Overlapping and occlusions (are parts clearly separated and completely visible?)	Depends on the viewing angle, but in general yes			
Explain the cleanliness of parts and environment (dust, fumes, etc.)	Clean as the products are ready to be shipped to the customer			
Is there any issue in handling many sensor devices and robotic platforms in the same environment? (connections etc.)	Not necessarily			



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8. Safety		
If sharp-edged or pointed components/tools must be handled, would the use of a robot change the risk of cutting, shearing, clamping or crushing for the human?	Yes, the risk would change as the robot or human or both should be aware of each others presence	
Assume that the subprocess would (partly) be taken over by a robot. Is there a danger of collision in the head/neck area?	As long as the robot stays below that region not.	
Assume that the transportation would (partly) be taken over by a robot. Is there a danger of collision with human on its path?	Yes, people would walk and work in the same area as the robot	
Assume that the considered sub-process is (partly) taken over by a robot. Are further safety precautions to be taken? (e.g., high speed, large impacts, large range of motion, working close to/at the range of motion limits, etc.)	As previous items would take care of most safety issues, most likely not.	
If heavy objects/tools must be handled, could it be dangerous if they tip over/fall against the human?	Depends on the weight of the product and robot, but in general yes	
Is there any situation in which safety equipment is needed? (safety shoes, gloves, protective glasses)	Yes	No
	x	
	Comment (If yes, please specify the type of protective clothing worn)	



	Safety shoes, hearing protection, sometimes safety glasses and gloves
Which is the main safety risk associated to robotic system within the workspace?	Collisions with the human/ unpredictable behaviour in a crowded work area





9. Physical Ergonomics					
What body parts are involved and what is the level of loading?	Very low	Low	Medium	High	Very high
			x		
	Comment				
	From the shoulders down to the toes				
What is the portion of the “loaded” vs “unloaded” phases (time duration) of the task for the human operator?	Loaded (0 - 100%)			Unloaded	
	50%			50%	
	Comment				
What are the main causes of risks to human health? (Examples: Handling high weights, high range, monotony, repetitiveness, other hazards, working in the extreme postures...)	High weight, repetitiveness, monotony				
Are there other external hazards? (e.g. noise, extreme temperatures, vibrations, PPE, psychological factors, machine driven work rate, etc.)	Noise				
How much does awkward positioning of arms or hands decrease, especially movements that require odd angles? (answers in percentual)					
How often the human operator takes breaks during a work shift which includes risky actions?	Minute		Hour		Day
					1x
	Comment				



	30 minutes lunchbreak, and a few restroom breaks	
What is the weight of the objects lifted manually (maximum and average)?	Max. [Unit: kg]	Avg. [Unit: kg]
	25	10





10. Task Execution and Performance				
	Total cycle	Setup	Inspection	Idle/Waiting
What is the Index time [Unit: sec]				
What is the number of operators per shift?	3			
How many parallel and serial sub-processes can be identified?	None as one operator handles one order at the time			
Can overlapping of the activities contribute to the reduction of the cycle times and how?	If the robot would assist yes			
Assume that the considered subtask is (partly) taken over by a robot. How high are the requirements for repeatability?	High: assembly operations (joining, screwing, clipping, ...) with high accuracy requirements	Medium: handling operations with medium accuracy requirements	Low: treatment operations (coating, painting, ...) with low accuracy requirements)	
	x			
	Comment			



How much is the closeness of agreement between several positions reached by the robot's end-effector for the same controlled position, repeated several times under the same conditions?					
Overall, how would you regard a possible automation impact on task execution and generic performances?	Beneficial	Challenging but possibly beneficial	Poor	Not sure	
		x			
	Comment				
Assume that the considered subtask is (partly) taken over by a robot. How and to what extent the performance change? (Improve, is the same, worsen..) How to measure the performance? (duration of task execution?)	-Possible increase in productivity - Reduction lifting activities				
Assume that the considered subtask is taken over by a cobot. How easy it is for the non-expert users to use?	Very easy	easy	normal	difficult	very difficult
			x		
	Comment				
	Depends on how the robot can be programmed, if its done through doing by example which it would be a tremendous step forwards, although a proper interpretation of the actions might be cumbersome				
How greatly the personal skills of different operators can affect the performance of the process?	To a large extent	Medium-level	The task needs minimum skill levels		
		x			



	Comment
	Depends how fast someone can pack a product and if the system can keep track of all these actions.



1. General Descriptions		
Company Name	San Raffaele	
Location (City/ Country)	Cassino (FR) Italy	
Date (DD/MM/YYYY)	10-6-2025	
Questionnaire filled by:	Name/Surname	Francesco Infarinato
	Affiliation	SRA
Provide a brief description of the working area:	A palliative care unit in the San Raffaele hospital in Cassino. The rooms are large and comfortable, furnished with a bed and a small table and a bedside table for the patient's belongings. An IV is hanging from the top of the bed and a bag connected to a catheter hangs in the middle of the length of the bed. There is a television, through a door you can access a bathroom with a shower.	



Provide a photo of the working area:



Provide a brief description of the use-case:

The environment is emotionally sensitive and medically complex, requiring the robot to navigate calmly, interact respectfully, and avoid interfering with ongoing care procedures. Tasks include patient engagement, symptom monitoring, object delivery, and communication support for staff and caregivers.

Provide a brief description what needs to be improved/ what is the aim of the robot implementation?:

The robot can be very useful to provide small objects to the patient while he is in bed, for example a small bottle of water, the TV remote control, the mobile phone. It could also help the staff to check the status of the patients in cases of emergency (falls, calls for help), or monitor the pain daily through specific questionnaires.



Provide a brief description of the sub-tasks (if applicable):	- The robot must be able to make a distinction between the role of doctors, nurses, patients and caregivers, based on visual criteria (clothing, badge, position) and adapt its behavior towards the specific role; - The robot must be able to verify whether the people who remain in the patients' room are authorized, promoting patients' safety and privacy; - The robot must be able to visually recognize the level of liquid in the urinary bag and warn the staff when it approaches the critical threshold (1500 ml), avoiding the risk of overflow and improving patients' comfort; - The robot must be able to detect the residual level of the infusion liquid and warn the staff when it is close to exhaustion (about 100 cc), avoiding unwanted interruptions in therapy and reducing the nursing workload; - The robot must be able to provide a clear and structured summary of the patient's main actions (e.g. requests, filling out scales, preferences), making them accessible to the healthcare team and the caregiver; - The robot must be able to accompany caregivers or visitors to a specific area of the department (e.g. patient's room, exit), improving reception and orientation.
What could be the main contribution of TORNADO? Please specify e.g., full automation of a process, HRC, learning from humans, etc.)	Multidomain advancement in Human-Robot Collaboration (HRC) through the integration of context-aware, learning-capable, socially acceptable robotic systems.

2. Interactions & Expectations

Users





Which users are involved with the robot, how often and does this happen direct or indirect?	User		Frequency of contact	Contact type		
	Medical Doctor		Hourly	Communication		
	Nurse		On demand	Communication		
	Patient		Continuous	Multimodal		
	Caregiver		On demand	Communication		
Which sub task involve human - robot interactions?	Recognition of people					
	Recognition of authorized persons					
	Guiding caregiver/ other persons through the department					
	Monitoring phlebotomy					
	Monitoring urine bag					
Are there activities which are not allowed to be done by the robot?	YES: intervention with medical equipment/decision making without human verification					
Should the robot be able to work unattended?	Yes	Partially		No		
		in defined, low-risk tasks				
Human to Robot						
How do you want to program the robot?	Programming by demonstration	Programming by guidance	Block based programming	Traditional programming	Other:	
	X	X				
How do you want to give an assignment to the robot?	Through speech	Through hand gestures	Through a wearable	Through push buttons	Other:	
	X	Someone				



How do you want to be able to interfere with the robot if something goes wrong (not life threatening)?	System error handling	Through speech	Through hand gestures	Through a wearable	Emergency button	Other:
		X			X	
Robot to human						
How should the robot confirm it understood the assignment?	Through facial expression	Through speech	Through a wearable	Through text	Through light/sound signals	Other:
		X		X	X	
How should the robot respond when the assignment is done?	Through facial expression	Through speech	Through a wearable	Through text	Through light/sound signals	Just stop
		X		X	X	
How should the robot make clear what it is doing or going to do next?	Through facial expression	Through speech	Through a wearable	Through text	Through light/sound signals	
		X		X	X	
How should the robot respond if something goes wrong?	Through facial expression	Through speech	Through a wearable	Through text	Through light/sound signals	Just stop
		X		X	X	
Should the robot be able to start a conversation/social talk?	Yes e.g. supportive questions					
What is the aim of the conversation?	Support					
Expectation management						
What level of maturity do you expect from the robot programming module	Flawless system	System with minor flaws	System with major flaws	Proof of principle		
		X				
What level of maturity do you expect from the object recognition module	Flawless system	System with minor flaws	System with major flaws	Proof of principle		
		X				



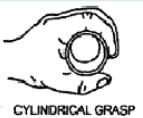
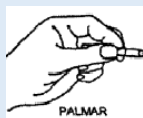
What level of maturity do you expect from the conversation module	Flawless system	System with minor flaws	System with major flaws	Proof of principle		
			X			
What level of maturity do you expect from the error handling module	Flawless system	System with minor flaws	System with major flaws	Proof of principle		
		X				
What level of battery life do you expect from the robot system	>8 hours	8 hours	4 hours	<1 hour		
			X			





3. Components to be handled				
How many different components and assembled parts are handled in the respective sub-task?	Pass small bottle of water/ mobile phone/ tv remote			
This is about the number of different shapes that must be handled. Two components with the same shape or a component that is handled several times are counted only once. Example subprocess "assembly of a shaft": The shaft is picked up and two identical ball bearings are mounted = shaft + ball bearing = 2 components are handled."				
What is the min-max component weights that are handled?	Min. [Unit: kg]		Max.	
Add up the weight of the products, packaging and filling material if they are handled jointly. Otherwise rate the component with the highest weight.			0,5kg (max. what patient can handle in general)	
What is the min.-max. dimensions of the component that are handled?	Min. (L x W x H) [Unit: mm]		Max. (L x W x H)	
Add up the height of the products, packaging and filling material if they are handled jointly			Ø7x20cm	
How fragile are the components? Are components susceptible to optical or functional impairments?	Highly fragile, Impairment due to careless handling	Impairment due to the application of a small force	Impairment due to the application of a high force,	Solid (no impairment due to force application)
			x	x
	Comment			



Do the components retain their shape despite the application of process forces? Do the parts deform solely due to the influence of gravity or weight forces?	Limp Deformation under low force 	Deformation under force 	Deformation under high force 	Solid 		
			X	X		
	Comment					
Can the components be gripped easily? Are there clearly defined surfaces for gripping?	CYLINDRICAL GRASP 	TIP 	HOOK or SNAP 	PALMAR 	SPHERICAL 	LATERAL 
	X		X	X		X
	Comment					
How slippery the components are while grasping?	Not in general					
Are the components statically positioned? Are they placed on a moving conveyer or similar? In the latter case, what is the speed range of the conveyer?	Statically on a table or something similar					



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Are the 3D models of the components available? (e.g., product CAD)	YES	NO
		x
	Comment (If yes, please provide the name of S/W)	
	But can be modelled quite easily	
What is the typical lot size? (i.e., number of parts per lot)	Min. (L x W x H) [Unit: mm]	Max. (L x W x H)
		1pc



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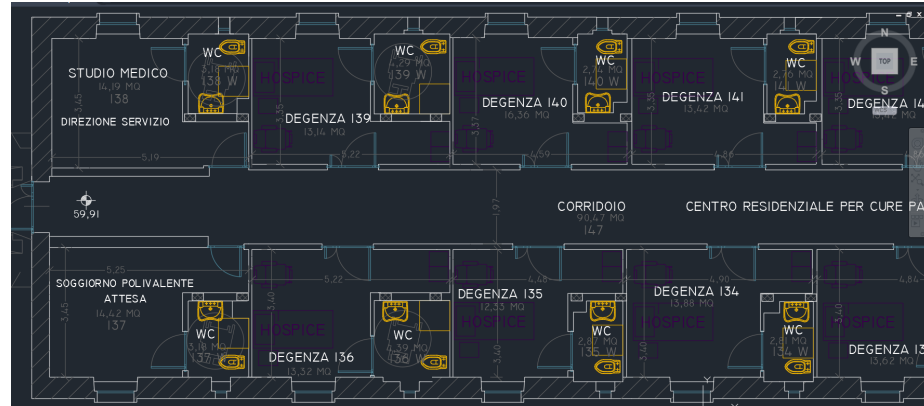
4. Navigation /transportation					
What is the min.-max. transportation distance between pick/place locations?	Min. [Unit: m]			Max.	
	1			50	
What is the min.-max. load weight to be transported?	Min. [Unit: kg]			Max.	
	N/A			N/A	
Are there static and/or dynamic obstacles (including humans) on the path of transportation?	Static			Dynamic	
	Furniture			Nurse/doctors/	
	Comment (If there are static ones, is it possible to construct a map of the environment or is the environment dynamically changing?)				
	Is it possible to have a map of the patient's room				
What is the ground level condition along the task trajectory? (explain the details; roughness, inclination, material, height, falls, even/uneven, change in the height of the flooring.)	Flat ground	Slopes	Stairs	Cabling	Rails
	X				
	Comment				
	Marble flat ground				
What is the best way of transporting a component in workplace?	Via robot gripper at all times (light and easily graspable objects)	Manual loading on mobile based, robotic transportation, and manual unloading	Collaborative loading on mobile based, robotic transportation, and collaborative unloading	Autonomous loading on mobile based, robotic transportation, and autonomous unloading	
	x				
How often this transportation task is performed? (Choose one, and put a number)	Minute	Hour	Day	Week	Month
			x		
	Comment				
	A few times a day				



	Very Slow	Slow	Medium Speed	Fast	Very Fast
In what speed the transportation is performed?		x			
	Comment				
	Should be adapted to the patient, ensuring he or she feels comfortable				
What is the minimum clearance of the transportation path?	Width [Unit: mm]			Height [Unit: mm]	
	900			2500	
Are there static markers on the floor or ceiling? (In case of the use of markers for navigation)	YES			NO	
				X	
	Comment (If no, can we place markers in the workspace, otherwise?)				
	Yes				
Explain how pick/place operations are performed?	Operator	Crane		Carrier	etc.
	Comment				
	N/A				
Is the path of transportation always the same?	YES			NO	
	x				
	Comment (If yes, is the direction defined (forward/backward or lateral)?)				
	Forward				
Are maps or other relevant data (system layout CAD) available?	YES			NO	
	X				
	Comment (If yes, please provide the name of S/W)				



standard CAD DWG file on request



Are there any restricted areas (where robots can't pass through)?

Yes, rooms not involved in the trial

Sketch the spaghetti chart (operators' paths in the workspace)

5. Manipulation					
What are the maximum force levels for the manipulation tasks?	In general low, it should match the patient/ object weights (light)				
At which speed are the manipulation tasks performed? Pieces/minute? (in Human Scale)	Very Slow	Slow	Medium Speed	Fast	Very Fast
	X	X			
	Comment				
	Patient should feel comfortable/ not being scared by sudden movements				
How much is the maximum Cartesian translation/rotation displacement at endpoint (operators' hand)?	Translation [Unit: mm]		Rotation [Unit: deg]		
	50cm		N/a		



Does this process need the modulation/tuning of robot Cartesian impedance during the execution of the task?	YES		NO			
	Comment					
	No Idea					
What is the worst state of orientation that currently occurs in the respective subprocess?	Precise order	2D Mixed	3D Chaotic			
			x			
	Comment					
How often this manipulation is performed? (Choose one, and put a number)	Minute	Hour	Day	Week	Month	
	Comment					
	Not that often sufficient space to move around					
In which direction the task (assembly, mounting) is performed?	Straight line from side		Straight line from above		Not a straight line / other (specify)	
	x					
	Comment					
	Straight line from direction of movement					
What range describes the tolerance limits of the sub-task?	<0.5mm		≥0.5 and <1mm		≥1mm	Other (specify)
						<2cm
	Comment					
What is the feeding orientation of manipulation objects?	Random		Arranged in a layer		Arranged in fixture	
	x					
	Comment					
	Yes			No		



Are there repetitive actions in this subprocess? If yes, what is the execution frequency?	x	
	Specify the frequency	
	A few times a day	
Are there any constraints on the working range of the robot? Please specify	T.b.d.	
Are there actions in which large-range changes in postures over the course of the task (e.g. walk to crawl, bend, stand, sit, etc.)? If yes, how these actions are combined with the motion in interaction (with objects, environment or both).	Yes	No
		X
	Comment (add the pictures, if applicable)	



6. Human Perception and Tracking				
Can a human skeleton be observed by an external camera? (e.g., obstacles such as desks may block the view)	YES			
Which human pose tracking technology seems to be most suitable?	Wearable Suit	Ground-mounted camera	Ceiling-mounted camera	
		X	X	
	Reason?			
	Final decision by the research partner			
How mobile is the human during the execution of the task? Can force-plates or sensor-insoles be used to measure ground reaction forces?	Not easy/ lightweight products			
Can wearable sensors such as EMG electrodes be attached the human body? Explain what body parts would be engaged in sensory measurements.	N/a			
How many people will be working in the same task? Is multi-person tracking required?	Maximum 4 people in general its 2			
How predictable and repeatable are the human movements?	Predictable for the manipulation tasks, for other taks less predictable.			
What is the maximum size of the workspace that can be tracked?	Length [Unit: m]	Width	Height	
	Comment			
Is the measurement of interaction forces needed? How?	Could be interesting but is upto the research partners			
How are the lighting (source, brightness, color temperature, direction) conditions?	Source	Brightness	Color temp.	Direction
	ceiling and bed head lamps	at least 300 lux	cold	stanze bene illuminate
	Comment			



Is the human wearing any fixed equipment in which sensors could be embedded? Working boots, helmet, etc.	No
Is a wearable metabolic system (face mask, heart rate chest belt) compatible with the work tasks?	No
Explain the environment around the worker; dirt, moisture, noise level(dB), magnetic interference and radio interference (objects, materials and other wireless systems).	Hospital ward, clean, flat, possibility to have liquids on the ground, wifi





7. Item perception				
How is the lighting condition for the visual perception? (source, brightness, color temperature, direction)	Source	Brightness	Color temp.	Direction
	ceiling and bed head lamps	at least 300 lux	cold	stanze bene illuminate
	Comment			
	well-lit hospital rooms			
What is the variability of the components to be detected through vision? This is to understand if template matching algorithms can be used effectively.	One type only	Few distinguishable types	High variation and high mix	
		X		
	Comment			
	Within one order a few items are used, between the different orders a high variation and high mix is possible			
How dynamic is the working environment for the sub-task?	Structured environment	Semi-structured with minor variability	Highly dynamic and varying scenes	
		X		
	Comment			
How much is the position tolerance (are parts exactly in the same place and orientation?)	<0.5mm	≥0.5 and <1mm	≥1mm	Other (specify)
			X	
	Comment			
Overlapping and occlusions (are parts clearly separated and completely visible?)	YES			
Explain the cleanliness of parts and environment (dust, fumes, etc.)	Clean			



Is there any issue in handling many sensor devices and robotic platforms in the same environment? (connections etc.)

No





8. Safety		
If sharp-edged or pointed components/tools must be handled, would the use of a robot change the risk of cutting, shearing, clamping or crushing for the human?	No	
Assume that the subprocess would (partly) be taken over by a robot. Is there a danger of collision in the head/neck area?	No (Patients will be replaced with mannequins)	
Assume that the transportation would (partly) be taken over by a robot. Is there a danger of collision with human on its path?	Yes, low to moderate	
Assume that the considered sub-process is (partly) taken over by a robot. Are further safety precautions to be taken? (e.g., high speed, large impacts, large range of motion, working close to/at the range of motion limits, etc.)	Yes, low speed is required while moving in hospital corridors and rooms	
If heavy objects/tools must be handled, could it be dangerous if they tip over/fall against the human?	N/A	
Is there any situation in which safety equipment is needed? (safety shoes, gloves, protective glasses)	Yes	No
		X
	Comment (If yes, please specify the type of protective clothing worn)	



	However, clinical staff may need gloves when interacting with surfaces previously touched by the robot.
Which is the main safety risk associated to robotic system within the workspace?	Unintentional physical contact





9. Physical Ergonomics					
What body parts are involved and what is the level of loading?	Very low	Low	Medium	High	Very high
					X
	Comment				
	Upper limbs (shoulders, arms, wrists) for writing/handling devices				
What is the portion of the “loaded” vs “unloaded” phases (time duration) of the task for the human operator?	Loaded (0 - 100%)			Unloaded	
				Quite 100%	
	Comment				
What are the main causes of risks to human health? (Examples: Handling high weights, high range, monotony, repetitiveness, other hazards, working in the extreme postures...)	Repetitive bending or reaching for IV/urinary bags Long static postures during patient monitoring Emotional stress in palliative setting				
Are there other external hazards? (e.g. noise, extreme temperatures, vibrations, PPE, psychological factors, machine driven work rate, etc.)	Generally: Risk of contagion or cross-contamination Psychological load (family interactions) High emotional strain in end-of-life care But in this case patients will be simulated using mannequins				
How much does awkward positioning of arms or hands decrease, especially movements that require odd angles? (answers in percentual)	No awkward positioning				
	Minute		Hour		Day



How often the human operator takes breaks during a work shift which includes risky actions?		2 or 3	
	Comment		
What is the weight of the objects lifted manually (maximum and average)?	Max. [Unit: kg]		Avg. [Unit: kg]
	1,5		0,3





10. Task Execution and Performance				
	Total cycle	Setup	Inspection	Idle/Waiting
What is the Index time [Unit: sec]				
What is the number of operators per shift?	N/a			
How many parallel and serial sub-processes can be identified?	N/a			
Can overlapping of the activities contribute to the reduction of the cycle times and how?	N/a			
Assume that the considered subtask is (partly) taken over by a robot. How high are the requirements for repeatability?	High: assembly operations (joining, screwing, clipping, ...) with high accuracy requirements	Medium: handling operations with medium accuracy requirements	Low: treatment operations (coating, painting, ...) with low accuracy requirements)	
	x			
	Comment			



How much is the closeness of agreement between several positions reached by the robot's end-effector for the same controlled position, repeated several times under the same conditions?					
Overall, how would you regard a possible automation impact on task execution and generic performances?	Beneficial	Challenging but possibly beneficial	Poor	Not sure	
		x			
	Comment				
Assume that the considered subtask is (partly) taken over by a robot. How and to what extent the performance change? (Improve, is the same, worsen..) How to measure the performance? (duration of task execution?)	See defined KPI's				
Assume that the considered subtask is taken over by a cobot. How easy it is for the non-expert users to use?	Very easy	easy	normal	difficult	very difficult
	x	x	x		
	Comment				
	With the patient in mind it is important not to put extra strain or stress on the patient. For nurses, doctors and caregivers it should be easy to normal				
How greatly the personal skills of different operators can affect the performance of the process?	To a large extent	Medium-level	The task needs minimum skill levels		
		x			
	Comment				



TORNADO

TORNADO-GA 101189557
D2.1 – End-user requirements - first version
Public (PU)

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Funded by
the European Union

TORNADO | foundation mOdelS for Robots that haNdle smAll, soft and Deformable Objects. The project funded under Grant Agreement No. 101189557 is supported by the EUROPEAN HEALTH AND DIGITAL EXECUTIVE AGENCY (HADEA) HADEA.B – Digital, Industry and Space | B.2 – Digital



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1. General Descriptions		
Company Name	MCC BEST VALUE LTD	
Location (City/ Country)	Limassol / Cyprus	
Date (DD/MM/YYYY)	31-3-2025	
Questionnaire filled by:	Name/Surname	Manos Efthymiades
	Affiliation	Category Manager
Provide a brief description of the working area:	The pilot takes place in a busy Distribution Centre in Inofita, Greece. It handles most of the goods for our store chain. The environment is active and unpredictable, with workers walking or driving forklifts. Packaging waste often ends up on the floor, and tasks like product sampling or quality checks can be requested at any time. Products come in different sizes and shapes.	



Provide a photo of the working area:	
Provide a brief description of the use-case:	Deployment of an Autonomous Mobile Robot (AMR) in a busy distribution center. The AMR supports daily operations by assisting with quality checks and collecting recyclable packaging waste. It operates in a dynamic environment where workers and forklifts move constantly, and tasks such as product sampling can be requested at any time. The AMR must safely navigate the space, respond to human instructions, and learn how to handle new types of waste through human guidance.
Provide a brief description what needs to be improved/ what is the aim of the robot implementation?:	The aim is to improve efficiency and safety in a busy distribution center by deploying an Autonomous Mobile Robot (AMR) that supports manual tasks such as packaging waste collection and quality checks. The AMR helps reduce delays, supports workers, keeps the environment clean, and enables easier separation and recycling of materials.



Provide a brief description of the sub-tasks (if applicable):	The robot will work in the fresh produce area of the distribution center, focusing on three main tasks: 1. Cleanliness Monitoring In the Produce Storage Area, the robot checks the floor for damaged products and alerts staff to clean up when needed. 2. Product Sampling 2.1 - In the Produce Receiving Area, the robot helps the Receiver check the quality of fruits and vegetables. If needed, it delivers samples to the Quality Control Department. 2.2 - In the Produce Storage Area, the robot checks product quality using its camera and sends a report. It may also deliver samples if required. 3. Recycling Collection The robot collects recyclable materials (paper, plastic, wood) from the floor and places them in the Recyclable Deposit Area inside the Produce Receiving Area.
What could be the main contribution of TORNADO? Please specify e.g., full automation of a process, HRC, learning from humans, etc.)	The AMR automates repetitive and time-sensitive tasks such as floor scanning, product sampling, and recyclable waste collection, improving operational efficiency and safety.



2. Interactions & Expectations						
Users						
Which users are involved with the robot, how often and does this happen direct or indirect?	User			Frequency of contact	Contact type	
	Warehouse Supervisors			Very frequent	End User	
	Warehouse Employees			Frequent	Bystander	
	Other people entering the warehouse			Incidental	Bystander	
Which sub task involve human - robot interactions?	Intervention 1 - Subtask 1 - Cleanliness Monitoring. In the Produce Storage Area, the robot checks the floor for damaged products and alerts staff to clean up when needed.					
	Intervention 2 - Subtask 2 - Product Sampling. The robot works alongside the Receiver during the unloading of fresh produce. The Receiver may instruct the robot to check specific items or deliver samples to the Quality Control Department.					
	Intervention 3 - Subtask 3 - Recycling Collection. If the robot encounters a recyclable material it does not recognize, it will send a notification so that a staff member can intervene and handle the item manually.					
Are there activities which are not allowed to be done by the robot?	NOT dealing with: 1. Handling Unknown or Unrecognized Materials 2. Operating Outside the Designated Area					
Should the robot be able to work unattended?	Yes		Partially		No	
	X					
Human to Robot						
How do you want to program the robot?	Programming by demonstration	Programming by guidance	Block based programming	Traditional programming	Other:	
	X	X				



How do you want to give an assignment to the robot?	Through speech	Through hand gestures	Through a wearable	Through push buttons	Other:	
	X	X		X		
How do you want to be able to interfere with the robot if something goes wrong (not life threatening)?	System error handling	Through speech	Through hand gestures	Through a wearable	Emergency button	Other:
		X	X		X	
Robot to human						
How should the robot confirm it understood the assignment?	Through facial expression	Through speech	Through a wearable	Through text	Through light/sound signals	Other:
	X	X			X	
How should the robot respond when the assignment is done?	Through facial expression	Through speech	Through a wearable	Through text	Through light/sound signals	Just stop
	X	X			X	
How should the robot make clear what it is doing or going to do next?	Through facial expression	Through speech	Through a wearable	Through text	Through light/sound signals	
	X	X			X	
How should the robot respond if something goes wrong?	Through facial expression	Through speech	Through a wearable	Through text	Through light/sound signals	Just stop
	X	X			X	



Should the robot be able to start a conversation/ social talk?	No					
What is the aim of the conversation?						
Expectation management						
What level of maturity do you expect from the robot programming module	Flawless system	System with minor flaws	System with major flaws	Proof of principle		
		X				
What level of maturity do you expect from the object recognition module	Flawless system	System with minor flaws	System with major flaws	Proof of principle		
	X					
What level of maturity do you expect from the conversation module	Flawless system	System with minor flaws	System with major flaws	Proof of principle		
			X			
What level of maturity do you expect from the error handling module	Flawless system	System with minor flaws	System with major flaws	Proof of principle		
	X					
What level of batterylife do you expect from the robot system	>8 hours	8 hours	4 hours	<1 hour		
		X				

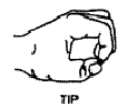
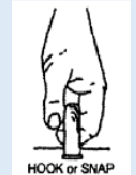
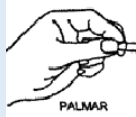
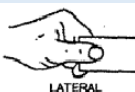
3. Components to be handled	
How many different components and assembled parts are handled in the respective sub-task?	Something between 10 to 15 components Plastic, paper, cardboard wrap, stretch film, cardboard box, wood, sampling of 3 kind of fruits
This is about the number of different shapes that must be handled. Two components with the same shape or a component that is handled several times are counted only once. Example subprocess "assembly of a shaft": The shaft is picked up and two identical ball bearings are	



mounted = shaft + ball bearing = 2 components are handled."

What is the min-max component weights that are handled?	Min. [Unit: kg]		Max.	
Add up the weight of the products, packaging and filling material if they are handled jointly. Otherwise rate the component with the highest weight.	0,005		5kg	
What is the min.-max. dimensions of the component that are handled?	Min. (L x W x H) [Unit: mm]		Max. (L x W x H)	
Add up the height of the products, packaging and filling material if they are handled jointly	5x5x5		1000x1000x1000	
How fragile are the components? Are components susceptible to optical or functional impairments?	Highly fragile, Impairment due to careless handling	Impairment due to the application of a small force	Impairment due to the application of a high force,	Solid (no impairment due to force application)
	x			
	Comment			
	Highly Fragile only for the Fruits & Veg products. The other components will be recyclable materials so the impairment is not a problem.			
Do the components retain their shape despite the application of process forces? Do the parts deform solely due to the influence of gravity or weight forces?				



	Limp Deformation under low force	Deformation under force	Deformation under high force		Solid	
	Comment					
	The Fruits & Veg products deform under low force. The other componets which are recacable materials, can indeed deform solely due to the influence of gravity or weight forces eg. Stretch film, cardboard box etc.					
Can the components be gripped easily? Are there clearly defined surfaces for gripping?	CYLINDRICAL GRASP 	TIP 	HOOK or SNAP 	PALMAR 	SPHERICAL 	LATERAL 
	X	X	X	X	X	X
	Comment					
	All components can be grasped easily. main difficulty lies in the variation in shape, size, weight.					
How slippery the components are while grasping?	Some of the components may be a little slippery eg. Strech film					
Are the components statically positioned? Are they placed on a moving conveyer or similar? In the	They are statically positioned					



latter case, what is the speed range of the conveyer?		
Are the 3D models of the components available? (e.g., product CAD)	YES	NO
		X
	Comment (If yes, please provide the name of S/W)	
What is the typical lot size? (i.e., number of parts per lot)	Min. (L x W x H) [Unit: mm]	Max. (L x W x H)
	N/A	N/A

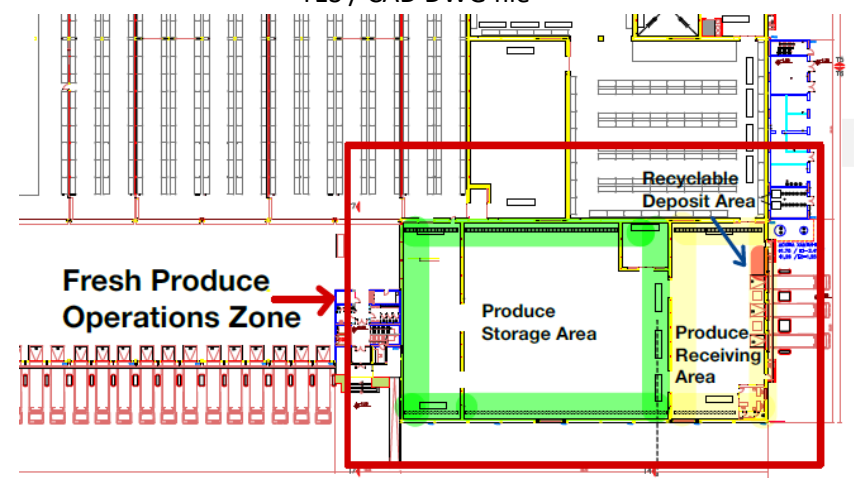


4. Navigation /transportation					
What is the min.-max. transportation distance between pick/place locations?	Min. [Unit: m]			Max.	
	0			100	
What is the min.-max. load weight to be transported?	Min. [Unit: kg]			Max.	
	0,005			5	
Are there static and/or dynamic obstacles (including humans) on the path of transportation?	Static			Dynamic	
				x	
	Comment (If there are static ones, is it possible to construct a map of the environment or is the environment dynamically changing?)				
	Employees, forklifts etc.				
What is the ground level condition along the task trajectory? (explain the details; roughness, inclination, material, height, falls, even/uneven, change in the height of the flooring.)	Flat ground	Slopes	Stairs	Cabling	Rails
	x				
	Comment				
	no inclination , floor is industrial concrete				
What is the best way of transporting a component in workplace?	Via robot gripper at all times (light and easily graspable objects)	Manual loading on mobile based, robotic transportation, and manual unloading	Collaborative loading on mobile based, robotic transportation, and collaborative unloading	Autonomous loading on mobile based, robotic transportation, and autonomous unloading	
	x			x	
How often this transportation task is performed? (Choose one, and put a number)	Minute	Hour	Day	Week	Month
	15 - 30				
	Comment				



	If autonomus loading and unloading process will be chosen, then the weight or the fullfilment of the mobile cart will trigger the transportation to the designated area				
In what speed the transportation is performed?	Very Slow	Slow	Medium Speed	Fast	Very Fast
			x		
	Comment				
	Walking speed so +/-5km/h				
What is the minimum clearance of the transportation path?	Width [Unit: mm]			Height [Unit: mm]	
	3000			5000	
Are there static markers on the floor or ceiling? (In case of the use of markers for navigation)	YES			NO	
				X	
	Comment (If no, can we place markers in the workspace, otherwise?)				
	WMS product location is available. Additional markets can be installed if needed.				
Explain how pick/place operations are performed?	Operator		Crane		Carrier etc.
	X				
	Comment				
	All recyclable materials are picked up by workers manually. The Fruit & Veg products for Q.C. and sampling are handled by operator.				
Is the path of transportation always the same?	YES			NO	
				x	
	Comment (If yes, is the direction defined (forward/backward or lateral)?)				
	Depending on the spot the material is collected the path will be different				
Are maps or other relevant data (system layout CAD) available?	YES			NO	
	Comment (If yes, please provide the name of S/W)				



	YES / CAD DWG file 
Are there any restricted areas (where robots can't pass through)?	NO - The robot's working area is predefined
Sketch the spaghetti chart (operators' paths in the workspace)	

5. Manipulation					
What are the maximum force levels for the manipulation tasks?	Max 5kg				
At which speed are the manipulation tasks performed? Pieces/minute? (in Human Scale)	Very Slow	Slow	Medium Speed	Fast	Very Fast
				8 pcs/ minute	
	Comment				
How much is the maximum Cartesian translation/rotation displacement at endpoint (operators' hand)?	Translation [Unit: mm]		Rotation [Unit: deg]		
	1500		180		
	YES		NO		



Does this process need the modulation/tuning of robot Cartesian impedance during the execution of the task?				
	Comment			
What is the worst state of orientation that currently occurs in the respective subprocess?	Precise order	2D Mixed	3D Chaotic	
			x	
	Comment			
How often this manipulation is performed? (Choose one, and put a number)	Minute	Hour	Day	Week
		20		
	Comment			
In which direction the task (assembly, mounting) is performed?	Straight line from side	Straight line from above	Not a straight line / other (specify)	
			x	
	Comment			
What range describes the tolerance limits of the sub-task?	<0.5mm	≥0.5 and <1mm	≥1mm	Other (specify)
			x	
	Comment			
	It's had to define tolerance for waste as shape is irregular. For fruits tolerance is more than 1mm but still not more than 30mm.			
What is the feeding orientation of manipulation objects?	Random	Arranged in a layer	Arranged in fixture	
	x	x		
	Comment			
	For waste it's random. For fruits is in a layer			
	Yes		No	



Are there repetitive actions in this subprocess? If yes, what is the execution frequency?	X	
	Specify the frequency	
	3MIN	
Are there any constraints on the working range of the robot? Please specify	NO	
Are there actions in which large-range changes in postures over the course of the task (e.g. walk to crawl, bend, stand, sit, etc.)? If yes, how these actions are combined with the motion in interaction (with objects, environment or both).	Yes	No
		X
	Comment (add the pictures, if applicable)	



6. Human Perception and Tracking			
Can a human skeleton be observed by an external camera? (e.g., obstacles such as desks may block the view)	Yes, provided that objects don't block the view		
Which human pose tracking technology seems to be most suitable?	Wearable Suit	Ground-mounted camera	Ceiling-mounted camera
		X	X
	Reason?		
	Because workers and vehicles keep moving in the area		
How mobile is the human during the execution of the task? Can force-plates or sensor-insoles be used to measure ground reaction forces?	N/A		
Can wearable sensors such as EMG electrodes be attached the human body? Explain what body parts would be engaged in sensory measurements.	N/A		
How many people will be working in the same task? Is multi-person tracking required?	For waste collection +1 person. For sampling +2 persons.		
How predictable and repeatable are the human movements?	highly predictable and repeatable		
What is the maximum size of the workspace that can be tracked?	Length [Unit: m]	Width	Height
	2700MM	2700MM	2700MM
	Comment		
Is the measurement of interaction forces needed? How?			
	Source	Brightness	Color temp.
			Direction



How are the lighting (source, brightness, color temperature, direction) conditions?	LED		white	From the ceiling to the ground
	Comment			
Is the human wearing any fixed equipment in which sensors could be embedded? Working boots, helmet, etc.	Safety vest and safety shoes			
Is a wearable metabolic system (face mask, heart rate chest belt) compatible with the work tasks?	N/A			
Explain the environment around the worker; dirt, moisture, noise level(dB), magnetic interference and radio interference (objects, materials and other wireless systems).	Temperature is between 6 and 10 degrees Celsius. Increased humidity (over 60%), wet floor. There is also wireless network 5g			



7. Item perception				
How is the lighting condition for the visual perception? (source, brightness, color temperature, direction)	Source	Brightness	Color temp.	Direction
	LED		white	From the ceiling to the ground
	Comment			
What is the variability of the components to be detected through vision? This is to understand if template matching algorithms can be used effectively.	One type only	Few distinguishable types	High variation and high mix	
			x	
	Comment			
How dynamic is the working environment for the sub-task?	Structured environment	Semi-structured with minor variability	Highly dynamic and varying scenes	
			x	
	Comment			



	It's very dynamic as people and vehicles are constantly moving			
How much is the position tolerance (are parts exactly in the same place and orientation?)	<0.5mm	≥ 0.5 and <1mm	≥ 1 mm	Other (specify)
				X
	Comment			
	For waste, no, they are not at the same place and orientation as they occur incidentally. For fruits orientation is not a problem as they are all round. Place may vary			
Overlapping and occlusions (are parts clearly separated and completely visible?)	Yes for the recyclable materials but not clearly visible for the fruit & veg products when in boxes			
Explain the cleanliness of parts and environment (dust, fumes, etc.)	In general Clean with some dust. An environment suitable for food storage			
Is there any issue in handling many sensor devices and robotic platforms in the same environment? (connections etc.)	no			



8. Safety		
If sharp-edged or pointed components/tools must be handled, would the use of a robot change the risk of cutting, shearing, clamping or crushing for the human?	YES	
Assume that the subprocess would (partly) be taken over by a robot. Is there a danger of collision in the head/neck area?	YES	
Assume that the transportation would (partly) be taken over by a robot. Is there a danger of collision with human on its path?	Yes, people would walk and work in the same area as the robot	
Assume that the considered sub-process is (partly) taken over by a robot. Are further safety precautions to be taken? (e.g., high speed, large impacts, large range of motion, working close to/at the range of motion limits, etc.)	NO	
If heavy objects/tools must be handled, could it be dangerous if they tip over/fall against the human?	YES	
Is there any situation in which safety equipment is needed? (safety shoes, gloves, protective glasses)	Yes	No
	x	
	Comment (If yes, please specify the type of protective clothing worn)	
	safety shoes, safety vests	
Which is the main safety risk associated to robotic system within the workspace?	Collisions with humans/employees or moving machineries	



9. Physical Ergonomics				
What body parts are involved and what is the level of loading?	Very low	Low	Medium	High
			x	
	Comment			
	ALL body parts			
What is the portion of the “loaded” vs “unloaded” phases (time duration) of the task for the human operator?	Loaded (0 - 100%)		Unloaded	
	30%		70%	
	Comment			
What are the main causes of risks to human health? (Examples: Handling high weights, high range, monotony, repetitiveness, other hazards, working in the extreme postures...)	Repetitiveness, Monotony, working in extreme postures			
Are there other external hazards? (e.g. noise, extreme temperatures, vibrations, PPE, psychological factors, machine driven work rate, etc.)	Noise, Vibration			
How much does awkward positioning of arms or hands decrease, especially movements that require odd angles? (answers in percentual)	Limited awkward positioning			
How often the human operator takes breaks during a work shift which includes risky actions?	Minute		Hour	Day
	Comment			



	1 break of 30mins in 8hrs of working	
What is the weight of the objects lifted manually (maximum and average)?	Max. [Unit: kg]	Avg. [Unit: kg]
	5 Kg	0,1Kg





10. Task Execution and Performance				
What is the Index time [Unit: sec]	Total cycle	Setup	Inspection	Idle/Waiting
	N/A			
What is the number of operators per shift?	1 person for reception of goods and 1 for waste collection			
How many parallel and serial sub-processes can be identified?				
Can overlapping of the activities contribute to the reduction of the cycle times and how?	N/A			
Assume that the considered subtask is (partly) taken over by a robot. How high are the requirements for repeatability?	High: assembly operations (joining, screwing, clipping, ...) with high accuracy requirements	Medium: handling operations with medium accuracy requirements	Low: treatment operations (coating, painting, ...) with low accuracy requirements)	
		x		
	Comment			



How much is the closeness of agreement between several positions reached by the robot's end-effector for the same controlled position, repeated several times under the same conditions?					
Overall, how would you regard a possible automation impact on task execution and generic performances?	Beneficial	Challenging but possibly beneficial	Poor	Not sure	
	x				
	Comment				
Assume that the considered subtask is (partly) taken over by a robot. How and to what extent the performance change? (Improve, is the same, worsen) How to measure the performance? (duration of task execution?)	increase in efficiency / See defined KPI's				
Assume that the considered subtask is taken over by a cobot. How easy it is for the non-expert users to use?	Very easy	easy	normal	difficult	very difficult
			x		
	Comment				
How greatly the personal skills of different operators can affect the performance of the process?	To a large extent	Medium-level	The task needs minimum skill levels		
		x	x		
	Comment				



TORNADO

TORNADO-GA 101189557
D2.1 – End-user requirements - first version
Public (PU)

Medium level for the Q.C. task but minimum skills for the collection of recyclable materials



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