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Study of the Applicability of Automated Transport for the Transportation of Material in Hospitals

MASTER THESIS

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1 Problem raising

Logistics as an area was already in V-VII century. When a group of people went to war, the army had to be provided with supplies, both in terms of food and weapons, and the care of the injured soldiers had to be organized. During the first industrial revolution, where water and steam powered systems helped production, the concepts of continuous production and standardization (replaceable parts) already appeared. This was followed by the second industrial revolution, where electrically driven systems helped manufacture, and it became increasingly important to organize inventory planning and shipping. Companies have become more and more specialized, the concept of outsourcing has been realized, according to which not all logistics activities are performed by the given company, but entrusts some of its sub-sectors to other companies, thus creating a competitive position in the market. During the Third Industrial Revolution, robots appeared to be able to perform certain sub-tasks of manufacturing, or even the whole task. The third industrial revolution was followed by the fourth. More than its predecessor, it is already completely factories here, complete material handling systems perform their task independently, they are able to communicate with each other, not collide. In many places, artificial intelligence, the digital twin pair, or the MS algorithm (machine learning) has been added to processes of larger companies. Figure 1 shows the infographics of the industrial revolutions.

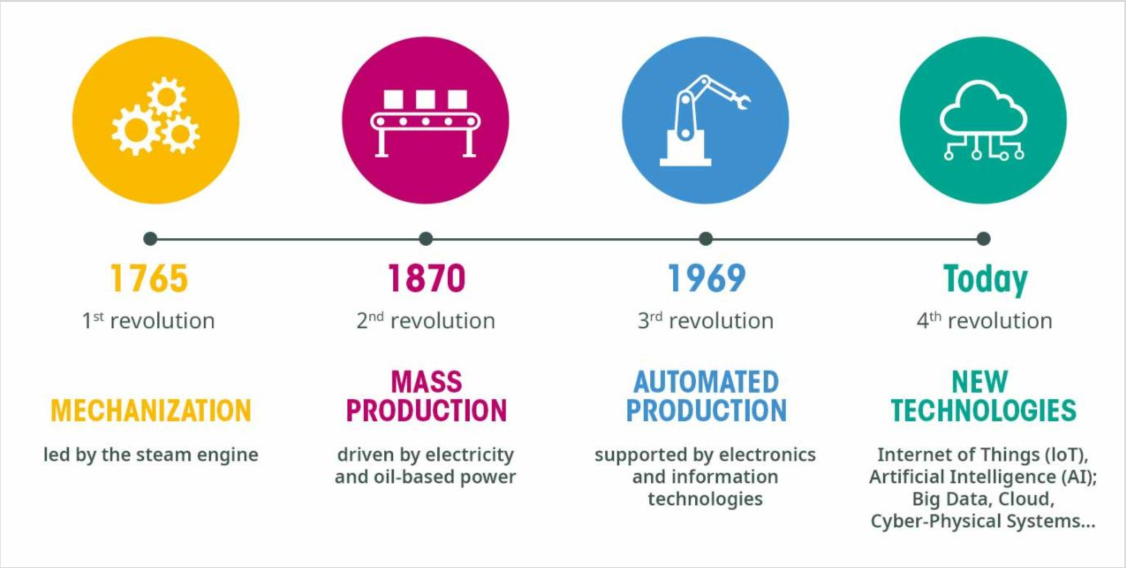

Figure 1: Main features of industrial revolutions

(Source: 0)

As in the past, in the 21st century, logistics is such an important factor that it is no longer possible to organize it with sufficient efficiency and optimization. We must constantly strive to make each process better, able to serve customer needs more efficiently. Anyone who is not a specialist even deals with logistics, because even if we only look at the household, the refrigerator has to be refilled if the products in it fall below a certain stock level. When he goes to the store, he commissions, as he has a pick-up list (shopping list) on the basis of which he fills the pick-up unit, in this case the shopping cart.

One of the most important guidelines in logistics is automation, industrial robots have now become everyday players in automated production lines and material handling equipment.

I will follow this line in my dissertation: which are the areas and the need of development about material handling in healthcare. This last months are particularly affected by the pandemic, and perhaps the biggest challenge is providing the right number of hospital nurses and doctors. Their potential shortage will significantly increase patients' time in the healthcare system, placing a particularly heavy burden on the industry, both in terms of care and materiality, not to mention the much worse life prospects of those who receive inadequate care.

Therefore, the aim of my dissertation is to present concepts that can provide a comprehensive picture about autonomous vehicles and robots cappable of handling material and at the same time adjusting this existing robots into a healthcare environment. As one of the most important tools for this, I detail the topic of robotization, in order to explore the possible application areas of machines, robots and robot systems in the health care system.

In carrying out my tasks, I will first explain how the need to automate tasks arose in order to improve logistics in many contexts of daily life and, after this, I will define the concept of robot, focusing on the AGVs and AMRs that in my case are of interest for this dissertation, as well as its specifications regarding the most important sensors and navigation.

After this, I will carry out a small study on the robot market and finally I will apply all this theory in order to find the best qualities of autonomous robots for their application in the field of healthcare.

2 Introduction

In the following chapter, I write about the more widespread robots, their fields of application, and the efficiency-increasing potential inherent in them. I will focus on human-robot collaboration, detailing the security sensors that can be connected to robots. I detail the logistics processes of hospitals separately in order to make them an integral part of further reasoning.

During the fourth industrial revolution, the responsibilities of hospital operators changed significantly, they needed skills to perform their new task, and they needed to be able to see and interpret complex systems. Non-production line robots can help with this. Robotics, automation and artificial intelligence pose significant challenges for healthcare. Hospital workers face a number of challenges due to the solutions offered by the latest technologies (such as reliability, management of new systems, devices, their integration into hospital processes). At the same time, patients or patients in need of rehabilitation - when using robots, for example - they may feel alien to the lack of human interaction. In many cases, financial difficulties are also caused by the rapid depreciation of assets and equipment, or by the obsolescence of technology, or even the acquisition of new ones. With regard to internal supply processes, both the optimization of operations and the utilization of capacities are of paramount importance at the level of the efficient operation of an individual institution and the entire sector. A significant part of this is the logistics processes, the automation of which is not a novelty in healthcare. To cite an example, AGVs (automatic guided vehicles) with different (even interchangeable) superstructures used for transport tasks.

2.1 Robots

The first step is to look at what a robot actually means. There are several definitions, the simplest of which I consider the following: A robot is a machine - especially one programmable by a computer - capable of carrying out a complex series of actions automatically.[3] Robots can be guided by an external control device or the control may be embedded within. Robots may be constructed on the lines of human form, but most robots are machines designed to perform a task with no regard to their aesthetics. However, I do not want to stop here, as there are systems that cannot be considered robots by the above definition making difficult to draw a line between robots and automated systems, however, robots that can be used in healthcare are of primary importance for delimiting the topic of the dissertation. The field of application of robots is very wide, their variety and character are very diverse. At the same time, healthcare and logistics processes are more characterized by mobile robots - of course, there are also stationary robots, for example for medicines or other processes that support patient care, such as the delivery of food or medicines. At the same time, mobile robots give the greatest room for maneuver to be integrated into the processes of the institution and, compared to a production plant, are not only used in a given production cell. Thus, the range of complete and robotic processes can be very wide, the comprehensive integration of almost the entire hospital logistics supply can be realized, so the previously separated processes are better connected to each other. Robots are suitable for transporting materials or supporting orientation in hospital infrastructure and, above all, for improving efficiency by partially or completely managing the internal supply chain. One important benefit of this is that hospital workers are much better able to focus on higher value-added processes and provide a more reliable and predictable service to both patients and hospital staff ("the robot does not get tired"), and there is also an increase in worker safety. important safety. (Figure 2).

Figure 2: Benefits of material handling automation in hospitals

(Source: [2])

Autonomous and collaborative mobile robots (AGV and AMR) provide a rapid return on investment according to various calculations. When they are not working, they are loaded automatically, resulting in seamless workflows and optimized internal logistics. The investment typically pays off in one year, as integration is easy and robots usually free up the time of two full-time employees, depending on the application, which can then be filled with more valuable tasks.

Traditional manufacturing robots are fixed in place or operate on a fixed track. They are unable to make independent decisions on how to perform the tasks they are assigned to do. An autonomous robot can make decisions on its own based on a set of parameters it takes from its environment. This feature greatly increases the amount of flexibility in assigned robotic tasks.

When using autonomous technology in conjunction with a mobile autómata platform, the androide can complete a higher number of tasks than previously thought. Machine learning and environmental awareness open smart robots' possibility to perform tasks previously unimaginable with normal robotics.

The AGV and AMR are part of the new generation of robotic 'assistants' that help us transport loads and materials. But they have some differences, I will explain in the following sections.

2.1.1 AGV - Automatic Guided Vehicles

AGVs have enough intelligence on board to follow predetermined programming commands. To navigate they use philoguided (they follow a magnetic band on the ground through the antenna they have incorporated) or optoguided (they follow a line painted on the ground through the camera they incorporate) or laserguided (they follow the mirrors installed in the corners to through a laser) which requires prior installation of the navigation aid elements. The AGV will be restricted to the predetermined routes of the aid elements. Yes, they are able to stop if they detect an obstacle but will not be able to go around it, but will have to wait for the obstacle to move or to be eliminated.

Figure 3: AGVs

(Source: [5])

2.1.2 AMR - Autonomous Mobile Robots

The AMR navigate thanks to the mapping that they initially carry out or that is introduced in their software. These robots use data from their cameras and sensors to detect their surroundings and choose the best route to reach their goal. It is able to detect obstacles and go around them autonomously. It is a typology that offers greater flexibility to the system. Another of its advantages is that it is a more economical solution since it does not need the installation of guides, mirrors or infrastructure in your workplace.

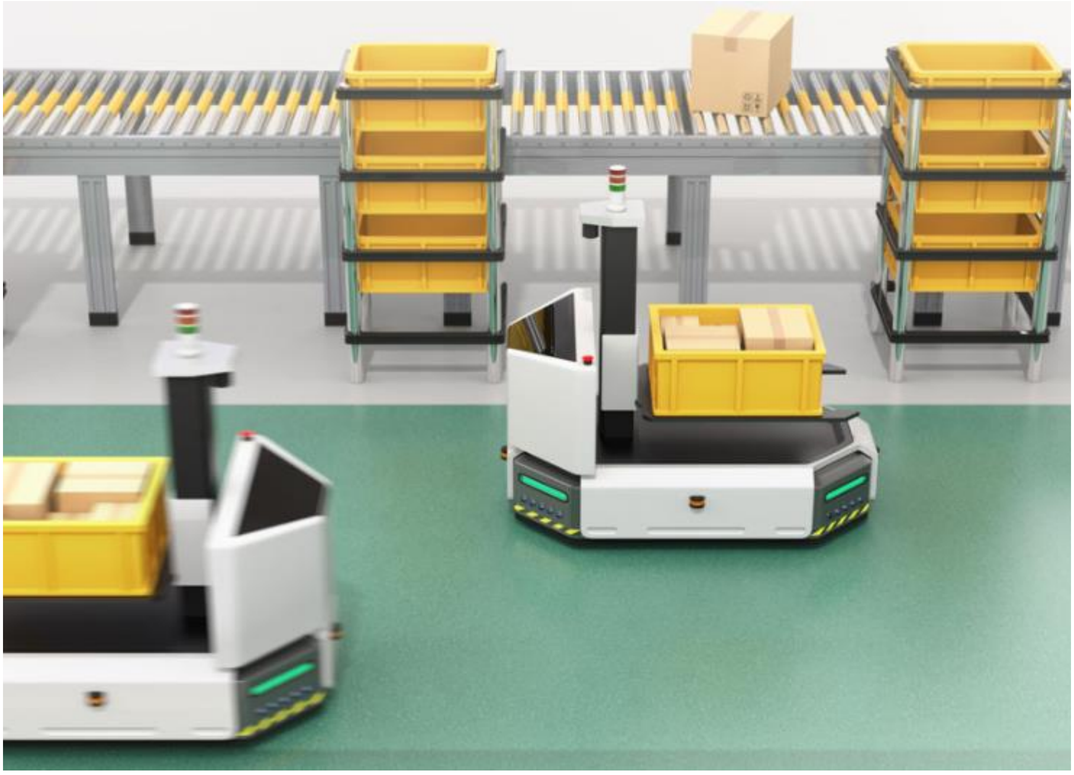

Figure 4: AMRs

(Source: [5])

2.2 Human-Robot collaboration

In order to discuss the applicability of hospital robots, it is essential to categorize robots based on their knowledge, function, and nature. We can talk about human-robot cooperation when the human, the robot and the workpiece (in our case, either the patient or an aid, workpiece) are at the same time, in one space, in a so-called collaborative workspace.[4]

The first to be mentioned is the immovably installed robot, the separation of which with a safety fence precludes any contact with humans.

The second category is coexistent, according to which the speed of a robot's movement depends on the proximity of the human. He uses a laser scanner to look at a person's closeness.[4]

The third and final category belongs to collaborative robots. Here, in each case, the workspace is completely shared, with the robot and the human performing tasks simultaneously. Figure 3 shows the categories.

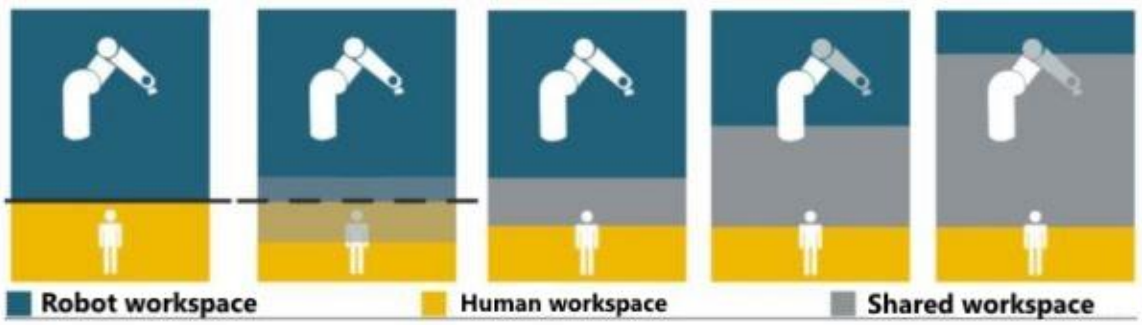

Figure 5: Areas of human-robot cooperation

(Source: [4])

In my dissertation I deal with robots classified in the fifth categorie, because the most common type of operation in human-robot hospital cooperation is when the robot, the workpiece (in our case we can talk about medicine, patient, etc.) and the human are located in the same space (cell, corridor) at the same time. Such collaboration is called collaborative robots, also known as kobots.

Pick-and-place robots, which are rarely used but can be really important, are often closed and fenced away from humans to perform standard (category 1 and 2) dedicated tasks, such as: drug delivery, kitchen assistance (eg loading the dishwasher, placing dishes on the tray) can also be performed.

2.2.1 Safety sensors for robots

According to Isaac Asimov, who wrote the three basic laws of the application of the robotics:

1. A robot may not injure a human being or, through inaction, allow a human being to come to harm.
2. A robot must obey the orders given it by human beings except where such orders would conflict with the First Law.
3. A robot must protect its own existence as long as such protection does not conflict with the First or Second Law.[1]

One of the most important elements in AGVs is their safety. Because they move autonomously, they need to integrate all kinds of measures that allow them to avoid possible obstacles. For example, it is easy for a person to cross the path of the AGV without realizing it. To avoid this type of situation, all kinds of tools and algorithms are used, such as presence sensors or computer vision. In this way, they are able to move around their work zone safely, since it allows them to recognize obstacles that are not registered on their map and to readjust their route based on these obstacles.

To the robots that work in the same physical space with hospital nurses, doctors and staff, it is essential to equip them with safety sensors. In terms of their function, the most important thing for sensors is to protect people, not to cause an accident under any circumstances. There are many regulations and principles for this. Here is the list of the most basic protection equipment.

- Safely limited speed: if the robot does not move too fast, then it is easier to stop.
- Proximity sensors, space detection
- Stop for mechanical contact: checks the torque of the axles, if it deviates from the specified value, it immediately stops the movement of the lever.

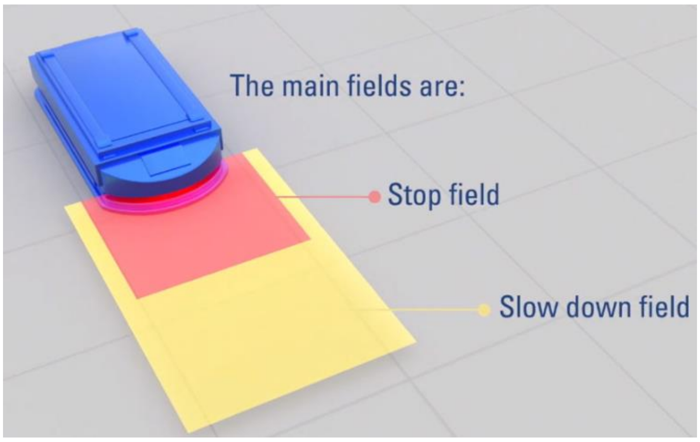

Figure 6: Sensor fields

(Source: [5])

2.2.2 Navigation system of AGVs and AMRs

AGVs and AMRs can use different technologies for location and navigation in the facilities:

Philoguided: the AGV moves guided by a conductive wire installed under the ground, which is accessed through small grooves where a rod connected to the vehicle is inserted. This guiding method is very simple, but it is the one with the least flexibility, since the AGV movement routes are limited to the routes with the wire installed. There are some more comfortable alternatives such as magnetic tapes that avoid doing work to install the thread.

Optoguided: the AGV moves guided by a strip of mirrors, which runs along the paths of the AGV, placed continuously on the sides of the roads (or on the ground) or in the corners where the AGV has to make a decision . By means of a retro-reflector the AGV can detect the guide. The installation of these mirror guides does not require a work as in the case of philoguiding, and the modification or creation of new routes is less complex, since it is enough to draw the new areas with mirror strips to define the movements in the AGV.

Laser guidance: the AGV is equipped with a rotating laser unit that scans to identify as many reflectors as possible in its surroundings to determine their position on the map of the facility that it has in memory. To map the facility, retro-reflective mirrors are placed in a vertical position at strategic points throughout the facility. These mirrors will be reference points with which to calculate the position of the AGV, in the same way as the Optoguided. The main advantage of this guidance method is the incredible simplicity with which you can create a pallet loading / unload station or modify a route.

2D-3D mapping (natural): this technology means that the installation of any external element to the AMR is not necessary, since by means of all the sensors it has (cameras, LIDAR, ultrasounds, ...) they are able to create a virtual map of the environment they are working on (in 2D or 3D depending on the technology). This greatly facilitates the commissioning of these devices, since it is simply necessary to move the AMR manually along the paths it is going to travel, mapping them and internalizing all the necessary information for later use. It is the most flexible and adaptive system.

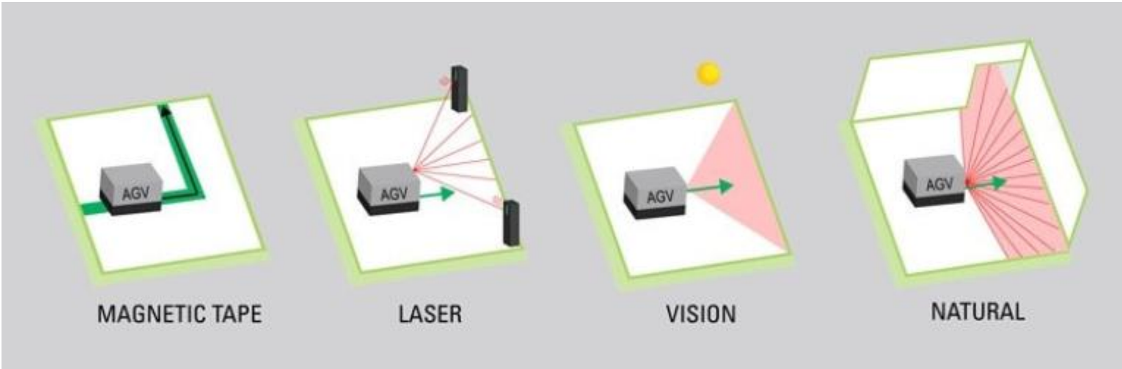

Figure 7: Navigation Systems

(Source: [5])

2.3 Autonomous delivery robots market

North America is one of the major markets for autonomous delivery robots. Many of the major market vendors are based out of here, and also the region has a high number of startups and manufacturers working toward the growth of autonomous delivery robotic technology. Also, the penetration of autonomous delivery robots across several end-users in the region is comparatively high when compared to other parts of the world.

In the hospitality and retail and logistics segments, the demand for these robots is very high; many retail and hospitality players are partnering with manufacturers to have a first-hand experience of the prototypes. For example, North America has a high degree of demand from the hospitality sector. Delivery robots are helping many prime hospitality establishments to gain tremendous attraction from media, which is an important channel in the region that influences tourists’ decision to select a hotel or resort.

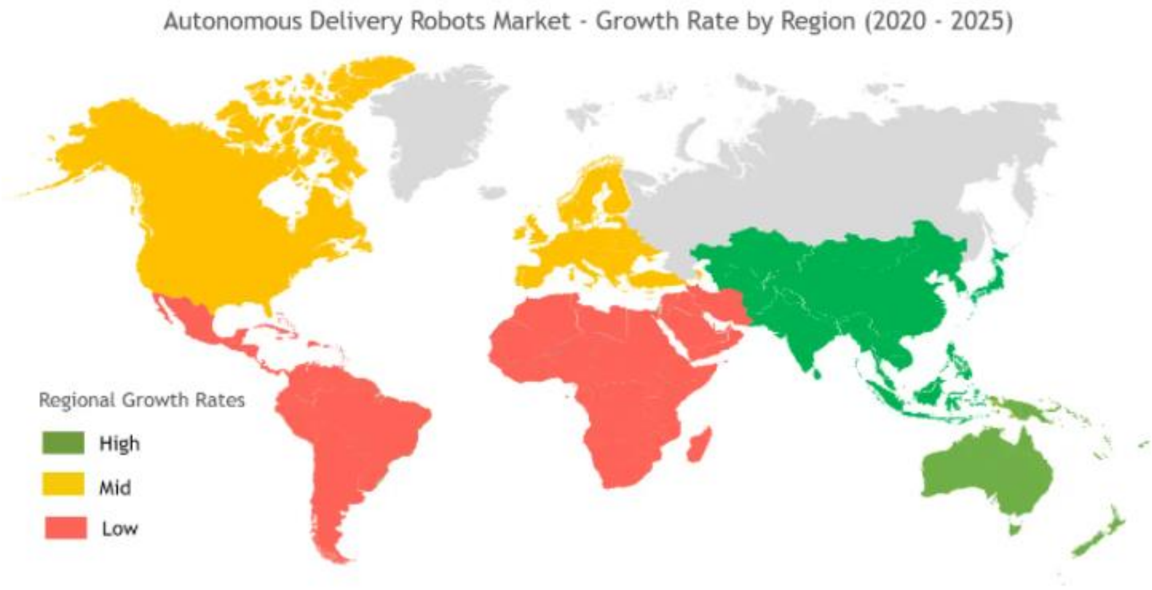

Figure 8: Market growth rate by region

(Source: [6][5])

The autonomous delivery robots market is highly competitive and consists of several major players. In terms of market share, few of the major players currently dominate the market. These major players with the prominent shares in the market are focusing on expanding their customer base across foreign countries. These companies are leveraging strategic collaborative initiatives to increase their market share and profitability. The companies operating in the market are also acquiring start-ups working on autonomous delivery robot technologies to strengthen their product capabilities.

December 2019 - Nuro partnered with Walmart to test the delivery of groceries from Walmart outlet to the customer's home using the delivery robot. Nuro's vehicles will deliver grocery orders of Walmart online to a select group of customers who use the service in Houston. Nuro has been developing a self-driving stack and combining it with a custom unmanned vehicle designed for last-mile delivery of local goods and services.

March 2020 - Aethon's mobile robots are being used by healthcare organizations to cope with the COVID-19 crisis. The company's robots are carrying out their mission of delivering medications, lab specimens, and meals along with handling larger loads such as linens and trash. The hospitals continue to perform over 5 million deliveries per year with Aethon's delivery robots and are even providing the hospital staff relief from miles of walking every day.

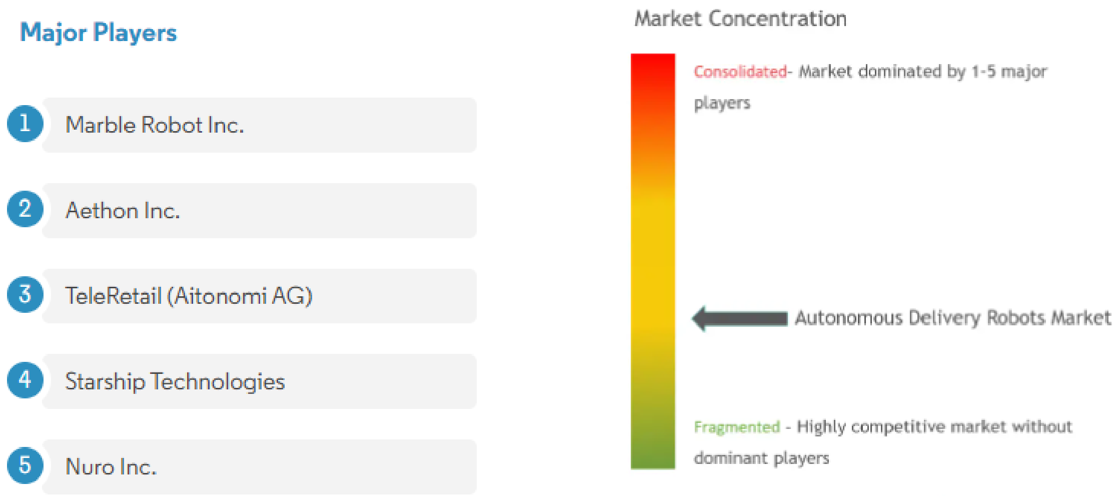

Figure 9: Major players at autonomous delivery robots market

(Source: [6][5])

2.4 Hospital logistics processes

There are many areas in healthcare that involve moving and transporting raw materials, semi-finished and finished products, pharmaceuticals, food, sanitation equipment, machinery, equipment, or even people to the right place. In order to have a high standard of care, these processes must work smoothly and optimally, suffice it to think only of the delivery of organs, the organization of the ambulance service or even the supply of medicines to a patient in a hospital.

A particularly important feature of Hungarian healthcare in terms of hospital logistics processes is the location of the facilities. There are so-called “separated” or pavilion-like hospitals, where each medical area is served in a separate building in a relatively large physical area (the historical reason for this is to avoid possible transfections between each area). At the same time, so-called “block” hospital systems within a building exist, and most modern hospitals today are already built in this approach. In both cases, different material handling challenges have to be faced: the former is characterized by horizontal transport tasks, while the latter is characterized by both vertical and horizontal logistics tasks.

In general, hospitals are not fundamentally process-oriented, but rather provide partial treatment that specializes in each treatment. The so-called patient journey, the main stages of which are:

- Feeling history, first visit to a specialist
- Diagnosis, testing the diagnosis
- Second specialist visit
- If necessary, intervention (such as surgery)
- Hospital care and rehabilitation
- Aftercare and control

Based on these, it cannot be stated that hospitals with obviously different problems can be expected to receive systematic, systematic treatment from hospitals, although this is a desirable future goal. In my dissertation, I would like to focus on the roboticization of the material transportation in a hospital.

Hospital material transportation include primarily procurement, inventory management, asset management, management of administrative processes, or even the hospital's entire enterprise resource planning (ERP) system. Hospital intralogistics processes are areas whose effective management can greatly improve hospital performance indicators, whether in terms of cost reduction, or even patient recovery rates, or just satisfaction (if measured and fed back). Improperly functioning internal logistics processes have a particularly strong impact on overall patient care, according to an article in a Harvard Business Review [14]. Based on this, the cause of malfunction and inadequate patient care can be traced back to internal logistics processes and process planning in 46% of cases.

Figure 10: Causes of operational breakdown in hospitals according to Harvard business review

(Source: [6][5])

The constant change of stimuli and needs of the health care system puts hospitals in the direction of continuous development. Based on these, the most basic goal is to increase the quality of service, one of the most important tools of which is to reduce lead times, which can be solved with robotization and better organization. In the course of my dissertation I deal with the former point. If I examine the logistics processes, transport must be well organized, it is important to set up some kind of system, standards classification of benefits. That’s why through my dissertation I will organize the transportation and material handling as one of the most important aspects in order to improve the hospital organization.

3 Distribution needs in a hospital

Patients should be fed, medicated, and waste disposed of. Most patients, unfortunately, can not go down and bring themselfs food, so this should be resolved at least three times a day. In addition, patients need to be provided with medicines, and nurses and doctors also need food. It is worthwhile to combine waste management, medicine and food supply, to solve them according to the same logical principles. The most obvious solution is to create a demand-driven robot system. However, there are a number of difficulties in implementing the system so we will need to think about a few preliminary needs:

- Should we transport a unit type cargo (container)? What varieties, how many? How many pieces? Should food transport be different from hazardous waste?
- Should we have a schedule? Should we differentiate between times of day? Do we work at night?
- How many robots should we use? How many receiving stations should we build?
- What area do we involve them in, how much should they be integrated into the logistics system of the hospital?

The goal is to plan optimal, better plans and schedules, so that the ground-level and system-level losses are as small as possible (as the Lean approach says: do not maintain a robotic truck unnecessarily, do not overload the system, there should be enough robotic trucks, with a schedule and dedicated time zones, the load distribution can be more optimal), the more information we can monitor about the system (location of robots, state of charge, daily deliveries for compiling statistics, position of elevators, generation of demands). A unified code system is needed on the basis of which the needs can be served, whether there should be a priority department (eg: emergency patient care needs are more important, blood transport, etc.).

With all this, we will analyze the different transport and material handling robots in order to adapt them to each of the hospital's needs in the following sections.

4 Robots applicable to different healthcare categories

4.1 Transportation of sensitive good

Probably the transport of sensitive materials in a hospital is one of the most important points in this area, since it is necessary to continuously transport both instruments necessary to perform operations, pills and medications or even blood or patient samples.

With this, it must be taken into account that it is not only enough with an autonomous robot that can move safely through the building, but also that a series of specifications will be necessary such as safe compartments, refrigerators or simply a space at an adequate temperature to protect the different materials.

We will distinguish three classifications for this type of materials: robots with closed compartments, without the possibility of handling materials; robots equipped with robotic arms for handling objects and finally robots with a trailer for larger and heavier materials.

4.1.1 Closed compartment robots, no manipulation tool

Considering different types of robots and each possible function, I have chosen four of them that have closed compartments ideal for the sensitive good transportation.

4.1.1.1 Tug robot

A good example of a robot with closed compartments is the TUG robot, showed in Figure 1. TUG mobile robots automate material delivery in hospitals, manufacturing, and hotels (see Figure 2). They are collaborative, safe, and efficient.

TUG automatically picks up and drops off carts, eliminating the labour that would otherwise be needed to load the robot. It also communicates with the IT system to automate the dispatching of the robot fleet and update the inventory system when materials are moved.

TUG can be installed quickly. Maps are quickly generated, routes and delivery points are digitally established, and charging stations are simply plugged into the wall.

Furthermore, an AGV is typically limited to the “back of house” and well defined or even dedicated travel lanes. A TUG can drive where people walk and work and become a collaborative technology seamlessly operating with the work environment.

Unlike fixed route AGVs, TUG can be reprogrammed onsite or even remotely whenever routes or delivery points need to change.

Figure 11: Tug robot

(Source: [36])

TUG is flexible; an AGV typically requires fixed specialty signifiers like tracks, wires, tape, and reflectors to navigate. Instead, TUG feature modern technology including camera- and laser-based navigational systems allow safe operation in nearly any indoor environment.

TUG has a map of the hospital stored in its memory and uses a scanning laser and 27 infrared and ultrasonic sensors to detect and model the environment in real time to maintain accurate position and avoid obstacles. The TUG communicates through the wireless network to control elevators and doors as well as respond to fire alarm systems. TUG automatically returns to its charging dock after completing a delivery, all of it can be seen in Table 1.

Figure 12: Tug robot

(Source: [8])

Specification Chart

<table>
<tr><td>Dimensions</td><td colspan="4">Height 47.7in/121.16 cm
Width 22.4in/56.9 cm
Length 33.8in/85.85 cm</td></tr>
<tr><td>Configuration</td><td>11 Drawer</td><td>9 Drawer
(2X Deep)</td><td>7 Drawer
(4X Deep)</td><td>Door
17”W, 31”H, 20.5”D</td></tr>
<tr><td>Weight</td><td colspan="4">---</td></tr>
<tr><td>Speed</td><td colspan="4">up to 30in/s (76cm/s)</td></tr>
<tr><td>Communications</td><td colspan="4">WiFi or 900MHz
Remote to Command Center</td></tr>
<tr><td>Payload</td><td colspan="4">500 lbs (226.8kg)</td></tr>
<tr><td>User Interface</td><td colspan="4">Multiple dispatch modes:
- Scheduled by software
- Touchscreen
- Programmed multi-stop
- Handheld requests</td></tr>
</table>

Runtime	10 hours with intermittent charging
Navigation and sensors	Overlapping laser Sonar Infrared sensors
Environmental	Interior use

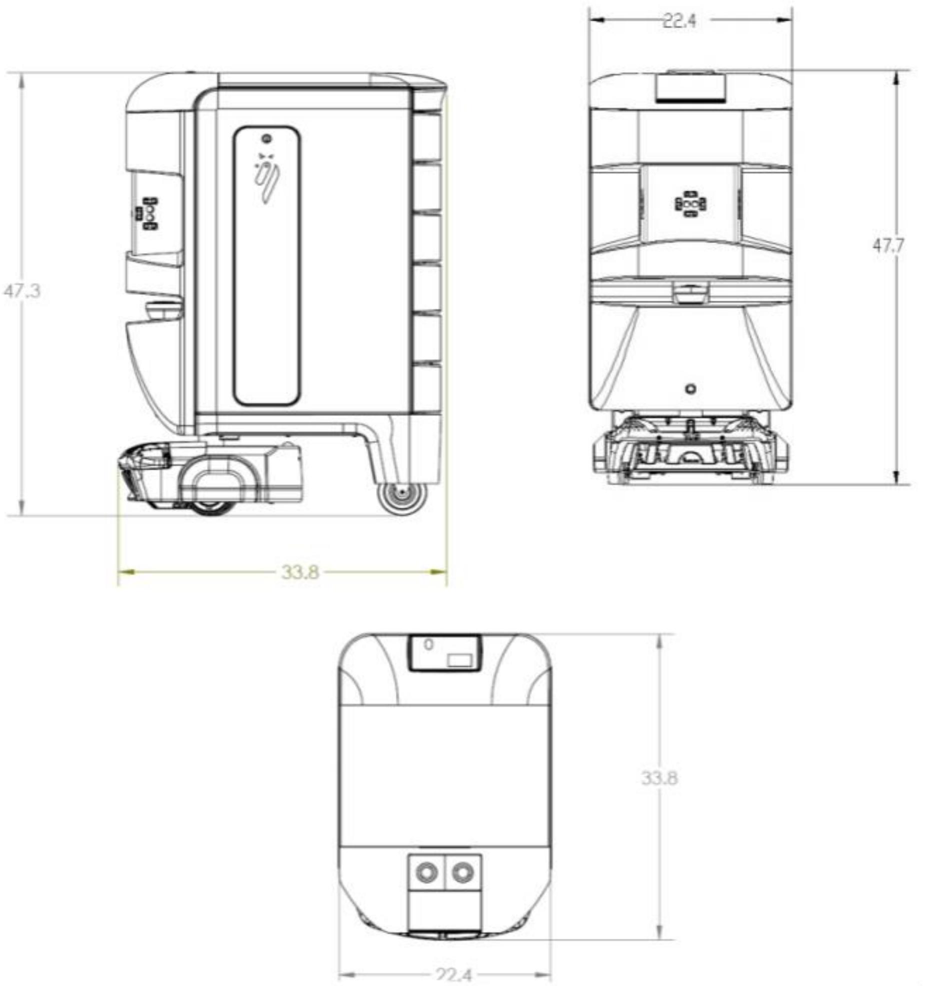

Figure 13: Tug dimensions

(Source: [36])

4.1.1.2 Savioke relay robot

The Savioke Relay Robot from swisslog is also a good option for the transportation of sensitive good. In the health area it has a safely navigation through busy public corridors. Relay provides trackable, chain-of-custody delivery while increasing productivity, saving labour costs, and improving patient care.

The Relay autonomous service robot provides secure chain-of-custody for delivery of medication, specimens, and other items throughout the hospital 24/7. Reliable, friendly, and nimble, Relay navigates safely through busy public corridors and lobbies, increasing productivity and job satisfaction by taking over the dull, time-consuming task of delivery.

Figure 14: Savioke Relay Robot

(Source: [9])

Specification Chart

Dimensions	Height 36in/92 cm Width 20in/51 cm Lenght 23in/52 cm
Weight	90 lbs (40.82kg)
Speed	7m/s
Communications	WiFi LTE Verizon or AT&T

Payload	10 lbs (4.5 kg)
User Interface	Display 7" touch screen Audio Stereo Lighting RGB LED base ring Cargo Lighting Illuminated Security: Automatic Lock
Runtime	Continuous 4 hours Charging Dock Floor mounted Dock & Relay 120V/3A 240V/1.5A
Navigation and sensors	Fully autonomous indoor navigation Obstacle avoidance Multi-floor navigation Elevator control Ability to ride in occupied elevators
Environmental	Interior use

Figure 15: Specifications Savioke Relay Robot

(Source: [9])

Relay's authentication options provide pharmacists with a verifiable trail for every medication delivered throughout the hospital. Additionally, sophisticated software and

“Uber-like” maps show real-time delivery status while tracking and reporting delivery history.

Figure 16: Using Savioke Relay Robot Examples

(Source: [9])

With lockable bin, smooth, trackable navigation and cleanable container, Relay provides a safe and secure option for delivering hazardous medications, controlled substances, blood, and other items that can not be sent through a pneumatic tube system.

Hospitals can easily save hundreds of thousands of dollars in labour each year by letting Relay take over the time-consuming task of delivery, Relay also boosts productivity and job satisfaction by allowing skilled technicians to focus on more valuable work.

Versatile payload provides a wide range of uses for this robot, from chemotherapy drugs to blood products, food to gifts, Relay's deep, safe and cleanable container accommodates the delivery of a large number of items that are transported by a hospital every day.

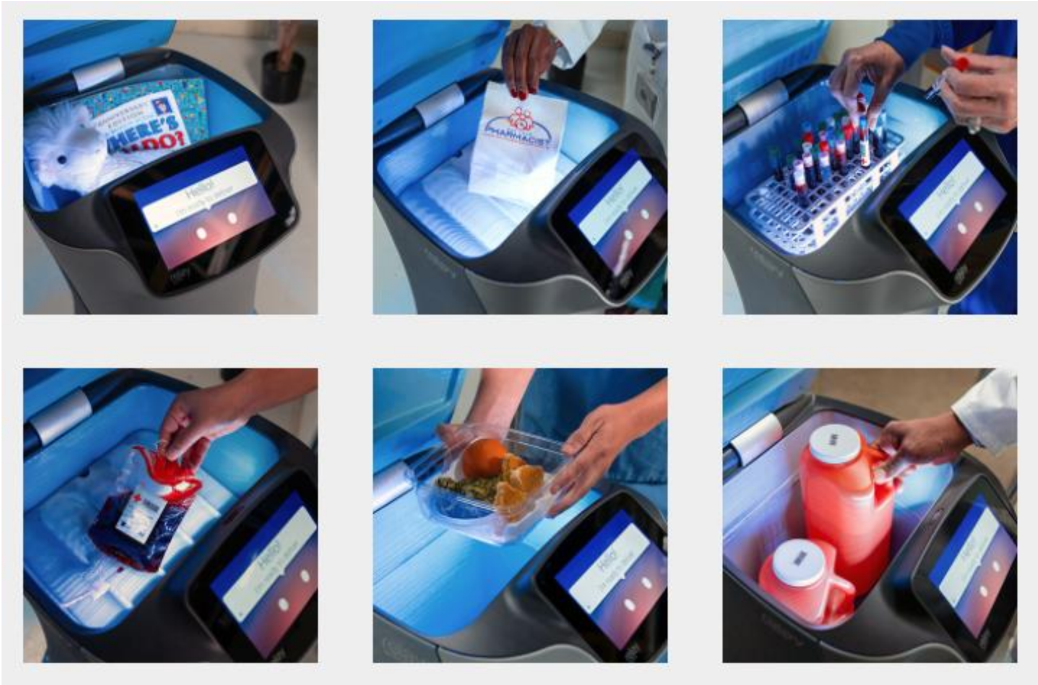

Figure 17: Different materials possible to introduce into the Savioke Relay Robot

(Source: [9])

4.1.1.3 TMiRob

Nine Sunplus Systems offers an efficient way of transporting medications, specimens, modular operation theatre supplies, clean and dirty linen and regulated drugs. It dramatically reduces man-power delivery tasks, shortens turnaround time, enables “lean” workflow pro-cesses.

Figure 18: Load variants in TMiRob

(Source: [10])

Every hospital has unique challenges, by automating TMI autonomous Mobile Robot, staff members are able to spend more time on higher-value patient care activities.

TMI has a map of the hospital stored in its memory and uses a scanning laser and in-frared and ultrasonic sensors to detect and model the environment in real time to maintain accurate position and avoid obstacles. The TMI communicates through the wireless network to control elevators and doors as respond to fire alarm systems. TMI automatically returns to its charging dock after completing a delivery.

NSS autonomous Mobile Robot includes proprietary self-navigation software idea for applying in the hospital environments.

TMI is perfect for both new construction and existing construction. By using smart, autonomous navigation technology TMI is able to deliver payloads directly to point-of-use locations rather than intermediate stations. Unlike AGV systems, it does not require extensive infrastructure planning, tracks, or wires is able to use existing and shared elevators and does not require a build-in guide system to navigate.

Specification Chart

Dimensions	---
Weight	---
Speed	---
Communications	WiFi Remote to Command Center
Payload	200 kg
User Interface	Touch screen QR Authenticator Fingerprint reader
Runtime	---
Navigation and sensors	Connect with the HIS (Hospital Information System)
Environmental	Interior use

There are three common options as load variants in TmiRobots, one with a big closed compariment, another with a trolly for larger and less sensitive materials, and one specifically for the transport of regulated drugs with different compartments

Figure 19: TmiRob for High Valued Consumables

(Source: [11])

Figure 20: TmiRob Trolly Delivery

(Source: [12])

Figure 21: TMiRob Regulated drugs delivery

(Source: [13])

This robot is suitable for unmanned delivery of controlled drugs about toxic drugs, narcotics, I class psychotropic drugs, 11 class psychotropic drugs, and medicines that need to be refrigerated.

4.1.1.4 HOSPI

HOSPI is a hospital delivery robot manufactured by Panasonic. HOSPI service robots were originally developed to be used in healthcare amid Japan's rapidly aging society. It features autonomous navigation capabilities, which allows it navigate using onboard sensors instead of obtrusive rail systems or delineated routes.

The HOSPI robot was launched in 2004. It was built to move autonomously through the pre-installed mapping information within them. It is installed with an on-board sensor and an advanced collision-avoidance system that helps it to move around avoiding obstacles, and stop if a person suddenly runs in front of it.

Figure 22: HOSPI – Hospital delivery robot

(Source: [14])

HOSPI is equipped with security features to prevent tampering, theft and damage during delivery. The robot's contents can only be accessed with ID cards. It is also able to deliver loads that are timely and loads that humans are incapable of carrying. Hospi is programmed and equipped with sensors to efficiently and flexibly navigate a hospital layout. It has a hospital's map data programmed to avoid obstacles such as patients in wheelchairs and complete deliveries with minimal supervision. New hospital routes can be programmed in advance, allowing flexibility. The autonomous robot communicates and relays information on its whereabouts to the control centre, enabling its location to be monitored and recorded at all times, delivering medicine and specimens.

Hospi can delivery fragile and bulky medicines, medical specimens such as lab samples and infectious blood samples or documentation like patients' case notes and medical records.

Specification Chart

Dimensions	Height 138,6 cm Width 63 cm Length 72,5 cm
Weight	170 kg
Speed	1 m/s (configurable)
Communications	Utilising Wi-Fi, HOSPI communicates and relays location details / operation history to the hospital control centre
Payload	Maximum 20 kg / 6 medication trays
User Interface	---
Runtime	Continuous operating time 9h
Navigation and sensors	- Autonomous travel via pre-programmed hospital map data (flexible in adapting to new routes e.g. new hospital ward, new hospital wing) - Avoids obstacles e.g. patients in wheelchairs, visitors, through sensors - A built-in camera option is also available.
Environmental	Interior use

4.1.1.5 Common specifications

Once these 4 robots with closed compartments have been considered, we can draw conclusions regarding the ideal specifications that a robot should have whose purpose is to transport sensitive good within the hospital.

The conclusions we reached are the following:

Dimensions	Height ± 117 cm Width ± 57 cm Lenght ± 70 cm
Weight	Variable weight
Speed	± 1 m/s
Communications	WiFi Remote to hospital center
Payload	Up to 230 kg
User Interface	Touch screen
Runtime	± 10 hours
Navigation and sensors	Infrared sensors Preprogrammed map data Camera
Environmental	Interior use

4.1.2 Robots equipped with a robotic arm

On many occasions, for the transport of these more delicate materials it may be interesting to have a robotic arm in the robot capable of manipulating these objects.

Some of the possibilities that exist with these characteristics are the robots in the following sections.

4.1.2.1 MKR (Muratec Keio Robot)

The Muratec Keio Robot is an autonomous omnidirectional mobile robot system for transport applications in the hospital domain. This robot has a chamber to transfer luggage, specimens, and other materials safely. The robot has sensor devices such as a stereocamera, laser range finder and ultrasonic sensors to recognize surrounding environment and user interfaces such as a touch panel display and a display scrolling messages for interaction with human beings.

Figure 23: MKR in use mode

(Source: [37])

This robot uses a hierarchical action control technique based on the prediction time of the action. The hierarchical control method considers various time scales for actions such as goal path planning, obstacle avoidance within the recognizable range, and emergency avoidance to deal with unexpected events. The robot moves more safely by using the estimated information about the obstacles to avoid them.

Specification Chart

Dimensions	Height 125 cm Width 55 cm Length 75 cm
Weight	70 kg
Speed	1 m/s

Communications	---
Payload	---
User Interface	Touch panel display Display scrolling messages
Runtime	Continuous operating time 1h Charging time 1.5h
Navigation and sensors	Omni-directional wheel with four-wheel drive and independence suspending suspension 1 Laser range finder 16 Ultrasonic sensors 1 Stereocamera Bumper switch
Environmental	Interior use

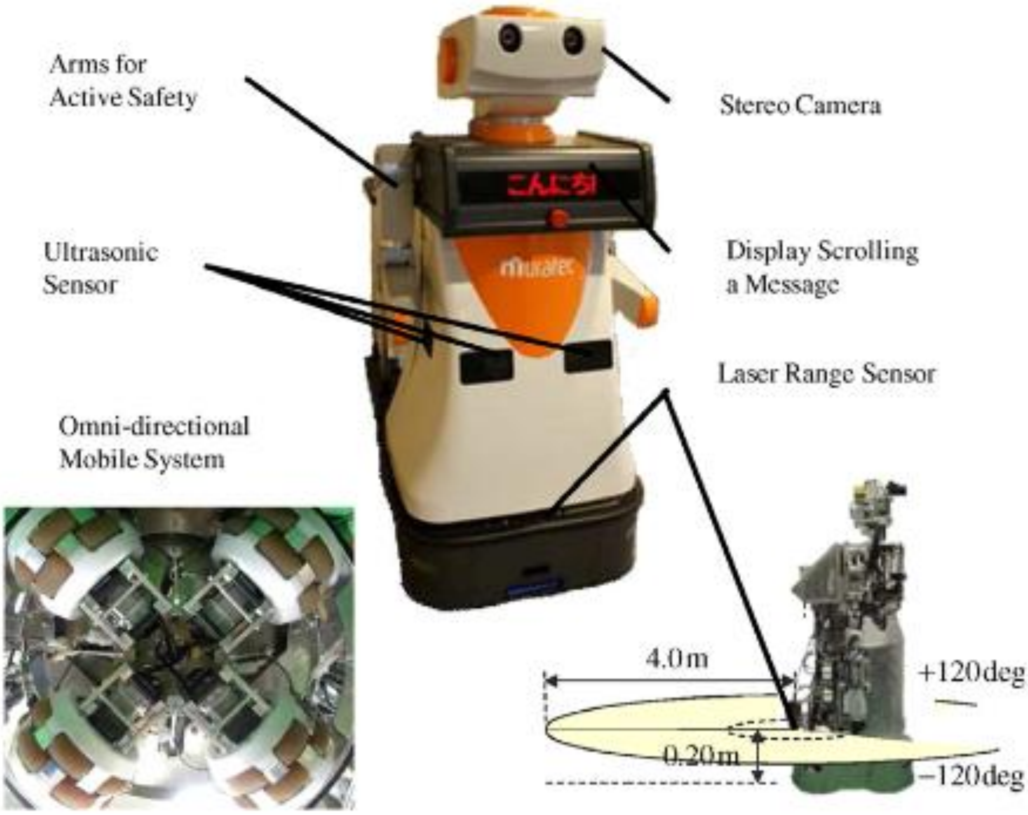

Figure 24: Distribution of the specifications in MKR

(Source: [37][37])

4.1.2.2 Moxi

The AGV vehicle stands out for being collaborative, capable of working in environments surrounded by humans and totally autonomous. Moxi incorporates Artificial Intelligence software composed of algorithms trained by Machine Learning. Thanks to the system, you learn to grasp and manipulate new objects in different situations, as well as to work in dynamic environments.

It carries out tasks like picking up supplies and taking them to patient rooms, delivering lab samples, picking up items from the central supply, and removing soiled bedding bags. Robots can support hospitals in their care workflows and give staff more time to care for patients.

Figure 25: Moxi robot

(Source: [16])

To operate in busy and semi-structured hospital environments, Moxi is comprised of:

- Social intelligence: expressive face, social conscience
- Mobile handling: compatible arm, hand and mobile base
- Human-guided learning: learn from human teachers

With an arm to reach, a gripper to pick up objects, and a movable base to move around, Moxi completes tasks from start to finish without help. The mobile base belongs to the Feth Robotics company. To hold the parts, it uses a robotic arm designed by Kinova and has a two-claw robot gripper manufactured by Robotiq at its end.

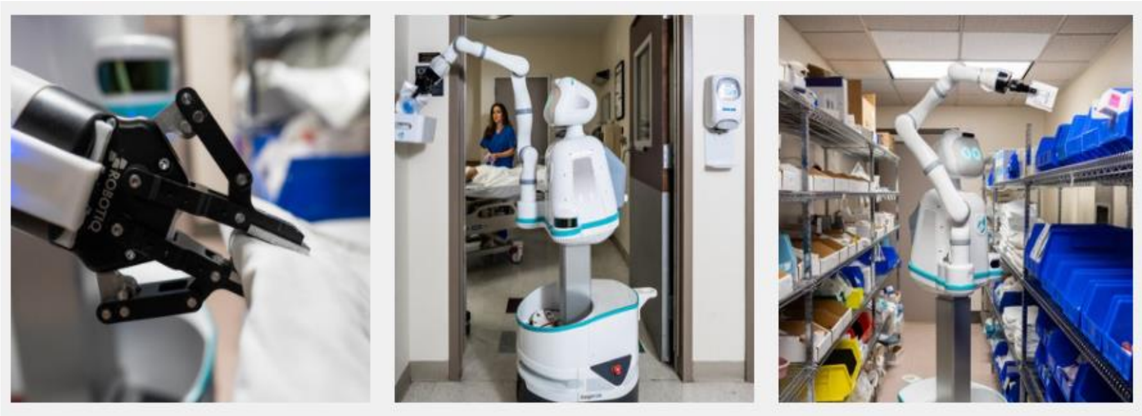

Figure 26: Moxi robot working

(Source: [18])

Moxi helps hospitals run 24/7 by assisting clinical staff with non-patient-facing tasks like:

- Running patient supplies

- Delivering lab samples

- Fetching items from central supply

- Distributing PPE

- Delivering medications

Moxi's software means it's simple to dynamically add new activities as your staff's needs change.

In the initial set-up, Moxi is joined by Diligent's implementation team that can add any number of operational workflows customized for your workspace.

From pilot to part of the team in weeks, not months

This robot has no infrastructure buildout, just digital learnings connected over the existing wi-fi, implementing Moxi is simple. Automation helps hospitals and clinical staff work smarter, not harder and thanks to Moxi nurses spend up to 30% of their time on non-value added tasks.

General Specifications

- Teammate: Moxi works side-by-side with staff
- Dexterous: Uses compliant arm and hand
- Autonomous: Completes tasks end-to-end
- Proactive: Helps staff before they ask

Designed to be compatible with the busy, semi-structured environments of hospitals, Moxi's core technical features include:

Social intelligence: opens elevators and doors on its own, won't bump into people or objects in hallways, happily poses for selfies.

Mobile manipulation: Moxi can grab, pull, open and guide objects, with no human assistance.

Human-guided learning: The more your staff uses Moxi, the more Moxi learns and adapts to your environment and way of doing things.

Moxi continuously adapts to changing hospital workflows by learning from human teachers along the way.

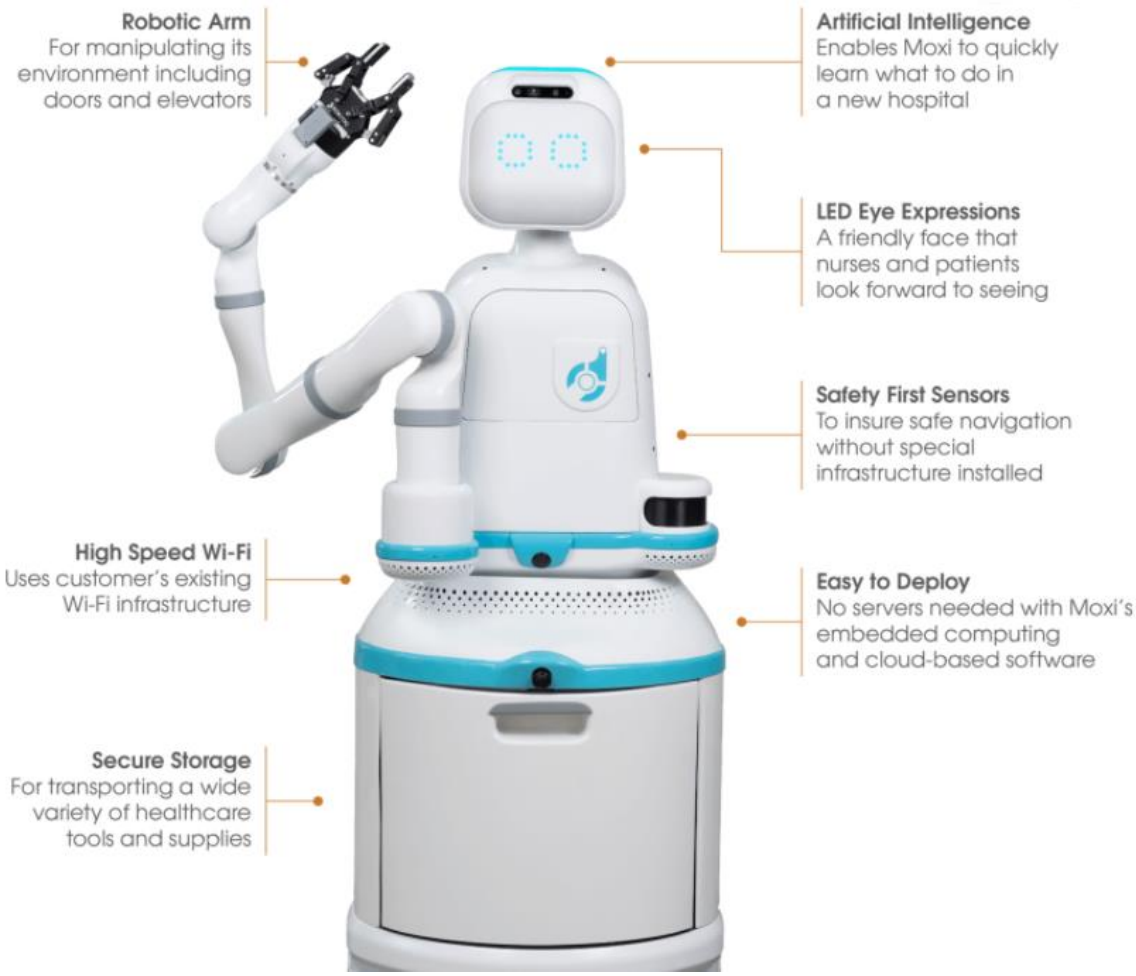

Figure 27: Moxi specifications

(Source: [18])

Specification Chart

Dimensions	Height 170 cm Width 65 cm Length 65 cm
Weight	---
Speed	---
Communications	High speed WiFi
Payload	---
User Interface	Touch panel display Interactive buttons
Runtime	---

Navigation and sensors	Cloud-based software Safety first sensors
Environmental	Interior use

4.1.2.3 Common specifications

Once these 2 robots with robotic arms have been considered, we can draw conclusions regarding the ideal specifications that a robot should have whose purpose is to transport and handle sensitive goods within the hospital.

The conclusions we reached are the following:

Dimensions	H ± 117 cm W ± 57 cm L ± 70 cm
Weight	Human person weight (±70 kg)
Speed	± 1 m/s
Communications	WiFi
Payload	---
User Interface	Touch panel display Buttons
Runtime	± 1 hour
Navigation and sensors	Safety sensors Preprogrammed map data Camera Stereocamera
Environmental	Interior use

4.1.3 Robots with tow

Finally, having robots with tow would be really useful for transporting sensitive goods which are heavier or larger materials. With this initial idea, I am going to present two options from Antheon that fit this need very well.

4.1.3.1 TUG Autonomous Mobile Robot

The TUG is a smart autonomous mobile robot that has become a common sight in hospitals as it delivers materials and supplies. TUG efficiently delivers carts of supplies to where they are needed including meals, linens, as well as removal of trash.

TUG automatically picks up and drops off carts, eliminating the labour that would otherwise be needed to load the robot. It also communicates with the IT system to automate the dispatching of the robot fleet and update the inventory system when materials are moved.

Figure 28: TUG Robot

(Source: [36])

TUG is flexible; an AGV typically requires fixed specialty signifiers like tracks, wires, tape, and reflectors to navigate. Instead, TUG feature modern technology including camera- and laser-based navigational systems allow safe operation in nearly any indoor environment.

Specification Chart

Dimensions	Height 47.7in/121.16 cm Width 22.4in/56.9 cm Length 44.7in/113.5 cm
Weight	---
Speed	30in/s (76cm/s)
Communications	WiFi or 900MHz
Payload	750 lbs (340.2 kg)
User Interface	Multiple dispatch modes: Scheduled Touchscreen ad-hoc Multi-stop “milk runs” Handheld ad-hoc requests Manufacturing system messages
Runtime	10 hours with intermittent charging
Navigation and sensors	Overlapping laser Sonar Infrared sensors
Environmental	Interior use

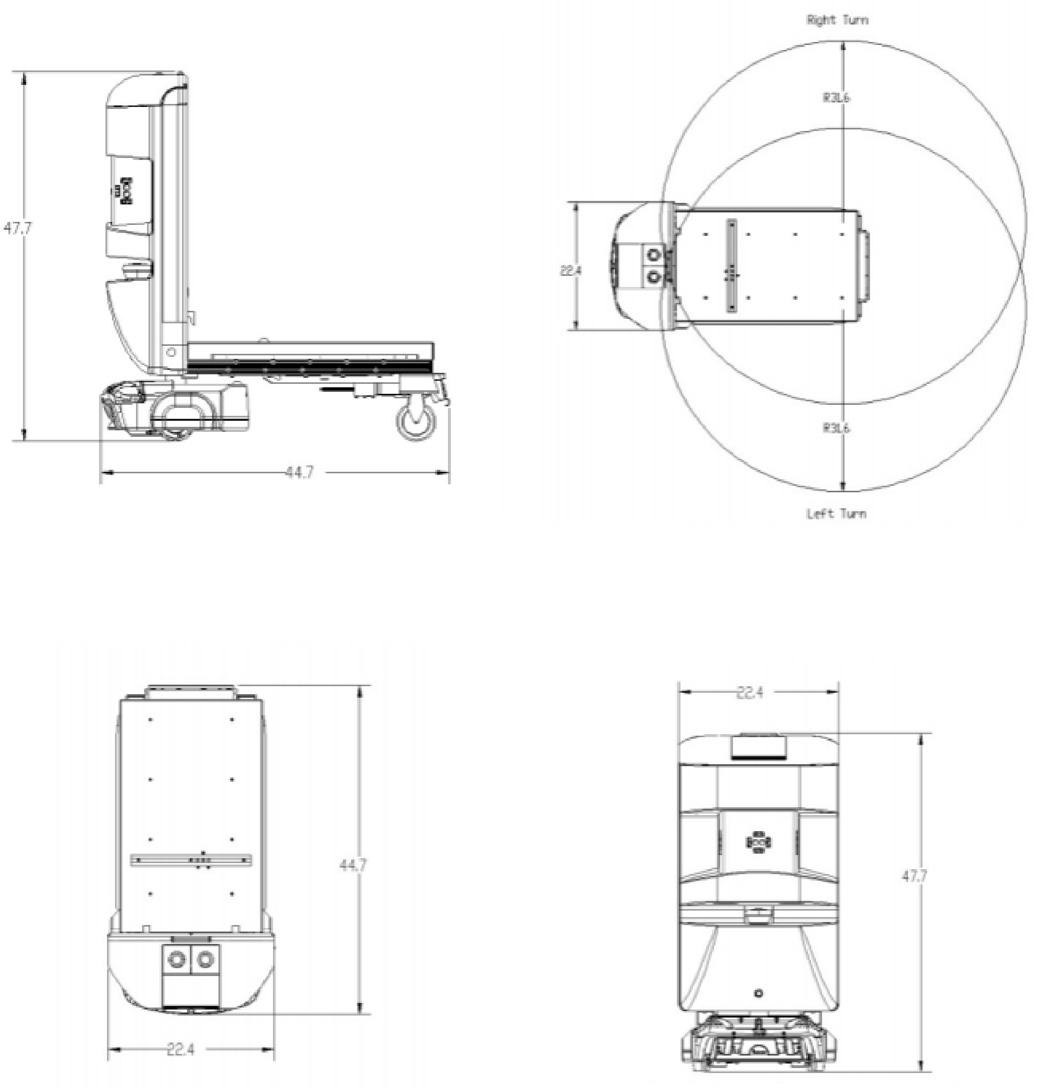

Figure 29: TUG Specifications

(Source: [36])

4.1.3.2 TUG T3 Autonomous Mobile Robot

The TUG T3 is the newest robot from Aethon and is a smart autonomous mobile robot that automates the transport of materials and supplies in hospitals, manufacturing facilities, electronics assembly, and distribution environments. TUG is different from traditional AGV systems in that it requires no infrastructure for navigation.

Figure 30: TUG T3 Robot

(Source: [38])

Specification Chart

Dimensions	Height 48.3in/122.7 cm Width 22.4in/56.9 cm Length 45.8in/116.4 cm Cart length: 38in/96.5 cm
Weight	---
Speed	30in/s (76cm/s)
Communications	WiFi or 900MHz
Payload	1000 lbs (453kg)
User Interface	Multiple dispatch modes: Scheduled Touchscreen ad-hoc Multi-stop “milk runs” Handheld ad-hoc requests Manufacturing system messages
Runtime	24 hours with intermittent charging

	Battery technology: Valve-Regulated Lead-Acid (VRLA)
Navigation and sensors	Overlapping laser Sonar Infrared sensors
Environmental	Interior use

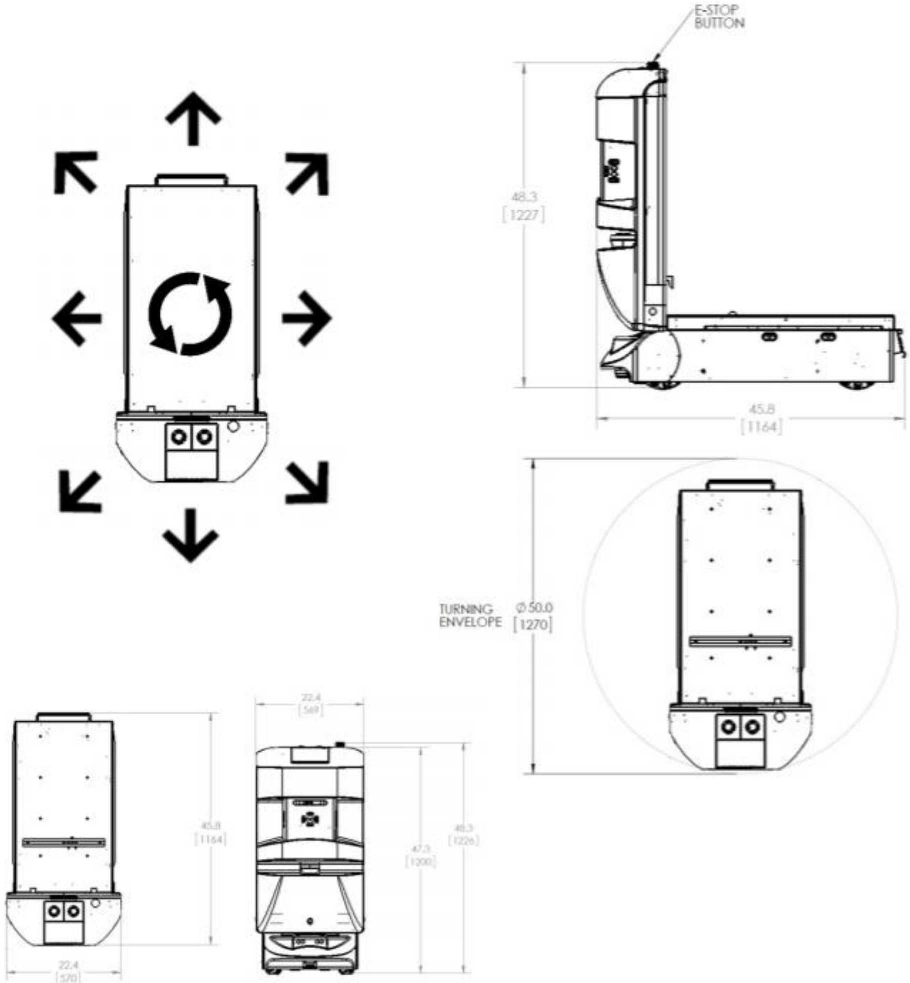

Figure 31: TUG T3 Robot Specifications

(Source: [38])

4.1.3.3 Common specifications

Once these 2 robots with tow have been considered, we can draw conclusions regarding the ideal specifications that a robot should have whose purpose is to transport and handle sensitive goods within the hospital.

The conclusions we reached are the following:

Dimensions	Height ± 121 cm Width ± 57 cm Length ± 115 cm
Weight	---
Speed	± 0,76 m/s
Communications	WiFi or 900MHz
Payload	Up to 450 kg
User Interface	Scheduled Touchscreen ad-hoc Multi-stop "milk runs" Handheld ad-hoc requests Manufacturing system messages
Runtime	Up to 24 hours with intermittent charging
Navigation and sensors	Cloud-based software Safety sensors Overlapping laser Infrared sensors
Environmental	Interior use

4.2 Transportation of bulk material

4.2.1 Underrider solution (compartment fixed/not fixed)

A study conducted at the Transcom 2017, an international scientific conference on sustainable, modern and safe transport stablished the requirements and technical specifications of AGV cart designed for healthcare facility.

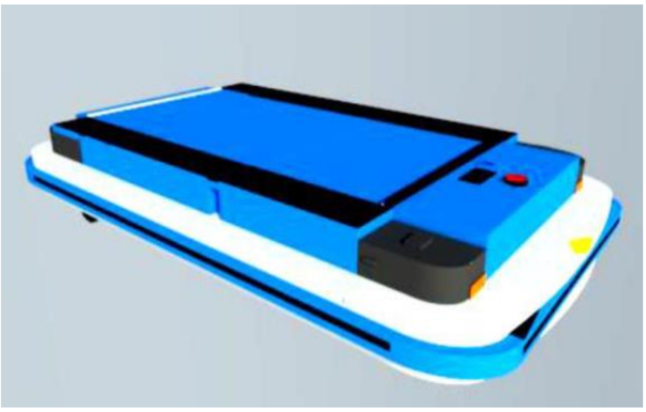

Figure 32: Transcom Underrider

(Source: [34])

Automated solution can streamline traffic flow of material in the hospital, control costs or reduce workload. This relieves hospital staff and allows them to spend most of their time on direct patient care. This increases safety in the hospital by minimizing potential injury to the staff when pushing heavy carts. The system monitors all major movements in the hospital and may prefer te most important jobs and tasks that can be completed first (e.g. surgical instruments transported first, then food for patients, bedding, eventually garbage, etc.). AGV is equipped with sensors to detect obstacles that allow safe stop before hitting obstacles that might be in the way. The system and its vehicles are reliable, safe, efficient and cost-effective. Applications and commands are mediated through a user-friendly touch screen. The system is fully integrated for automatic control of doors, elevators, trolley washers, garbage dump truck, etc.

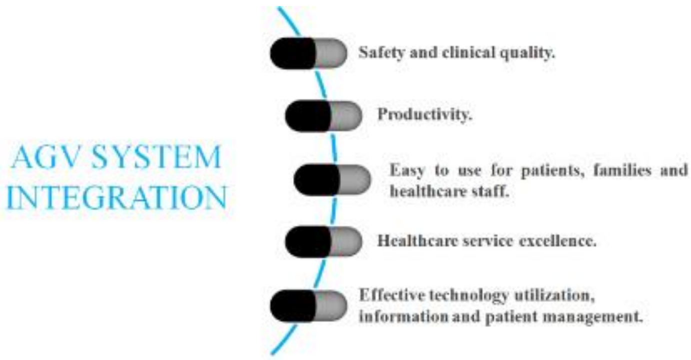

Figure 33: AGV System integration

(Source: [34])

Specification Chart

Dimensions	Height 32 cm Width 63 cm Length 127 cm
Weight	---
Travel Speed	2m/s
Communications	WiFi
Payload	500 kg
User Interface	User-friendly touch screen
Runtime	Battery Capacity: 100 Ah
Navigation and sensors	Sensors to detect obstacles
Environmental	Interior use

After this study, we can choose some existing robots with these specifications really useful for the healthcare environment.

4.2.1.1 MiR100 Robot

The MiR100 is a safe and cost-effective mobile robot that quickly automates your internal transport and logistics operations. The robot optimizes workflows, freeing up staff so that you can increase productivity and reduce costs.

The MiR100 can be used in virtually any situation where employees are in charge of pushing carts or making deliveries thanks to its extraordinary flexibility and smart technology.

The highly flexible MiR100 autonomously transports up to 100 kg (220 lbs). It can be equipped with custom top modules such as containers, shelves, elevators, conveyors, and even a collaborative robot arm, depending on the requirements of each application. The upper modules are easily changed, so that the robot can be used for different tasks.

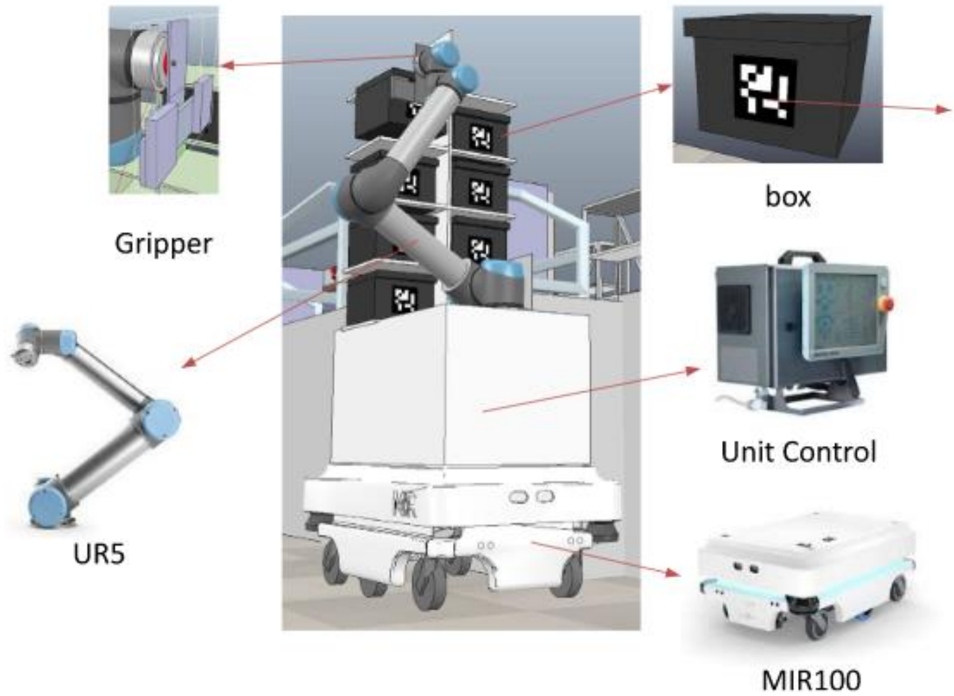

Figure 34: Details on possible robot add-ons

(Source: [34])

The MiR100 robot safely manoeuvres avoiding collisions with people and obstacles, going through doors and in and out of elevators. The building's CAD files can be download directly to the robot, or they can be programmed using the simple online interface, which requires no programming experience. The mission of the robot can be easily adapted using a smartphone, tablet or computer connected to the network.

With integrated sensors and cameras and sophisticated software, the MiR100 is able to identify the environment and take the most efficient route to its destination, safely avoiding colliding with obstacles or people. Without the need to make modifications to your installations with expensive and inflexible cables or sensors, the robot offers a fast return on investment, with a payback period of even one year only.

Figure 35: MiR100 Robot

(Source: [19])

Specification Chart

Dimensions	Height 13.9in/35.2 cm Width 22.8in/58 cm Length 35in/89 cm
Weight	---
Speed	Forwards: 1.5 m/s Backwards: 0.3 m/s
Communications	WiFi router: Dual-band I/O connections: USB and Ethernet REST, Modbus
Payload	220 lbs (100kg)
User Interface	Buttons Emergency stop button
Runtime	10 hours Battery technology: Li-NMC
Navigation and sensors	-SICK safety laser scanners (two pieces): 360º visual protection around robot -3D camera Intel RealSense Detection of objects ahead 50-1800 mm above floor (two pieces) -Ultrasound sensor (four pieces)
Environmental	Interior use

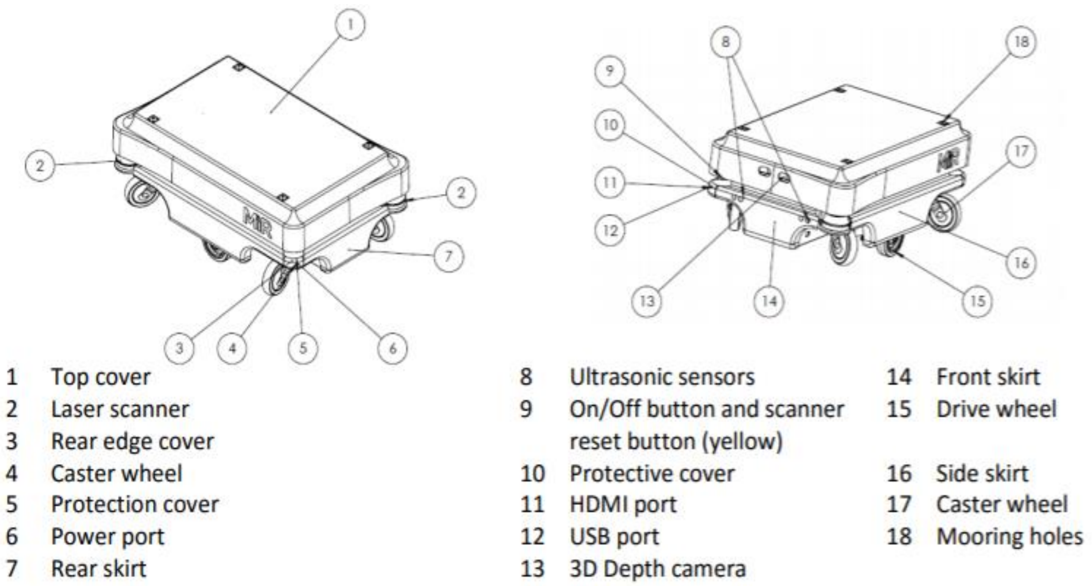

Figure 36: MiR100 Robot Specifications

(Source: [40])

4.2.1.2 SESTO Magnus

SESTO Magnus is a bi-directional, compact Autonomous Mobile Robot that is able to carry payloads up to 300kg despite its compact size. Having the highest payload rating in its compact class, SESTO Magnus is specially built for tight navigation in space-scarce facilities whilst avoiding obstacles in its path. Powered by SESTO's proprietary user-friendly interface, operators can easily deploy SESTO Magnus for material transportation using a tablet or laptop.

Figure 37: SESTO Magnus Robot

(Source: [20])

Using a single mobile platform, SESTO Magnus is highly versatile and can be configured with limitless applications of autonomous material transportation. From components and parts in manufacturing, laundry and meal services in hospitality and care facilities, to central sterile services and dispensaries in hospitals, SESTO Magnus allows for various top module configurations depending on the user’s requirements. Having the highest payload rating in the compact class, SESTO Magnus is designed to automate material handling processes in the manufacturing, commercial and healthcare industries.

Specially built for tight navigation in space-scarce facilities, SESTO Magnus is able to autonomously travel through spaces as narrow as 0.9 metres wide, avoiding obstacles in its path whilst carrying a payload of up to 300kg. Its same-speed bi-directional capability means the autonomous mobile robot can reverse out of dead ends without doing a spot turn.

Figure 38: SESTO Magnus Robot carrying a tray

(Source: [20])

Powered by SESTO’s proprietary user-friendly interface, operators can easily deploy the SESTO Magnus for material transportation using a tablet or laptop. The robot provides high uptime of up to ten hours on a single charge and fast battery charging in three hours. SESTO Magnus is an addition to SESTO Robotics’ suite of autonomous mobile robot solutions that are scalable and versatile.

Specification Chart

Dimensions	Less than 0.9 meters wide
Weight	---
Speed	---
Communications	With lifts and switches map, it communicates automatically when it reaches the destination Routes include narrow aisles and corridors
Payload	300kg
User Interface	User-friendly interface – Tablet or laptop to deploy SESTO Magnus
Runtime	10 hours Battery charging: 3 hours
Navigation and sensors	Low range 270º 2D LIDARS
Environmental	Interior use

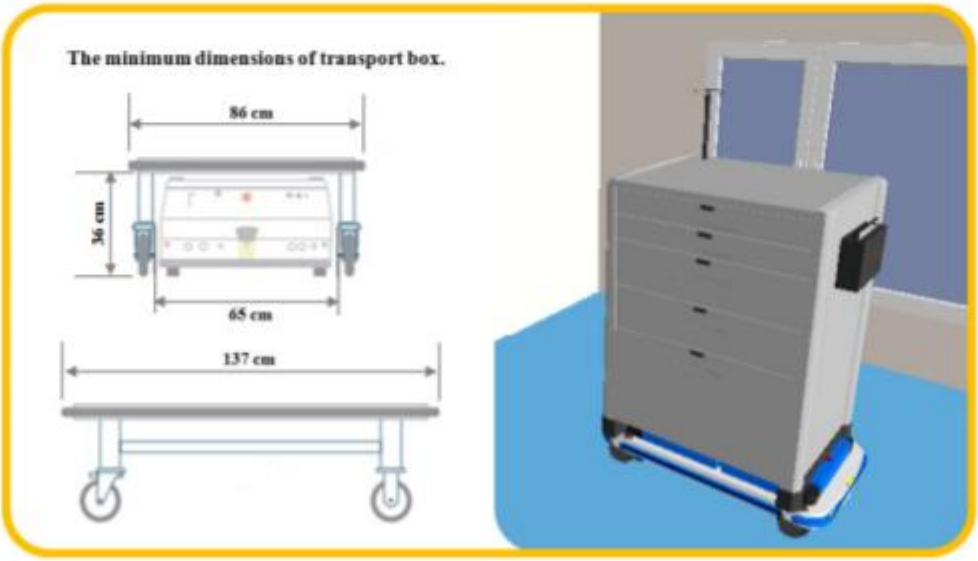

Figure 39: SESTO Magnus Robot dimensions

(Source: [20])

4.2.1.3 OMRON Mobile Robots

The Omron LD Mobile Robot is a self-navigating autonomous mobile robot (AMR) designed to dynamically move material in challenging environments that can include confined aisles, as well as dynamic and populated locations. Unlike traditional Autonomously Guided Vehicles (AGVs), Omron Mobile Robot requires no facility modifications such as floor magnets or navigation beacons, saving users' deployment costs. The LD includes Omron's proprietary software and controls that allow it to intelligently navigate around unplanned people and obstacles, incapacitating traditional AGVs, and can be programmed and up and running in one day. Designed for developers, integrators, and end users, the system can be customized for a variety of applications and payloads.

Figure 40: Omron LD Mobile Robot

(Source: [21])

Omron mobile robots fully comply with the safety standard. They use an integrated laser and other sensors to detect obstacles in their path and, depending on the speed of travel, activate an emergency stop to avoid a collision of the vehicle.

Sensory acuity provides an additional method of "localization" for the integrated laser, to allow the robot to operate in frequently changing environments. Identify the ceilings and overlap the "light map" with the "floor map."

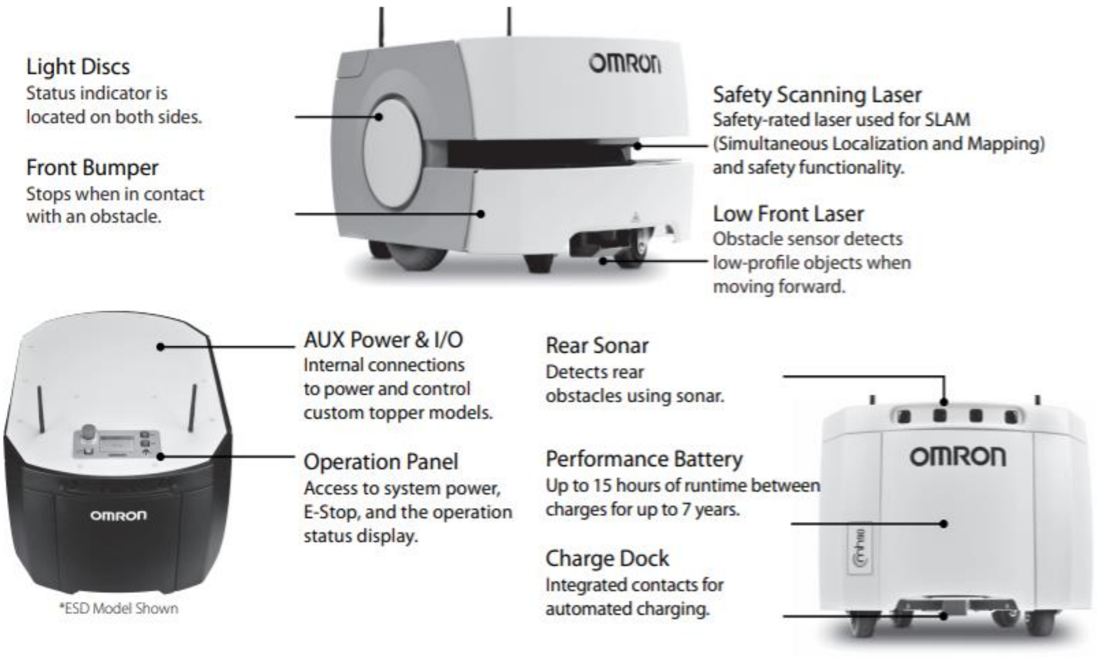

Figure 41: Omron LD Mobile Robot Specifications

(Source: [41])

Specification Chart

Dimensions	Height 38.3 cm Width 50 cm Length 69.9 cm
Weight	---
Speed	1.8 m/s
Communications	WiFi Wireless Ethernet Port
Payload	60 kg
User Interface	Screen/Touch panel Buttons
Runtime	Battery: 15 hours (continuous) Recharge time: 4 hours
Navigation and sensors	- Safety rated main laser - Lower laser - Side lasers (patented)

	- Front bumper - Rear sonar - Rear laser
Environmental	Interior use

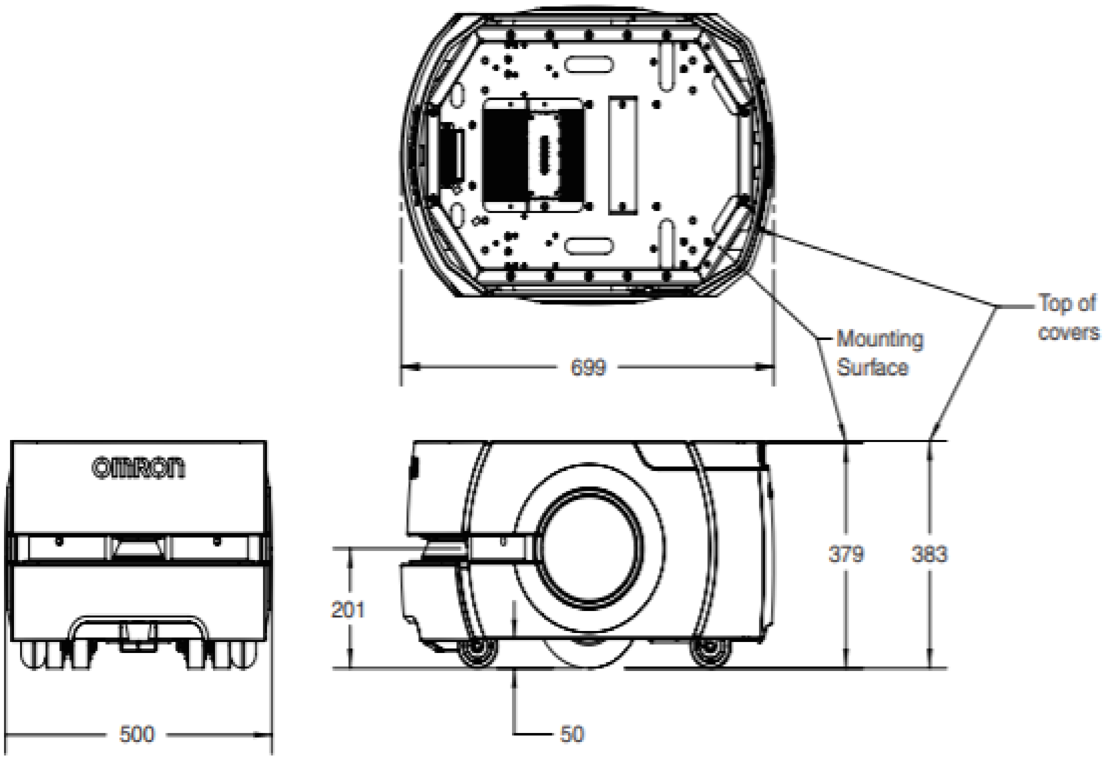

Figure 42: Omron LD Mobile Robot dimensions

(Source: [41])

4.2.1.4 PAL Robotics

PAL Robotics is a new autonomous delivery robot, designed and targeted for use in hospitals. The vehicle is designed to autonomously navigate throughout the hospital to pick and and deliver items such as food, medication, lab samples, surgical supplies, bedding or nursing supplies.

This solution is a response to the ongoing demands of the corona virus pandemic, and the need to keep front line health workers safe.

Figure 43: PAL Robotics delivery robot

(Source: [28])

The PAL Delivery Robot is designed as a custom payload for the PAL Robotics TIAGo base. TIAGo is a mature and well-established solution with hundreds of units in operation around the world in a variety of applications.

The novel addition to this new solution is the addition of additional positioning accuracy, which reduces deployment time.

The company Accerion provides positioning solutions, enabling high-performance mobile robots and AGVs for intralogistics, with virtual lines or grid mapping to allow for free navigation. The advanced technology inside the system enables submillimetre-level positioning without any additional infrastructure.

Figure 44: Load variants in PAL delivery robot

(Source: [28])

Specification Chart

Dimensions	50 cm diameter 30 cm height
Weight	---
Speed	1 m/s
Communications	Open Source Platform OS + ROS Hydro Navigation Software
Payload	50-100 kg
User Interface	User panel Stereo microphone
Runtime	---
Navigation and sensors	RGB-D camera Laser range-finder
Environmental	Interior use

The most useful disposition in our case will be a complet load with a robotic arm, camera, microphone, speaker and a comfortable interaction with the user.

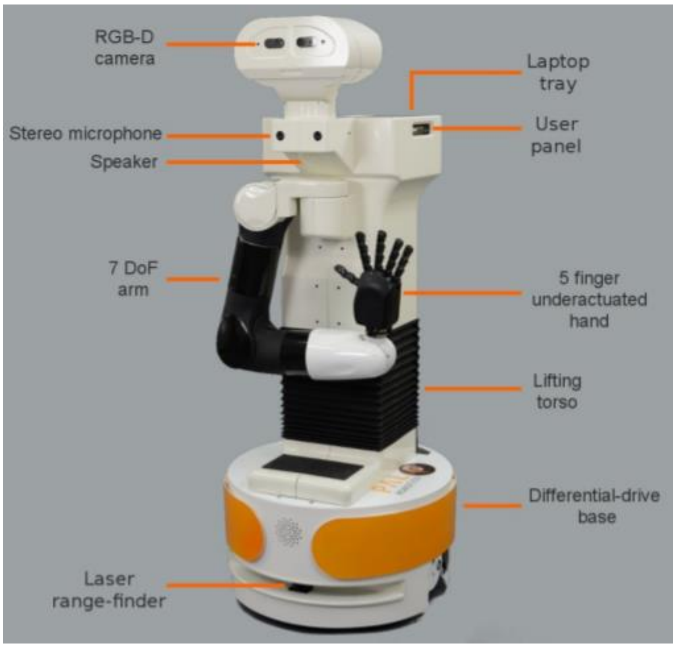

Figure 45: TIAGo Robot features

(Source: [30])

4.2.1.5 Common specifications

Once these underrider general example has been used as a reference for the other four possible solutions, we can draw conclusions regarding the ideal specifications that a robot should have whose purpose is to transport and handle bulk material within the hospital.

The conclusions we reached are the following:

Dimensions	Height ± 33,8 cm Width ± 55,25 cm Length ± 84 cm
Weight	---
Speed	± 1,6 m/s
Communications	WiFi Ethernet Port
Payload	Up to 200-300 kg
User Interface	Screen/Touch panel Buttons
Runtime	Battery: 10-15 hours Recharge time: 3-4 hours
Navigation and sensors	Laser scanners Safety sensors Ultrasound sensor Rear sonar Rear laser
Environmental	Interior use

4.3 Food transportation

As the last transportation need, we have the distribution of food in the hospital. In this section we will analyse the room service robot options to distribute meals among patients.

4.3.1 Amy waitress robot

Robot waitress is an innovative functional robot that can act as an interactive assistant for any service sector. Robot waitress can carry out reception duties, deliver food and drink create an interactive shopping experience and provide consultative and informative explanations.

Figure 46: Amy waitress robot

(Source: [23])

Specification chart

Dimensions	Length: 78 cm Width: 56 cm Height: 150 cm
Weight	---
Food Handling	Arms with large bearing capacity Driving wheels
Speed	0.1-0.8 m/s
Communications	WiFi
Payload	5 kg
User Interface	Speech interaction Touch screen
Runtime	10 hours per day

Navigation and sensors	Trackless navigation Obstacle navigation SLAM Lidar Sensor Ultrasonic obstacle avoidance sensor
Environmental	Interior use

Figure 47: Amy waitress robot specifications

(Source: [23])

4.3.2 Dexter delivery robot

Dexter Dish Delivery Robot is one new concept which delivers hot food to patients saving cost, manpower and improving efficiency.

Figure 48: Dexter delivery robot

(Source: [23])

The Dish delivery Robot uses a cloud brained system for information and processing such as map management, route planning and updating Menu's. The system comes complete with a three-layer tray each capable of loading up to 10kg. The system also has auto docking and one-time multi point transportation.

The system is carried with multiple sensors and can be autonomously positioned in various locations. The delivery robot has deep optimization of the obstacle avoidance algorithm. The system can perceive the real time environmental changes around it and will bypass obstacles in any planning path. It will autonomously select the best optimal route back to ensure a human reliable experience.

Specification chart

Dimensions	Length: 60 cm Width: 45 cm Height: 106 cm
Weight	---
Food Handling	Driving wheels
Speed	Up to 0.7 m/s

Communications	WiFi
Payload	30 kg
User Interface	Touch screen
Runtime	10 hours per day
Navigation and sensors	---
Environmental	Interior use

4.3.3 Waiter robot (Beta-G)

Versatility is one of the strengths of this robot. It is designed to perform two main tasks. On the one hand, Penny is in charge of distributing the dishes around the tables. After diners have finished savouring the served menus, the robot also functions as a dishwasher.

Figure 49: Waiter robot (Beta-G)

(Source: [42])

The waiter robot (Beta-G) comprises a base and an automatic dumbwaiter, which has three levels for trays. The dumbwaiter is enclosed to keep the food within it warm and clean. At the table, a draw bridge door is lowered, and the required tray is lifted to the door and is rolled out onto the door. The base houses the motors driving four meconium wheels, power electronics, and the power source. The power source consists of two 24V lithium polymer (LiPo) batteries to supply power to the robot. To enable the robot to serve tables of different heights, a motorized lifting table is installed between the base and the dumbwaiter.

Specification chart

Dimensions	Height: 115 cm Diameter: 50 cm
Weight	---
Food Handling	Driving wheels
Speed	Up to 0.7 m/s
Communications	WiFi
Payload	30 kg
User Interface	Touch screen
Runtime	10 hours per day
Navigation and sensors	---
Environmental	Interior use

4.3.4 CSJBot

She is the latest new delivery cart of high-class outer appearance. This vending robot is equipped a quality transparent closed door with magnetic lock which would pop against it arrived at appointed destination locations.

Figure 50: CSJBot vender robot

(Source: [32])

Using the SLAM algorithm and IRT (Image Recognition Technology), this robot is guided by intelligent planning towards huge crowds, detecting current consumers and precisely searching for potential consumers who will then have an extraordinary "the person" experience.

Carried with multiple sensors, the robot can autonomously position in the environment. Through the deep optimization of the obstacle avoidance algorithm, it can perceive the real-time environmental changes around it. The robot can then bypass the obstacles in the planning path and select the best optimal route to ensure the humans around it a safe and reliable experience on its way back to target point.

It may require technicians to create route planning and setup before use, after tht the robot can start working among crowds.

HD touch screen presents the patient with mobile advertisement, video ads, promotion reminders, goods push, check goods information, showing map and so on.

This robot is also equipped with a backend cloud platform which enables it to plan the commodity routes, manage map and other information while also transferring the data for storage.

Figure 51: CSJBot vender robot specifications

(Source: [32])

Specification chart

Dimensions	Length: 85 cm Width: 80 cm Height: 143 cm
Weight	---
Food Handling	Driving wheels
Speed	Up to 0.7 m/s
Communications	WiFi
Payload	Max. weight: 30 kg
User Interaction	Touch screen
Runtime	10 hours per day
Navigation and sensors	SLAM Technology
Environmental	Interior use

4.3.5 MSR-100A

The MSR-100A is designed to serve dual purposes of autonomous small package delivery and mobile advertisement. It utilizes the Intelligent Transfer Navigation System (IT's NAVI) to move on its own from one point to another while avoiding obstacles along the way.

Figure 52: MSR-100A Robot

(Source: [27])

This robot has the purpose of cutting down manpower spent on room deliveries, the MSR-100A can be effectively utilized to safely courier small to medium sized items less than 30kg from one indoor location to another. The MSR-100A can also be asked to roam an open area, such as the lobby, where it will greet patients, display messages, and dispense snacks and drinks. Last but not least, the MSR-100A is outfitted with proximity sensors and a collision prevention system to provide an exciting yet safe experience for guests.

Specification chart

Dimensions	Length: --- Width: --- Height: ---
Weight	---
Food Handling	Driving wheels

Speed	0.7 m/s
Communications	WiFi
Payload	30 kg
User Interaction	Touch screen
Runtime	---
Navigation and sensors	Intelligent transfer navigation system (NAVI) Sensors and collision prevention system
Environmental	Interior use

4.3.6 Common specifications

Once these five delivery robots have been considered, we can draw conclusions regarding the ideal specifications that a robot should have whose purpose is to transport and handle food within the hospital.

The conclusions we reached are the following:

Dimensions	Height ± 128,5cm Width ± 57,8cm Length ± 68 cm
Weight	---
Speed	Driving wheels Arms with large capacity (optional)
Communications	Up to 0,7 m/s
Payload	WiFi
User Interface	Up to 30 kg
Runtime	Touch screen
Navigation and sensors	10 hours
Environmental	Obstacle navigation SLAM Lidar Sensor Collision prevention system

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List of figures

Annexes

Closed compartment robots for sensitive goods comparison table

	Tug Robot	*Savioke Relay*	*TMiRob*	*Hospi*	***CONCLUSION***
Dimensions	H – 120 cm W – 57 cm L – 86 cm	H – 92 cm W – 51m L – 52 cm	---	H – 139 cm W – 63 cm L – 72 cm	***H ± 117 cm*** ***W ± 57 cm*** ***L ± 70 cm***
Weight	---	40,8 kg	---	170 kg	***Variable weight***
Speed	0,76 m/s	7 m/s	---	1 m/s	***± 1 m/s***
Communications	WiFi Remote to command center	WiFi	WiFi Remote to command center	WiFi Remote to hospital center	***WiFi*** ***Remote to hospital center***
Payload	227 kg	4,5 kg	200 kg	20 kg	***Up to 230 kg***
User Interface	- Scheduled by software - Touch screen - Programmed multi-stops - Handled requests	- Touch screen - Audio stereo - Lightning LED	- QR Authentication - Touch screen - Fingerprint reader	---	***Touch screen***
Runtime	10 hours	4 hours	---	9 hours	***± 10 hours***
Navigation and sensors	- Overlapping laser - Sonar - Infrared sensors	- Multi-floor navigation - Elevator control	- Connected to Information System	- Preprogrammed map data - Camera	- ***Infrared sensors*** - ***Preprogrammed map data*** - ***Camera***
Environmental	Interior use	Interior use	Interior use	Interior use	***Interior use***

Robots equipped with a robotic arm comparison table

	MKR	*Moxi*	***CONCLUSION***
Dimensions	Height 125 cm Width 55 cm Length 75 cm	Height 170 cm Width 65 cm Length 65 cm	***H ± 117 cm*** ***W ± 57 cm*** ***L ± 70 cm***
Weight	70 kg	---	***Human person weight (±70 kg)***
Speed	1 m/s	---	***± 1 m/s***
Communications	---	High speed WiFi	***WiFi***
Payload	---	---	**---**
User Interface	- Touch panel display - Display scrolling messages	- Touch panel display - Interactive buttons	- ***Touch panel display*** - ***Buttons***
Runtime	Continuous operating time 1h Charging time 1.5h	---	***± 1 hour***
Navigation and sensors	- Omni-directional wheel with four-wheel drive and independence suspending suspension - 1 Laser range finder - 16 Ultrasonic sensors - 1 Stereocamera - Bumper switch	- Cloud-based software - Safety first sensors	- ***Safety sensors*** - ***Preprogrammed map data*** - ***Camera*** - ***Stereocamera***
Environmental	Interior use	Interior use	***Interior use***

Robots with tow comparison table

	TUG	*TUG T3*	*CONCLUSION*
Dimensions	Height 47.7in/121.16 cm Width 22.4in/56.9 cm Length 44.7in/113.5 cm	Height 48.3in/122.7 cm Width 22.4in/56.9 cm Length 45.8in/116.4 cm Cart length: 38in/96.5 cm	***Height ± 121 cm*** ***Width ± 57 cm*** ***Length ± 115 cm***
Weight	---	---	---
Speed	30in/s (76cm/s)	30in/s (76cm/s)	***± 0,76 m/s***
Communications	WiFi or 900MHz	WiFi or 900MHz	***WiFi or 900MHz***
Payload	750 lbs (340.2 kg)	1000 lbs (453kg)	***Up to 450 kg***
User Interface	Multiple dispatch modes: - Scheduled - Touchscreen ad-hoc - Multi-stop "milk runs" - Handheld ad-hoc requests - Manufacturing system messages	Multiple dispatch modes: - Scheduled - Touchscreen ad-hoc - Multi-stop "milk runs" - Handheld ad-hoc requests - Manufacturing system messages	- ***Scheduled*** - ***Touchscreen ad-hoc*** - ***Multi-stop "milk runs"*** - ***Handheld ad-hoc requests*** - ***Manufacturing system messages***
Runtime	10 hours with intermittent charging	24 hours with intermittent charging Battery technology: Valve-Regulated Lead-Acid (VRLA)	***Up to 24 hours with intermittent charging***
Navigation and sensors	- Overlapping laser - Sonar - Infrared sensors	- Cloud-based software - Safety first sensors	- ***Cloud-based software*** - ***Safety sensors*** - ***Overlapping laser*** - ***Infrared sensors***
Environmental	Interior use	Interior use	***Interior use***

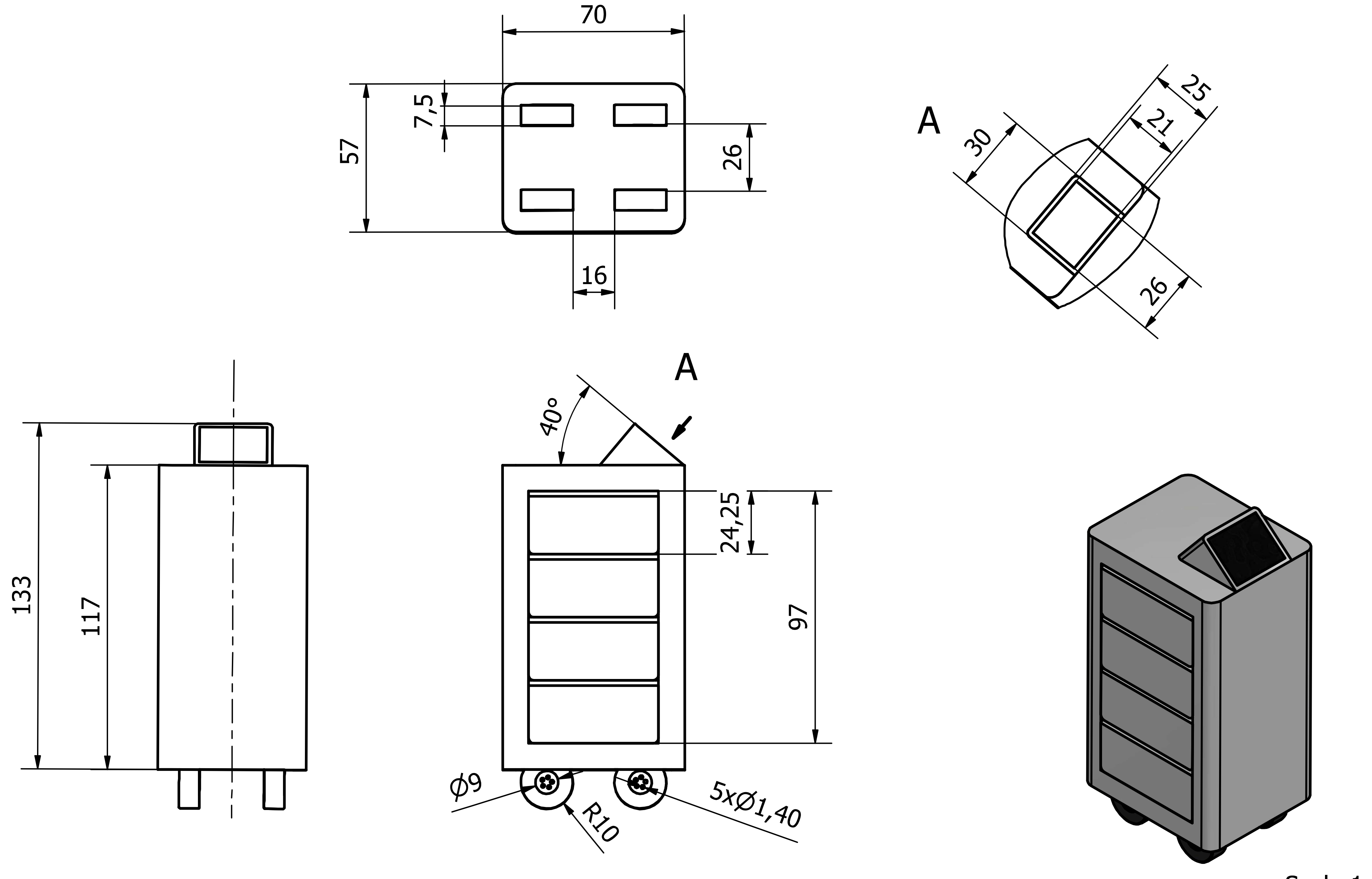
Underrider solutions comparison table

	General Underrider	*MiR100 Robot*	*SESTO Magnus*	*OMRON*	*PAL Robotics*	***CONCLUSION***
Dimensions	Height 32 cm Width 63 cm Length 127 cm	Height 13.9in/35.2 cm Width 22.8in/58 cm Length 35in/89 cm	Less than 0.9 meters wide	Height 38.3 cm Width 50 cm Length 69.9 cm	Height 30 cm Diameter 50 cm	***Height ± 33,8 cm*** ***Width ± 55,25 cm*** ***Length ± 84 cm***
Weight	---	---	---	---	---	---
Speed	2m/s	Forwards: 1.5 m/s Backwards: 0.3 m/s	---	1.8 m/s	1 m/s	***± 1,6 m/s***
Communications	WiFi	- WiFi router: Dual-band - I/O connections: USB and Ethernet - REST, Modbus	- With lifts and switches map, it communicates automatically when it reaches the destination - Routes include narrow aisles and corridors	- WiFi - Wireless - Ethernet Port	- Open Source Platform - OS + ROS Hydro - Navigation Software	- ***WiFi*** - ***Ethernet Port***
Payload	500 kg	220 lbs (100kg)	300kg	60 kg	50-100 kg	***Up to 200-300 kg***
User Interface	User-friendly touch screen	- Buttons - Emergency stop button	- User-friendly interface - Tablet or laptop to deploy SESTO Magnus	- Screen/Touch panel - Buttons	- User panel - Stereo microphone	- ***Screen/Touch panel*** - ***Buttons***
Runtime	Battery Capacity: 100 Ah	10 hours Battery technology: Li-NMC	10 hours Battery charging: 3 hours	Battery: 15 hours (continuous) Recharge time: 4 hours	---	***Battery: 10-15 hours*** ***Recharge time: 3-4 hours***
Navigation and sensors	Sensors to detect obstacles	- SICK safety laser scanners (two pieces): 360° visual protection around robot - 3D camera Intel RealSense Detection of objects ahead 50-1800 mm above floor (two pieces) - Ultrasound sensor (four pieces)	Low range 270° 2D LIDARS	- Safety rated main laser - Lower laser - Side lasers (patented) - Front bumper - Rear sonar - Rear laser	- RGB-D camera - Laser range-finder	- ***Laser scanners*** - ***Safety sensors*** - ***Ultrasound sensor*** - ***Rear sonar*** - ***Rear laser***
Environmental	Interior use	Interior use	Interior use	Interior use	Interior use	***Interior use***

Food transportation robot’s comparison table

	Amy	*Dexter*	*Beta-G*	*CSJBot*	*MSR-100A*	***CONCLUSION***
Dimensions	Height: 150 cm Width: 56 cm Length: 78 cm	Height: 106 cm Width: 45 cm Length: 60 cm	Height: 115 cm Diameter: 50 cm	Height: 143 cm Width: 80 cm Length: 85 cm	Height: --- Width: --- Length: ---	***Height ± 128,5cm*** ***Width ± 57,8cm*** ***Length ± 68 cm***
Weight	---	---	---	---	---	---
Food Handling	Arms with large bearing capacity Driving wheels	Driving wheels	Driving wheels	Driving wheels	Driving wheels	***Driving wheels*** ***Arms with large capacity (optional)***
Speed	0.1-0.8 m/s	Up to 0.7 m/s	Up to 0.7 m/s	Up to 0.7 m/s	0.7 m/s	***Up to 0,7 m/s***
Communications	WiFi	WiFi	WiFi	WiFi	WiFi	***WiFi***
Payload	5 kg	30 kg	30 kg	Max. weight: 30 kg	30 kg	***Up to 30 kg***
User Interface	Speech interaction Touch screen	Touch screen	Touch screen	Touch screen	Touch screen	***Touch screen***
Runtime	10 hours per day	10 hours per day	10 hours per day	10 hours per day	---	***10 hours***
Navigation and sensors	- Trackless navigation - Obstacle navigation - SLAM Lidar Sensor - Ultrasonic obstacle avoidance sensor	---	---	SLAM Technology	- Intelligent transfer navigation system (NAVI) - Sensors and collision prevention system	- ***Obstacle navigation*** - ***SLAM Lidar Sensor*** - ***Collision prevention system***
Environmental	Interior use	Interior use	Interior use	Interior use	Interior use	***Interior use***

Ideal robots plan for its category



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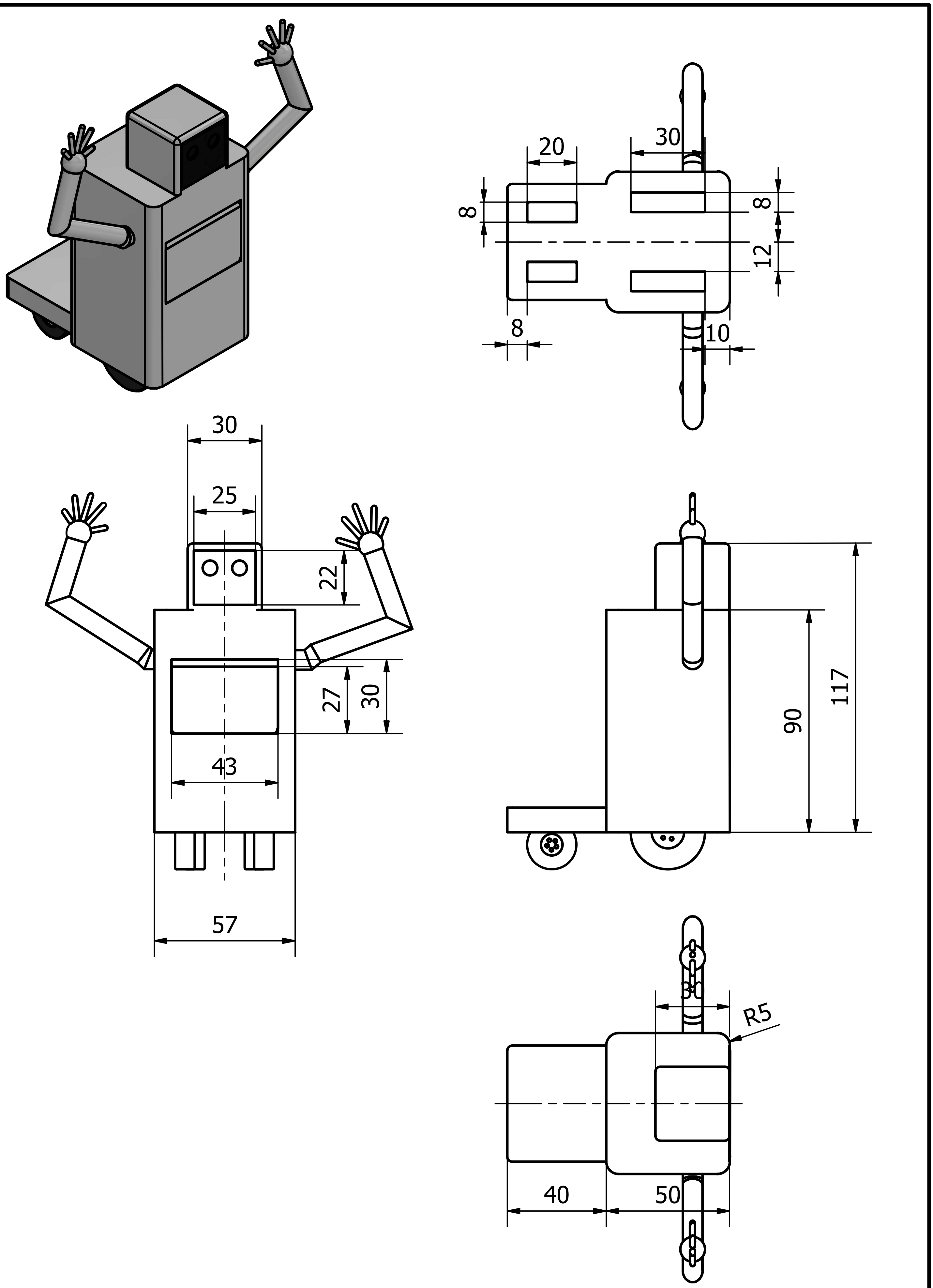

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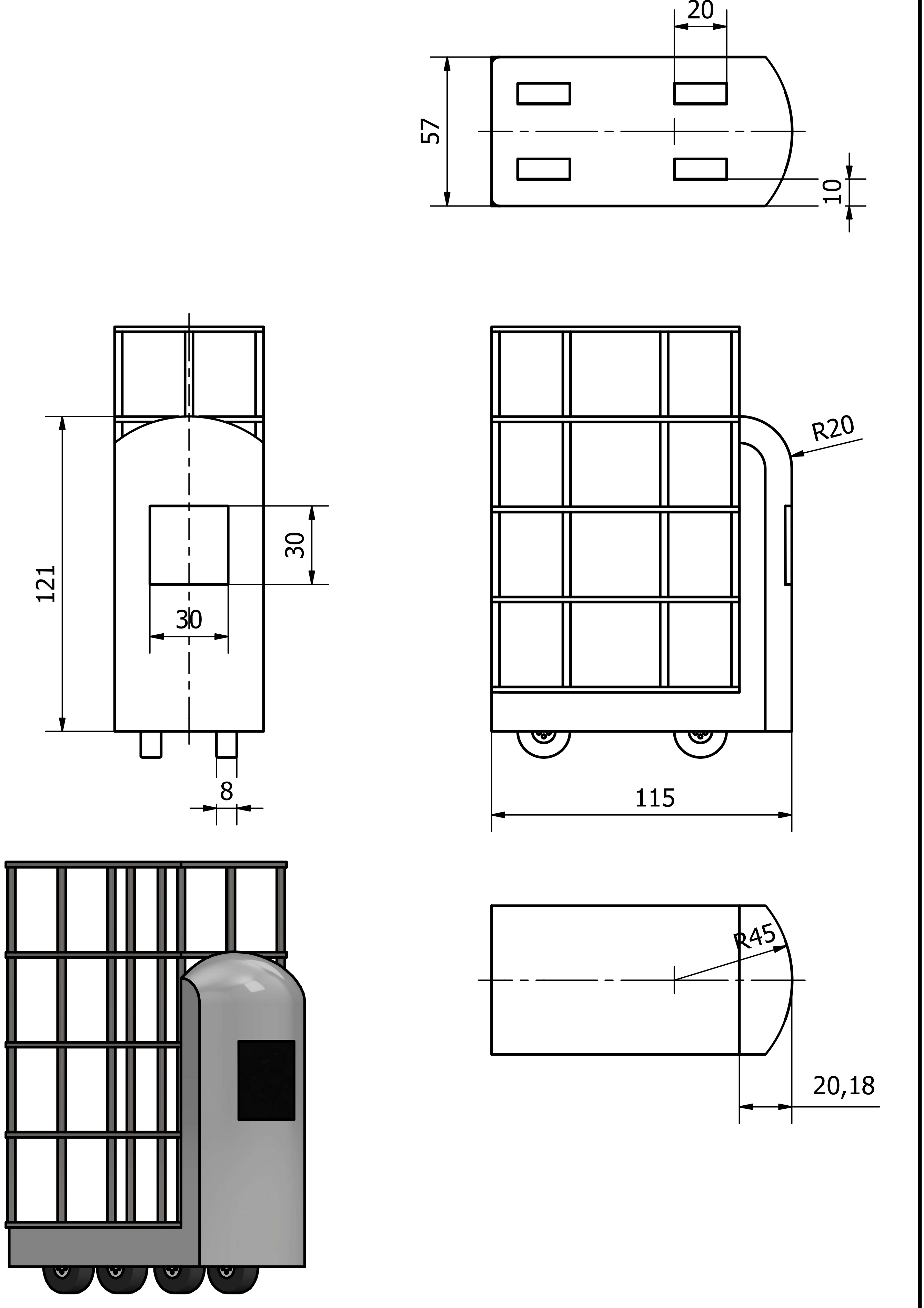

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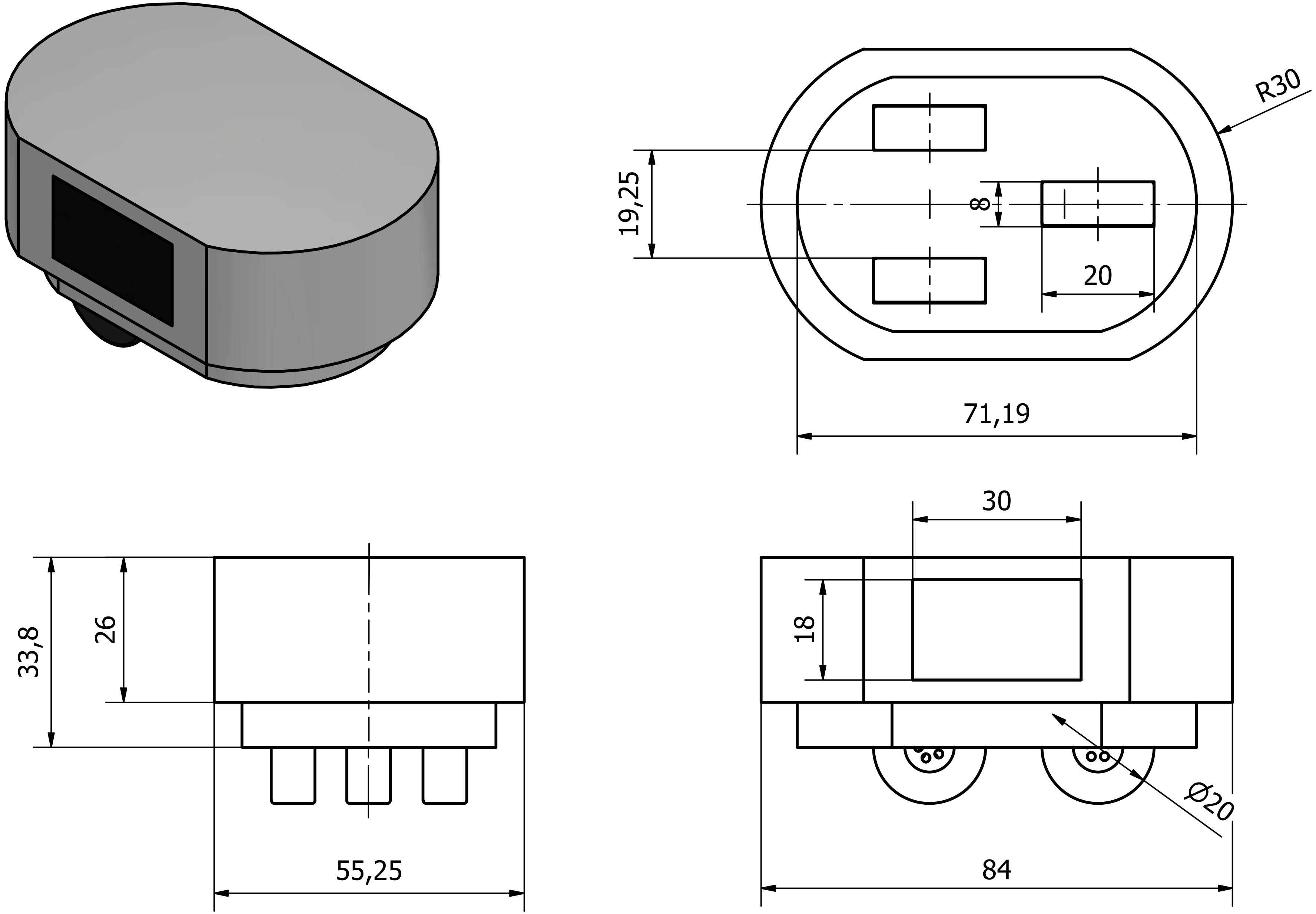

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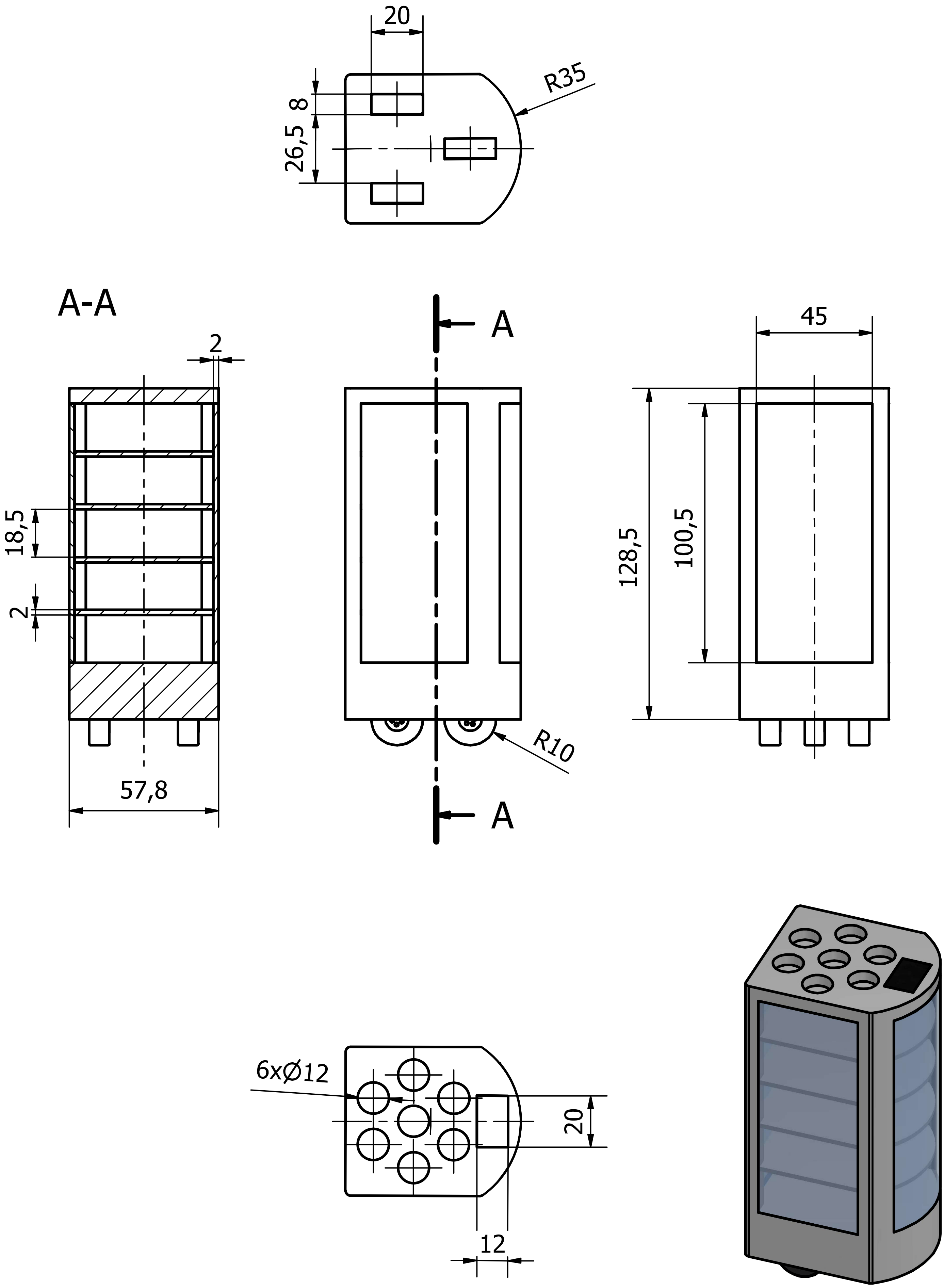

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FOOD TRANSPORT ROBOT	CLARA PALACIOS	05/19/21	1/1