# DESIGN AND DEVELOPMENT OF AN AUTONOMOUS DELIVERY ROBOT FOR ENHANCING COMMUNITY SERVICES AND ACCESSIBILITY AS A MOBILITY AID

***Project Reference No.:*** *49S_BE_3190*

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**Keywords:**

Autonomous Mobile Robot, Indoor Navigation, Stair Climbing, Multi-level Mobility, Simultaneous Localization and Mapping (SLAM), Nav2, ROS2, Gazebo Harmonic, Digital Twin, Accessibility, Mobility Aid

**Introduction:**

The growing demand for inclusive and accessible infrastructure in modern society has brought to light a critical gap in indoor mobility solutions, particularly for individuals with physical disabilities, the elderly, and those recovering from medical conditions. In environments such as hospitals, senior citizen living facilities, rehabilitation centres, and multi-storey office buildings, the challenge of transporting goods, medicines, meals, and essential materials across multiple floors places a significant physical burden on both occupants and caregivers. For individuals with mobility impairments or age-related limitations, this challenge is not merely an inconvenience but a daily barrier to independence and dignity.
Existing solutions such as elevators and escalators, while effective, are costly to install, require significant structural modifications, and are often unavailable in older buildings. Manual delivery by staff, though common, is labour-intensive, time-consuming, and unsustainable as a long-term solution, especially given the ageing global population and rising demand for community care services. There exists, therefore, a compelling need for an intelligent, autonomous system capable of bridging this accessibility gap without reliance on existing vertical transport infrastructure.

This project proposes the development of an Autonomous Indoor Delivery Robot designed to navigate multi-level indoor environments, including staircases, while carrying payloads of up to 8–10 kg. By integrating LiDAR-based navigation, autonomous path planning, and a user-friendly interface, the robot aims to serve as both a logistics assistant and a mobility aid, reducing physical strain on users and caregivers alike. The system is envisioned as a socially impactful solution that promotes inclusivity, enhances community service delivery, and contributes to the vision of smarter, more accessible built environments.

**Objectives:**

1. To design and develop an autonomous multi-level indoor delivery robot capable of navigating staircases and transporting payloads of up to 8–10 kg, thereby eliminating physical barriers faced by elderly individuals, persons with disabilities, and caregivers in elevator-free indoor environments.
2. To implement a robust LiDAR-based SLAM and Nav2 path planning system that enables safe, reliable, and repeatable autonomous navigation through complex indoor corridors and staircases, ensuring consistent service delivery in community care settings such as hospitals, senior citizen living facilities, and rehabilitation centres.
3. To develop an inclusive and accessible user interface — comprising both an onboard HMI touchscreen and a mobile application — that allows users of varying technical proficiency, including elderly occupants and medical staff, to assign delivery tasks, monitor robot status, and schedule missions with minimal effort.
4. To integrate a digital twin developed in Gazebo Harmonic alongside real-time operational health monitoring and predictive maintenance analytics, ensuring long-term system reliability, reduced downtime, and sustainable deployment in resource-constrained community service environments.

**Methodology:**

The development of the Autonomous Indoor Delivery Robot follows a structured, phase-wise methodology encompassing mechanical design, electronic integration, software architecture, and iterative testing.

**Mechanical Design and Fabrication**

The robot platform was designed using Fusion 360 CAD software, with careful attention to load distribution, structural balance, and modularity. The chassis was fabricated to support a payload capacity of 8–10 kg, with a dedicated enclosed storage compartment for secure transport of goods such as medicines, meals, and documents (Fig. 2). The overall form factor was optimized to navigate standard indoor corridor widths while maintaining stability during motion. Stair-climbing mechanism design is currently under research, with candidate approaches being evaluated for compatibility with the existing chassis architecture.

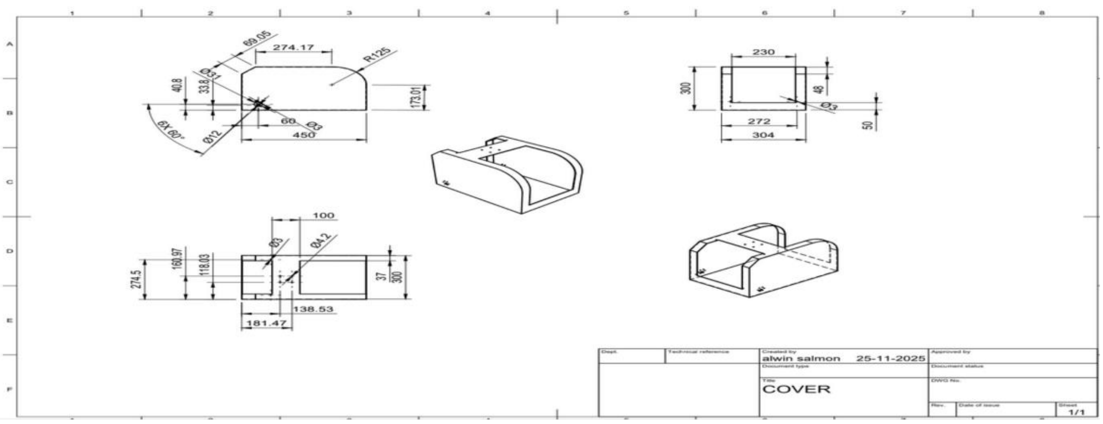


Figure 1: CAD Design

**Current Implementation — Phase I**

In the first phase of development, a Raspberry Pi 5 serves as the sole onboard computing unit. The robot has been successfully deployed on flat indoor surfaces, achieving autonomous navigation using a 2D LiDAR sensor (RP LiDAR C1) mounted at an appropriate height for corridor-level obstacle detection (Fig. 3). The LiDAR interfaces with a ROS2-based SLAM Toolbox to construct a real-time occupancy grid map of the environment (Fig. 4), which is subsequently used by the Nav2 navigation stack for autonomous path planning and obstacle avoidance. At this stage, the robot is capable of receiving goal waypoints, planning collision-free paths, and executing deliveries on a single floor.

**Phase II — Planned Upgrades**

In the next phase, the computational architecture will be significantly upgraded. The Raspberry Pi will be replaced by an NVIDIA Jetson Orin Nano Super as the primary processing unit, handling real-time LiDAR-based localization, SLAM, and Nav2 path planning, leveraging its AI accelerator for enhanced perception performance. A Raspberry Pi 5 will be retained in the system, dedicated exclusively to driving the onboard 8-inch HMI touchscreen and managing the task scheduling interface. Low-level motor control will be delegated to an STM32 microcontroller, enabling precise closed-loop wheel actuation. An IMU (MPU-9250) will be integrated for sensor fusion alongside LiDAR and wheel odometry, improving localization robustness. AprilTag-based pose estimation will support accurate autonomous docking at charging stations.

**Stair-Climbing Mechanism Development**

This system is intended to deploy a mechanical assistance structure that enables the robot to overcome stair edges. The precise mechanism configuration — including geometry, actuation sequence, and structural integration — is currently under active research and will be validated first through Gazebo Harmonic simulation before physical prototyping and testing.

**Digital Twin and Validation**

A virtual prototype of the robot will be developed in Gazebo Harmonic, replicating sensor behaviour, navigation logic, and mechanical interactions with the environment. This digital twin will be used to evaluate stair-climbing strategies, refine design parameters, and reduce physical trial-and-error, thereby minimising material waste and supporting sustainable engineering practices. Physical validation will subsequently be performed for navigation accuracy, payload stability, stair-climbing performance, and docking precision.

## Result and Conclusion:

Figure 2: Development of Robot

Figure 3: Storage Area

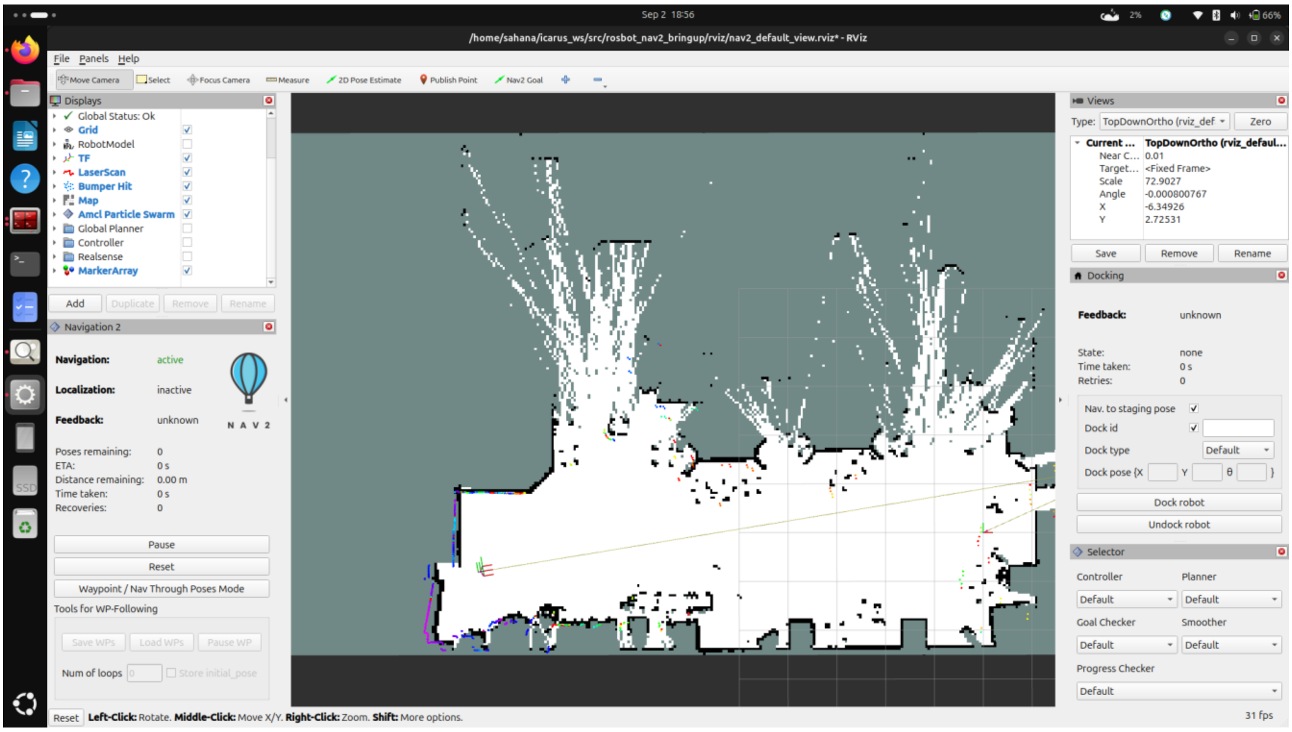


Figure 4: Mapping of the robot in an indoor environment

## Results

The first phase of the project has yielded a functional autonomous delivery robot platform capable of navigating flat indoor surfaces without human intervention. The robot successfully constructs an accurate occupancy grid map of its environment in real time using the RP LiDAR C1 and ROS2-based SLAM Toolbox, as shown in Fig. 4. Using the Nav2 navigation stack, the robot demonstrated reliable autonomous path planning and obstacle avoidance across corridor environments, executing point-to-point deliveries with consistent repeatability. The enclosed storage compartment (Fig. 2) proved structurally stable during navigation trials, maintaining payload integrity throughout delivery runs. The system responded correctly to dynamically placed obstacles, replanning paths in real time without manual intervention. These results confirm the viability of the core navigation architecture as a foundation for the complete multi-level system.

## Conclusions

The outcomes of Phase I validate the fundamental premise of this project — that an affordable, autonomous robotic platform can reliably perform indoor delivery tasks, laying the groundwork for a system with meaningful social impact. When fully realised, this robot addresses a genuine and growing accessibility challenge faced by elderly individuals, persons with physical disabilities, and the caregivers who support them in multi-level environments such as senior citizen living facilities, hospitals, and rehabilitation centres. By autonomously transporting essential goods — medicines, meals, documents, and medical equipment — across floors without reliance on elevators or manual labour, the system reduces physical strain on both occupants and staff, promotes independence, and contributes to a more inclusive built environment. The planned integration of stair-climbing capability, an accessible HMI interface, and predictive maintenance will further enhance the platform's suitability for long-term community deployment. This project demonstrates that robotics and assistive technology, when designed with social purpose, can meaningfully improve quality of life for vulnerable populations while simultaneously advancing the state of autonomous indoor mobility systems.

## Project Outcome & Industry Relevance:

The successful development of this autonomous indoor delivery robot yields a practically deployable platform with significant relevance across multiple sectors of society and industry. In the healthcare sector, the robot addresses a critical operational need by autonomously transporting medicines, medical supplies, and patient meals across floors in hospitals and rehabilitation centres, reducing the burden on nursing staff and minimising human error in time-sensitive delivery tasks. In senior citizen living facilities and assisted care homes, the platform functions directly as a mobility aid, enabling residents with physical limitations to request and receive essential items without dependence on caregivers, thereby preserving dignity and promoting independent living. In corporate office buildings and educational institutions such as universities, the robot offers an efficient solution for inter-floor logistics, reducing manual workload and improving operational efficiency in environments where elevator access may be limited or congested.

From an industry perspective, the system contributes to the growing field of autonomous mobile robots (AMRs) in indoor logistics, demonstrating a cost-effective architecture built on widely accessible hardware and open-source software frameworks such as ROS2 and Nav2. The incorporation of a digital twin, predictive maintenance analytics, and a user-friendly HMI positions the platform as a scalable and maintainable solution suitable for long-term industrial adoption. The stair-climbing capability, once fully validated, addresses a gap that currently limits the deployment of most commercial delivery robots to single-floor or elevator-equipped environments, opening new market opportunities in the large segment of existing multi-storey buildings that lack adequate vertical transport infrastructure. Overall, this project demonstrates that socially purposeful robotics can simultaneously advance academic research, address real-world accessibility challenges, and contribute meaningfully to the development of inclusive, smarter built environments.

**Working Model vs. Simulation/Study:**

In Phase I, a fully functional physical prototype has been constructed and experimentally validated. The robot successfully performs autonomous navigation on flat indoor surfaces, with real-time LiDAR-based SLAM mapping and Nav2-driven path planning executed onboard using a Raspberry Pi 5. Physical testing has confirmed reliable obstacle detection and avoidance, accurate occupancy grid map generation, and repeatable point-to-point autonomous delivery within corridor environments.

In Phase II, the physical model will be upgraded with the NVIDIA Jetson Orin Nano Super as the primary computation unit, a Raspberry Pi 5 for HMI, and an STM32 microcontroller for low-level motor control. The stair-climbing mechanism, currently under research, will be physically fabricated and integrated into the existing chassis once the design is finalised.

**Project Outcomes and Learnings:**

**Key Outcomes**

The primary outcome of this project, at its current stage, is a functional autonomous ground robot platform that demonstrably performs LiDAR-based SLAM mapping and Nav2-driven navigation on flat indoor surfaces. The successful integration of the RP LiDAR C1, ROS2 middleware, SLAM Toolbox, and Nav2 navigation stack on a Raspberry Pi 5 establishes a validated, working software and hardware architecture that forms the foundation for the complete multi-level delivery system. The robot's ability to dynamically replan paths around obstacles and execute repeatable deliveries confirms the feasibility of the proposed system for real-world community service applications. Additionally, a detailed CAD model of the robot chassis and storage compartment has been completed in Fusion 360. A digital twin environment is being progressively developed in Gazebo Harmonic, providing a simulation-backed validation pipeline for future design iterations.

**Learnings**

The process of designing and implementing this system yielded substantial technical and interdisciplinary learnings for the team. From a systems integration perspective, the team developed hands-on experience in bridging mechanical design, embedded electronics, and autonomous software frameworks — gaining a practical understanding of how hardware constraints directly influence software architecture decisions. Working with ROS2 and Nav2 reinforced the importance of modular, well-structured software design in robotics, where individual components such as localization, path planning, and motor control must communicate reliably in real time. The team also developed an appreciation for the iterative nature of robotics development — early physical testing revealed practical challenges in LiDAR placement, sensor calibration, and map consistency that were not anticipated during the design phase, underscoring the value of rapid prototyping and experimental validation. From a social and human-centred design perspective, the team gained a deeper awareness of the real accessibility challenges faced by elderly individuals and persons with disabilities in multi-level environments, which continuously informed and motivated design decisions throughout the project. Finally, researching stair-climbing mechanisms highlighted the complexity of mechanical locomotion in unstructured environments and the critical role that simulation plays in de-risking design choices before committing to physical fabrication.

**References:**


1. [1] G. S. Kim, H. Chung, and B.-K. Cho, "MOBINN: Stair-Climbing Mobile Robot With Novel Flexible Wheels," *IEEE Transactions on Industrial Electronics*, vol. 71, pp. 9182–9191, 2024, doi: 10.1109/TIE.2023.3319739.
2. [2] T. Kim *et al.*, "Development of an Indoor Delivery Mobile Robot for a Multi-Floor Environment," *IEEE Access*, 2024, doi: 10.1109/ACCESS.2024.3381489.
3. [3] S. Ibrayev, A. Ibrayeva, B. Amanov, and S. Tolenov, "Development of a Service Robot for Hospital Environments in Rehabilitation Medicine with LiDAR-Based Simultaneous Localization and Mapping," *International Journal of Advanced Computer Science and Applications*, vol. 15, no. 11, 2024, doi: 10.14569/IJACSA.2024.01511102.
4. [4] J. Palacín, R. Bitriá, E. Rubies, and E. Clotet, "Path Planning of a Mobile Delivery Robot Operating in a Multi-Story Building Based on a Predefined Navigation Tree," *Sensors*, vol. 23, no. 21, p. 8795, Oct. 2023, doi: 10.3390/s23218795.


**Future Scope:**

The future scope of this project includes:

1. **Stair-Climbing Mechanism Validation and Multi-Floor Deployment:** The most immediate direction for future work is the finalisation, fabrication, and experimental validation of the stair-climbing mechanism, which will enable the robot to operate across multiple floors without dependence on elevator infrastructure. Once validated, the system will be tested in real-world multi-level environments such as hospital wings, senior citizen living facilities, and university buildings, with performance metrics collected for navigation accuracy, payload stability, stair-climbing reliability, and energy consumption across extended operational periods.
2. **Enhanced Human-Robot Interaction and Accessibility Features:** Future iterations of the system will explore more sophisticated user interaction modalities, including voice command integration, multi-language support, and gesture-based control, to further improve accessibility for elderly users and individuals with varying physical and cognitive abilities. Integration with a centralised building management system could also allow the robot to coordinate deliveries across multiple units or floors autonomously, enabling deployment at institutional scale in hospitals and assisted care facilities.
3. **Fleet Scalability and AI-Driven Predictive Maintenance:** Future work will investigate the deployment of multiple robot units operating collaboratively within the same building, requiring the development of multi-robot coordination, task allocation, and traffic management algorithms. Concurrently, the operational telemetry data collected during deployment will be used to train machine learning models for predictive maintenance, enabling the system to anticipate component wear and schedule maintenance proactively, thereby extending operational lifespan and ensuring uninterrupted service delivery in critical community care environments.