# MODULAR 3D MODELLING OF AN AUTONOMOUS DELIVERY ROBOT FOR LAST-MILE LOGISTICS

## Executive Summary

As e-commerce expands, last-mile delivery remains a critical and costly logistical challenge. Autonomous delivery robots (ADRs) offer a sustainable and scalable solution, especially in campus and gated environments. This case study presents a 3D CAD-based design of a modular ADR prototype. The design emphasizes component interchangeability, terrain adaptability, and sensor integration using software like SolidWorks and Fusion 360. Stress analysis, battery compartment design, and drive system modelling are included, providing a comprehensive product design exercise suitable for mechanical engineering and robotics students.

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## 1. Introduction

Autonomous delivery robots are increasingly used for low-weight, short-distance transport in controlled zones. Their mechanical design must accommodate navigation sensors, motors, battery units, and delivery compartments—while maintaining lightweight, shock-resilient structure. This study models an ADR system with modularity at its core, allowing different terrains and payloads with ease of assembly and testing.

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## 2. Problem Identification

Major design challenges include:

- **Terrain Adaptability**: Navigating uneven sidewalks or indoor surfaces requires an optimized suspension system.
- **Payload Constraints**: Robots must be light yet carry packages of up to 10 kg.
- **Sensor Integration**: The shell design must support LIDAR, cameras, and ultrasonic sensors.
- **Maintenance Ease**: Replaceable parts and compartment access without tools are ideal.

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# 3. Literature Review

- Delivery robots like *Starship* and *Amazon Scout* use six-wheel designs and structured outer shells with thermal insulation.
- Design research suggests that modularity improves reliability and reduces mean time to repair (MTTR).
- Standards for service robots (ISO 13482:2014) define impact tolerance and pedestrian safety requirements.

Sources:


- Zhang, H. & Kuffner, J. (2021). *Designing Autonomous Ground Robots*
- ISO 13482:2014 – Safety Requirements for Personal Care Robots
- Starship Technologies Product Documentation


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# 4. Design Objectives

- **Modularity**: 4 detachable sections—sensor mount, drive unit, battery pod, and cargo box.
- **Compactness**: Fit within 600 × 450 × 500 mm envelope.
- **Sensor Support**: LIDAR slot, camera mount, and ultrasonic slots integrated.
- **Water Resistance**: Design tolerates light rain with sealed joints and IP54 casing.

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# 5. Design Process

**Tools Used**:

- SolidWorks for solid modelling
- Fusion 360 for CAM and exploded views
- Blender for render animation (optional)

**Process**:

1. Created dimension constraints from component specs (motor size, battery pack dimensions).

2. Designed inner aluminum frame with plastic casing for weight reduction.
3. Applied standard fasteners and hinge models from McMaster-Carr library.
4. Simulated hinge access and loading/unloading movements.

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## 6. Modelling and Simulation

**Specifications**:

- Base Frame: Aluminum 6061-T6
- Outer Casing: ABS Plastic with 3 mm wall
- Max Load: 12 kg
- Wheel Diameter: 180 mm (with 25 mm rubber coating)
- Turning Radius: 90 cm

**Simulation Results**:

- FEA shows <1.2 mm deflection under static load at max payload.
- Drop-test simulation (15 cm height) confirms shock absorption by wheel-arm suspension.
- CAD simulations validate hinge functionality and internal clearance.

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## 7. User Interaction Flow

1. **Package Load**: Top lid opens upward with gas-spring support.
2. **Navigation Start**: Onboard controls activate sensors and motors.
3. **Obstacle Detection**: Ultrasonic sensors and LIDAR check for obstructions.
4. **Delivery Complete**: Compartment opens via user QR authentication.

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## 8. Evaluation and Improvements

**Initial Feedback (from simulation and design review group)**:

- Suggested adding a pull-handle in case of battery failure.

- Proposed solar panel integration for passive charging.
- Liked tool-less modular locks for each section.

**Post-Design Modifications**:

- Increased wheelbase width by 20 mm for better stability.
- Added cable management path between sections.
- Considered heat-dissipating vents near motor casing.

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## 9. Conclusion

The modular autonomous delivery robot design offers a robust, adaptable, and lightweight prototype suitable for controlled urban logistics. Through 3D modelling and simulation, the system demonstrates feasibility for real-world testing and academic prototyping.

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## 10. References


- Zhang, H. & Kuffner, J. (2021). *Designing Autonomous Ground Robots*
- ISO 13482:2014
- SolidWorks Component Library
- Starship Technologies Tech Briefs
- Autodesk Fusion 360 Support