

CHAPTER 1 – INTRODUCTION

This chapter describes the general idea of why this research is conducted and what are the objectives and the end goal of this research.

1.1 Background

At PT Sat Nusapersada Tbk Batam, the internal logistics for transporting materials between production zones and warehouses currently rely on manual forklifts and human-operated jacks. Although this method has been sufficient for the facility's needs in the past, it also poses considerable operational risks like the uncontrolled backing up of materials during the peak production hours. Operator's repetitive action may also lead to slowdowns or wrong handlings of the highly sensitive electronic components. These delays create bottlenecks that prevent the facility from delivering a continuous, fast-paced high tech production line.

The current AMRs in multiple sectors which include manufacturing, warehouses, and hospitals demonstrates their capacity to operate autonomously in active environments because of their advanced hardware and control software, making them ideal for solving material handling problems. AMR system enables robots to operate without a central unit because it allows them to communicate and negotiate with other resources whereas AGV systems require specific routing and dispatching by a control unit (Fragapane *et al.*, 2021). PT Sat Nusapersada Tbk has previously prototyped an AMR, however its design lacked the mechanical robustness and payload capacity required for factory floor dynamics and was limited to smaller and lighter components.

This thesis proposes the design and prototype of an AMR chassis and lifting mechanism specifically optimized for autonomous various material transport. Navigation performance and sensor fusion behavior are evaluated using the company's existing hardware platform as a functional proxy under a ROS navigation stack.

1.2 Research Problem

While PT Sat Nusapersada Tbk has previously attempted a trial of an AMR, they faced significant operational challenges. The previous prototype copied the style and design similar to commercial service robots, e.g. restaurant waitress robots. This design lacked the mechanical robustness required for factory floor dynamics, resulting in unstable navigation. It was also targeted towards smaller components and less volume. The company requires AMR that is able to handle at least 100kg with better navigation and improved motion smoothness, which would mean better components and/or improved software integration. Achieving reliable localization in indoor environments is a fundamental challenge on its own (Teng *et al.*, 2024). Wheel odometry suffers from error accumulation driven by wheel slippage and uneven surfaces, while IMU integration alone is subject to bias drift. LiDAR-based SLAM provides the correction needed to prevent this drift and fusing all three components has been shown to reduce position error by up to 67.68% compared to single-sensor approaches (Duc *et al.*, 2024). However, the individual quantitative contribution of each sensor has not been characterized for compact differential-drive AMRs with autonomous navigation, which this thesis aims to address alongside the mechanical design.

1.3 Research Objectives

Based on the research problems mentioned in the previous chapter, the objectives of this research are:

1. To develop a mechanical design optimized for various material handling up to 100kg payload AMR.
2. To develop a lifting mechanism suitable for a compact and low profile autonomous mobile robot.
3. To investigate the individual contribution of LiDAR, wheel encoder, and IMU to positional accuracy with autonomous navigation.

1.4 Research Questions

The following questions will guide the focus and scope of the thesis work.

1. Question 1: To what extent does the proposed mechanical design meet the safety and stiffness requirements for a 100kg payload?
2. Question 2: How does the load on the scissor lift affect the vertical positioning accuracy of the NEMA 23 Stepper Motor?
3. Question 3: How does the removal of LiDAR, Encoder, and IMU affect the positioning error?

1.5 Hypothesis

With the objective being set, several hypotheses are to help the continuity of the thesis.

1. Hypothesis (H1): The proposed design will achieve a minimum Factor of Safety (FoS) of 2.0 and maximum displacement less than 5mm across all components under both ideal and non-ideal conditions for a 100kg load.
2. Hypothesis (H2): The NEMA 23 Stepper Motor will experience average positioning error of 5mm with maximum load of 50kg.
3. Hypothesis (H3): The fully fused configuration will achieve a mean positional error of less than 5cm. Disabling LiDAR will cause cumulative drift exceeding 10cm, while disabling the IMU will introduce orientation noise that increases error by 5cm and disabling the encoder will result in positional error increase by 15cm.

1.6 Research Scope and Limitation

The objective of this research is to develop and validate a differential-drive AMR for material handling purposes to be used in indoor industrial areas. The main activities of this research will be the mechanical development and simulation-based evaluation of the vehicle as a prerequisite for autonomous navigation. Specifically, the study will focus on two main aspects within this scope:

- Mechanical System Development, this involves the design of the whole AMR and testing of the scaled-down lifting mechanism.

- Basic Autonomous Navigation Using, the control system is limited to standard mapping and localization.
- Applicability of the simulation to the prototype making, this involves simulation based on a designed production area map only in this company.

With the two main aspects set, certain limitations are to be expected in this study, which are:

- This thesis work will primarily focus on the material handling capability, lifting mechanism and navigation using differential-drive for the production area, which limits other kinds of alternatives.
- This thesis work represents the foundation for further research and implementation of AMR for the company, purposely excluding advanced autonomous features to focus on base design and initial computing for further use in the future.
- Short time constraints of three months limit the duration of further improving the simulation and prototyping process.
- All procurements have to be acknowledged and approved by supervisors at the company which extends the lead time.

1.7 Significance of Study

This study is significant both as a practical starting point for AMR at PT Sat Nusapersada Tbk Batam and as a reference within mechatronics research in industrial context. Operationally, the work delivers an evaluated mechanical design and component selection as well as simulation-based verification of autonomous navigation. These outcomes provide the company with a foundation for reducing manual material movement and preparing for future deployment of autonomous transport systems. Academically, this study establishes a clear methodology that connects structural autonomous robot design with current navigation component testing.