

CHAPTER 2 – LITERATURE REVIEW

This chapter demonstrates the explanation of the existing research related to this thesis work. It summarizes, synthesizes, and critically evaluates relevant academic sources to identify what is known and what is not yet known.

2.1 Company Overview

PT Sat Nusapersada Tbk Batam is a leading high-technology electronics manufacturing company based in Batam, Riau Islands, Indonesia. Established in 1990, the company has grown from a small supplier of printed circuit boards (PCBs) assembly and mechanical parts into one of Indonesia's largest Electronic Manufacturing Services (EMS) providers, offering fully integrated production solutions that combine PCB fabrication, plastic molding and metal stamping.

This company's services support a wide range of high-tech applications, including network equipment, consumer electronics, automotive components, and multimedia devices for global clients across Asia, Europe, and North America. Their reputation is anchored in consistent quality, reliability, and advanced manufacturing capabilities, supported by international certifications such as ISO 9001 and ISO 14001, and a workforce trained to meet stringent industry standards. (PT Sat Nusapersada Tbk Batam, no date)



Figure 2.1 PT Sat Nusapersada Tbk Building

2.2 Theoretical Perspectives

2.2.1 Autonomous Mobile Robots (AMRs)

Autonomous Mobile Robots (AMRs) signify a new generation of intelligent devices that are capable of navigating alone in dynamic industrial areas. They are different from the Automated Guided Vehicles (AGVs) that are common in the industry because the latter always need a fixed or pre-determined infrastructure of magnetic tape or inductive wiring for their movement, while on the other hand AMRs use their onboard processing and sensors to get the information about the surroundings and make decisions accordingly. This change in the technology has made it possible for AMRs to move around in an unrestricted manner, i.e., no specific paths are already there for AMRs.

The navigation of AMRs rests on the close collaboration between various technologies, such as sensor integration and Simultaneous Localization and Mapping (SLAM) algorithms. A combination of different perception technologies such as Light Detection and Ranging (LiDAR), computer vision cameras, and odometry sensors enables the systems to generate topological maps of the facility in real time. The mapping skill gives rise to the possibility of going through dynamic paths and preventing obstacles in real-time, with the unit being able to instantly reroute itself as it comes across barriers.

When it comes to modern intralogistics, AMRs are being deployed more and more frequently to carry out the task of managing materials more efficiently in the logistic cycle of the warehouse, manufacturing, and hospital sectors. The activities the robots can include but are not limited to: moving raw materials, picking components according to the production plan, and conducting inventory assessment autonomously. With the AMRs doing these low economic value or zero-value-added processes, they allow the human workforce to be moved to more cognitive tasks. This arrangement produces a work environment where the output is increased. (Zach Isbell, 2024)

2.2.2 AMRs vs AGVs

(KUKA, no date)

Table 2.1 Comparison of AGVs and AMRs

Feature	AGVs	AMRs
Navigation	Operate along fixed pre-determined paths, guided by magnetic wires, QR codes, or floor markings.	Navigates using sensors, cameras, and SLAM.
Flexibility	Not adaptive to changes in production layouts.	Adaptive to dynamic environments in real time.
Adaptation of routes & fleet	Often requires structural changes.	Scalable and adaptable via software, no conversion required.
Sensors	Use basic sensors, primarily for collision avoidance.	Use advanced sensors, (LiDAR, cameras) for detection, navigation, and dynamic response.
Safety	Often reliant on external safety equipment.	Integrated safety mechanisms that could detect people and obstacles and respond actively.
Advantages	Proven, cost-effective solution for standardized production processes.	Intelligent, scalable solution for changing requirements.
Disadvantages	Limited flexibility and heavily dependent on infrastructure and wires.	Higher initial investment, technologically and financially.

Using a higher processing power processor could cost an AMR higher than an AGV, but it is more effective to invest in AMR compared to the AGV system static guides. Higher processing power in AMR made further integration possible.

Developing AMR is way more beneficial compared to AGV for long-term investment. Removing the pre-requisite static guides in an AGV system makes an AMR system simpler in terms of installation so that it could be done faster. Most of the costs are invested into the possibility of future development by using a more powerful processor instead of a minimum controller. (Mobile Industrial Robots, no date)

2.2.3 ROS 2



Figure 2.2 ROS 2 Logo

Robot Operating System (ROS) is an open-source software to build robotics applications. It includes tools and libraries that are used for the algorithms and driver to make a robot. Even though it can run on macOS or Windows, it runs natively on Ubuntu. ROS 2 is not an operating system in the traditional sense, but it is an open source “structured communications layer” that is built above the host operating system to deal with the complexity of robotic software. It operates on a peer-to-peer topology in which single processes, known as ‘nodes’, communicate through a language-neutral messaging system. Such a modular structure is important for contemporary robots since it enables developers to work with a ‘deep-stack’ of software that includes everything from low-level motor drivers to high-level navigation logic and at the same time making code reusable and easy to debug. (Quigley *et al.*, no date)



Figure 2.3 Jazzy Jalisco Logo

The primary development framework chosen for this research is ROS 2 Jazzy Jalisco. It is equipped with a solid and secure environment and is supported until 2029. It acts as a structured communication layer that makes large-scale software integration through peer-to-peer topology easier. This is a great asset for the AMR in a way that it can deal with an entire software stack from driver-level actuators to high-level perception tasks using LiDAR. The framework accommodates the easy organization of nodes such as the C++ modules for real-time control and Python scripts for flexible

navigational logic by utilizing the language-neutral interface definition language (IDL).(Open Robotics, 2026)

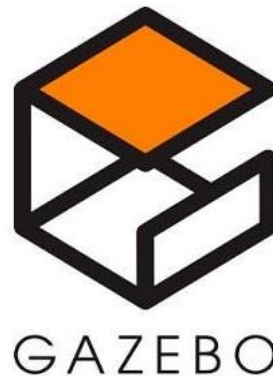


Figure 2.4 Gazebo Logo

This research will use Gazebo Harmonic to create the AMR's kinematic model and mainly tests the differential system's interaction that consists of two drive motors and two caster wheels along with the industrial floor surface. This set-up is advantageous due to its mechanical simplicity and efficiency. Moreover, Nav2's incorporation in Jazzy distribution has given motion planning and collision avoidance algorithms of a higher level, which are very useful for carrying out the difficult indoor navigation with heavy loads. The software tools allow the robot to directly calculate positioning parameters like velocity and orientation from the internal sensor data, thus creating a stable reference for autonomous operation.(Open Robotics, 2026)

2.2.4 Micro-ROS



Figure 2.5 Micro-ROS Logo

Micro-ROS integrate all major core concepts such as nodes, publish/subscribe, client/service, node graph, etc. onto microcontrollers. The client API of micro-ROS is based on the standard ROS 2 Client Support Library. It is suitable to use with Teensy 4.1, where user can code with external tool such as Arduino. It supports transfer with USB, UART or even Ethernet UDP.



2.2.5 Localization



1. **Position Tracking:** The robot knows its initial position and the objective is to track its movement as time goes.

2. Global Localization: The robot does not know its initial position and must locate itself within the environment.
3. Kidnapped Robot Problem: The robot is kidnapped (moved) to a new location without being told, requiring it to recover its true pose.

To solve these problems, probabilistic approaches are often used. The robot has a “belief” about its current position, expressed as a probability density function (PDF). This belief goes through two stages of updating: the prediction phase, in which the robot calculates its new place given control inputs (odometry) and the perception (correction) phase, in which it corrects the estimate and reduces the uncertainty using sensor measurements.(Panigrahi and Bisoy, 2022)

2.2.6 Simultaneous Localization and Mapping (SLAM)

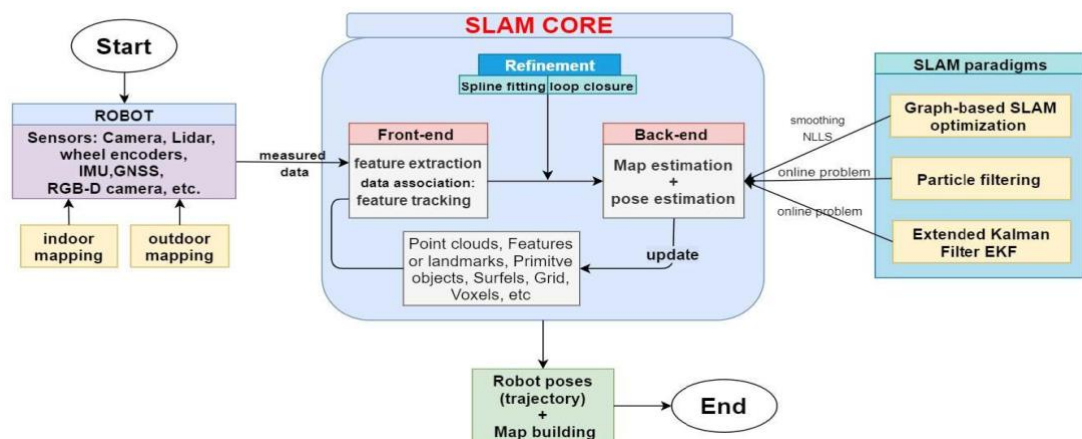


Figure 2.8 SLAM Concept

SLAM is a solution that allows a robot to simultaneously build a map of an unknown environment and estimate its own position within that map. This is essential for indoor autonomous navigation where external positioning systems like GPS are unavailable. SLAM operates using probabilistic methods to handle the noise and uncertainty in sensor measurements.

2.2.5.2.1 General Monte Carlo Localization (GMCL) SLAM

General Monte Carlo Localization (GMCL) is a ROS-compatible localization package that extends the Adaptive Monte Carlo Localization (AMCL) module by incorporating multiple advanced particle filter strategies to improve pose estimation accuracy in

known 2D map environment (Hatem, Ali and Khalil, no date). The system uses three particle filter algorithms which include Optimal Filter, Auxiliary Particle Filter and Self-adaptive Filter as its advanced operating system which extends AMCL core system. This requires a robot to determine its location by deploying random digital “particles” throughout a map which then form clusters when the robot’s sensors detect environmental objects. Wheel slip tends to lead to severe odometry drift under the physical weight of a 100kg payload because the system loses its ability to track location which results in the “kidnapped robot” effect which causes complete loss of global positioning. GMCL pulls the particle distributions toward high probability areas with no need for extensive processing resources. This system achieves faster performance together with less processing time while significantly decreasing pose-tracking errors which make it suitable for industrial settings that require dynamic operation and limited computational resources (Zuo *et al.*, 2025).

2.2.7 Finite Element Analysis

The Finite Element Analysis (FEA) method serves as an advanced computational technique which engineers use to solve complex boundary value problems. The Finite Element Method (FEM) serves as the foundation of FEA which uses numerical methods to solve partial differential equations through the creation of algebraic equation systems. The FEA method enables engineers to examine complex structural designs unlike the traditional analytical methods which are derived from classical strength of materials that can only handle basic geometric shapes with standard load distribution patterns. (Zienkiewicz, Taylor and Zhu, 2005)

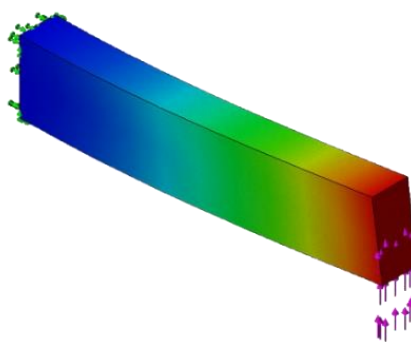


Figure 2.9 Finite Element Analysis

The basic concept of FEA relies on discretization which transforms a continuous physical space into multiple smaller sections that are known as elements. The elements

which make up the system include one-dimensional beams and two-dimensional shells and three-dimensional shells which connect through special points called nodes. The mesh system comes into existence through the complete combination of all these elements. The unknown field variable within each element shows its different values through shape functions which normally use polynomial functions. The solver uses this method to study nodal points which transforms an infinite-degree-of-freedom system into distinct points. Simulation accuracy depends on mesh density due to finer meshes providing more precise results even though they do demand higher computational power (Cook, Malkus and Plesha, 2002).

2.2.7.1 Mechanical Design Safety

In mechanical design, structural safety is quantified through two primary measures, the Factor of Safety (FoS). This determine whether a structure can endure the intended load without it deforming or yielding that compromises the core functionality.

The Factor of Safety is defined as the ratio of a material's allowable stress or yield strength to the maximum von Mises stress value under a certain load condition.

$$FoS = \frac{\sigma_{allow}}{\sigma_{max}} \quad (2.1)$$

For mobile robot chassis and material handling structure subjected with static loads and known material properties, a minimum FoS of 1.5 is acceptable, while a minimum of 2.0 is standard to account for load variability and manufacturing tolerances. (Budynas and Keith Nisbett, 2015)

2.2.8 Scissor Lifting Mechanism

Scissor lifts or pantograph mechanisms function as parallel structure systems that display strong structural integrity while performing vertical movements. The mechanisms operate through a system of cross-linked components that transform minor horizontal or diagonal movements into upward motion. It is found that mechanical drive systems which use electric motor-powered lead screw mechanisms provide better operational precision, enhanced safety, and lower expenses than traditional hydraulic or pneumatic systems.(Chaturvedi, Mishra and Parmar, 2017)



Figure 2.10 Scissor Lift with Lead Screw

2.2.8.1 Force Actuation

The power screw functions as the main element which translates torque into force within the scissor lift's mechanical system. The system typically involves an electric motor driving a lead screw that moves a traveling nut or coupling. The motion operates the base rollers of the scissor arms which results in platform elevation.

The lead screw provides two advantages in this system because it demonstrates “self-locking” capabilities. The mechanism achieves weight and external load stability through lead screw selection which uses suitable pitch and helix angle according to modern mechanical design standards which describe this function as a “self-locking pair”. (Chaturvedi, Mishra and Parmar, 2017)

2.2.9 Existing AMR Designs

There are state-of-the-art platforms that have evolved significantly, with current mechanical systems now provide support for robots to navigate through complex environments.

2.2.9.1 MIR100



Figure 2.11 MIR100

This AMR is the entry-level “standard” for indoor logistics AMR. It is optimized for flat-surface transport with sleek design. Specifications:

- Payload Capacity: 100kg
- Dimensions (L x W x H): 890mm x 580mm x 352mm

- Weight (without load): 70kg
- Maximum Speed: 1.5m/s
- Lifting: requires separate top-module
- Battery Run-time: 10 hours
- Positioning Accuracy: $\pm 50\text{mm}$ to a wall; $\pm 10\text{mm}$ to a docking marker
- Navigation Components: 2x SICK S300 LiDAR and Intel RealSense cameras, Ultrasonic sensors, IMU, wheel encoders (MiR, 2023).

2.2.9.2 PUDU T150



Figure 2.12 PUDU T150

The T150 is the upgrade to the PUDU series, moving from service robot to industrial kind. Specifications:

- Payload Capacity: 150kg
- Dimensions (L x W x H): 835mm x 500mm x 1350mm
- Weight (without load): 81kg
- Maximum Speed: 1.2m/s
- Lifting: -
- Battery Run-time: 12 hours (No-load)
- Positioning Accuracy: $\pm 30\text{mm}$ to a wall; $\pm 10\text{mm}$ to a docking marker
- Navigation Components: 2x LiDAR, 2x Depth Cameras, AI Processing (Pudu Robotics, 2026).

2.2.9.3 Geek+ M200C



Figure 2.13 Geek+ M200C

The M200C is unique because its capability to switch navigation modes depending on the factory zone. Specifications:

- Payload Capacity: 200kg
- Dimensions (L x W x H): 740mm x 550mm x 280mm
- Weight (without load): 45kg
- Maximum Speed: 1.5 m/s (empty); 1.2m/s (loaded)
- Lifting: 60mm (Pin-lift)
- Battery Run-time: 8 hours
- Positioning Accuracy: $\pm 20\text{mm}$ to a wall; $\pm 10\text{mm}$ to a docking marker
- Navigation Components: LiDAR, Camera, IMU (Geek+, no date).

2.2.10 LiDARs

LiDAR (Light Detection and Ranging) is an active remote sensing system which provides AMRs with their primary visual capability through sending out high-speed laser beams and detect when those beams return from nearby objects. The sensor produces a high-definition digital representation of its surroundings through Time-of-Flight (ToF) measurements. Industrial AMRs cannot operate without LiDAR technology which delivers data needed for SLAM and for immediate obstacle detection and avoidance (Raj *et al.*, 2020).

2.2.10.1 Slamtec RPLiDAR S3



Figure 2.14 RPLiDAR S3

The Slamtec RPLiDAR S3 is an advanced 2D laser scanner which employs ToF technology to deliver a maximum measurement of 40 meters with a sampling rate of 32,000 points per second. Its small size and complete 360° field of vision make this sensor an economical solution and ideal to perform both SLAM and global localization tasks in indoor spaces. This LiDAR provides direct USB-to-serial connection which enable it to function with ROS-based system that operate on Intel NUC hardware (Slamtec, 2026).

2.2.10.2 Hypersen HPS-3D160-Pro



Figure 2.15 HPS-3D160-Pro

The Hypersen HPS-3D160-Pro operates as a solid-state 3D ToF LiDAR which creates high-resolution depth maps through its internal mechanism. The system requires no moving internal components which allows it to operate effectively under mechanical vibrations that occur in heavy-duty AMRs. The sensor generates a volumetric “flash” which enables the robot to identify complex obstacles (Hypersen, 2021).

2.2.10.3 SICK TiM240



Figure 2.16 TiM240

The SICK TiM240 is an industrial-grade 2D LiDAR system which is recognized for its robust design and extreme reliability. The system uses HDDM+ (High-Definition Distance Measurement) technology to eliminate environmental “noise” which includes ambient light, dust, and steam that typically confuses ordinary sensors. It uses Ethernet communication together with its ROS driver support to create commercial solutions like for MiR100 (SICK, no date).

2.2.10.4 LiDARs Comparison

Table 2.2 LiDARs Comparison Table

Feature	Slamtec RPLiDAR S3	Hypersen HPS- 3D160-Pro	SICK TiM240
Detection Type	2D Planar	3D Volumetric	2D Planar
Field of View	360°	76° x 32°	240°
Interface to Mini PC	USB 3.0 (Plug-and- Play)	Ethernet (Requires Switch)	Ethernet (Requires Switch)

Data Complexity	Low (Laser Scan Array)	High (3D Point Cloud)	Low
Cost Category	Budget-Friendly / Research	Mid-Range / Specialized	High / Industrial Standard
ROS Support	Supported (sllidar_ros)	Moderate (SDK-based)	Supported (sick_scan_xd)

2.2.11 Inertial Measurement Unit

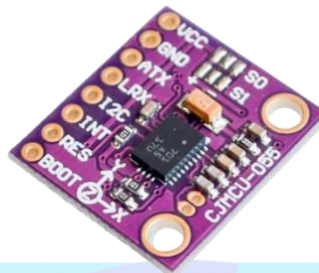


Figure 2.17 IMU BNO055

An Inertial Measurement Unit (IMU) is an electronic sensor component that measures a body's specific force, orientation, and angular rate through accelerometers, gyroscopes, and conditionally magnetometers. By integrating these measurements over time, an IMU is able to give an estimation of position, velocity, and orientation relative to a known starting point. In the context of AMRs, IMU serves as the sensor that provides continuous pose estimation between external sensor such as LiDAR scan matches (Woodman, 2007).

2.2.11.1 Accelerometer

The accelerometer measures specific force such as the non-gravitational acceleration acting on the sensor body along one or more axes. In a three-axis accelerometer, measurements are taken along the x, y, and z axes simultaneously. By integrating the acceleration signals over time, velocity is obtained, which then results to displacement. Accelerometer measurements are subject to bias, noise, and the influence of gravity, meaning the that position estimation might accumulate error over time (drifting) (Teodori and Neuner, 2023).

2.2.11.2 Gyroscope

The gyroscope measures angular velocity about one or more axes. In a three-axis gyroscope, rotational rates about the roll, pitch, and yaw are measured simultaneously. Integrating these measurements would result in angular displacement or change in orientation. For differential drive AMRs, the yaw measurement is particularly important as it directly corresponds to the robot's heading during turns. This component is subject to drift caused by sensor bias and noise, which requires the user to generate external correction (Woodman, 2007).

2.2.12 Paired-Sample T Test Method

This type of T-Test method is a procedure used to determine whether the mean difference between two sets of observations is zero. The steps to do this method are:

1. Calculate the average (Mean) of Differences ($\bar{D}$):

$$\bar{D} = \frac{\sum D_i}{n} \quad (2.2)$$

2. Calculate the Standard Deviation (σ) for the Differences:

$$\sigma = \sqrt{\frac{\sum (D_i - \bar{D})^2}{n - 1}} \quad (2.3)$$

3. Calculate the Test Statistic (t):

$$t = \frac{\bar{D} - \mu_D}{\sigma / \sqrt{n}} \quad (2.4)$$

With $H_0: \mu_D \leq 0$ and $H_1: \mu_D > 0$

4. Compare to a critical value from the t-distribution table based on the degree of freedom

$$df = n - 1 \quad (2.5)$$

and chosen significant level (α) is 0.05 (Montgomery and Runger, 2018).

5. If it's inside of the rejection area, then reject H_0 and conclude there is a statistically significant difference between the two conditions.

2.3 Review of Previous Studies

Table 2.3 Previous Studies Review

Year	Title	Note
2022	Mechanical Improvement on Autonomous Mobile Robot	The study proved the welded chassis could support heavy loads, but the six-wheel configuration and lack of design alignment caused excessive friction. This thesis considers six-wheel configuration with better design alignment to enhance kinematic performance.
2022	Development of Indoor Logistic AMR Based on ROS 2	Although the multi-LiDAR merging created computational latency, the implementation of the LiDAR merge and specific component selections will be implemented in this thesis
2025	The Analysis of Localization Algorithms for ROS-Based Mobile Industrial Robots	The study demonstrated that EKF and AMCL present trade-offs. EKF is prone to long-term drift while AMCL is computationally expensive in dynamic environments. The proposed hybrid localization approach combining both algorithms is considered for this thesis.

2.3.1 Mechanical Improvement on Autonomous Mobile Robot

This thesis is by Muhammad Ichsan, a batch of 2015 Mechatronics student at Swiss German University in 2022. The objective of this thesis work is to improve the mechanics of AMR with the goal of being able to work in big spaces, factories, or public areas, as well as implementing a locking mechanism for the AMR chassis. The robot used a rectangular chassis made of hollow iron to lower the center of gravity and increase stability with iron plates cover.

The design also utilized a differential drive system with two drive motorized wheels and four caster wheels (two at the front and two at the back) to support the heavy load of 100kg. A custom locking mechanism was also developed to autonomously latch onto and pull a cart carrier. The overall dimensions of the AMR are 879 x 659 x 289 mm.



Figure 2.18 AMR Chassis (Previous Study 1)

The results are that the welded hollow iron frame successfully supported the target load. The 6-wheel configuration resulted in excessive friction and kinematic constraints, making the AMR difficult to turn and prone to slippage on uneven surfaces. This study was also mainly about mechanical fabrication. The navigation system was not fully implemented, meaning the locking mechanism could not be tested dynamically (Muhammad Ichsan, 2022). Based on that, the mechanical design of the AMR that is developed in this research will be improved for this thesis. The 6-wheel configuration will be the configuration for this thesis work but with improved alignment.

2.3.2 Development of Indoor Logistic AMR Based on ROS 2

This thesis is written by Michael Jonathan, a batch of 2018 Mechatronic student at Swiss German University in 2022. This study focused on the software and electronic architecture of an indoor AMR, specifically the transition from ROS 1 to ROS 2 (Foxy Fitzroy). This research aimed to implement a multi-LiDAR SLAM system to eliminate blind spots and improve navigation repeatability. The system used a Teensy 4.1 microcontroller for low-level motor control and an external Intel NUC Mini PC for high-level ROS 2 navigation. A custom ROS 2 package was also developed to merge data from two RPLIDAR S1 units, which creates a 360° field of view to solve the “blind spot” issue common in single LiDAR robots. The study utilized Micro-ROS for efficient communication between the microcontroller and the PC and MQTT for communicating with the “Calling Stations”.

The results are the use of multiple LiDARs and complex merging algorithms created high computational loads, causing latency in obstacle avoidance. The study also reported issues with the RS-485 Modbus motor drivers, while they were precise, the communication latency occasionally affected the smoothness of the motion control loop. They connected a 120Ω resistor between the A and B port of the Teensy's RS-485 communication module and the ZLAC8015D BLDC Motor Driver's A and B port. This made the communication runs smoothly (Jonathan, 2022).

Some of the components from this research will be used for this thesis, including the architecture, component selection, and improvement of the electronic components.

2.3.3 Analysis of Localization Algorithms for ROS-Based Mobile Industrial

Robots

This study is written by Yaping Wu and published in the Journal of Engineering Mechanics and Machinery in 2025. It is focused on the analysis and evaluation of localization algorithms for ROS-based mobile industrial robots, specifically comparing the Extended Kalman Filter (EKF) and Adaptive Monte Carlo Localization (AMCL). This research's objective is to determine the applicability of these algorithms. The system used a ZOTAC PC (Intel Core i7) for path planning and NVIDIA Xavier edge module for vision processing. The robot was equipped with a 16-beam Robosense 3D LiDAR, an Intel RealSense D435 depth camera, and an Xsens MTi-300 IMU, integrated within the ROS 2 framework. The study implemented the "robot_localization" package to fuse odometry and IMU data for the EKF implementation and the "amcl" package for particle-filter-based-localization.

The results are that AMCL achieved higher positioning accuracy and lower variance in static, structured environments. EKF demonstrated faster convergence and better recovery in dynamic scenarios. It is reported that while EKF is robust to sensor dropouts, it is prone to drift over time, whereas AMCL offers high precision but can be computationally expensive and sensitive to repetitive textures. They proposed a hybrid localization approach that uses EKF for rapid startup and AMCL for steady-state

precision. Even though all of the electrical components are different, the hybrid approach is still considerable to be implemented in this thesis work. (Wu, 2025)

2.4 Research Gap and Novelty

Despite recent development in AMR in the previous sections, several gaps remain unaddressed. This chapter will identify these gaps and the original findings and contribution of this thesis.

2.4.1 Research Gap

Despite the advancements in AMR development in previous studies, gaps still remain regarding mechanical efficiency, computational latency and localization robustness. Jonathan built upon a previously developed AMR chassis by integrating autonomous navigation using a multi-LiDAR merging system and roserial communication, but he encountered high computational latency from the merging algorithms which required manual hardware interventions and limited deployment reliability (Jonathan, 2022). Wu demonstrated that relying on a single localization algorithm presents inherent trade-offs, EKF is prone to long-term drift while AMCL is computationally expensive (Wu, 2025) yet neither study quantifies how each sensor contributes to or degrades localization performance when removed from the fusion. The hardware platform used in Jonathan's work lacked lifting mechanism, restricting the system's ability to handle diverse material handling operations that require vertical movement.

2.4.2 Novelty

This thesis presents three original contributions which fill the gaps not addressed in the reviewed literature. First, an original mechanical design of a differential-drive AMR chassis optimized for multi-purpose material handling up to 100kg, validated through FEA simulation. Second, scissor lift mechanism which addresses the vertical actuation and actuator component analysis gap. Third, a quantitative sensor contribution analysis isolating the individual effect of each navigational components within a ROS 2 sensor fusion stack.