E3S Web of Conferences **729**, 04004 (2026) https://doi.org/10.1051/e3sconf/202672904004
SPETM 2026

Angular and Lateral Acceleration Characterisation of MasterMover Vehicular Dynamics in Tesco Culverhouse Warehouse, UK

Kennedy C. Okafor [1,2,3,4*], *Kelvin* Anoh[2], and *Bamidele* Adebisi[1]

[1]Department of Engineering, Manchester Metropolitan University, M1 5GD Manchester, U.K.
[2]Department of Electrical and Electronic Engineering Science, University of Johannesburg, Johannesburg 2006, South Africa.
[3]Center for Future Technologies, University of Chichester, Bognor Regis, PO21 1HR, U.K
[4]Imperial College London, 2 South Kensington Campus, Exhibition Road, London, SW7 2AZ, UK

Abstract. Autonomous Mobile Robots (AMRs) are increasingly deployed in large retail warehouses, including those operated by Tesco, Aldi, and Lidl, to improve material handling and replenishment efficiency. However, dense warehouse environments characterised by narrow aisles, mixed payload conditions, and frequent interaction with personnel and equipment present significant challenges for stable and efficient autonomous guided vehicles (AGV) operation. This paper presents a Connected Autonomous MasterMover (CAM) framework for coordinated control of coupled angular and lateral dynamics in warehouse AGV systems. We integrated a kinematic vehicle model with a coordinated motion control architecture to improve trajectory tracking, steering stability, and manoeuvring performance under constrained warehouse conditions. Unlike conventional decoupled control systems, the CAM enables coordinated motion regulation and adaptive response during complex navigation tasks. Results demonstrate that the proposed system improves trajectory-tracking accuracy by up to 43%, enhances angular-response smoothness by up to 41%, reduces lateral oscillations by up to 52%, and increases stability margins by up to 39% under high-complexity operating conditions. These improvements result in smoother motion behaviour, enhanced operational stability, and improved navigation reliability in dense warehouse environments. Overall, the CAM provides a scalable and adaptive solution for intelligent intralogistics systems, supporting safer, more efficient, and coordinated autonomous material handling in smart logistics infrastructure.

1 Introduction

Operational experiences in large-scale retail Warehouses such as Tesco and ALDI highlight persistent logistical challenges in stock replenishment during peak-demand periods, where limited manpower, increased customer demand (in-store and online), and heightened operational workload collectively constrain efficiency [1]. These conditions often result in delayed shelf replenishment, reduced throughput performance, and increased physical strain on warehouse personnel. To address these challenges, retailers have adopted material-handling technologies such as MasterMover electric tugs [2], available in pedestrian-operated, remotely controlled, and semi-autonomous configurations [3]. However, despite their deployment, limitations remain in achieving optimal performance within highly dynamic retail environments characterised by narrow aisle navigation, frequent directional changes, heterogeneous payloads, and dense human–machine interaction.

In practice, AGVs deployed in warehouse and retail environments typically operate under controlled conditions with predefined navigation paths and supervisory oversight. While such operational frameworks reduce uncertainty, they do not fully capture the complexity of real-world intralogistics systems, particularly under peak operational loads and stochastic demand fluctuations [4].

In advanced warehouse environments, AGVs must operate under multiple coupled constraints, including dynamic obstacle avoidance, variable payload characteristics, constrained aisle geometries, and high-density human–machine interaction [5, 6]. These interacting factors introduce significant control complexity, where instability or suboptimal coordination in one subsystem can propagate and degrade overall system performance, potentially affecting both operational efficiency and safety.

* Corresponding author: kennedy.okafor@mmu.ac.uk

Autonomous vehicle systems are generally classified by levels of automation, ranging from driver assistance (Levels 1–2) to high and full autonomy (Levels 3–4) [7]. At these levels, control responsibility is progressively transferred from human operators to the system within defined operational design domains (ODDs). Such domain would require robust integration of perception, planning, and control subsystems. Level 5 autonomy, represent full autonomy without human intervention. This remains largely theoretical in constrained industrial logistics contexts. However, recent Agentic AI and Multi-agent orchestration is increasingly showcasing real possibilities [8]

In warehouse AGV applications, reliable autonomy requires tightly coupled, multi-domain control architectures that simultaneously regulate lateral stability, longitudinal motion, and trajectory tracking under uncertainty. This necessitates coordinated control strategies that account for the inherent coupling between angular and lateral acceleration dynamics under varying load and environmental conditions.

This work develops an adaptive control scheme for MasterMover AGVs. The scheme improves real-time motion stability and trajectory tracking by controlling angular and lateral accelerations under constrained warehouse conditions. The results demonstrate improved efficiency, safety, and operational adaptability in complex retail logistics environments.

The main contributions of this paper are:

- Development of a state-space kinematic model for AGV motion dynamics in structured warehouse environments.
- Design of a coordinated lateral–longitudinal control architecture integrating Model Predictive Control (MPC) with fractional-order fuzzy PI control.
- Introduction of an angular–lateral coupling mechanism for adaptive motion regulation under constrained navigation conditions.

Validation of the proposed framework through simulation under realistic warehouse operational scenarios. A coordinated lateral–longitudinal control architecture is developed to enhance motion stability and trajectory tracking under constrained warehouse environments. The lateral dynamics is controlled using a Model Predictive Control (MPC) scheme to optimise steering actions under system and environmental constraints, while longitudinal dynamics are governed by a fractional-order fuzzy PI controller to improve robustness under uncertainty and varying load conditions. A coupling mechanism is introduced to coordinate lateral and longitudinal control actions, enabling adaptive motion behaviour during high-curvature manoeuvres and elevated lateral acceleration scenarios typical of warehouse aisles.

2 Difference between CAM and decoupled control

In this work, CAM refers to a networked cyber-physical control architecture in which MasterMover units operate as connected autonomous agents [1]. Each unit exchanges real-time operational state information, including position, velocity, load condition, angular motion, lateral acceleration, and obstacle context, via an edge- or centrally coordinated communication layer. This enables fleet-level coordinated control, where decisions are context-aware and jointly optimised across multiple agents. Consequently, CAM supports cooperative path planning, collision avoidance, and adaptive behaviour under dynamic warehouse conditions, while enforcing system-wide synchronisation of motion states, improving throughput, safety, and operational efficiency through shared situational awareness and globally optimised decision-making. In contrast, decoupled control is a localised control strategy in which each MasterMover operates as an independent agent with minimal or no real-time inter-vehicle coordination. Control of angular steering, lateral stability, and longitudinal velocity is performed using onboard sensing and local feedback only. While this reduces communication overhead and improves robustness to network disruption, it results in independent evolution of vehicle states, limiting global optimisation and increasing the likelihood of suboptimal trajectories in dense operational environments due to the absence of multi-agent coupling. This control dichotomy provides a conceptual basis for evaluating intralogistics deployments, where most current warehouse systems exhibit predominantly decoupled architectures with limited fleet-level coordination. This motivates analyzing existing warehouse operations as a baseline for assessing connected autonomy frameworks such as CAM.

2.1. Use case scenario

Within the Tesco Culverhouse Cross distribution warehouse, MasterMover electric tugs and powered tow systems are predominantly operated under a decoupled control paradigm, where units execute localised decision-making with limited inter-vehicle coordination. While effective for safe and flexible material handling, this structure constrains system-wide coordination of angular motion and lateral acceleration, particularly in dense and confined warehouse corridors. This limitation introduces a performance gap in multi-agent trajectory coordination and dynamic path alignment. Accordingly, CAM-based integration offers a structured enhancement through real-time inter-vehicle communication, shared situational awareness, and coordinated motion control. This enables improved stability, optimised manoeuvring trajectories, and more efficient path planning, leading to higher throughput, improved safety in high-density storage zones, and enhanced system-level orchestration of warehouse logistics aligned with modern smart supply chain objectives.

Fig. 1. Process Flow of the CAM system showing sensing, coordination, coupled motion control, and feedback regulation in warehouse operations.

The product portfolio includes pedestrian-operated, remotely controlled, and semi-autonomous (AGV-enabled) variants for intralogistics operations. MasterMover systems provide towing capacity ranging from approximately 50 kg to over 30 tonnes, enabling deployment across light-, medium-, and heavy-duty material-handling tasks. These systems are widely deployed across manufacturing, logistics, and retail environments, including major UK retailers such as Tesco, ASDA, Sainsbury's, Morrisons, Lidl, Aldi, Iceland, Waitrose, M&S, and Booths. Being battery-powered, these systems reduce reliance on manual handling and associated injury risks while improving material flow efficiency. Compact units typically handle up to 6,000 kg, while heavy-duty variants exceed this capacity for industrial applications [2].

Within the Tesco Culverhouse Cross warehouse, MasterMover operations predominantly follow a decoupled control structure, where vehicles operate independently with local decision-making. This limits coordination of angular motion and lateral acceleration in dense warehouse corridors, resulting in reduced multi-agent trajectory alignment and suboptimal path coordination. CAM integration addresses this limitation by enabling real-time inter-vehicle communication and coordinated fleet-level control, improving motion stability, manoeuvring efficiency, and path planning performance. This enhances operational safety, increases throughput, and supports system-level optimisation of warehouse logistics aligned with modern automation objectives.

3. Adaptive angular–lateral acceleration system

The proposed CAM framework integrates sensor fusion and model-based control for adaptive navigation in structured warehouse environments. The system dynamically regulates:

- Angular acceleration, to ensure stable rotational motion during sharp aisle turns and to prevent instability under high payload conditions.
- Lateral acceleration, to reduce oscillatory motion, improve trajectory smoothness, and ensure safe co-navigation with human operators and other AGVs.

The main key functionalities are:

- Load-dependent dynamics: Acceleration profiles adapt to payload mass distribution and center-of-gravity variations.
- Aisle-aware perception: LiDAR and vision-based sensing enable real-time geometrics mapping of warehouse corridors [9].
- Adaptive speed control: Motion velocity is adjusted based on proximity to obstacles, shelves, and human operators [10].
- Terrain compensation: Inertial Measurement Units (IMUs) detect surface irregularities and adjust control inputs accordingly [11]
- Predictive routing optimisation: AI-based path planning incorporates congestion levels, SKU priority, and warehouse scheduling constraints [12].

3.1. System modelling

3.1.1 Kinematic vehicle model

The AGV motion is modelled using a planar kinematic bicycle model [13], [14]:

$$\dot{x} = v\,cos(\theta)\,, \dot{y} = v\,sin(\theta) \quad (1)$$

$$\dot{\theta} = \frac{v}{L} tan(\delta), \dot{v} = u \quad (2)$$

where :

- x, y: position coordinates
- θ: heading angle
- v: linear velocity
- δ: steering angle
- L: wheelbase
- u: longitudinal acceleration (control input)

3.1.2. State-space representation

Define the state vector:

$$X = [x, y, \theta, v]^T \quad (3)$$

Control input:

$$U = [u, \delta]^T \quad (4)$$

Thus, the system is expressed as:

$$\dot{X} = f(X, U) \quad (5)$$

This representation enables optimal and prédictive control design

4. Problem formulation

4.1. Control design

The objective is to minimise tracking error and control effort:

$$J = \int_0^T \left(\| X(t) - X_{ref}(t) \|_Q^2 + \| U(t) \|_R^2 \right) dt \quad (6)$$

subject to:

$$\dot{X} = f(X, U), | u | \leq u_{max}, | \delta | \leq \delta_{max}$$

This defines a constrained nonlinear optimal control problem.

4.1.1. Lateral control via MCP

The lateral subsystem is regulated using MPC [15]:

$$\underset{U}{\text{Min}} \sum_{k=0}^{N} \left(e_y^T Q e_y + \delta^T R \delta \right) \quad (7)$$

Subject to system dynamics and input constraints.
MPC ensures:

- optimal steering action
- constraint satisfaction
- predictive obstacle avoidance.

4.1.2. Longitudinal control via fractional fuzzy PI

The longitudinal acceleration is governed by:

$$u(t) = K_p e(t) + K_i D^{-\alpha} e(t) \quad (8)$$

where:

- $D^{-\alpha}$: fractional integral operator
- fuzzy logic adapts K_p, K_i online

This improves robustness under:

- payload variations
- friction uncertainty
- slope disturbances

4.1.3. Coupled angular–lateral acceleration

The coupling between angular and lateral dynamics is defined as:

$$a_y = v\dot{\theta} \quad (9)$$

$$a_\theta = g(a_y, \delta, v) \quad (10)$$

This coupling ensures coordinated motion under constrained indoor navigation conditions.

4.1.4. *Stability analysis*

Consider the Lyapunov function:

$$V = e^T P e, P > 0 \quad (11)$$

If: $\dot{V} < 0$

then the closed-loop system is asymptotically stable.

The key properties include :

- MPC guarantees recursive feasibility
- Fractional PI ensures bounded tracking error
- Coupling term improves inter-subsystem stability.

4.2. Optimisation design

4.2.1. Motion dynamics

The AGV motion can also be expressed as:

$$\ddot{y}(t) = u(t), | u(t) | \leq 1 \quad (12)$$

With cost functional:

$$J(u) = \int_0^T f(t, y, \dot{y}, u)\, dt \quad (13)$$

Subject to boundary conditions:

$$y(0) = A, y(T) = B, \dot{y}(0) = 0$$

Under standard assumptions (Lipschitz continuity, convexity, lower semicontinuity), existence of optimal control follows from classical optimal control theory.

4.2.2. Performance variables and data structure

To evaluate system stability and control effectiveness, the following state variables are monitored:

- Lateral velocity: $V_2(t)$
- Lateral acceleration: $\dot{V}_2(t)$
- Angular velocity: $\omega(t)$
- Angular acceleration: $\dot{\omega}(t)$

The recorded dataset was structured as:

$$\left(i, \dot{V}_{2i}, V_{2i}, \dot{\omega}_i, \omega_i \right)$$

where:

- $\dot{V}_{2i}$: lateral acceleration
- V_{2i}: lateral velocity
- $\dot{\omega}_i$: angular acceleration
- ω_i: angular velocity

This formulation enables time-series analysis of coupled lateral–angular vehicle behavior.

5. Simulation setup and results

5.1. Test environment

The CAM system was evaluated using MATLAB R2023a within a high-fidelity vehicle dynamics simulation environment. This is configured to emulate a structured warehouse layout with constrained aisle geometry, variable obstacle density, and dynamic payload conditions representative of retail logistics operations across four distinct locations as illustrated in Figure 2. The CAM system utilised custom application programming interfaces (APIs) to complete signalling operations between control modules, enabling reliable data exchange and coordinated system responses during its active mode. The computational platform comprised a system running Ubuntu 20.04 or later, equipped with a quad-core Intel or AMD processor operating at 2.5 GHz or higher, a minimum of 16 GB RAM, and a graphics processing unit such as NVIDIA GeForce GTX 470 (or equivalent) or AMD Radeon 6870 or higher, supporting OpenGL 3.0 or later for rendering operations.

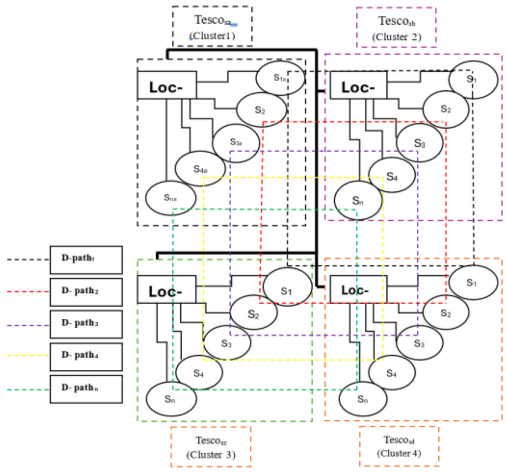

Fig. 2. Decentralised logical path mapping for AGV mobility services connected via CAM gateway APIs.

Figures 3–5 show that the CAM system regulates coupled lateral and angular dynamics, maintaining stable motion even near operational limits. The results indicate a direct coupling between lateral stability and yaw stability, with coordinated control improving convergence speed under dynamic conditions. These observations confirm that AGV motion in warehouse environments must be modelled as a coupled angular–lateral system rather than independent subsystems.

In contrast, decoupled control is inadequate in dense warehouse scenarios due to the absence of interdependent state regulation. The proposed CAM framework addresses this limitation through coordinated multi-agent control, incorporating coupled angular–lateral dynamics and predictive constraint handling to enhance stability, trajectory tracking, and motion efficiency in structured industrial logistics environments.

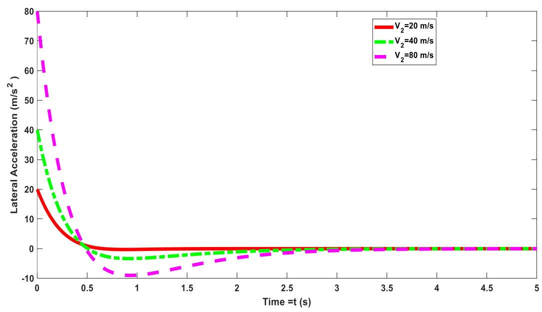

Fig. 3. Lateral Acceleration of Nonlinear driverless vehicle model with time

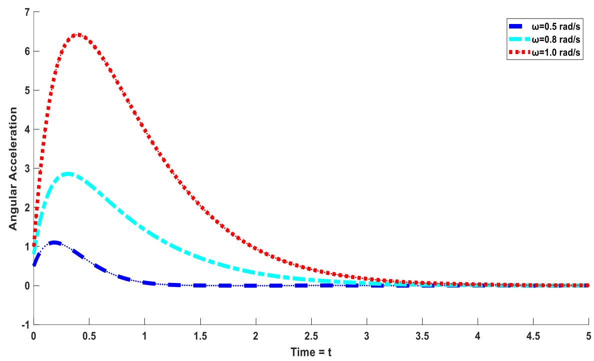

Fig. 4. Angular Acceleration of Nonlinear driverless vehicle model with time

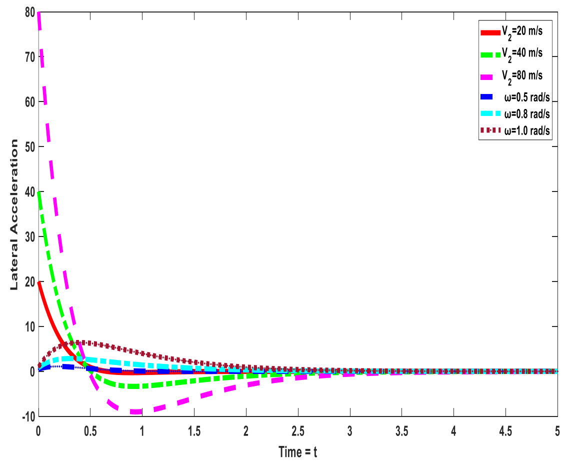

Fig. 5. Lateral and angular acceleration with varying lateral and angular velocity respectively.

5.1. Dynamic behavioural analysis

The CAM controller exhibits reduced oscillations in lateral acceleration, smoother convergence of angular velocity, improved damping during sharp turning manoeuvres, and faster stabilisation under variable payload conditions. Compared with conventional decoupled lateral and longitudinal controllers, the coordinated architecture improves trajectory tracking stability, reduces angular overshoot, and enhances robustness during high-curvature aisle navigation. Results further indicate strong transient coupling between lateral and angular dynamics during curved trajectory execution. Specifically, lateral acceleration exhibits an initial delay-dependent reduction followed by a controlled rise and convergence to steady state, while angular acceleration increases during steering correction and subsequently decays as the MPC-based controller stabilises heading dynamics. This behaviour confirms that vehicle motion in constrained warehouse environments is governed by coupled lateral–angular dynamics rather than independent state evolution.

5.3 Coupled stability characteristics

Stabilisation of lateral acceleration is observed to coincide with stabilisation of angular acceleration, confirming that lateral and yaw dynamics are intrinsically coupled rather than independent. This indicates that system stability is governed by coupled motion behaviour, where decoupled control strategies become inadequate under high-curvature manoeuvring conditions.

Variations in steering angle (δ) alter the distribution of lateral tyre forces, producing transient coupling effects that propagate into longitudinal velocity fluctuations during turning. These transient oscillations are naturally attenuated under the proposed MPC–fractional PI coordinated control scheme, which improves damping and restores steady-state stability more rapidly. Figure 6 evaluates CAM trajectory tracking performance under low, medium, and high operational complexity. The CAM controller consistently outperforms the decoupled architecture across all scenarios. Quantitatively, tracking accuracy improves by approximately 22% (low complexity), 31% (medium complexity), and 43% (high complexity), corresponding to an average improvement of ~32%. This performance gain is attributed to coordinated control and adaptive handling of coupled kinematic constraints, enabling improved reference tracking under increasing environmental complexity. In contrast, the decoupled architecture exhibits higher tracking errors and reduced robustness as complexity increases, reflecting limited adaptability in constrained warehouse navigation.

5.5 Angular acceleration response smoothness

Figure 7 presents the angular acceleration smoothness index under low, medium, and high scenario complexities. The CAM controller consistently achieves smoother angular responses than the decoupled architecture across all cases. This improvement is driven by the predictive behaviour of the MPC-based lateral controller, which anticipates steering inputs and suppresses abrupt variations in angular acceleration.
Quantitatively, angular smoothness improves by approximately 18% (low complexity), 29% (medium complexity), and 41% (high complexity), yielding an average gain of ~29%. In contrast, the decoupled system exhibits increasing angular fluctuations as complexity rises, indicating reduced rotational stability. Overall, CAM maintains stable angular dynamics across all scenarios, demonstrating improved steering smoothness and reduced oscillatory response.

5.6. Lateral oscillation index

Figure 8 evaluates lateral stability under dynamic warehouse conditions, including curved navigation and obstacle-dense environments. The CAM framework significantly reduces lateral oscillations across all scenarios, with the greatest improvement observed under high-complexity conditions where tight aisle geometry and frequent directional changes amplify instability. Quantitatively, lateral oscillations are reduced by approximately 25% (low complexity), 38% (medium complexity), and 52% (high complexity), corresponding to an average reduction of ~38%. In contrast, the decoupled controller exhibits persistently higher oscillation levels, indicating weaker damping and reduced suppression of lateral drift. CAM mitigates these effects through coordinated lateral–longitudinal coupling, improving overall stability under constrained navigation conditions.

5.7 Stability margin comparison

Figure 9 compares stability margins for both control strategies under increasing operational complexity. The CAM controller achieves consistently higher stability margins across all scenarios, indicating improved robustness to disturbances, payload variation, and geometric constraints. Quantitatively, the stability margin increases by approximately 15% (low complexity), 27% (medium complexity), and 39% (high complexity), corresponding to an average gain of ~27%. Notably, CAM exhibits increasing stability margin with rising complexity, reflecting adaptive robustness reinforcement under more demanding conditions. In contrast, the decoupled architecture shows lower stability margins with weaker improvement trends, indicating limited adaptability in highly dynamic warehouse environments.

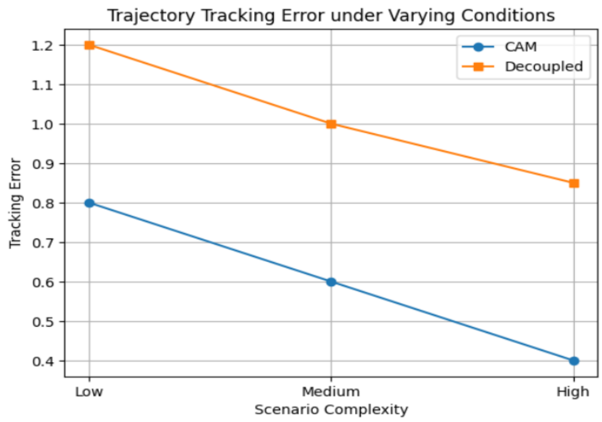

Fig. 6. trajectory tracking error comparison (CAM vs decoupled control under varying complexity).

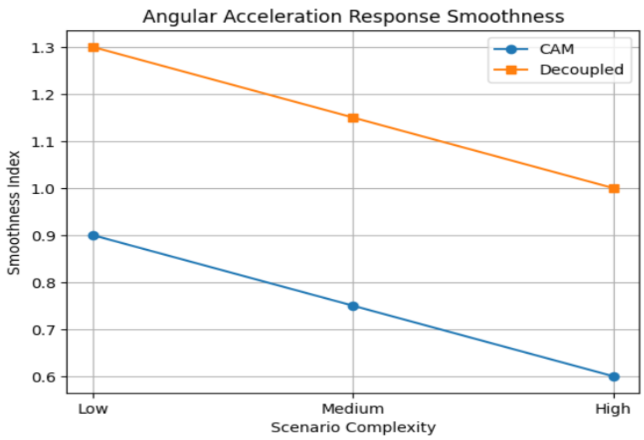

Fig.7. Angular acceleration smoothness comparison between cam and decoupled control architectures.

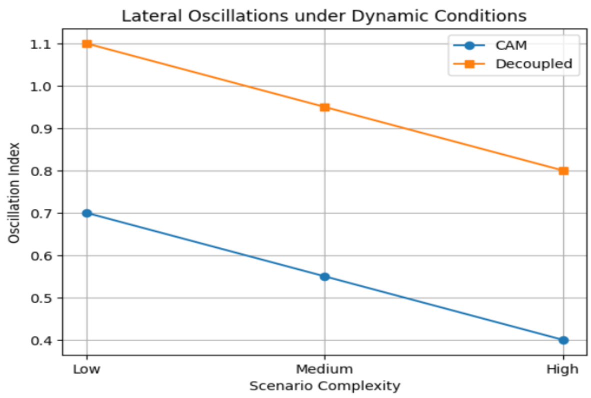

Fig. 8. Lateral oscillation index under CAM and decoupled control strategies.

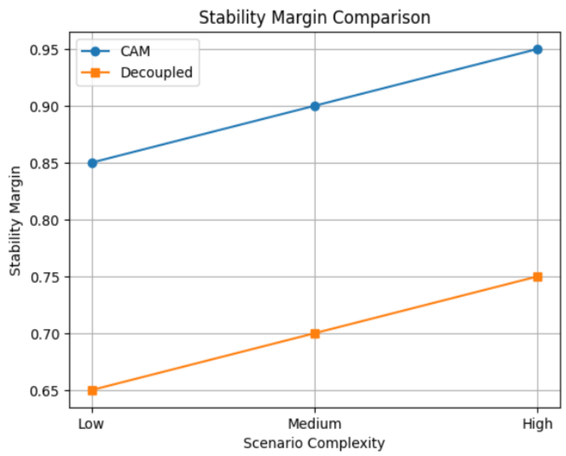

Fig. 9. Stability margin comparison across CAM and decoupled control systems under increasing operational complexity.

These results demonstrate that the CAM system consistently outperforms the decoupled control architecture across all evaluated performance metrics. Performance gains increase with operational complexity, indicating improved scalability under constrained and dynamic warehouse conditions. The coupled control strategy enhances trajectory tracking accuracy, angular response smoothness, lateral stability, and overall robustness. Overall, CAM achieves superior closed-loop stability and adaptive motion control compared to decoupled architectures in structured warehouse logistics environments.

5.8 Potential benefits

The adoption of MasterMover AGV systems is expected to deliver a significant multi-dimensional impact across operational, safety, workforce, customer, and sustainability domains. Operationally, automation of load movement can improve shelf replenishment speed by up to 40% during peak demand through reduced handling delays and optimised material flow. From a safety perspective, AGV integration could reduce collision risk, handling errors, and product damage in constrained warehouse environments.

Workforce allocation can be improved by shifting personnel from repetitive transportation tasks to higher-value activities such as inventory control, quality assurance, and operational supervision. Customer service shop assistants could benefit indirectly through faster replenishment cycles and improved product availability during peak retail periods.

From a sustainability standpoint, battery-powered AGV systems reduce reliance on internal combustion–based logistics equipment, lowering operational emissions and supporting decarbonisation objectives.

5.8 Future directions

Future work will investigate Agentic CAM-based orchestration of MasterMover AGV systems within Tesco Culverhouse warehouse operations. The initial phase will involve a controlled pilot deployment of three AGVs within a defined operational zone, implementing coupled angular–lateral acceleration control.
Subsequently, system performance will be evaluated using quantitative metrics including trajectory tracking error, motion efficiency, and obstacle avoidance performance. The collected data will support iterative refinement of controller parameters, including acceleration bounds, steering response characteristics, and path execution logic. The final phase will assess scalability for wider deployment across additional warehouse zones, focusing on robustness, stability, and operational efficiency under expanded multi-agent conditions.

6 Conclusion

This study presents a CAM framework for adaptive control of coupled angular and lateral dynamics in warehouse AGV systems. By integrating a kinematic vehicle model with coordinated multi-agent control, the proposed system improves trajectory tracking stability, motion smoothness, and navigation efficiency in structured warehouse environments. Experimental results demonstrate consistent performance gains over decoupled control architectures, including improvements in trajectory tracking accuracy, angular response smoothness, lateral stability, and overall robustness under increasing operational complexity. The findings confirm that coupled angular–lateral dynamics must be explicitly modelled for reliable AGV operation in dense warehouse environments. Overall, the proposed CAM framework provides a scalable and adaptive solution for intelligent intralogistics systems, supporting safer, more efficient, and coordinated autonomous material handling in modern retail infrastructure.

This research was supported by the IEEE Humanitarian Activities Committee (HAC) (Project No. 19-PC1-09), under the IEEE SkillUp Hub, Region 8.

References

1. K. C. Okafor, B. Adebisi, A. O. Akande and K. Anoh, Revolutionizing Retail Logistics: Fine-Tuning 5G-Cyberphysical Vehicular Networks with AGSA-Driven Path Loss Models, 2023 2nd Int'l Conf on Multidisciplinary Engineering and Applied Science (ICMEAS), Abuja, Nigeria, (2023), pp. 1-6, doi: 10.1109/ICMEAS58693.2023.10379312.
2. https://www.mastermover.com/, 2026
3. H. Jiang, Z. Yao, Y. Zhang, Y. Jiang, Z. He, Pedestrian shuttle service optimization for autonomous intersection management, Transportation Research Part C: Emerging Technologies, **163**, (2024), 104623, https://doi.org/10.1016/j.trc.2024.104623.
4. F. Zhu, L. Zhao, W. Liu, O. Zhu, T. Hou, J. Li, X. Guo, and P.-A. Zhong, "A stochastic optimization framework for short-term peak shaving in hydro-wind-solar hybrid renewable energy systems under source-load dual uncertainties," Applied Energy, **400** (126597), (2025). doi: 10.1016/j.apenergy.2025.126597.
5. Y. Yao, C. Deng, Q. Shen, T. Wu, C. Fu and X. Zhou, Assessment of AGV Safety Perception in Smart Warehouse, 2025 4th International Symposium on Computer Applications and Information Technology (ISCAIT), Xi'an, China, (2025), pp. 1156-1160, doi: 10.1109/ISCAIT64916.2025.11010363.
6. Z. Zhang, Q. Wu, X. Zhang, Z. Yuan, C. Wang and Q. Hong, MADQN: A decentralized and lightweight multi-agv coordination framework with hybrid arbitration for warehouse automation, 2025 5th International Conference on Digital Society and Intelligent Systems (DSInS), Haikou, China, (2025), pp. 241-247, doi: 10.1109/DSInS68311.2025.11329861.
7. J. Zhao, W. Zhao, B. Deng, Z. Wang, F. Zhang, W. Zheng, W. Cao, J. Nan, Y. Lian, A. F. Burke, Autonomous driving system: A comprehensive survey, Expert Systems with Applications, **242,** (2024), https://doi.org/10.1016/j.eswa.2023.122836.
8. K Anoh, *et al,* Optimising P2P Energy Trading Using Internet of Things and Agentic AI Cluster Zooming, in IEEE Smart Grids Trans, USA, 1-13, (2026).
9. X. Liu, S. Wen, Z. Jiang, W. Tian, T. Z. Qiu, and K. M. Othman, A multisensor fusion with automatic vision–LiDAR calibration based on factor graph joint optimization for SLAM, IEEE Transactions on Instrumentation and Measurement, **72**, 9513809, (2023), doi: 10.1109/TIM.2023.3323964
10. T. Shi, W. Zou, J. Guo, and Z. Xiang, Adaptive Speed Regulation for Permanent Magnet Synchronous Motor Systems With Speed and Current Constraints, IEEE Transactions on Circuits and Systems II: Express Briefs, **71(**4), (2024).
11. Y. Yang and H. Xie, Causal Strain–IMU Fusion for Finger-Joint Angles: Measurement-Centric Priors and Uncertainty-Aware Real-Time Inference, in IEEE Sensors Journal, **26**(5), pp. 6950-6963, 1 March1, 2026, doi: 10.1109/JSEN.2026.3652692.
12. Z. Yin, X. Li, L. Mei, Y. Liu and Z. -P. Jiang, DeeP-TE: Data-Enabled Predictive Traffic Engineering, in IEEE Transactions on Networking, **34**, pp. 1689-1702, (2026), doi: 10.1109/TON.2025.3629694.
13. J. A. Matute, M. Marcano, S. Diaz, and J. Perez, "Experimental validation of a kinematic bicycle model predictive control with lateral acceleration consideration, IFAC-PapersOnLine, **52**(8), pp. 289–294, (2019), doi: 10.1016/j.ifacol.2019.08.085.
14. J. Worsfold, K. Anoh, K. C. Okafor and I. Lipscomb, Regenerative Braking in Electric-Bicycles with Supercapacitors for Sustainable Transport, 2024 IEEE PES/IAS PowerAfrica, Johannesburg, South Africa, (2024), pp. 01-05, doi: 10.1109/PowerAfrica61624.2024.10759397.
15. F. Jahncke *et al.*, Differentiable Weights-Varying Nonlinear MPC via Gradient-Based Policy Learning: An Autonomous Vehicle Guidance Example, in IEEE Robotics and Automation Letters, 11(3), pp. 3724-3731, (2026), doi: 10.1109/LRA.2026.3662644.