

The Business Case for **AMRs in Manufacturing**



Contents

- 01** EXECUTIVE SUMMARY
- 02** COMPETITIVE ADVANTAGE THROUGH AUTOMATION
- 03** ONE COMPANY. TWO SCALED AMR DEPLOYMENTS.
- 04** GREENFIELD FACILITY
- 05** BROWNFIELD FACILITY
- 06** DEPLOYMENT CONSIDERATIONS
- 07** CONCLUSION

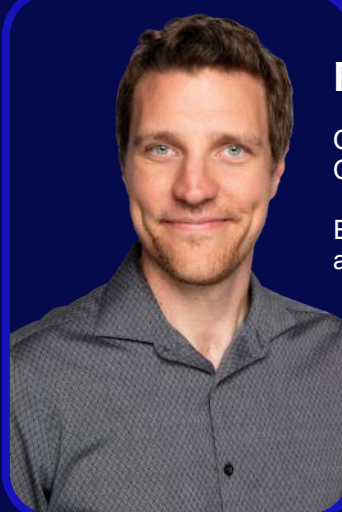
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01 EXECUTIVE SUMMARY

In the United States, manual forklifts represent the backbone of material handling operations across manufacturing facilities nationwide, with over 1 million estimated units currently in operation¹. This staggering number underscores the critical role these powered industrial vehicles play in American manufacturing and logistics. Despite the growing trend toward automation, manual forklifts remain the predominant choice for manufacturers, with the U.S. forklift market valued at \$9.11 billion in 2023² and projected to reach \$35.7 billion by 2034³. However, this widespread reliance on manual operation comes with significant challenges—these vehicles are responsible for over 20,000 accidents annually, resulting in nearly 100 fatalities each year⁴. With approximately 70% of all forklift incidents in the United States preventable through proper safety training and policy⁵, manufacturers face mounting pressure to reconsider their material handling strategies while balancing productivity demands, safety concerns, and mounting cost pressures.

Chang Robotics partnered with OTTO by Rockwell Automation to implement one of the world's largest deployments of autonomous mobile robots (AMRs). The OTTO autonomous material handling solution was deployed at a billion-dollar company that is a household name in consumer goods. The Fortune 500 manufacturer chose OTTO AMRs for their flexibility, reliability, and safety, as well as their long-term cost in comparison to alternatives.

The following conclusions were drawn after a detailed analysis of the OTTO solution vs alternative material handling methods for the customer. When compared for productivity and costs:

- **OTTO was 15% the cost of a full-time equivalent for manual cart movement**
- **OTTO was 30% of the costs associated with a driver and a forklift**
- **OTTO was 66% the cost of an AGV equivalent**
- **OTTO was 50% the cost of a conveyor equivalent**



The project resulted in an **ROI of less than two years** and an **IRR of >50%**. Payback drivers included labor savings, increased productivity, improved safety and ergonomics for operators, lower workers' compensation premiums, reduced turnover costs, and lower capital costs.

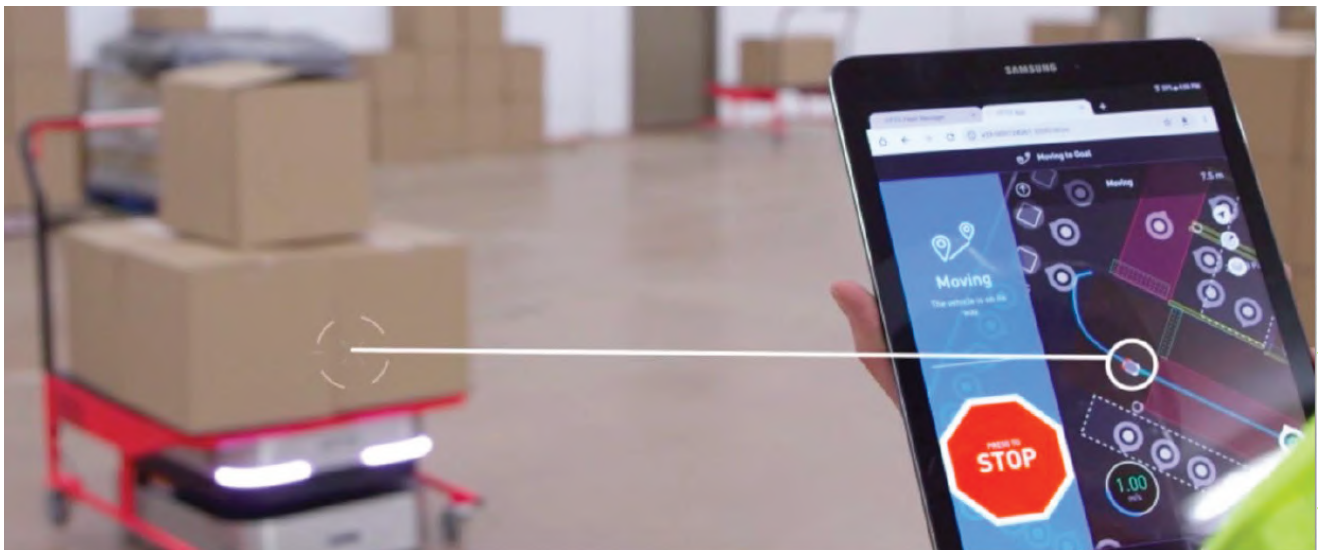
1: <https://www.nist.gov/document/permis-09-forklift-safety-whitepaperpdf>
2: <https://www.grandviewresearch.com/industry-analysis/us-forklift-market-report>
3: <https://finance.yahoo.com/news/us-forklift-market-expected-reach-164500835.html>
4: <https://www.cdc.gov/niosh/docs/2001-109/default.html>
5: <https://www.indtrk.org/training>

02 COMPETITIVE ADVANTAGE THROUGH AUTOMATION

Automation has long been used to improve efficiencies within manufacturing as a way to gain a competitive advantage. To see how automation has made an impact, we need only look at the automotive industry, where automation made Ford's mass production possible and profoundly changed the world.

Today, many factories have automated significant portions of their operations, resulting in isolated "islands of automation" that remain disconnected. That's because one of the last forms of automation to make its way onto factory floors is material handling. Moving materials has remained predominantly a human task. And because it has been considered one of the lowest valued tasks on the factory floor, material handling has been ripe for automation.

Advancements in robotics, computing power, and AI have made way for a new class of automation for material handling to emerge. The autonomous mobile robot, or AMR, combines the flexibility of a human with the efficiency of a conveyor while safely moving materials in pedestrian-heavy areas. The first industrialized implementations of the technology have occurred in the last decade. Yet, there have been few examples of meaningfully scaled deployments in manufacturing.



Learn the top reasons why manufacturers are implementing AMRs [in this blog](#).

03 ONE COMPANY. TWO SCALED AMR DEPLOYMENTS.

OTTO, a pioneer of the AMR industry, partnered with Chang Robotics to implement one of the world's largest deployments of AMR technology.

Chang Robotics was initially retained to evaluate various material handling technologies for two facilities, one greenfield and one brownfield. AMRs, conveyors, forklifts, and automated guided vehicles (AGVs) were evaluated for comparative productivity and costs. The OTTO autonomous material handling solution was selected for both facilities.

OTTO autonomous mobile robots

15% THE COST
of a full-time human labor equivalent

30% THE COST
of a driver and forklift

Cost savings resulted in:

ROI OF <2 YEARS
and

IRR OF >50%

OTTO autonomous mobile robots were found to be 15% the cost of a full-time equivalent for manual cart movement and 30% of the costs associated with a driver and a forklift. OTTO was also compared against fully automated technologies and was a fraction of the cost of traditional conveyance and automated guided vehicles (AGVs). These cost savings resulted in an **ROI of less than two years and an IRR of >50%.**

What follows is the team's look inside both facilities and the associated business cases that made the deployment possible.



04 GREENFIELD FACILITY

The 1 million square foot facility was designed from the ground up with state-of-the-art technologies to optimize efficiencies and save costs while maintaining an environment safe for workers.

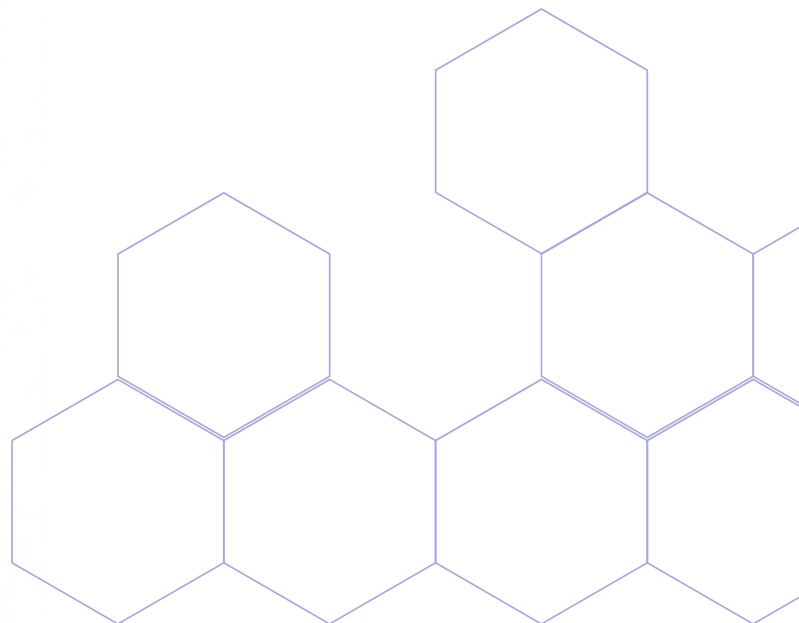
OTTO AMRs were used to move work-in-progress (WIP) materials in a round-trip pick-up and drop-off cycle between human workers and automated machining cells.



The operation is 100% reliant on AMR technology and 400,000SF in the facility have been dedicated for this purpose with AMRs traveling 1,100 miles and completing 5,200 missions each day.

In advance of the AMR deployment at both facilities, Chang Robotics and OTTO worked with the client on system design. Simulation was used to test the process, performance, and behavior of the AMR fleet. AMRs were then tested in a physical off-site space to validate simulation results.

The design process also took into account the National Institute of Occupational Health and Safety (NIOSH) guidelines for ergonomic design of worker interfaces with the AMRs. Using a thoughtful design for the work process, material handoffs minimized repetitive loading for workers, instead delegating autonomous picking to AMRs.





Form Factor

Chang Robotics ultimately selected OTTO 100, which has a maximum payload of 330 lbs (150 kg). OTTO 100 autonomously docks with a collection of custom tooling carts, enabling the efficient transport of materials and ergonomic interaction with the carts. Custom fixtures were attached to the carts to enable interfacing with automated packaging equipment.

OTTO 100 is roughly the size of a carry-on luggage piece laid flat. The compact form factor allows for the creation of narrow vehicle aiseways and precision navigation in tight spaces.

Greenfield Alternative Transport Methods: Cost Comparisons

The team conducted a cost comparison of human transport with carts (before) vs automated transport with OTTO 100 (after). The result was that OTTO was a tenth of the cost of its labor equivalent.

OTTO vs Labor

At the greenfield facility, OTTO AMRs were evaluated as a way to optimize worker productivity and address ongoing labor shortages—enabling employees to focus on higher-value tasks while OTTO handled repetitive material movement.

Shifts / Day	3	OTTO 100 AMRs per Worker	1.5
Burdened Rate / Hour	35	Total OTTOs For 1 FTE 3 Shift Operation	4.5
Hours / Shift	8	ROI IN 15 MONTHS	
Operating Days / Year	363		

OTTO vs Conveyor

Conveyors were also originally evaluated for intraplant transport.

	Fixed Conveyance	OTTO
Flexibility	Cannot be easily retooled	Flexible in tooling, format, and routing
Productivity	250 Linear Feet	1 OTTO
Capital Cost Ratio	2	1

OTTO is half of the cost of a conveyor system equivalent.

05 BROWNFIELD FACILITY

The second AMR deployment took place at a brownfield facility. The conversion to AMR intraplant logistics allowed for a safer facility with transport occurring around people and operators in legacy aisleways and machine centers. The 750,000SF facility was retrofitted to optimize for transport efficiencies with AMRs. As part of the project, 350,000SF was converted to AMR transport in lieu of forklifts.



Like the greenfield facility, this operation is 100% reliant on AMR technology. 175 vehicle miles per day are traveled, representing 900 pallet load missions for unique round-trip pick-up and drop-off maneuvers. All manual forklift traffic and pallet staging has been eliminated from the AMR zone, which has increased safety and allowed for LEAN material distribution.

AMRs provide pallet transport for three mission-critical workflows: Raw Material (RM), Work-in-progress (WIP), and Finished Goods (FG). AMRs collect materials from pallet stands or conveyor interfaces and deliver them to equipment cells for interface with AGV systems.

To convert the brownfield facility for AMR use, existing legacy equipment was modified to enable automated pallet exchange with OTTO. At the software level, OTTO was integrated with the site's central systems to allow for batching, ordering, and Kanban replenishment. Goods are delivered just-in-time, thereby reducing buffer stock.

Form Factor

Chang Robotics ultimately selected OTTO 1500, which has a maximum payload of 4,200 lbs (1,900 kg). OTTO 1500 interfaced with all pallet types required in the facility, including CHEP, PICO, and GMA. The AMR autonomously docks with custom-built pallet stands and roller conveyors. Automated conveyor ports interface with OTTO 1500, enabling mechanical automation that relies on the vehicle's power, sensors, and communication capabilities.



Brownfield Alternative Transport Methods: Cost Comparisons

Two cost comparisons were considered as part of the business case for AMRs at the brownfield facility.

OTTO vs Traditional Forklift Labor Equivalent

Shifts / Day	3	OTTO 1500 AMRs per Worker	1.5
Burdened Rate / Hour	35	Total OTTOs For 1 FTE 3 Shift Operation	4.5
Hours / Shift	8		
Operating Days / Year	363		

ROI IN <2 YEARS

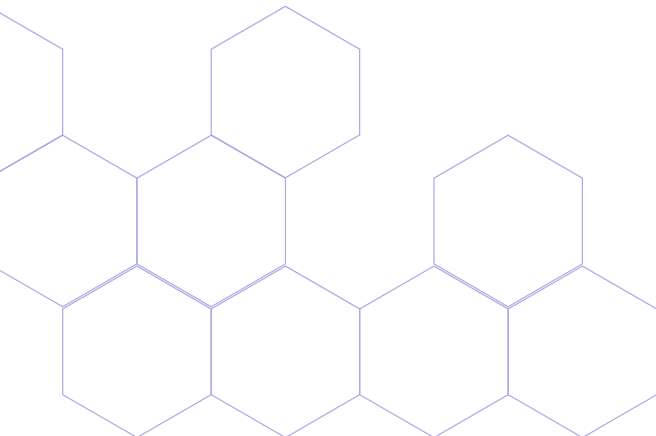
OTTO vs AGVs

AMRs are often considered to be 'smart' AGVs, because they allow for dynamic routing in changing spaces. Some of the key differences between AGVs and OTTO AMRs are detailed in the table below.

	AGV	OTTO
Footprint	Requires a footprint larger than the pallet	Navigates within the footprint of the pallet
Commissioning & Ongoing Support	AGVs require more extensive commissioning and calibration due to fork tine accuracy, pallet pocket sensing, and rack slotting	OTTO 1500 can self-route around obstacles and pedestrians, making it ideal to interface with work cells or production machinery
Ergonomics	AGVs can access loads on the ground	OTTO requires the pallet to be at lifting height
Productivity	AGVs obtain better productivity in picking and manipulating pallets	OTTO works better in dynamic spaces
Capital Cost Ratio	1.5	1

OTTO is 66% of the cost of an AGV.

The general conversion factor for an "at scale" design is 4 AMRs for every 3 forklifts, making the ratio of AMRs to manual forklifts 1:0.75. AGVs are roughly equivalent to manual forklifts in terms of productivity, however, they require more space for lanes and maneuvering.



06 DEPLOYMENT CONSIDERATIONS

A number of deployment considerations were taken into account for the deployment of the OTTO autonomous material handling solution.

Design

System design is critical for the success of AMR implementations. Simulation was used to compare machine and material staging configurations to aid the layout simulation. Simulating the process options ahead of time de-risked the deployment well before the commissioning of the fleet started.

The team also used simulation sensitivity analysis to test various AMR scenarios. For example, the physical layout was modeled and tested against various parameters like vehicle speed, traffic management, and opportunity charging.

Learn more about the design stage of an AMR deployment [in this blog](#).



Safety

The downside to manual material handling goes beyond poor utilization of a limited human workforce—it also presents health and safety risks. According to the US Department of Labor, material handling is the number one cause of compensable injuries⁶. The various mechanisms for transport that are human-powered, such as traditional fork trucks, are fraught with safety issues that can result in injury or death.

OTTO AMRs are pedestrian-safe robots that utilize safety-rated sensors. Simply put, OTTO is designed to work safely around people and other facility equipment. This is made possible through sensor fusion and onboard AI to enable local route planning and collision avoidance. OTTO routinely navigates traffic with other vehicles at intersections and passing scenarios using OTTO Fleet Manager. “Rules of the road” can be custom configured per site, including speed limits, queuing, and zoning. OTTO can also accommodate overhanging loads. 3D cameras can be utilized to detect obstacles outside of the LiDAR footprint.



OTTO is designed to work safely around people and other equipment.

6: <https://www.nist.gov/document/permis-09-forklift-safety-whitepaperpdf>

07 CONCLUSION

At the greenfield facility, OTTO 100 efficiently transported carts of materials and goods across the facility, enabling workers to be redeployed to more value-added tasks. AMRs travel faster over long distances, and their maximum speed is 4.5 miles per hour (a light jog). In short transports and docking maneuvers, humans are faster and more nimble.

As a general conversion factor for a large workspace (>100,000 SF), a designer can use an AMR to human equivalency factor of 1:1. For smaller spaces (<50,000 SF), a more detailed study of maneuvers may be needed to establish the true relationship.

At the brownfield facility, OTTO 1500 transports loaded pallets of finished goods and raw materials up to 4,200 lb. It is compatible with all of the pallets in the facility which included:

- Common wooden pallet types
- Plastic pallets
- Supersack on pallets
- Vendor supplied raw material pallets
- Manufactured WIP and finished goods pallets

OTTO 1500 is capable of interfacing with manual or automated forklifts via the use of pallet stands, which enable load transfer by driving underneath the pallet load and lowering their lift attachment.

The Network Effect of Scale

As more AMRs are deployed, the entire fleet becomes more efficient. In an operation with substantial human labor, the humans cannot simultaneously communicate with each other. Humans rely on hearing, line of sight, and communication devices like radio. One human that is idle is not instantaneously alerted to a condition of extra work being required somewhere else in the operation. With AMRs, the communication is immediate and the dispatch from fleet management software to an idle AMR is done using a combination of computer logic and AI. Therefore, as the AMR fleet size grows, the efficiency of the fleet improves. For large footprint operations at scale, AMR efficiency can exceed human efficiency.

Chang Robotics and OTTO transformed this CPG manufacturer's operations by providing a flexible, reliable, and safe solution that would optimize material movement throughout the manufacturing facilities. OTTO AMRs were found to be more flexible than a conveyor and safer than a forklift. AMRs operate 24/7, 365 days a year and do not lose productivity based on fatigue or delay factors. The deployment resulted in an ROI of less than two years in both the greenfield and brownfield projects, and yielded significant cost savings for our customer as they developed their factory of the future and created new resiliency for their business.

To learn more, visit www.changrobotics.ai/contact.

