Industrial Automation Safety & Visibility Enhancement Design Report

1. Overview

This report presents a comprehensive industrial automation solution designed to enhance safety, automation, and visibility across a robotic CNC work cell. The system comprises a robot operating on 4 Parker servo drives traveling along a rail, interfacing with six individual CNC machines. The objective is to integrate commercially available industrial hardware that can be smoothly incorporated into the existing system while maintaining independent control over its own software. The solution focuses on interoperability using industrial communication protocols including Ethernet/IP, Modbus TCP, and IO-Link, ensuring clean software separation and minimal physical rewiring. All hardware selections comply with industrial safety standards and prioritize modularity, software independence, and IO mapping capabilities.

2. Hardware Selection Summary

2.1 LIDAR Safety Scanners (8 Units)

Eight Banner Engineering SX5-B6 safety laser scanners have been selected to provide comprehensive area protection. Seven scanners will protect static zones: five positioned between CNC machines, one at the front of the cell (West end), and one additional unit mounted to the robot for mobile protection. These scanners support Ethernet/IP, Modbus TCP, and PROFINET protocols, ensuring seamless integration with the existing control infrastructure. The SX5-B6 features a 275° scanning angle, configurable field resolutions from 30mm to 200mm, and can simultaneously monitor up to 4 configurable fields (safety and warning). With a maximum safety field range of 5.5m and Type 3/PLd/SIL 2 safety ratings, these scanners meet stringent industrial safety requirements. The units are priced at approximately $3,200 each, totaling $25,600 for all scanners.

2.2 Machine Vision Cameras (6 Units)

Six Banner Engineering VE Series Smart Cameras have been selected to monitor each CNC machine's process and capture event-based snapshots or live feeds. These cameras feature factory communications via EtherNet/IP and Modbus/TCP for seamless integration with the existing control system. The VE Series offers six optically isolated I/O ports for triggering and event detection, supporting both snapshot and live video capture capabilities. With advanced machine vision processing built-in, these cameras can detect tool wear, part defects, and process anomalies in real-time. Estimated at $2,800 per camera, the total cost for all cameras is $16,800.

2.3 Autonomous Mobile Robot (1 Unit)

One Omron MD-650 Autonomous Mobile Robot has been selected for transporting materials up to 220kg from the staging area to the quality control zone. The MD-650 offers a maximum payload capacity of 650kg (providing comfortable margin for the 220kg requirement) and operates at speeds up to 2.2 m/s with ±10mm positioning accuracy. This AMR features industrial-grade SLAM laser sensors, real-time mapping capabilities, and automatic obstacle detection using visual and laser sensing technology. The robot can be programmed through Python and C interfaces, ensuring compatibility with the existing robot control infrastructure. The MD-650 includes a comprehensive safety system compliant with ISO 3691-4 standards and operates for 8 hours on full payload with <20-minute fast charging. Estimated cost is $45,000.

2.4 Pressure Sensitive Safety Mats (6 Units)

Six Tapeswitch ArmorMat industrial safety mats have been selected for placement in front of each CNC mill. These pressure-sensitive mats are designed for personnel sensing applications and trigger output responses when an operator is present in the protected zone. The ArmorMat features industrial-duty construction with moisture, chemical, and abrasion resistance for long life in harsh industrial environments. These mats support press-at-any-point actuation and are available in anti-static and flame-retardant versions with 12mm thickness. Each mat includes an M12 connector for easy integration with the existing IO system and can be connected to the IO-Link master for seamless communication. Priced at approximately $328 per mat, the total cost is $1,968.

2.5 IO-Link Master Gateway (1 Unit)

One IFM AL1940 IO-Link Master with Modbus TCP interface has been selected as the central communication gateway. This 8-port IP67-rated master provides flexible integration with Ethernet/IP, Modbus TCP, and OPC UA protocols, serving as the bridge between the safety devices, cameras, and the existing Parker servo drives. The AL1940 supports up to 8 IO-Link devices simultaneously, allowing connection to all pressure safety mats and auxiliary sensors. The master features robust industrial construction with extensive diagnostic capabilities and can be programmed through Python and C interfaces, ensuring clean software separation from the robot's proprietary control system. Estimated cost is $570.

3. Integration Strategy

The integration strategy emphasizes clean software separation and minimal physical rewiring while leveraging the existing Parker servo drives' Ethernet/IP and Modbus TCP communication capabilities. The proposed architecture maintains the robot's proprietary software independence while providing unified access to safety, automation, and visibility systems through standardized industrial protocols. Communication Architecture: - LIDAR scanners connect directly via Ethernet/IP for real-time safety monitoring - Machine vision cameras use Modbus TCP for process monitoring and event triggering - Pressure safety mats connect to the IO-Link master, which bridges to Modbus TCP - The AMR operates independently with Python/C programming interfaces for material handling tasks - All safety devices communicate through the IO-Link master to the existing IO interface Software Independence: - Each hardware component maintains its own independent software control - The IO-Link master acts as a protocol translator, enabling clean separation - Python and C programming interfaces are available for custom logic implementation - No modifications

required to the robot's proprietary control software - All safety devices can be configured and monitored independently IO Mapping: - Utilize existing unused IO ports in the robot's control cabinet - Map safety device outputs to appropriate IO addresses for real-time monitoring - Configure event-based triggers for cameras and safety mats - Implement fail-safe logic through the IO-Link master for emergency responses

4. Installation & Layout

The physical installation layout has been designed to maximize safety coverage while maintaining operational efficiency. The layout diagram (see attached PNG) illustrates the positioning of all components relative to the robot rail and CNC machines. LIDAR Scanner Placement: - Five scanners positioned between each pair of CNC machines (total of 5 inter-machine zones) - One scanner at the West end of the cell (front entrance protection) - One scanner mounted to the robot for dynamic protection during robot movement - Each scanner configured with 275° scanning angle and appropriate safety field resolution Camera Positioning: - Six cameras positioned to monitor each CNC machine individually - Cameras mounted at optimal angles to capture tool engagement and part processing - Each camera connected to the control network via Ethernet with local I/O for event triggering Safety Mat Placement: - Six pressure-sensitive mats placed directly in front of each CNC mill - Mats sized to provide adequate operator detection zone while maintaining accessibility - Connected to the IO-Link master via M12 connectors for reliable signal transmission AMR Navigation: - The MD-650 AMR operates between the staging area and quality control zone - SLAM-based navigation enables dynamic path planning and obstacle avoidance - Charging station located at staging area for autonomous operation - Safety systems integrated with cell safety through Modbus TCP communication Wiring Strategy: - Utilize existing cable trays and conduit where possible - Minimize new cabling through strategic placement of network switches - Use standard industrial cable specifications (IP67 rated for harsh environments) - Implement proper grounding and shielding to prevent electromagnetic interference

5. Conclusion

The proposed solution provides a comprehensive industrial automation upgrade that significantly enhances safety, automation, and visibility across the robotic CNC work cell while maintaining clean software separation and minimal physical rewiring. The total estimated hardware investment of $90,938 delivers immediate operational benefits through improved worker safety, enhanced process visibility, and increased automation capabilities. Key advantages of this solution include: - Full compliance with industrial safety standards (Type 3/PLd/SIL 2, ISO 3691-4) - Seamless integration with existing Parker servo drives via Ethernet/IP and Modbus TCP - Independent software control for each hardware component - Modular architecture allowing future expansion or modification - Comprehensive diagnostic and monitoring capabilities - Reduced labor requirements through AMR automation The selected hardware components from Banner Engineering, Omron, Tapeswitch, and IFM represent proven industrial solutions with strong vendor support and extensive field deployment history. The combination of safety laser scanners, machine vision cameras, autonomous mobile robot, pressure safety mats, and IO-Link communication infrastructure creates a robust foundation for safe, efficient, and visible manufacturing operations. This implementation strategy ensures that the existing robot control system continues to operate without modification while providing enhanced safety and visibility through standardized

industrial communication protocols. The clean separation of software control systems allows for independent troubleshooting, maintenance, and future upgrades without disrupting core robotic operations.

6. Cost Summary

Item	Quantity	Unit Cost	Total Cost
Banner SX5-B6 Safety Laser Scanner	8	$3,200	$25,600
Banner VE Series Smart Camera	6	$2,800	$16,800
Omron MD-650 AMR	1	$45,000	$45,000
Tapeswitch ArmorMat Safety Mat	6	$328	$1,968
IFM AL1940 IO-Link Master	1	$570	$570
		TOTAL	**$89,938**

Note: All costs are estimated based on 2024 industrial market pricing. Actual costs may vary based on specific configurations, quantities, and vendor agreements. Installation and integration costs are not included in hardware estimates.