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PRACTITIONER PERSPECTIVES

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The Smart Toolbox

Digital Transformation of Tool and Equipment Management

Turbulent times in the manufacturing and industrial sectors have forced leaders to focus on their organizations' digital transformation to survive.

As part of this ongoing adaptation process, decision-makers are evaluating business and technological processes for optimization and automation, investigating new competencies and business models, and seeking new product and revenue opportunities.

Tools and equipment management is essential to every technological process and one of the key influencing factors of product and service quality.

In this paper, we explore the top challenges in tool and equipment management in the current environment.

You'll learn about the attributes that make a solid management system, and delve into a proposed solution, the Smart Toolbox system, which is being researched and developed in the Kharkiv office of GlobalLogic Ukraine.

You'll also find useful information about the major features and high-level architectures of hardware and software components in such a system.

Finally, we'll take a look at new business opportunities the Smart Toolbox (or a similar solution) can unlock for an organization. You'll take away the next steps required for Smart Toolbox research and development.

Challenging Times for Global Industry

Traditionally, most tools, equipment, and processes in manufacturing, construction, aftermarket services, and related sectors were executed manually by skilled workers as operators. Humans controlled and supervised most aspects of the manufacturing and service processes.

People collected instrument readings according to established procedures, then verified, analyzed, aggregated, and prepared data for decision-making. Leaders made tactical and strategic decisions and communicated these to workers, who then adjusted their processes to align with the new vision and direction.

It worked well enough for moderately competitive local environments. However, these traditional, manually intensive workflows are no longer an option in the volatile, uncertain, complex, ambiguous (VUCA), and highly competitive world of modern manufacturing.

The COVID-19 pandemic seriously affected world economies. The majority of large organizations and small businesses were suddenly faced with two options: either find their way to rapidly adapt to a volatile and ambiguous situation, or quit.

Fortune reported that 94% of Fortune 1000 companies were forced to repurpose or reshape their supply chains.

Products and materials produced in Chinese factories are a critical part of logistics and business strategies for many organizations worldwide.

Since 2001, the year China joined the W.T.O., U.S. imports from China have risen from $100 billion to $500 billion. The E.U. is not far behind, and the curve of import trend goes up, increasing its rate.

However, escalating trade tensions between the U.S. and China are already impacting supply chains barely recovered from COVID-19 disruption.

The Russian invasion of Ukraine and the Russian-Ukraine war added instability to the situation in manufacturing for global organizations and the world economy as a whole.

Global migration is another factor, as up to 103 million refugees have relocated over the last 20 years (UNHCR 2022).

Concurrently, the impact of climate change is worsening which causes catastrophic flooding, heat waves and droughts in one part of the Earth and ice melting at the poles (UN FOUNDATION 2022).

Industries must show great responsibility in organizing their processes and development by always considering the potential consequences of breaking the 1.5-degree warming threshold of preindustrial times.

These and similar disruptive events are adding pressure on governments and international business organizations.

Not surprisingly, economists worldwide have started to warn humanity about the 'perilously close' recession in 2023 (World Bank 2023).

These conditions present a new and rapidly evolving set of challenges for the industrial sector. Organizations must find smarter ways to respond to the challenges and build more sustainable businesses.

This calls for optimizing, improving, and automating business processes; developing new competencies; and searching for new opportunities in the equation of people, intelligence, processes, and innovation.

Industrial businesses are being called on to create competitive benefits and innovative products and services uniquely targeting their customers.

This calls for a greater focus on digital transformation (DX).

This is not the time to deprioritize innovation and lose momentum on the journey to Industry 4.0.

Organizations must keep looking ahead for new, creative ways to bring technologies such as big data and AI, innovation accelerators, the Internet of Industrial Things (IoIT), digital twins, and advanced robotics to shop floors, construction sites, assembly lines, and supply chains.

Tool Management in an Industrial Organization

Business and technological processes within an industrial organization or service shop are diverse and comprehensive, encompassing multiple stages, interconnections, quality checkpoints, and approval gates.

Tools play a crucial role at almost every stage of these processes, regardless of their complexity.

The quality of tool management within an organization directly impacts the outcomes of these processes and influences their overall characteristics.

Among the numerous challenges faced by industrial organizations, several are typically encountered and resolved in one way or another:

1. Missing, incorrect, or outdated data. Throughout the lifecycle of a tool, various types of information are generated, such as tool availability, usage, repairs, losses, and decommissioning. If tool events are tracked manually, the likelihood of constant errors increases significantly.

2. Access protection. Tools are valuable and expensive organizational assets, and access should be restricted to authorized personnel only. Supervisors must be aware of who had access to specific tools, when it occurred, and if any tools are missing from their designated toolboxes.

3. Timely maintenance. Tools should be regularly checked for issues such as physical wear and tear, damages, and miscalibration. The quality of timely maintenance directly impacts the quality of outcomes produced using these tools.

4. Completeness in the workplace. Staff members should always have an adequate supply of the specific tools they require to fulfill their daily tasks. If the quality of information regarding the status of available tools is poor, supervisors may struggle to determine the exact toolset for which they are responsible at any given moment.

5. Compliance with regulatory standards. Tool usage may be subject to self-imposed rules or certified by organizations such as ISO, NCCER, or NIMS. Additionally, industrial or governmental regulations may need to be adhered to. In any case, supervisors and leaders must consistently manage all tooling records and undergo regular audit procedures.

By effectively addressing these challenges and implementing robust tool management practices, industrial organizations can enhance processes, optimize outcomes, and comply with relevant regulations.

It takes a comprehensive tool and equipment management system to address the aforementioned challenges. Such a system should incorporate the following key attributes:

Availability: A complete set of tools must be readily available for staff to efficiently carry out their daily tasks. The number of available tools should correspond to the workload of all workers across shop floors, service shops, and other relevant areas.

Security: Put measures in place to ensure the security of tools and prevent unauthorized access. All instances of successful and unsuccessful access attempts should be logged for future reference.

Accessibility: Staff should be well-informed about the location of the tools they require to perform their tasks. They should be able to quickly and easily access the tools they are authorized to use.

Traceability: Supervisors need clear visibility regarding tool usage, including information about which tools were used by whom, for how long, and whether the tools have been returned to their designated toolboxes.

Figure 1 - A modern shop floor.

Trackability: Supervisors should have immediate knowledge of the current status of toolboxes, including which tools are currently in use, which are overdue for return, and if any tools are missing. They should receive timely notifications if a tool has been taken out of a restricted area.

Maintainability: Supervisors should possess comprehensive information regarding the physical condition of tools. This includes identifying tools that require immediate repair, scheduling maintenance for specific tools, determining when maintenance is due, and identifying tools that need to be replaced.

An organization or business that establishes tool management based on the aforementioned quality attributes will experience a significant reduction in time and effort waste involved in product production or service provision.

Implementing such an organized tool management system enables supervisors and leaders to enhance core capabilities crucial for successful business development and transformation, namely hyper-awareness, informed decision-making, and rapid execution.

Consequently, this paves the way for cost-effective optimizations of business and technological processes throughout the organization.

Achieving these improvements in the past was challenging when relying solely on traditional approaches to process transformation.

However, advancements in IT and OT, the convergence of these technologies, the emergence of diverse sensors and actuators, the availability of low-cost edge computing devices, and advancements in data collection, storage, processing, analysis, and decision-making approaches and technologies have made these changes possible. Additionally, the development of cloud technologies has further facilitated the implementation of these transformations.

According to surveys conducted by PTC in 2021 and Foundry in 2022, approximately 91-92% of the organizations that responded are already embarking on their digital business transformation journey.

However, these organizations are currently in various stages of implementation, ranging from the planning phase to the rollout stage.

The Foundry survey (Foundry, 2022) further reveals that 32% of respondents intend to seek assistance from their technology partners in developing their digital strategy, while 34% plan to involve their technology partners to receive recommendations for relevant technologies and services.

Additionally, 29% of survey respondents plan to seek recommendations from technology partners on process redesign and automation.

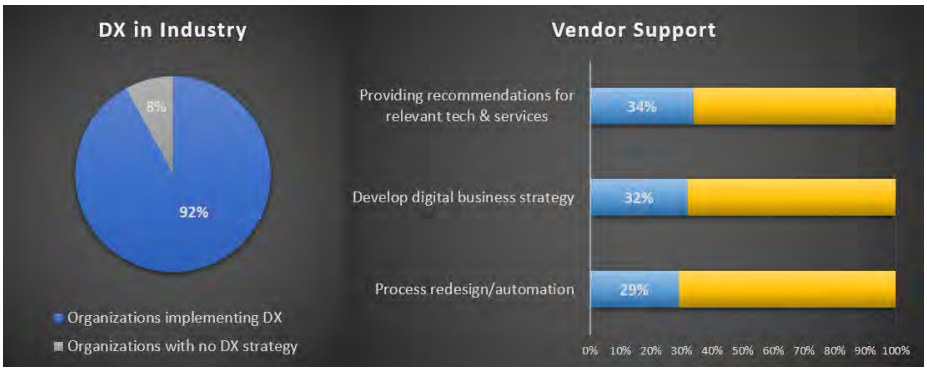


Figure 2 - Data Transformation in industrial organizations.

Therefore, it is not surprising that the market now offers a variety of computerized maintenance management systems (CMMS) that include tool management as part of their asset management capabilities.

Additionally, there are dedicated asset management software solutions specifically designed for the management of tools and equipment.

The software currently available in the market addresses tooling challenges by providing intuitive UIs for entering information about tools and equipment, scheduling their usage and maintenance, tracking their latest location, and generating comprehensive reports and charts for analysis.

Some software even incorporates tool location tracking through bar tags, Bluetooth tags, or RFID tags.

However, existing solutions often lack real-time data and advanced analytical insights regarding tool usage.

Furthermore, they may not have robust tool access protection capabilities or the ability to predict upcoming tool maintenance requirements.

Smart Toolbox as a Solution for Tool Management Challenges

As part of GlobalLogic Ukraine's business opportunity and expertise development initiative, the industrial experts team based in the Kharkiv office has taken on the challenge of addressing issues related to tool management.

They have developed a proof of concept solution that utilizes Industry 4.0 technologies.

This solution, named Smart Toolbox, aims to overcome many challenges associated with tool management.

Smart Toolbox is a tool management system designed to be installed directly at job sites. Its primary objectives are to ensure secure access to tools, gather comprehensive tool usage statistics, and transmit the data to a cloud storage system for processing, aggregation, storage, and visualization.

Figure 3 - Smart Toolbox

What sets Smart Toolbox apart is its unique composition, consisting of two interconnected components:

Hardware unit

This device is installed directly on the tool box and serves as a control mechanism for regulating access to the tools.

It tracks and manages the movement of tools, including when tools are taken out of or returned to the tool box.

Fleet management and reporting platform

This cloud-based software system is responsible for managing the hierarchy of Smart Toolbox installation locations.

It handles the provisioning, configuration, and control of Smart Toolbox hardware units.

Additionally, it manages tool records and generates comprehensive statistical reports.

Together, these components form an integrated tool management solution, enabling efficient control, tracking, and reporting of tool usage.

The target audience for the Smart Toolbox primarily consists of individuals working on shop floors, service shops, or construction sites. As an example, for a manufacturing shop floor, the following personas can be identified:

David Smith, 47 years old, Worker

David's role involves verifying the quality of products at an interim stage of the assembly line.

He highly values having the right tools and equipment available when needed. David is frustrated when the cycle time of his work is prolonged due to difficulties in locating tools or encountering malfunctions.

He prefers user interfaces that are simple and intuitive, as he is not particularly fond of gadgets and computers.

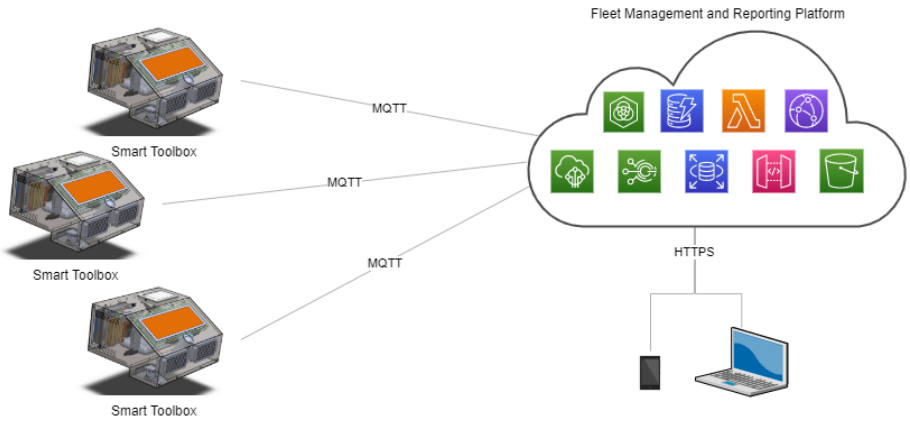


Figure 4 - Components of Smart Toolbox solution

Mio Heath, 35 years old, Supervisor

Mio is responsible for supervising the team, including David. She assigns tasks to the workers for each shift.

Mio ensures that David has access to the specific toolbox required for executing each task.

Rachel Joseph, 28 years old, IT Support

Rachel provides IT support for the Smart Toolbox system and assists with any technical issues that may arise.

At the start of his shift, David receives a task list from Mio.

Each task specifies the necessary tools from a particular toolbox, to which David already has access.

To begin a task, David logs into the Smart Toolbox hardware unit using the built-in face identification feature.

The system successfully recognizes him, grants him access, and opens his personal dashboard screen. The dashboard displays David's usage records for the current day, enabling him to quickly review the tools he has used, their durations, and estimated usage values.

When David takes a tool from the toolbox, the built-in RFID reader scans the RFID tag attached to the tool, records the usage session, and initiates tool usage tracking.

Upon completing the task, David returns the tool to the Smart Toolbox. He logs in again, places the tool back into the toolbox, and the device scans the RFID tag, recording the end of the tool usage session for David.

Mio, as David's supervisor, holds responsibility for the shop floor, and tool management falls within her area of expertise. Her main concern is maintaining all tools in optimal condition and ensuring their availability at the start of her and David's shift. She diligently collects tool usage statistics, generates reports, and ensures timely maintenance.

Mio strongly dislikes when tools are unexpectedly lost or damaged. An experienced computer user, she is proficient in complex reporting in Excel and seamlessly syncing data between her smartphone and laptop.

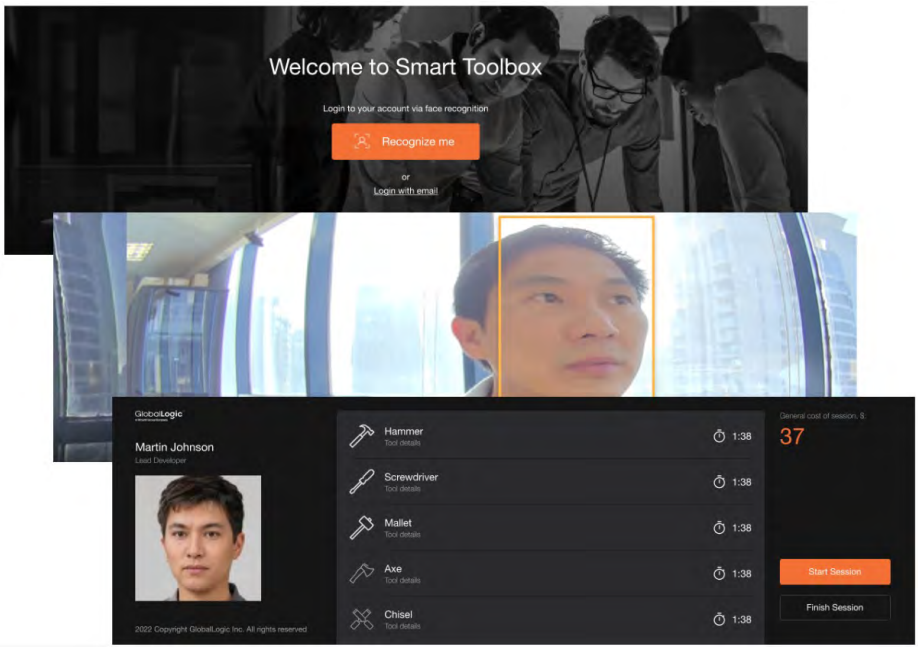


Figure 5 - User screens of Smart Toolbox hardware unit

In her work, Mio primarily interacts with the Fleet Management and Reporting web application.

She accesses this application using both her laptop and smartphone.

Before the shift begins, Mio verifies that the Smart Toolboxes are stocked with all the necessary tools for David and other workers to complete their tasks.

She also ensures that all workers have access to the Smart Toolboxes.

During the shift, Mio regularly checks the current status of the Smart Toolboxes to monitor the availability of tools in use, any overdue tools, or any missing tools.

At the end of the shift, Mio generates various analytical reports on tool usage and ensures that all tools have been returned to the Smart Toolboxes.

Rachel, who works in the IT department, is responsible for the setup of both hardware and software on the shop floor.

While some tasks can be performed remotely, others require her physical presence at the hardware equipment installed in the shop floor. Rachel appreciates when new equipment can be easily configured with just a few clicks and requires minimal attention afterward.

On the other hand, she dislikes encountering undocumented software or equipment behavior without any relevant clues in the logs. With a bachelor's degree in computer science, Rachel possesses the skills to independently resolve the majority of issues that arise.

Rachel primarily interacts with the Fleet Management and Reporting platform, but she occasionally logs into the Smart Toolbox hardware unit to verify its configuration.

Using her laptop, Rachel accesses the platform through the web interface. Within the platform, she manages the organization hierarchy, relocates existing Smart Toolboxes to different departments, and provisions new Smart Toolboxes.

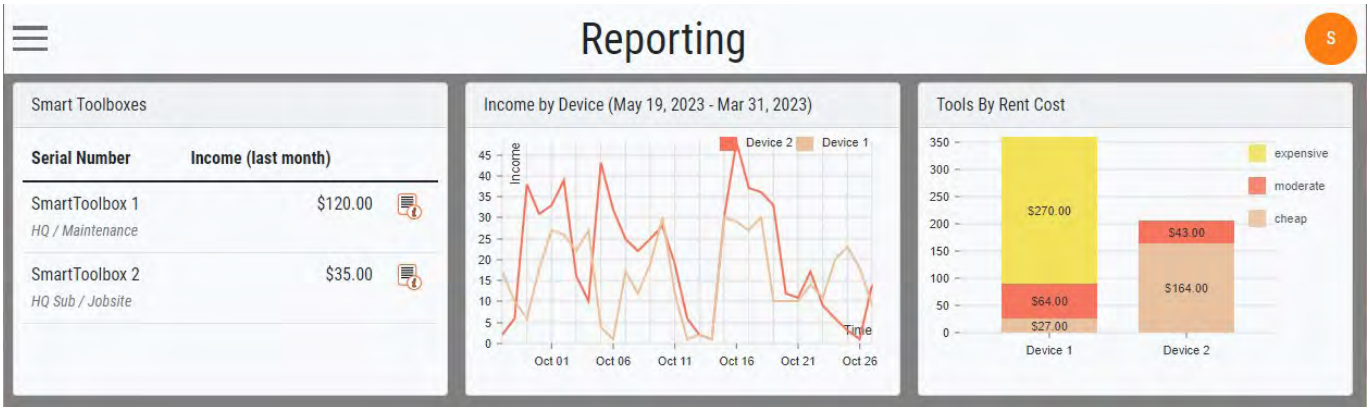


Figure 6 - Reporting page of Smart Toolbox Fleet Management and Reporting application

Additionally, Rachel is responsible for addressing any software issues that may arise with the Smart Toolbox configuration.

She is accustomed to working with the status dashboard, configuration tools, and diagnostics features to ensure smooth operations.

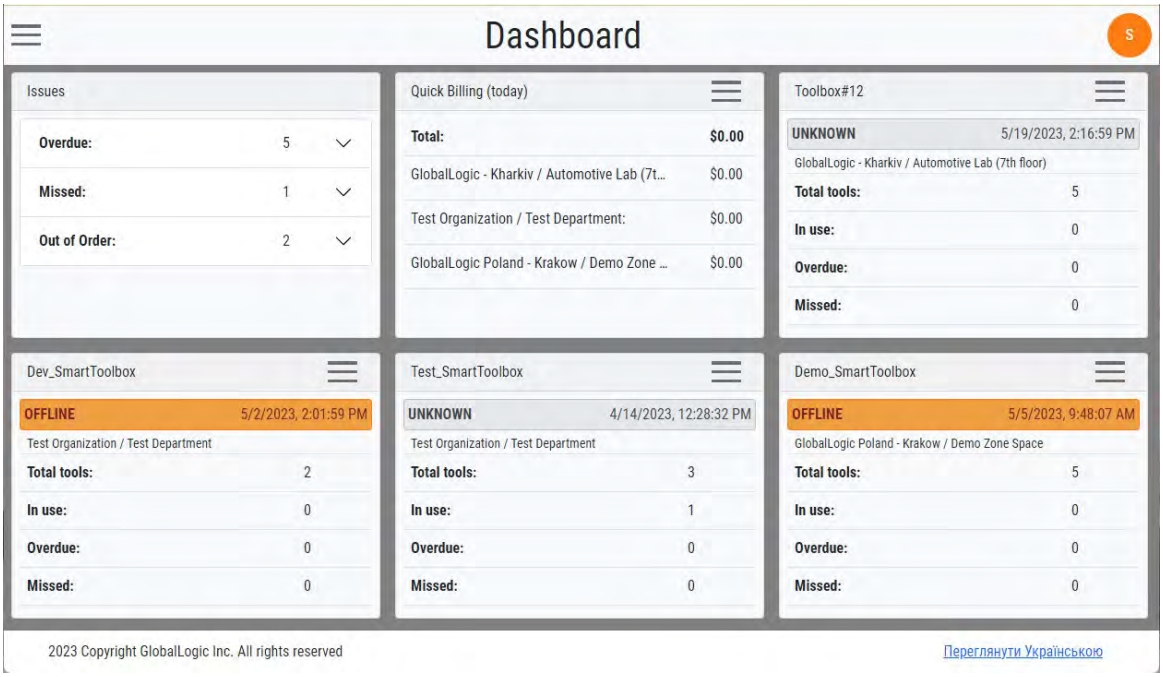


Figure 7 - Dashboard page of Smart Toolbox Fleet Management and Reporting application

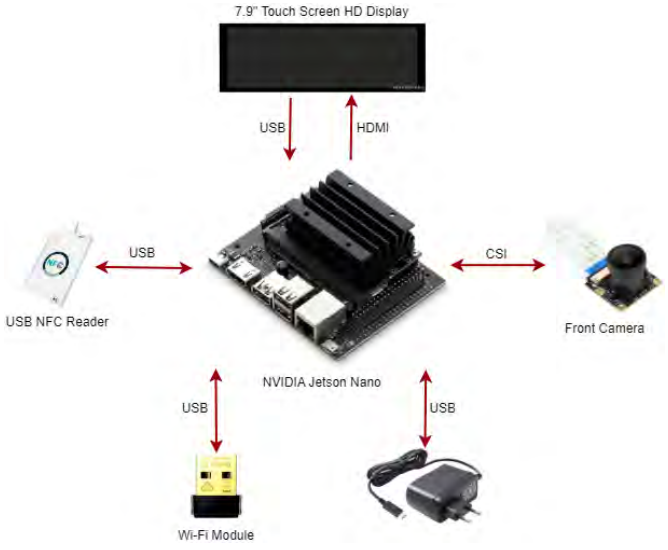
High-Level Architecture of Hardware Unit

At the heart of the Smart Toolbox hardware unit lies the NVIDIA Jetson Nano 2GB board.

This powerful board not only enables the connection of the necessary hardware to support the functionality of the Smart Toolbox but also facilitates the development of AI-capable features, such as facial recognition.

Its advanced technical capabilities make it an ideal foundation for implementing the Smart Toolbox system.

#	Component	Model	Usage
1	Touch Screen	Waveshare 7.9" LCD 400x1280 HDMI Capacitive Touch Screen	Touchscreen interface to interact with Smart Toolbox
2	USB NFC Reader	ACR122U	Reader of RFID tags attached to tools stored in Smart Toolbox
3	Front Camera	Waveshare IMX477-160 12.3MP Camera	Camera to implement face recognition for user authentication to Smart Toolbox
4	Power Supply Unit	Sunny 5□ 4A TYPE-C	AC-DC convertor to power the Jetson Nano board
5	Wireless USB Adapter	TP-LINK Archer T600U Nano	Extends built-in communication capabilities with wireless connection over Wi-Fi



These components are connected via different interfaces to the main board, as illustrated at left.

Figure 8 - Hardware components of Smart Toolbox hardware unit

The software operating on the Smart Toolbox hardware unit is developed specifically for Jetson Linux, also known as Linux4Tegra, which is a Linux distribution based on Ubuntu 18.04 designed for use with NVIDIA Jetson boards.

The core of the application is written in C++ (C++14) and utilizes the Qt5 framework. All application and user data are stored locally in an SQLite database.

The NFC reader is responsible for reading the RFID tags of the tools, following the PC/CS standard. The implementation of face detection and recognition features relies on the OpenCV and dlib libraries.

Furthermore, the software communicates with the Fleet Management platform via the AWS IoT SDK.

Access to the SQLite database is facilitated through the sqlite3 library.

The logical organization of the software components is depicted in the following component diagram.

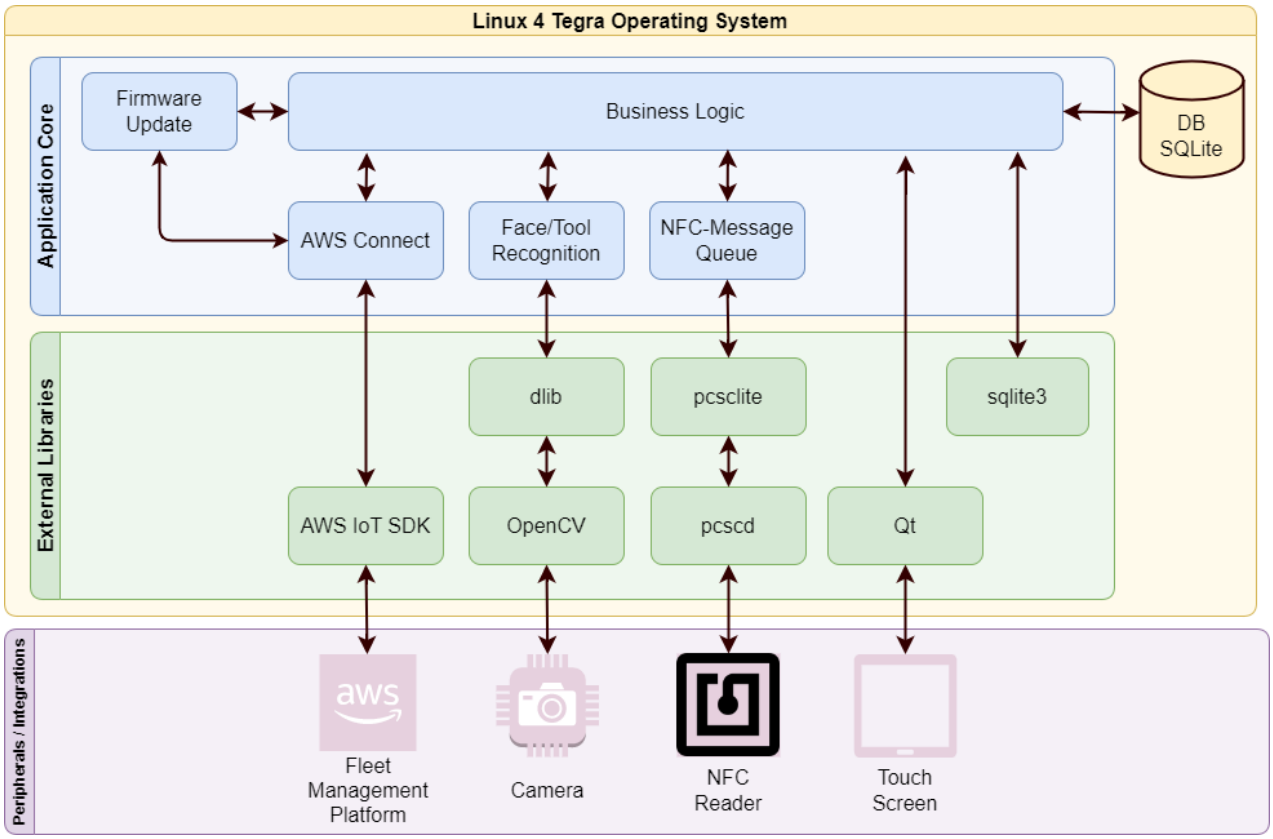


Figure 9 - Component diagram of Smart Toolbox hardware unit

High-Level Architecture of Fleet Management Platform

The Fleet Management and Reporting platform is a cloud-based serverless solution designed for multiple tenants.

It enables organizations and their departments to provision, configure, and manage Smart Toolboxes.

The platform offers interfaces for receiving telemetry from hardware units, aggregating the data, and transforming it into valuable insights through charts and reports.

Implemented on AWS, the platform consists of user-facing applications and data processing services.

Users interact with the platform through a responsive web application that is developed using JavaScript, React, and Python.

The application is designed to be compatible with both large and small screens. It is hosted as a serverless application, with the backend deployed on AWS Lambda and the frontend on AWS CloudFront.

The frontend communicates with the backend via AWS API Gateway. User management is handled by the AWS Cognito identity provider. User, application, and device data are stored in PostgreSQL, hosted as an RDS service, DynamoDB for key-value database, and S3 for object storage.

All communication within the platform is secured using the HTTPS protocol.

Each Smart Toolbox is automatically configured as a digital entity on AWS. Upon creation, isolated communication endpoints, authentication certificates, and metadata are provisioned for each Smart Toolbox.

These digital entities are organized into thing groups associated with the respective organizations that own them, ensuring access to Smart Toolboxes is restricted to their designated owners.

Smart Toolbox telemetry is injected into the AWS IoT Core service using the MQTT protocol. Each hardware unit has access only to its designated set of MQTT topics.

The data received by IoT Core is processed by IoT Core rules, aggregated by a dedicated aggregation service hosted on AWS Lambda, and stored as time-series data in DynamoDB.

Recommended reading:

Architectural drift and erosion in software development can seriously impact the business and go-to-market strategy, causing delays, decreased quality, and even product failure.

Architectural gap detection workflows have historically been manual, time consuming, and prone to human error. There's a better way to detect architectural gaps – with automation.

Read More

The following diagram provides a high-level overview of the solution's architecture.

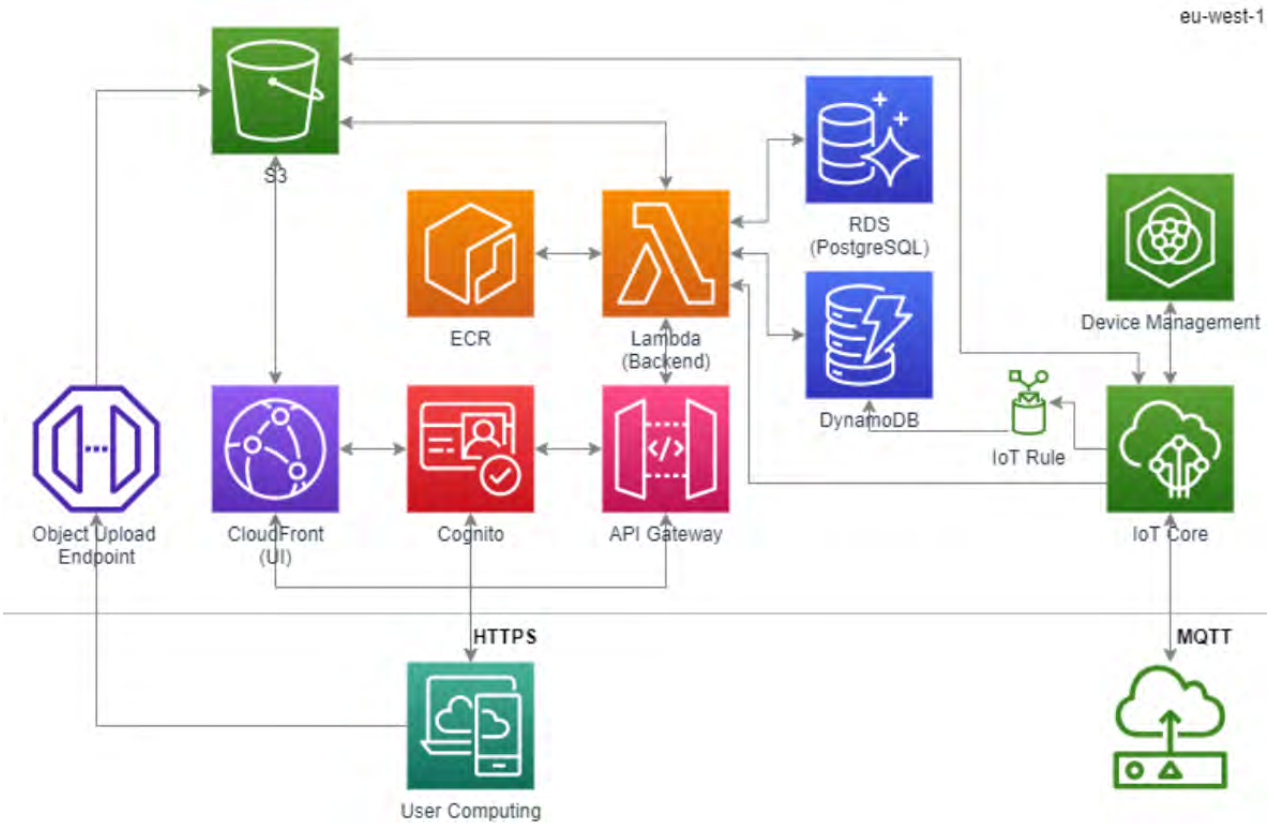


Figure 10 - High-level architecture of Smart Toolbox Fleet Management and Reporting platform software

New Opportunities with Smart Toolbox

Smart Toolbox brings forth new opportunities for both tool and equipment providers and their customers in the realm of traditional tool and equipment management.

Providers now have the ability to offer diverse business models for tool and equipment ownership, including options such as rent, leasing, subscription, and pay-as-you-use. This effectively revolutionizes the traditional ownership model and introduces the concept of equipment-as-a-service.

By leveraging the telemetry data collected by Smart Toolboxes, providers can precisely target the specific needs of their customers. They can identify usage patterns, track rates of wear and breakage, and enable condition monitoring and predictive maintenance of tools and equipment.

This level of insight empowers providers to optimize their research and development, production, logistics, marketing, and sales processes, resulting in improved efficiency and cost-effectiveness.

For organizations utilizing tools and equipment, Smart Toolbox allows for optimization of capital expenses by converting them into operational expenses. They can choose to share or transfer the responsibility of tool supply and maintenance to providers, reducing the burden on their own resources.

Implementing tool management within organizations enhances transparency regarding tool usage, while also aiding in theft and loss prevention.

The data collected by Smart Toolboxes offers valuable insights into various organization-wide processes, such as people management, planning, and asset management.

This data can serve as a valuable resource for driving the transformation towards predictive quality in the production of manufactured products and services.

Overall, Smart Toolbox opens up new avenues for tool and equipment providers and their customers, facilitating improved efficiency, cost optimization, and enhanced decision-making in the realm of tool and equipment management.

What's Next?

Today, Smart Toolbox has implemented fundamental yet essential features that serve as the building blocks for more comprehensive functionality.

The team showcased the Minimum Viable Product (MVP) version of Smart Toolbox during the Göteborg Engineer Day on November 9, 2022, in Sweden.

The presentation was part of a masterclass titled "Equipment as a Service: a case of digital transformation within the Construction industry" (Ingenjörsdagen 2022), and it received positive feedback from the audience.

Moving forward, the team has ambitious plans to enhance and expand the functionality of Smart Toolbox.

The roadmap includes features such as:

- tool detection and recognition using an additional camera
- incorporating a relay module to control the magnet lock on the tool compartment
- integrating a voice assistant
- and implementing geofencing, among other advancements.

These features not only address important business challenges but also contribute to the evolution and experimentation with Smart Toolbox, aligning it with the digital twin concept and the broader scope of Industry 4.0.

By incorporating environmental data through these new features, Smart Toolbox further enriches its digital footprint in the digital world.

According to Lv and Fersman (2022), a system that can collect information about its physical environment, utilize computational resources to represent its behavior over time, and exchange data about its physical and virtual environments can be characterized as a digital twin.

This realization opens up remarkable opportunities for the digital transformation of tool and equipment management in various industries.

The ongoing development and expansion of Smart Toolbox's functionality, along with its alignment with the digital twin concept, position it as a digital transformation catalyst in the realm of tool and equipment management across industries.

References

Sherman, Erik. (February 21, 2021). 94% of the Fortune 1000 are seeing coronavirus supply chain disruptions. Fortune. Retrieved from https://fortune.com/2020/02/21/fortune-1000-coronavirus-china-supply-chain-impact/.

Foundry. (2022). Digital Business Study. Foundry. Retrieved from https://resources.foundryco.com/download/digital-business-executive-summary.

Ingenjörsdagen. (2022). Göteborg 9th of November - Engineer Day 2022 Archive 2022. Ingenjörsdagen. Retrieved from https://ingenjorsdagen.se/en/goteborg-2022/.

Lv, Z., & Fersman, E. (Eds.). (2022). Digital Twins: Basics and Applications. Springer International Publishing.

PTC. (2021). The State of Industrial Digital Transformation. PTC. Retrieved from https://www.ptc.com/-/media/Files/PDFs/IoT/State-of-Digital-Transformation-2021.pdf.

UN Foundation. (2022). Climate Issues To Watch In 2023: Toward COP 28 And Faster, More Urgent Climate Action. UN Foundation. Retrieved from https://unfoundation.org/blog/post/climate-issues-to-watch-in-2023-toward-cop-28-and-faster-more-urgent-climate-action.

UNHCR. (2022). Refugee Statistics. UNHCR. Retrieved from https://www.unhcr.org/refugee-statistics/.

World Bank. (2023, January 10). Global Economic Prospects: Sharp, Long-lasting Slowdown to Hit Developing Countries Hard. World Bank. Retrieved from https://www.worldbank.org/en/news/press-release/2023/01/10/global-economic-prospects.