Item Traceability for Reducing Production Losses and Risk of Defective Product Dispatch

Given the potential for problems on the production line to result in losses due to rejects or equipment downtime as well as the risk of defective products being shipped, how to rapidly identify the causes of problems and determine the scope of their consequences are major concerns in manufacturing. In response, Hitachi has developed an item traceability solution that addresses this challenge by utilizing IoT data to provide a high level of traceability. This article describes the solution and the future potential for factory-wide optimization envisaged by the smart factory maturity model.

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1. Introduction

With the manufacturing industry facing increasingly diverse customer needs over recent years along with labor shortages and falling numbers of experienced staff caused by the shrinking of the working-age population, boosting the efficiency of flexible production, improving quality management and assurance, and making the best use of production resources are all key issues for the value chain.

Of these, improving quality management and assurance comes with a variety of requirements that derive from the heightened concern for safety, security, and quality among customers. This is happening against a background in which work is going into improving quality accountability, appealing to safety as a way of enhancing brand image, and gaining certification under strict international standards that help expand sales.

The top priority here is to improve the level of traceability. There are two forms of traceability corresponding to the vertical and horizontal directions respectively. Horizontal traceability refers to data on the goods that are manufactured as they move through the value chain, including raw materials, parts, intermediate goods, and end products, while vertical traceability tracks the operational data captured and held at each step along this chain.

While many manufacturers have installed manufacturing execution systems (MESs) to implement lot-level traceability across their production processes, it is rare for horizontal traceability to extend back to raw materials at suppliers or forward to products after they have been shipped. Similarly with vertical traceability, it is also rare for traceability data to be so fine-grained as to allow product and quality information to be tracked at the level of individual items. In other words, the installation of an MES on its own still does not provide enough data to follow the history of individual products (items), nor to undertake the analyses and actions needed to address the key value chain challenges. The main reason for this is that, while progress may have been made on installing particular systems or automating certain processes, these amount to no more than localized improvements. What is needed, rather, is to establish the infrastructure for integrated management of traceability information.

Implementing this higher level of traceability should be worthwhile not just in terms of accountability, in the sense of being able to track information from raw materials to the shipping of finished goods, but also can be expected to deliver benefits in its own right. These include reducing the costs of repeated inspections or reject products and making it quicker to isolate the causes when problems arise in the production process.

For example, when a problem happens on a production line, a wide variety of production data needs to be collected to determine the cause of the problem, such as details of rejected products, production node data such as filling machine valve numbers, or inspection system data. All of this takes time. This fault-finding work requires a comprehensive understanding of conditions on the line as a whole, a skill that is limited to certain people. Even more time and cost are incurred when problems become more than just operational matters and instead develop into quality issues, with additional inspections being needed along with work to determine the extent of the consequences. Accordingly, workloads, costs, and rejects can be reduced by using horizontal traceability to tie together data from different steps in the production process, and through the transparency provided by maintaining up-to-date vertical traceability in the form of item production and quality inspection history data.

Moreover, the consequences can be very severe if products suspected of being defective get out into the marketplace, and this is another important consideration in the tracking of information not only in the production process, but also from raw materials to shipped products. If products affected by production problems leave the site and get as far as the customer, the result can be a lot of work and heavy costs associated with contacting customers and performing repairs under warranty. Recalls by the automotive and other industries are a prime example, one that is frequently reported in the media. Such incidents can also develop into a major corporate problem, causing a loss of trust by customers and suppliers. Accordingly, by ensuring that traceability allows for a rapid response, significant benefits can be anticipated from keeping such negative consequences to a minimum.

The challenges to implementing the advanced forms of traceability discussed above are the collection of data, the integrated management of traceability information, and the automation of its presentation. This article describes an item traceability solution for factories that offers ways of overcoming these challenges.

Key features of this solution are that it puts in place infrastructure for the collection and integrated management not just of information from all of the plant and equipment in the factory, but also of quality and production data obtained from IT systems, and that it provides functions for viewing and monitoring production and inspection records at the level of individual items. By doing so, the solution helps to improve utilization and lower inspection costs through the early detection of anomalies and rapid fault-finding with item-level analysis of production history.

The technical issues include expansion capabilities and how to present large quantities of different types of traceability data while ensuring it is up-to-date. The ability to scale seamlessly is an essential requirement for expanding the scope of both horizontal traceability (from individual processes to multiple sites) and vertical traceability (types and quantities of data handled).

2. Item Traceability for Item-by-item Tracking of Production and Inspection History

Item traceability provides details of production history and quality results indexed by keys such as product ID or production node, presenting information about production and quality at the level of individual items. It is able to monitor this information in real time and detect anomalies in the production process.

Figure 1 shows a block diagram of an Internet of Things (IoT) factory data platform from Hitachi that combines the Hitachi Digital Solution for Manufacturing/IoT (HDSM/IoT) and Hitachi Digital Supply Chain/IoT (DSC/IoT).

2. 1 Overview of Item Traceability Solution

The item traceability solution is able to identify where problems arise and determine the extent of any consequences at the level of individual items, using trace IDs to link production and quality management information from the plant and provide a view of production nodes, production results, and quality results.

The solution also allows the monitoring intervals, monitoring duration, and number of divergences to be specified for the upper and lower control values set for production and quality measurements in the production process. Through continuous monitoring of this information and by issuing alerts when abnormal trends are evident, this reduces losses due to rejects or equipment downtime as well as the risk of defective product dispatch by identifying equipment problems more quickly and detecting trends before they lead to problems.

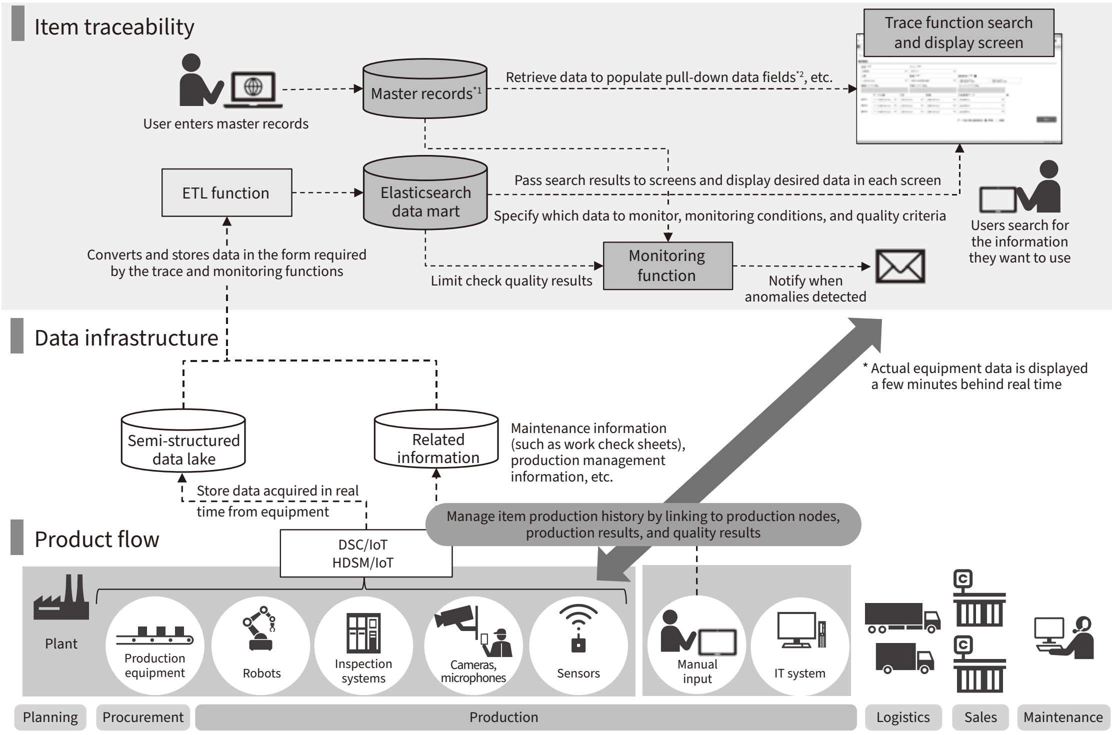
2. 2 Item Traceability Solution Functions

The item traceability solution is made up of an extract, transform, and load (ETL) function, a monitoring function, and a trace function.

The ETL function deals with production and quality management information from the plant that is collected in the primary data mart on the data platform, converting

Figure 1 — Block Diagram of Item Traceability

Item traceability works in tandem with a factory IoT platform for collecting and archiving item-level production and quality information to make production history and quality results available to users.



ETL: extract, transform, load DSC: Hitachi Digital Supply Chain/IoT HDSM: Hitachi Digital Solution for Manufacturing IoT: Internet of Things
*1 Master data for production management held by users
*2 Equipment name, quality management data field, etc.

this information and storing it in the secondary data mart in a form that can be used for item traceability.

The monitoring function monitors production and inspection results collected from the plant in real time and issues alerts if values exceed their thresholds.

The trace function searches the large quantity of item-linked production and inspection results collected from the plant and displays the retrieved data along with the relevant process.

For the real-time collection and archiving of production and quality information at the level of individual items, item traceability uses Elasticsearch[*1] as its data mart. Elasticsearch is a full-text search engine able to index a wide range of content and quickly extract the required data from large datasets. Its application programming interface (API) is based on the fast, scalable, and simple representational state transfer (REST)[*2] architecture and can handle distributed design and both structured and unstructured data.

2. 2. 1 ETL Function

Node-RED[*3] is a visual programming tool (that does not require the writing of code) for defining data processing flows, including data input and output, data operations such as merge and split, and output to the data mart. It is used to create an environment for handling data that is user-led. It can also present large quantities of different types of traceability data that is up-to-date and features extensive expansion capabilities for seamlessly expanding the scope of both horizontal traceability (from individual processes to multiple sites) and vertical traceability (types and quantities of data handled). To help customers reap rapid benefits, Hitachi can augment the solution by supplying templates and other resources for addressing specific customer challenges.

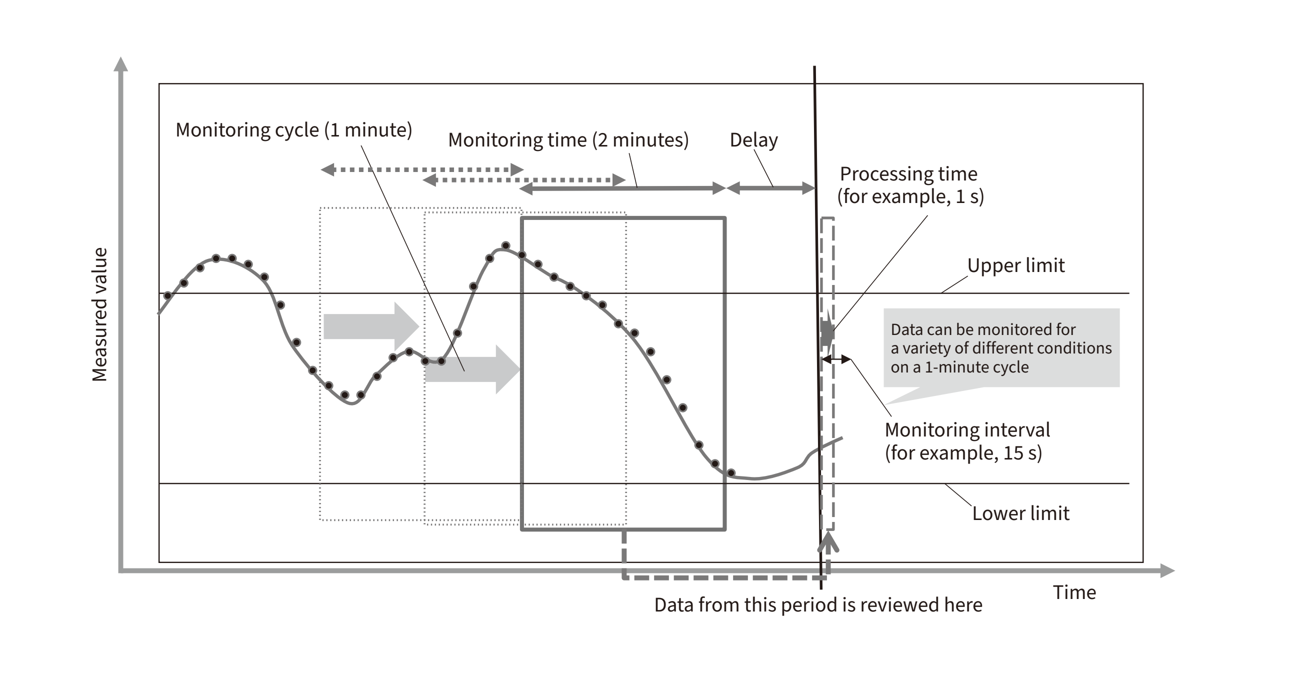
2. 2. 2 Monitoring Function

This function sets the monitoring intervals, monitoring duration, and number of divergences for the upper and lower control values used to monitor for abnormal trends in the production and inspection results from the production process in real time. It also issues alerts when abnormalities are detected.

*1 Elasticsearch is a registered trademark of Elasticsearch BV.
*2 An API developed in accordance with a philosophy and set of design principles for interoperation between different software on distributed systems.
*3 Node-RED is a registered trademark or trademark of JS Foundation in the USA and other countries.

Figure 2 — Overview of How Monitoring Function Works

Monitoring and delay times are specified and the time it takes for data to arrive is taken into consideration ensuring reliable notification when monitoring limits are exceeded.



A monitoring plugin (Watcher) runs in Elasticsearch where it monitors specified indexes. The data loaded into Watcher is compared against the settings stored in the master database and the specified alert action is performed if the required conditions are not satisfied. The function can monitor for abnormal trends as well as anomalies and the alert action can take the form of notifying the relevant people in real time, which is done by using the mail function to send emails to specified addresses. **Figure 2** gives an overview of how this function provides reliable notification of when data exceeds its monitoring limits, taking account of the time it takes for data to arrive.

2. 2. 3 Trace Function

This function searches the production history using product ID and equipment (production node) as keys and presents the results in tabular or graphical form. It retrieves the data from the secondary data mart used to store production and inspection results from the plant, and from master data such as quality management indicators or equipment names and other production management information.

To facilitate use with modification management and quality management, it presents information about modifications or changes that occurred in the production process for a product. One application is for investigating and analyzing the causes of defects, which can be done more quickly by utilizing information about modifications or changes that was acquired automatically from the production process. By doing so, the function can isolate the causes of a problem and accurately determine the extent of the consequences that will arise from it. **Figure 3** shows an example for the item traceability use case where production history

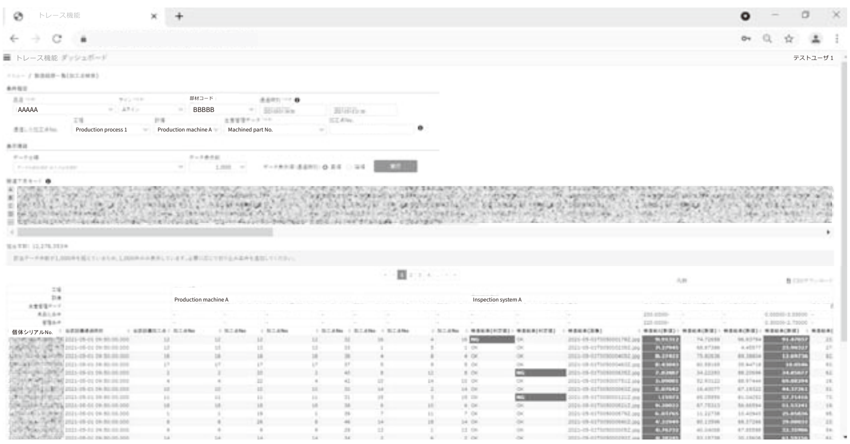


Figure 3 — Example Production History List Displayed by Trace Function

The function makes it easy to identify when abnormal situations occur by tabulating production history based on the production and quality results for products that match the specified search condition specified by parameters such as product ID or production node.

data is tabulated based on the production and quality results for a product that was identified by specifying search keys such as the product ID or production node.

The trace function enables remedial action to be implemented quickly, with products or equipment of concern, such as those associated with alerts from the monitoring function, able to serve as prompts for an investigation into which products were affected by a problem and which items of equipment were responsible, which can be determined using the various functions for searching the production history. The trace function provides the following five functions.

(1) Screen for displaying results distribution by node

Presents statistics for a specified combination of production node and production or quality results.

(2) Product serial number list

Lists the product IDs, case IDs, and other such data that satisfy the specified conditions.

(3) Production history (search by product ID)

For products that match the entered criteria, such as product ID or case ID, this displays production history sorted by production node, production results, or quality results.

(4) Production history (search by production node)

For selected equipment or time periods, this displays the production history for matching products sorted by production node, production results, or quality results.

(5) Time-based production and inspection results

Displays trend graphs of the specified production results or quality results for a specified time period.

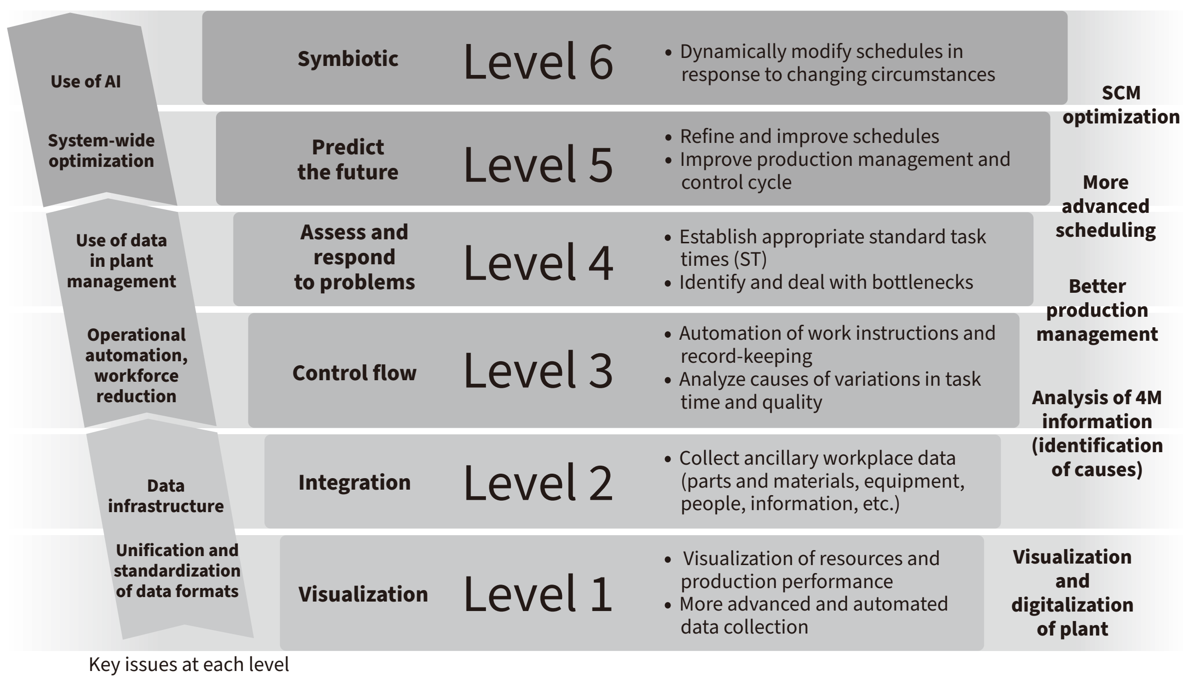
2. 3 Benefits of Item Traceability Solution

Use of the item traceability solution can reduce the workload associated with collecting information and investigating the causes of rejects or equipment issues, tasks that in the past have consumed a large number of work hours. It can also eliminate the need for skills held by specific individuals able to keep track of the overall condition of the production line, reduce the workload for large-scale sampling of items with suspected quality issues, and reduce rejects. Companies that have adopted the solution have achieved significant reductions in rejects and time spent dealing with production problems. The lower level of rejects also delivers environmental value by reducing the amount of product that goes to waste.

Another benefit is that, by detecting abnormal trends, the automatic monitoring function can prevent problems before they occur. In terms of quality assurance, by providing integrated management and archiving of traceability information from the production process, the solution also improves accountability when dealing with quality inquiries from the marketplace or distribution system.

Figure 4 — Hitachi's Smart Factory Maturity Model

Using this model to make the smart factory transition on the basis of scenarios in which the factory moves through progressively higher levels of maturity is important for putting initiatives into practice and generating business benefits.



AI: artificial intelligence SCM: supply chain management 4M: human, machine, material, and method

3. Conclusions

Quality management and quality assurance are among the issues that value chains must address. This article has focused on these in the context of the manufacturing workplace and described an item traceability solution that delivers a high level of traceability.

This solution is a real-world example of the cyber-physical system (CPS) approach to overcoming challenges using cyberspace representations of manufacturing plants, and in which the comprehensive and timely collection, integrated management, and presentation of human, machine, material, and method (4M) data from manufacturing processes is used to provide feedback to the factory floor. It corresponds to level 4 in the smart factory maturity model: "Assess and respond to problems" (see **Figure 4**).

A wide variety of different uses for item-level traceability data can be anticipated in the future. Examples relevant to factories include predictive applications such as simulations for quality prediction, system-wide optimization covering multiple sites or processes, and extending traceability throughout the value chain by linking traceability and supply chain management (SCM) information.

The item traceability solution is but one example from a wide range of manufacturing solutions that combine operational and information technology (OT and IT) built up by Hitachi over many years in its own operations. Along with supplying these solutions to the manufacturing industry, Hitachi also intends to help customers overcome challenges and enhance business value by expanding its product range and accelerating the deployment of total seamless solutions.

Reference

1) S. Tanaka et al., "IoT Platform Solution for Manufacturing that Connects the Manufacturing Site and Management through Data," Hitachi Review, 67, pp. 212–218 (Feb. 2018).

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