Comprehensive Traceability Technology for Value Creation in Manufacturing

For manufacturers to go on providing safety and security to their customers, it is important that, along with ensuring the quality of their products, they also establish relationships of trust by means of those products. This article describes the technology and concepts behind comprehensive traceability that delivers new value to customers in the process of establishing this trust by linking products to data about events and workers as well as the products themselves. It also describes how traceability is used in practice in the automotive industry. Finally, the article discusses ideas about how traceability will be handled in the future across the entire lifecycle, from product development and prototyping to manufacturing, maintenance, and repair.

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1. Introduction

The manufacturing industry in recent years has seen production facilities and procurement routes spreading across the globe, with products being supplied to markets around the world. Moreover, the reliable maintenance of production and inspection records so that they can be disclosed when necessary is now standard practice in the industry, and is increasingly becoming a requirement from customers. Meanwhile, greater use of electronics is making products more complex, with a wider range of variations in terms software as well as hardware. The automotive industry is a clear example of this. When a problem occurs with such a product, it takes a lot of work to collect and analyze the data needed to track down the cause. This in turn creates a need for traceability practices that manage data on things like parts sourcing and manufacturing processes in a way that links it to products.

It is also anticipated that measures for preventing the spread of COVID-19 will feature in various aspects of future economic activity, and as such it is likely that this will include an increasing number of areas where there is a need to keep records of contacts between products and people across the production, distribution, and sales processes.

This article describes the technology and concepts behind comprehensive traceability that delivers new value to customers in the process of establishing the trust that such record-keeping fosters, linking products to data about events and workers as well as the products themselves (see **Figure 1**).

2. Three "Boundaries" Connected by Traceability

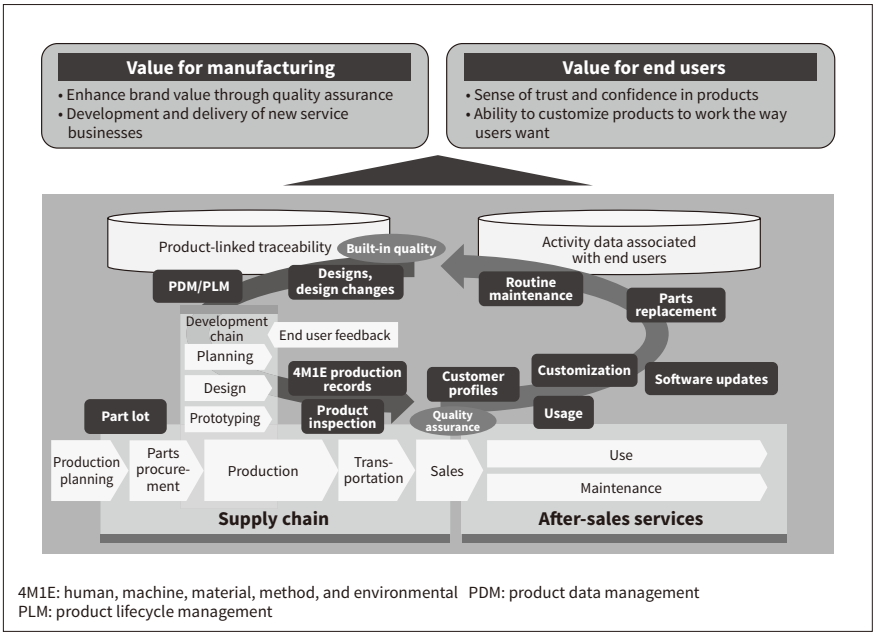
Among the key considerations for achieving traceability are three "boundaries" that afflict operations and the ways of thinking needed to connect them. **Figure 2** shows the relationship between these three "boundaries" and this section describes the associated issues and countermeasures.

(1) Terminology "boundaries"

Data management for traceability requires the collection of data handled by various different departments such as design, procurement, production, quality assurance, and

Figure 1 — Comprehensive Traceability that Encompasses the Entire Product Lifecycle

Comprehensive traceability delivers value to both manufacturers and end users, extending its scope beyond the manufacturing process to also tie-in how the product is used in the marketplace and its maintenance and update history, providing this as feedback so that products can be designed with built-in quality.



4M1E: human, machine, material, method, and environmental PDM: product data management
PLM: product lifecycle management

sales. The part numbers and the names of products and processes used in each department are frequently expressed using department-specific terminology or abbreviations that are only meaningful within that particular organization. This lack of terminological consistency frustrates the integration of collected data. Investigations need to be carried out with an awareness of the definitions of words to prevent this from becoming an obstacle to communication between departments, such as the collation of name lists and dictionaries or codes for identifying specific products.

Figure 2 — Key Considerations for Connecting Three "Boundaries" of Manufacturing

The diagram shows the three "boundaries" of terminology, data, and organization that need to be taken into account when implementing traceability, and how the three important considerations for connecting these "boundaries" relate to one another.

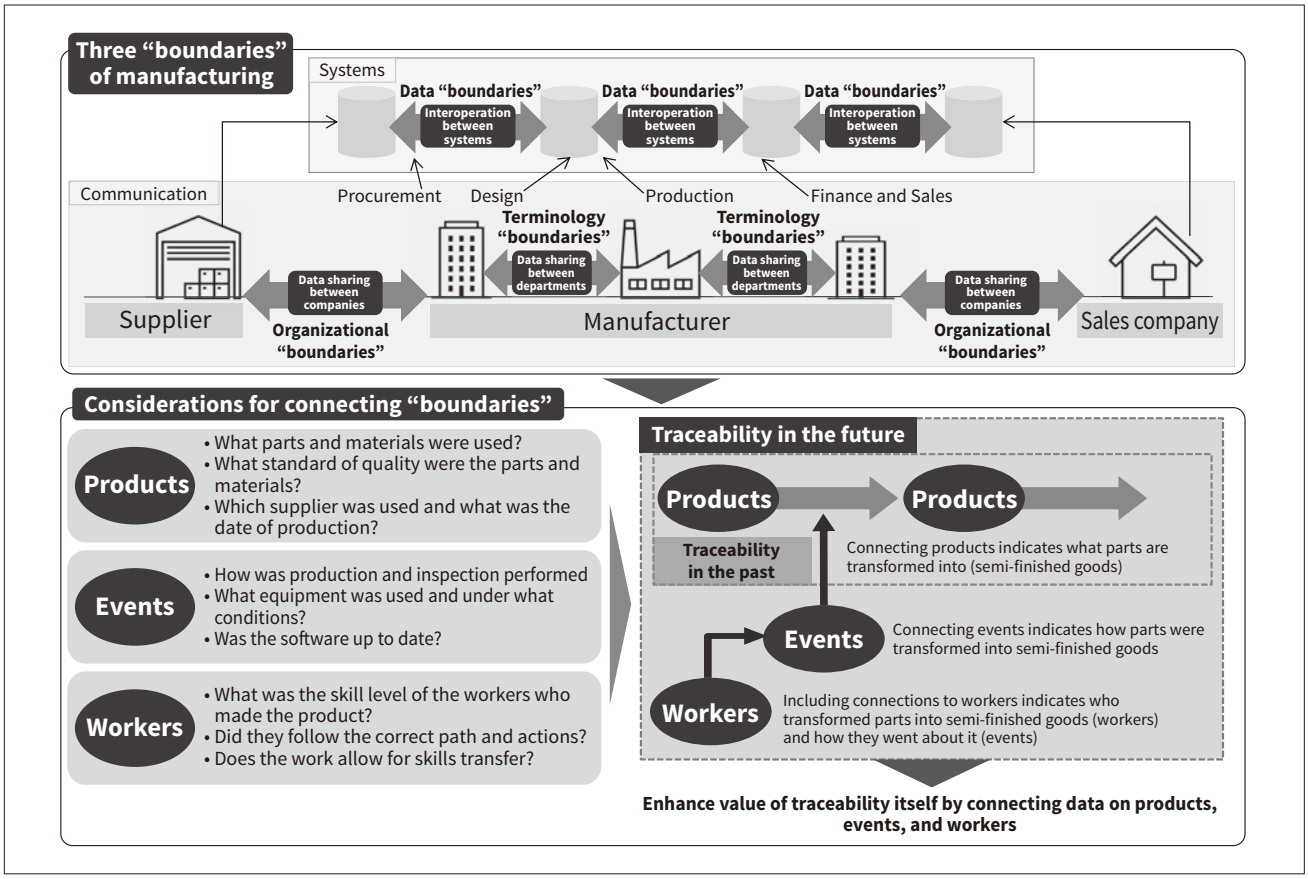
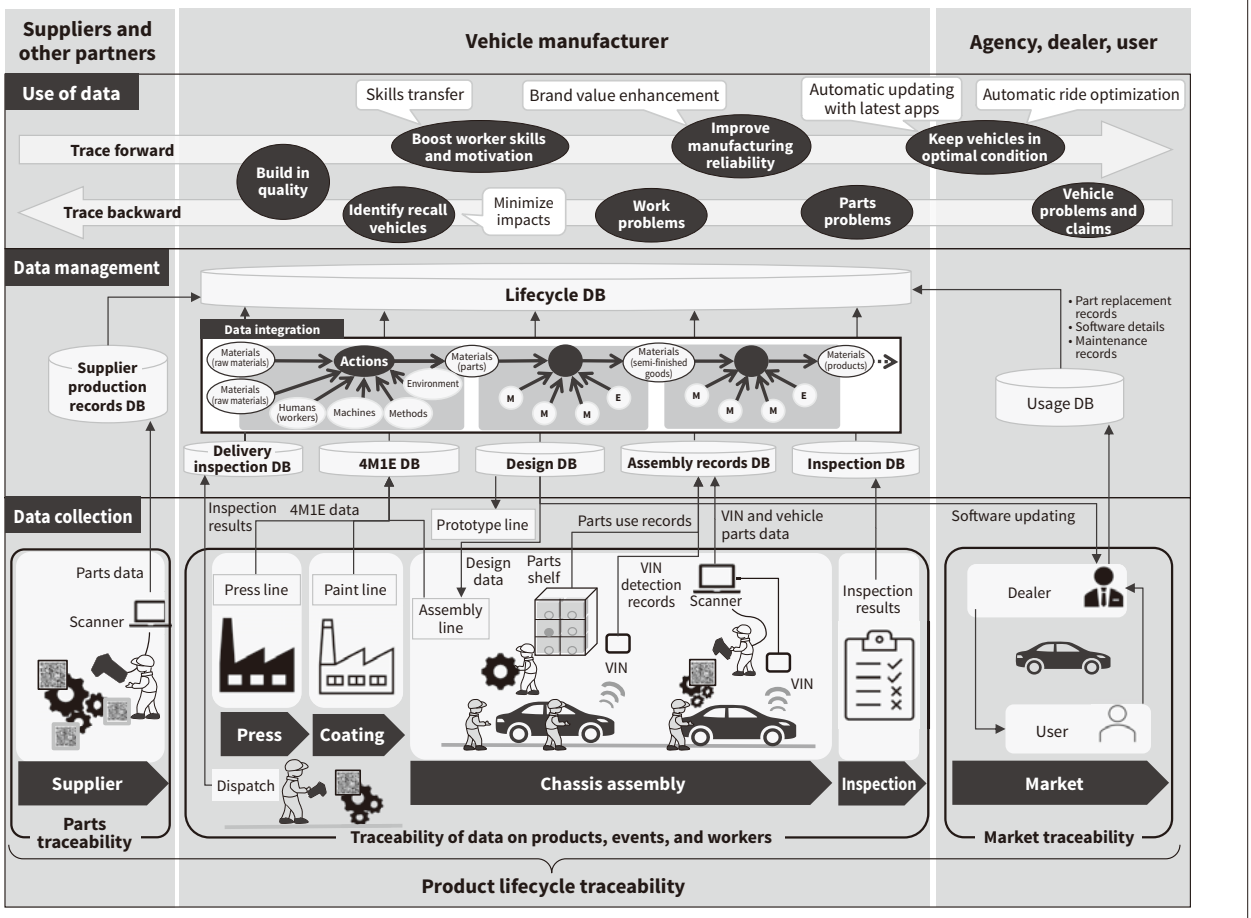


Figure 3 — How Traceability Data is Collected, Managed, and Used in Automotive Manufacturing

A lifecycle database is created by collecting parts data from suppliers, design and production data from the factory, and details of how customers use the product from dealers. Value can be provided to end users as well as to the factory by tracing this data in the forward and backward directions.



VIN: vehicle identification number DB: database

(2) Data "boundaries"

Computer system implementation in manufacturing typically occurs from the bottom up on the basis of need, with it being common for different departments to build or install management systems based on different design concepts. This makes interoperation between different department systems difficult. Rather than the tight coupling of systems, it is better when implementing traceability to focus on the relevant data and to link this data together in ways that are meaningful. If a flag is defined that assigns a meaning to a particular digit in a part number, for example, it can have a standard interpretation within the system concerned but requires data conversion when interoperation with other systems is involved. Attaching a universal key to collected factory data so as to clarify its meaning makes it possible to relate that data to other data in a meaningful way. The accelerating trend toward collecting and using traceability data globally is another reason why global standardization of the assignment of meaning to data is something that warrants further work.

(3) Organizational "boundaries"

It is not uncommon for different companies and departments to pursue different polices with respect to manufacturing and to think about data management differently. Unless all of the stakeholders involved in implementing traceability across multiple organizations are aligned in what they are seeking to achieve, they will find it difficult to work together smoothly. The exchange of data between companies, in particular, faces a different order of difficulty to that for companies seeking to sort things out internally. A key consideration is to proceed on the basis of a consensus across the entire organization and between different companies about things like the goals, their importance, and the benefits of its use, based on a customer-first approach that sees traceability as being about forging a relationship of trust with customers by way of products.

A key factor in the successful implementation of traceability is the question of how to create an environment that seamlessly connects the above three "boundaries".

3. Three Factors to Consider when Implementing Traceability

An important factor in traceability is to link data together in a way that maintains consistency on the basis of the three considerations of products, events, and workers. This involves asking how a product changes in the process of transforming materials into finished goods, by what means (events) this transformation takes place, and what skills are possessed by the people who do this work (workers). The lower half of **Figure 2** shows how traceability of products, events, and workers links data together and the associated relationships.

(1) Product traceability

Product traceability tracks the materials used in the parts that go into a product in a way that ties this data to the product itself. Materials, parts, semi-finished goods, optional parts, and so on are tagged with identifiers (ID) that are linked to the finished product along with data about where they come from. When product traceability is in place, it is possible to trace the scope of influence when a problem occurs in the production process by looking at the component parts and how they relate to the problem. This traceability can be done on the basis of assigning IDs to each and every part or to the smallest quantity (typically a "lot") by which parts are handled during storage and distribution.

(2) Event traceability

Event traceability links products to the events that happened to them, such as the equipment and conditions used in their manufacture or the records kept as a result of this work. This includes a wide variety of data, including production line or other production machinery settings, environmental details such as temperature and humidity at the factory, and inspection results. Linking events to the changes that happened to products clarifies the impact of the production process on product quality and can provide feedback for building in quality from a process perspective.

(3) Worker traceability

Workers are the main actors in the manufacturing process. Worker traceability links in data about the workers who were involved in the above events, including details of their movements during work and how competently they performed their actions. This collection of data on workers is also considered necessary for the purpose of boosting worker skills and motivation by giving them pride in the quality of the products and by uncovering the cause-and-effect relationships between quality and the skills of individuals.

Product traceability has predominated in the past, linking data about the origin of parts and materials to products. In the future, however, a new form of traceability that links the events involved in bringing products together and the actions of the workers involved in those events will enable the fostering of trust with customers as well as provide them with reassurance.

4. How Traceability Systems are Used

Using the automotive industry as an example, **Figure 3** shows how traceability data is collected, managed, and utilized. The following sections describes the key considerations for this collection, management, and utilization of data on an automotive production line.

4. 1 Data Collection

It is important that data be collected in a way that takes account of where it will be used, especially the human, machine, material, method, and environmental (4M1E) data that serves as the basis for product, event, and worker traceability. Measures that enable automatic data collection are also needed so as not to add to staff workloads at manufacturing workplaces. This can be done using data acquisition technologies such as image recognition or radio frequency identification (RFID) and other electronic tags. Likewise, to avoid problems when the data is used, collection also needs to convert any data that is specific to particular machines or codes that are only used on the production line to codes with a simple data structure that are standardized across the company. While there is sometimes a direct link between vehicles and parts at the time of data collection, a useful way to simplify data collection when this is not the case is to instead link vehicles to their parts on the basis of time. This is done by cross-referencing the time a vehicle passed through a particular process with the times when parts were used.

4. 2 Data Management

The management of collected data involves collecting vehicle histories for archiving in a lifecycle database by linking the data together in ways that make sense for its intended use, based on the 4M1E data, assembly records, and other data contained in specific databeses. As each process uses different ID numbers to identify products, including material lot numbers, part serial numbers, the code stamped onto the engine block, and the vehicle identification number (VIN), it is important to have data management procedures and rules that allow these IDs to be linked together. Parts data, such as the relationship between material lot numbers and part serial numbers held by suppliers, also needs to be handled in such a way that in the end it can be linked to the serial number of the vehicle it is used in.

There are also moves toward requiring end-product vehicle manufacturers to maintain revision history records for automotive computer software, such as in the stipulations being formulated by Working Party 29 (WP29), the World Forum for Harmonization of Vehicle Regulations*. This requires the collection of this after-market data via dealers and its inclusion in the vehicle history data held in the lifecycle database.

To enable the smooth implementation of traceability throughout the value chain, Hitachi has formulated guidelines (rules) that specify data flows and other data collection practices for this traceability data that have been widely distributed across the departments involved in the project.

4. 3
Putting Data to Use

While traceability data records allow for the tracing of data in both the forward and backward directions, Hitachi believes that forward tracing for tracking the influence that any given step in the manufacturing process has on subsequent steps will be particularly important in the future.

Along with the objective of motivating and upskilling workers through built-in quality, forward tracing can also enhance brand value by providing transparency in the vehicle production process for assurance of product quality and to improve the reliability of manufacturing. As vehicles make greater use of electronics, it is also becoming possible to automate the updating and management of automotive software to ensure that software is always kept up to date even when upgrading is done remotely. By automatically customizing software to suit individual driving styles, these technologies can be used to provide each driver with the best possible driving experience.

Backward tracing, meanwhile, can quickly get to the causes of any problems that occur by using the VIN to obtain data such as the production line on which the vehicle was manufactured, the date of manufacture, and details of the parts used and equipment conditions.

It can also help improve the design quality of new vehicles by providing feedback to design departments about any quality issues identified from traceability data.

5. Conclusions

The future is likely to see more products such as vehicles or smartphones and other electronic devices that go through repeated cycles of hardware and software updating, evolving in step with how they are used in practice. Moreover, by utilizing automatic customization to provide users with the value inherent in personalized goods, these products will bring companies and their customers closer together.

Meanwhile, comprehensive traceability that encompasses the entire product lifecycle is set to deliver new value by collecting a wide variety of data that continues to change along with the products themselves. Hitachi also believes that manufacturers can better secure their competitiveness in global markets by establishing Internet of Things (IoT) platforms for holding this traceability data.

The essence of manufacturing remains unchanged in this new normal. As it works in partnership with fields such as logistics or consumer goods and services as well as manufacturing, Hitachi intends to continue striving to create new value by drawing on its expertise in comprehensive traceability acquired from automotive and other manufacturing operations.

* World Forum for Harmonization of Vehicle Regulations. An organization dedicated to tasks such as identifying common technical rules for the automotive industry covering fields such as autonomous driving.

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