# Use of AI to Enhance Steel Production Value Chain

Hitachi offers a wide variety of solutions to the challenges posed by rationalization, operational efficiency improvement, and other issues facing customers in the steel and non-ferrous metal industries. This article describes three of these solutions in terms of how they use data and AI. Planning Optimization Service MLCP is used to improve operational efficiency through the optimization of plant production plans, HITSODAS is used to improve quality and yield through the analysis of large amounts of data from high-speed control systems that operate on timescales in the order of tens of milliseconds, and the Hitachi Motor Predictive Diagnosis Solution uses a patented Hitachi algorithm for the analysis of motor current signals to improve the efficiency of electric motor maintenance.

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## 1. Introduction

Hitachi has a track record of supplying electrical machinery control systems for the equipment used in the production of steel products such as high-quality automotive sheet, work that has involved it in the optimization of different types of equipment. In recent years, however, the steel industry has been faced with falling prices for its products due to oversupply and the resulting supply-demand imbalance, with the result that Hitachi's customers in the steel and non-ferrous metal industries are under pressure to rationalize and improve operational efficiency.

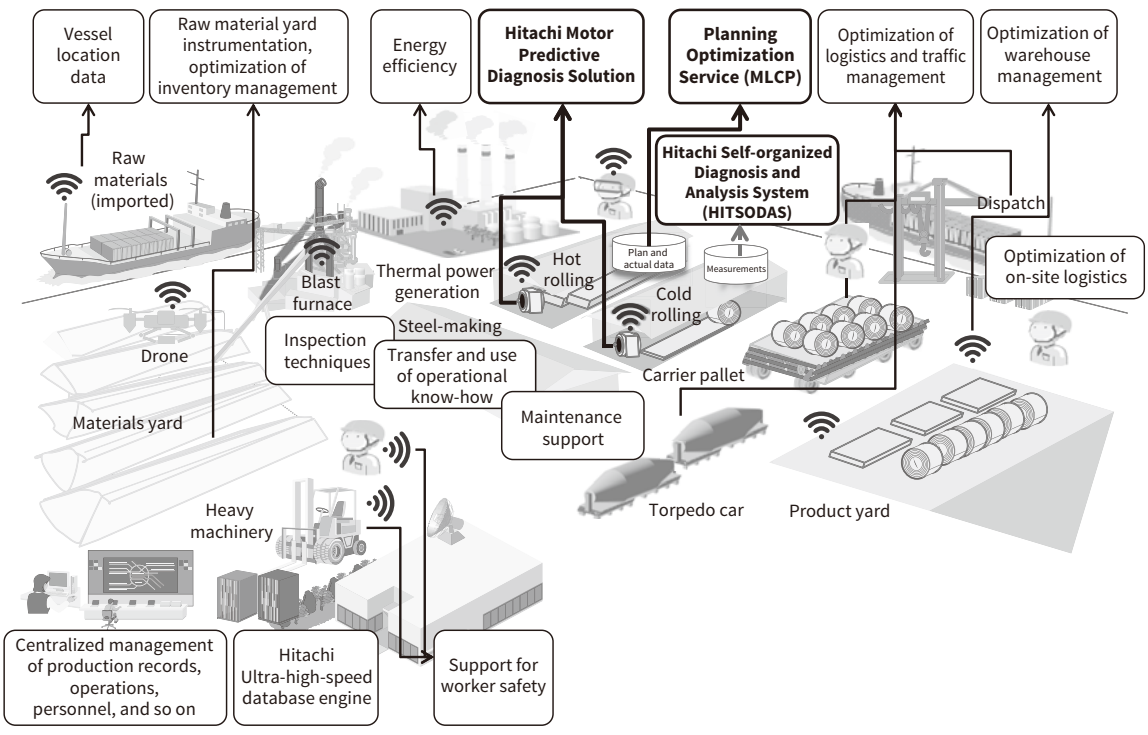
Hitachi offers a wide variety of solutions that address these customer challenges through the plant-wide optimization of customer operations. This article describes three of these solutions in terms of how they use data and artificial intelligence (AI). Machine Learning Constraint Programming (MLCP) is used to improve operational efficiency through optimal plant scheduling, the Hitachi Self-organized Diagnosis and Analysis System (HITSODAS) is used to improve quality and yield through the analysis of large amounts of data from high-speed control systems that operate on timescales in the order of tens of milliseconds, and the Hitachi Motor Predictive Diagnosis Solution improves the efficiency of electric motor maintenance by means of predictive diagnosis that uses a patented Hitachi algorithm to analyze motor current signals (see **Figure 1**).

## 2. Optimization of Production Planning Using MLCP

As production planning (scheduling) in the steel industry is a task that only a small number of highly experienced staff are able to perform, its reliance on particular individuals has become a cause for concern. Moreover, the high level of difficulty means that the work has resisted attempts to computerize it by conventional methods. In response, Hitachi is seeking to overcome this challenge through the use of its Hitachi AI Technology/MLCP, a planning optimization service.

**Figure 1 — Steel Mill Layout**

The diagram shows the solutions available from Hitachi for each step in the production process, equipment is lined up from the unloading of raw materials from ships on the left to product dispatch on the right. The thick lines indicate areas that are a particular focus for Hitachi.




MLCP: machine learning constraint programming

The reliance of production planning on particular individuals can be attributed to the following three reasons.

(1) High level of difficulty

Planning needs to take several dozen considerations into account. Along with equipment constraints, these also include materials, delivery times, and customer-specific requirements. There are also cases where not all conditions can be satisfied, meaning that planning needs to settle for a certain level of quality in which some conditions are deliberately loosened.

(2) Frequent plan revisions

Issues such as changes to orders or problems with equipment arise on a daily basis, each time requiring plan revisions. Revising plans quickly without compromising their quality calls for the judgement of experienced staff.

(3) Inability to document know-how

Because steel is produced to order, the product variations are complex with a wide variety of grades and sizes. This makes expertise difficult to document. Updating staff know-how is also difficult given how the requirements change with changes to equipment or to the product mix.

To address these issues, Hitachi has been using big data analytics to replicate the production plans of experienced staff, working on the computerization of planning work through the use of MLCP to enable on-the-spot generation of optimal plans (see **Figure 2**).

The main features of the system are as follows.

(1) Machine Learning

This involves learning how to replicate the know-how of experienced staff by analyzing plan data that they have prepared. In particular, this provides a similar level of planning flexibility to that of experienced staff by replicating their expertise in how to relax constraints when not all constraints can be satisfied. The system also updates the know-how of experienced staff by continuing to learn from planning data after installation.

(2) Mathematical Optimization Engine

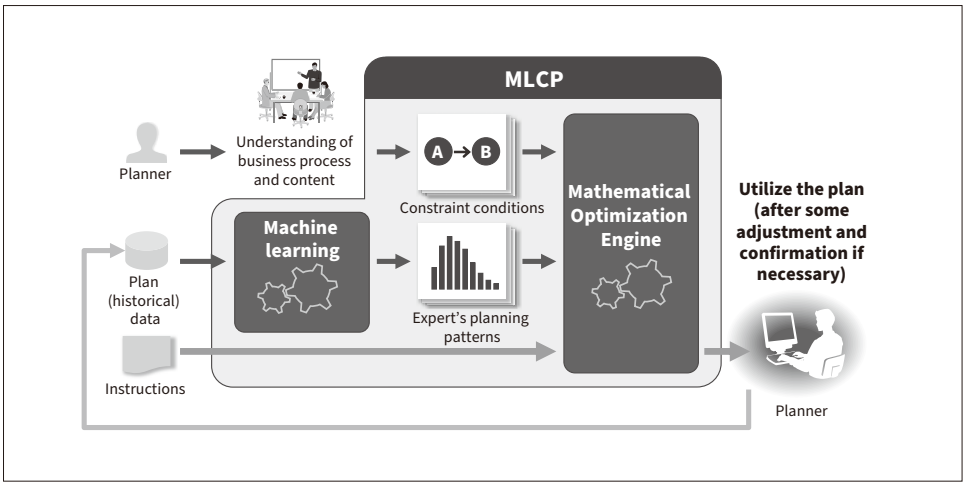
The optimization engine delivers higher quality planning by identifying which plans offer the best performance in terms of the evaluation criteria while still satisfying multiple constraints.

Along with this IT, there is also scope for further improving plan accuracy by acquiring the necessary elements such as operational data, etc. from operational technology (OT) control systems.

With MLCP, customers are able to produce high-quality plans quickly and overcome the problem of planning being so dependent on the expertise of particular individuals.

**Figure 2 — Block Diagram of Planning Optimization Service Hitachi AI Technology/MLCP**

The service uses big data analytics to replicate plans produced by experts. Optimal plans can be produced as needed.




High-quality plans also make production more efficient, reduce roll wear and the amount of warm-up material, improve product quality, and facilitate reliable operation.

Future plans include incorporating MLCP into OT control systems to enhance their functionality.

## 3. Hitachi Self-organized Diagnosis and Analysis System (HITSODAS)

The requirements for improving the quality and yield of flat steel products include reducing the length of off-gauge strip, preventing strip breakage, and maintaining consistent strip flatness. While in-depth analysis is needed to achieve these objectives, the problem with this is that steel is produced in a wide range of grades and strip thicknesses and widths, such that not only is the manual analysis of large amounts of time-series data very time-consuming, the results also tend to vary depending on the skill of the person doing the analysis.

To address these challenges, Hitachi has drawn on the extensive expertise it has built up over time to develop and supply its HITSODAS system for making strategic use of data collected from plants to support their operational maintenance.

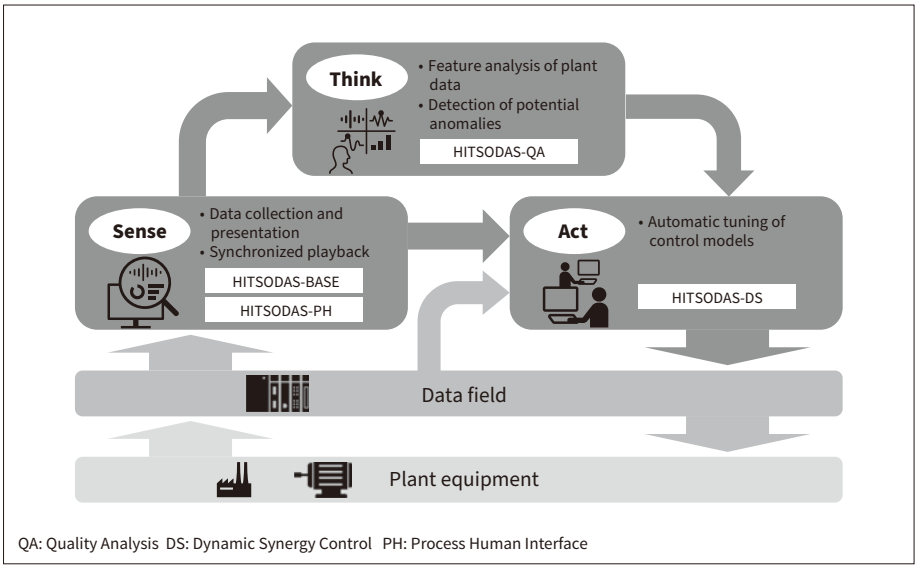
HITSODAS is made up of a core set of functions for data collection and graphical display (HITSODAS-BASE) together with three expansion functions: HITSODAS-QA (Quality Analysis), HITSODAS-DS (Dynamic Synergy Control), HITSODAS-PH (Process Human Interface). **Figure 3** shows a block diagram of the system and its data flow.

Using HITSODAS to work with data enables effective system improvements to be made through an iterative cycle in which the user extracts data from the data field (sense), considers ways of using this data to solve problems (think), and then makes improvements to the actual control systems (act).

The "sense" step involves extracting and presenting plant data from the data field. The data field is supplied with plant data from the HITSODAS-BASE data collection system. HITSODAS-PH also gives access to video from

**Figure 3 — HITSODAS Data Flow**

HITSODAS is equipped with functions for improving the quality of steel products that provide ongoing access to plant and equipment data.




QA: Quality Analysis DS: Dynamic Synergy Control PH: Process Human Interface

plant cameras that can be replayed in sync with the data to provide a broader view of what is happening in the plant.

The "think" step involves using the data analysis and other tools provided by HITSODAS-QA to look for the causes of problems and their solutions in the collected data. Detecting signs of abnormal behavior in the signals collected from the plant can help to quickly track down where the causes of product issues lie.

The "act" step involves conducting testing on the control systems based on the potential solutions identified in the "think" step. HITSODAS-DS provides functions that make the task of using plant data for control model tuning more efficient.

Hitachi launched the latest version of HITSODAS featuring enhanced graphical functions and ease-of-use in 2019. The user base is growing, especially outside Japan, including for the operational support service that uses the software.

## 4. Efficient Maintenance Using Predictive Diagnosis of Motor Currents

Unplanned equipment outages or higher maintenance and inspection costs are among the issues that arise with the electric-motor-driven systems used at a wide variety of industrial plants. To address these issues, Hitachi has launched a predictive diagnosis solution that uses AI to analyze motor currents and automatically detect and highlight problems such as motor degradation or abnormal operation.

The predictive diagnosis technology used by the solution draws on Hitachi's experience with motor manufacturing and maintenance, incorporating OT knowledge and Hitachi's own AI analysis techniques. As degradation in motor-driven systems causes changes in the motor load, these changes also manifest in the motor current. By extracting feature values from these tiny changes in motor current behavior that are indicative of the degradation in the system and using a machine learning technique (a form of AI developed by Hitachi), highly precise predictive fault detection can be achieved by identifying motor abnormalities in the available data (see **Figure 4**).

The main features of the solution are as follows.

(1) Greater workplace safety as inspection and diagnosis can be performed remotely

(2) Lower maintenance workload and costs achieved by consolidating the monitoring, analysis, and diagnosis of multiple motors

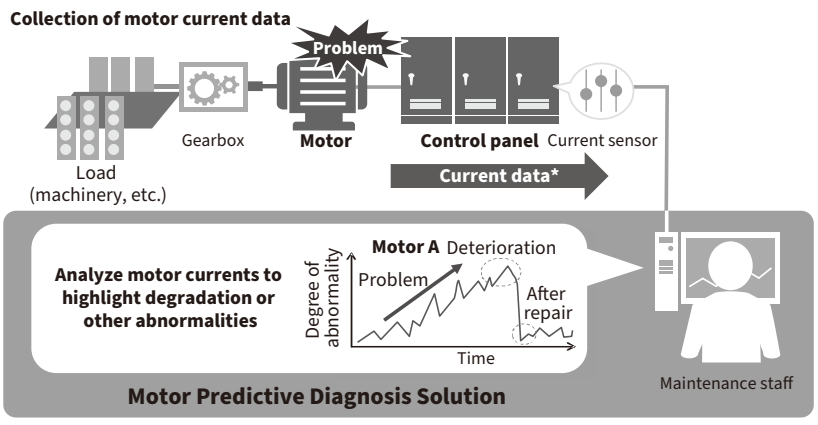
(3) Ability to individually prioritize motor maintenance as the condition of each motor is monitored separately

(4) Help to address the shortage of experienced staff by standardizing work that previously relied on worker intuition and rules of thumb

(5) Facilitation of highly sensitive diagnosis by extracting feature values on the basis of engineering knowledge from motor manufacturers

System installation is simplified by the use of clamp sensors that fit over cables to measure the currents needed for predictive diagnosis, with everything housed together in a control panel in the electrical room. This reduces the number of site visits needed for sensor maintenance compared to the past practice of attaching the sensors to the motors themselves.

The current data is analyzed by the AI-based predictive diagnosis algorithm to indicate where signs of motor degradation are present, providing data about the extent of degradation for each motor. By only performing maintenance on those motors in need of repair or replacement, this helps with both preventing unexpected equipment outages and reducing maintenance workloads.




* The means by which current data is acquired differs depending on the equipment being driven.

**Figure 4 — Overview of Motor Predictive Diagnosis Solution**

This solution uses Hitachi's patented predictive diagnosis algorithm to analyze motor current data and detect abnormal motor behavior.

While the service is currently restricted to alternating current (AC) motors only, support for direct current (DC) motors is being added along with the development of a more advanced version of the solution that can also visualize and diagnose the condition of the motor gearbox and the downstream equipment it is being used to drive.

Along with reducing staff workloads, the service also makes maintenance more efficient and supports safe and reliable plant operation.

## 5. Conclusions

This article has described some of the solutions that Hitachi can offer to enhance the steel production value chain. In the future, Hitachi intends to continue delivering value to customers by offering solutions that draw on its comprehensive capabilities, combining its expertise in OT and IT to address the ever-changing challenges facing customers.

### References


1) M. Kayama et al., "Analysis System for Steel Manufacturing Plant: How to Handle Plant Data for their Strategic use to Control and Diagnosis," The Papers of Technical Meeting on Metal Industries Division (MID), IEE Japan, Vol. 22, pp. 7–11 (Oct. 1999) in Japanese.

2) K. Kuribayashi et al., "Advances in Steel Industry Control Systems in Era of IoT," Hitachi Review, 65, No. 5, pp. 41–46 (Jun. 2016).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